Matthias Kühle-Weidemeier (Hrsg.)

Waste-to-Resources 2011
4. Internationale Tagung MBA und Sortieranlagen

Mechanisch-biologische Abfallbehandlung und automatische Abfallsortierung

Tagungsband
(Originalsprachenausgabe)

24. - 26. Mai 2011

Veranstalter
wasteconsult INTERNATIONAL

In Zusammenarbeit mit

Universität Rostock Traditio et Innovatio

Mit Unterstützung der

ASA

iwwg international waste working group

Gold Sponsor
Vecoplan®

Cuvillier Verlag

Matthias Kühle-Weidemeier (Hrsg.)

Waste-to-Resources 2011

4. Internationale Tagung MBA und Sortieranlagen

Mechanisch-biologische Abfallbehandlung und automatische Abfallsortierung

Tagungsband
(Originalsprachenausgabe)

24. - 26. Mai 2011

Veranstalter

wasteconsult INTERNATIONAL

In Zusammenarbeit mit

Universität Rostock Traditio et Innovatio

Mit Unterstützung der

ASA

iwwg international waste working group

Gold Sponsor

Vecoplan®

Cuvillier Verlag

Bibliografische Information der Deutschen Nationalbibliothek
Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.d-nb.de abrufbar.
1. Aufl. - Göttingen : Cuvillier, 2011

978-3-86955-747-2

Nonnenstieg 8, 37075 Göttingen
Telefon: 0551-54724-0
Telefax: 0551-54724-21
www.cuvillier.de

1. Auflage, 2011
Gedruckt auf säurefreiem Papier

978-3-86955-747-2


Vecoplan®

Das Unternehmen Komptech.

Komptech ist ein führender internationaler Technologieanbieter für Maschinen und Anlagen für die mechanische und mechanisch-biologische Behandlung fester Abfälle und für die Aufbereitung von Biomasse als erneuerbarer Energieträger.

Die Marke Komptech besteht seit 1992 und steht für höheren Kundenutzen, der insbesondere durch

Praxisorientierung

und

Pioniergeist „Innovation serienmäßig"

entsteht.

Unternehmenskennzahlen

Gruppenumsatz 2010: ca. 88 Mio. €
80% des Umsatzes in Europa (ca. 10% in Osteuropa), Rest insbesondere in USA, Iran, Japan und Australien

10 Unternehmen an 7 Standorten in 5 Ländern weltweit (Österreich, Deutschland, Slowenien, Großbritannien, USA)

Mitarbeiter: ca. 480

Die Komptech-Produktpalette umfasst mehr als 30 unterschiedliche Maschinentypen, mit denen unsere Kunden die wesentlichen Verfahrensschritte moderner Abfallbehandlung und Biomasseaufbereitung abdecken:

- **Zerkleinerungstechnik**
- **Sieb- und Separationstechnik**
- **Kompostierungstechnik**

Modularer Aufbau mit unterschiedlichen Leistungsklassen vereinfacht die Kombination zu kompletten Systemen und Anlagen.

Die Kunden von Komptech sind private und kommunale Entsorgungsunternehmen und Dienstleister auf der ganzen Welt.

www.komptech.com

KOMPTECH
TECHNOLOGY FOR A BETTER ENVIRONMENT

Komptech GmbH
Kühau 37, A-8130 Frohnleiten
T +43 3126 505 0
info@komptech.com

wasteconsult **www.wasteconsult.de**

INTERNATIONAL

consultancy • design engineering • research • transfer of knowledge

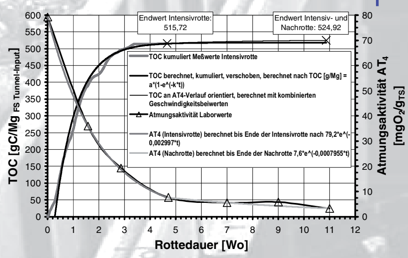
Mechanical biological waste treatment

Design engineering and optimisation of MBT plants

The staff of **Wasteconsult** is and has been significantly involved in research, plant design and optimisation of the mechanical biological waste treatment and its emission control. Based on this, we design and optimise MBT plants for you.

Pilot projects

We supplement our experience by own pilot tests and research results in the area of MBT optimisation and emission measurement & treatment. We have developed and tested what others just know from books!



Sampling and analytics

Waste treatment needs a permanent control and adaption to the varying waste composition and changed boundary values.

Wasteconsult offers an extensive attendance of your MBT beginning with sampling and ending with the evaluation of the analytical results. This is a precondition for stable and economically operation of your MBT.

Emission measurement

Do you want to know what gets into your exhaust gas treatment and what is in its output? Do you want to adjust the MBT for an economically optimised operation of a regenerative thermal oxidation of the exhaust gas? We have experience with the measurement technique and accomplishment of long continous emission measurements. We can analyse your biogas from the digestion or your landfill gas for the main and trace components.

At Wasteconsult you are in best hands for design engineering, optimisation and analytics in all aspects of MBT!

wasteconsult www.wasteconsult.de
INTERNATIONAL
consultancy • design engineering • research • transfer of knowledge

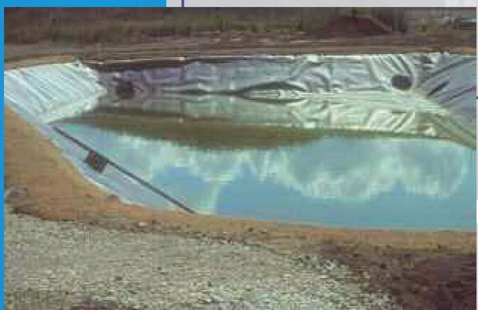
Landfills and contaminated land

Design engineering

The **Wasteconsult** staff has extensive experience in the whole area of design engineering, bid invitation and construction supervision of

- Landfill covers and liners
- Operation and emplacement concepts
- Gas collection and treatment
- Leachate and groundwater collection and treatment

Our know how about MBT landfills is unique.



Monitoring, aftercare and reuse

Landfills and contaminated sites need a long lasting supervision. Wasteconsult designs your aftercare measures and monitors groundwater, leachate, gas and the landfill installations. Furthermore we propose possibilities for the reuse of the landfill area. Depending on the legal regulations (financial support) in your country, wind energy or photovoltaics might be an attractive solution. Our new concept **DepoSolar®** combines the function of landfill cover sealing and solar electricity production.

In-situ stabilisation

An important step to minimise the aftercare duration and costs is the active contol of closed landfill sectors. This starts with leachate re-infiltration to enhance the gas production and the anaerobical stabilisation. When the gas yield or the methane concentration are to low, the time has come for a methane oxidising cover or for the start of in-situ aeration of the landfill. This will accellerate the stabilisation of the landfill significantly and save money because of the reduced leachate contamination and the shortened aftercare phase.

Contaminated land

Based on the long lived experience of our staff we can offer the whole package of engineering services for the remediation of contaminated land:

- Site investigation and risk assessment
- Design of clean up operations
- Construction supervision & control of occupational security

Take advantage of our experience!

Inhalt

III Strategien der Abfallwirtschaft

IV MBA-Technik

V MBA-Anlagenbeispiele und Betriebserfahrungen

VI Optimierung der MBA

VII Emissionen und Emissionsbehandlung

VIII Emissionsminderung und Aufbereitung von Biogas

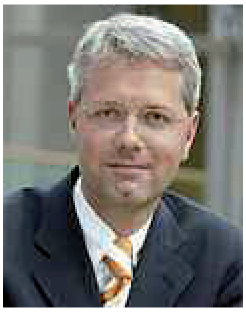
IX Deponierung von behandelten Abfällen

X Abfallanalytik und Prozesskontrolle

Hinweis

Dieser Tagungsband wurde durch Wasteconsult international, Dr. Kühle-Weidemeier mit großer Sorgfalt zusammengestellt. Fehler sind trotzdem nicht auszuschließen. Für die Richtigkeit der Angaben in diesem Buch wird von Wasteconsult und den Verfassern keinerlei Haftung oder Gewährleistung übernommen. Die Verantwortung für den Inhalt liegt bei den Autoren selbst.

Sofern in den Beiträgen Markennamen verwendet wurden, bestehen dafür möglicherweise Schutzrechte, auch wenn darauf nicht ausdrücklich hingewiesen wird.



Grußwort von Bundesumweltminister Dr. Norbert Röttgen

Als mir die Schirmherrschaft für die 4. Internationale Fachtagung „MBA - Waste-to-Resources" angetragen wurde, habe ich sehr gerne zugesagt. Denn die MBA-Technologie international voran zu bringen, ist eine Aufgabe von großer internationaler Bedeutung für den Schutz von Klima, Umwelt und Ressourcen. Die Kreislaufwirtschaft als nachhaltige Abfallwirtschaft mit modernen und effizienten Behandlungstechniken ist praktizierter Umweltschutz auf höchstem technischen Niveau. Mehr denn je kommt es deshalb darauf an, die Abfallwirtschaft international zu einer echten Kreislaufwirtschaft weiter zu entwickeln, die die Ressourcen und das Klima noch stärker als bisher schützt. Deutschland kann und will hier seine Erfahrungen weitergeben und sein technologisches Know-How anbieten.

Die zunehmende Nutzung natürlicher Ressourcen stellt die Abfallwirtschaft vor neue Herausforderungen. Angesichts des weltweit steigenden Ressourcenverbrauchs ist es in Zukunft unumgänglich, die in den Abfällen enthaltenen Rohstoffe in noch stärkerem Maß als bisher wieder in den Wirtschaftskreislauf zu integrieren. Immer noch landen zu große Mengen an Rohstoffen auf Deponien. Auch wenn die Müllverbrennung umweltverträglicher als die Deponierung ist, werden auch dabei immer noch viel zu viele wertvolle Inhaltsstoffe der Abfälle verschwendet – und auch die dabei anfallende Energie wird noch zu wenig genutzt. Dabei geht es nicht nur um die klassischen Wertstoffe wie Eisen, Aluminium und Kupfer, Papier, Glas oder Kunststoffe. Es geht auch um Rohstoffe, die bereits in den nächsten Jahren absehbar knapp werden, wie z.B. die seltenen Erden und andere wichtige Metalle wie Titan, Tantal und Niob, die sowohl für die elektronische Industrie als auch für Solarkollektoren wichtig sind. Auch Phosphat, das für eine ausreichende Sicherung der Versorgung der Weltbevölkerung mit Nahrungsmitteln nicht zu ersetzen ist, geht in großen Mengen verloren. Dieser Entwicklung muss durch eine neue Rohstoffstrategie entgegen gesteuert werden, die verstärkt auch Abfälle einbezieht. Das ist nicht nur ein Gebot der wirtschaftlichen Vernunft, sondern auch ein Beitrag zum Schutz der Umwelt. Beides zu verbinden gebietet es auch, Bioabfälle zunehmend als Kompost zu verwerten, um Böden zu verbessern, oder sie als Energieträger zu nutzen, damit natürliche Ressourcen wie Torf oder fossile Brennstoffe geschont werden. Hier liegen große Potenziale, die weiter ausgebaut werden müssen.

Dazu kommt: Durch die energetische Nutzung von Abfällen in Form von Strom, Wärme oder Kälte können fossile Ressourcen geschont, fossiles CO_2 vermieden und Emissionen von Klima schädigendem Deponiegas deutlich reduziert werden – das hilft dem Schutz des Klimas und ist damit ein wesentlicher Faktor im Kampf gegen den globalen Klimawandel.

Die MBA-Technologie in ihren vielfältigen Varianten ist ein wichtiger Beitrag zu einer Ressourcen schonenden Abfallwirtschaft – insbesondere auch für die Entwicklungs- und Schwellenländer. Sie setzt Maßstäbe für eine moderne Kreislaufwirtschaft weltweit. Dass die internationale Fachtagung „MBA – Waste-to-Resources" ein Leitmedium der internationalen Kreislaufwirtschaft geworden ist, zeigt sich nicht zuletzt daran, dass sie jetzt schon zum vierten Mal ausgerichtet wird. Und ich bin sicher: Auch diesmal wird sie nicht nur ein hervorragendes Diskussionsforum, sondern auch ein Anstoß für große Fortschritte auf dem Weg zu einer nachhaltigen Weltwirtschaft sein – einer Weltwirtschaft, in der wirtschaftlicher Fortschritt eng mit dem Schutz von Umwelt und natürlichen Ressourcen verbunden sein muss. Ich wünsche der Veranstaltung viel Erfolg!

Dr. Norbert Röttgen

Bundesumweltminister

Die Wahl der richtigen Technik: MBA-Verfahrenstypen und ihre Vor- und Nachteile

M. Kühle-Weidemeier

Wasteconsult international, Langenhagen, Germany

Den Beitrag können Sie unter www.wasteconsult.de/mbt-selection.pdf herunterladen.

Um weitere Information über den Vortrag zu erhalten, kontaktieren Sie bitte den Autor:

Adresse des Verfassers:

Dr.-Ing. Dipl.-Geogr. Matthias Kühle-Weidemeier
Wasteconsult international
Robert-Koch-Str. 48 b
D-30853 Langenhagen
Telefon +49 511 23 59 383
Email tagung@wasteconsult.de
Website: www.wasteconsult.de

Relevance, Targets and Technical Concepts of Mechanical-Biological Treatment in Various Countries

Wolfgang Müller and Anke Bockreis

University of Innsbruck

Abstract

Different concepts of mechanical-biological waste treatment are explained alongside with parameters to assess the performance of the systems with respect to regulatory requirements

Inhaltsangabe

Der Beitrag beschreibt verschiedene Konzepte der mechanisch-biologischen Abfallbehandlung sowie die Bewertung im Hinblick auf gesetzliche Zielvorgaben

Keywords

Aerobic stabilisation; Anaerobic digestion; Biological drying; respiration activity,

1 Introduction

Mechanical Biological Treatment (MBT) is a generic term for the integration of a number of waste management processes such as materials recovery facilities (MRF), refuse derived fuel (RDF) production, mechanical separation, sorting, composting and pasteurising. In order to minimise environmental nuisance for odour, fly and noise nuisance, these facilities are required to be housed within a building and normally under negative pressure. The use of bio-filters is also required to treat any odour problems.

The MBT process is designed to take residual or black bin waste and process it so that valuable recyclable materials can be separated out and the biomass or “compostable” element is separated out and processed through an In Vessel Composting (IVC) or an Anaerobic Digestion (AD) system.

2 MBT Systems

MBT is often referred to 3 main types of MBT system that can process the organic element of the waste stream:

- Aerobic stabilisation
- Anaerobic digestion
- Biological drying

What is common to all types is that there is a front end mechanical processing of the waste. This will be through some form of shredding and additional treatment to separate the materials from organic to non organic materials. The differences are in the type of the biological treatment (aerobic or anaerobic) and the treatment target (stabilisation or drying to foster subsequent separation stages).

2.1 Aerobic Stabilisation

The key target of this approach is to stabilise the waste and hence reduce the amount of biodegradable municipal waste (BMW) going to landfill. This is based on the requirements of the EU landfill directive and was implemented in different EU member states with different methods to determine the reduction of the biodegradables content in the waste (see section 3).

For the purpose of BMW diversion from landfill an MBT plant could simply compost all waste without any separation and landfill the residues. This might be a first stage of the development of a waste treatment system and would help to meet current legal requirements in terms of BMW diversion. It would be a straightforward solution which would not rely on markets for products from the process like RDF etc.

The more common approach is shown in figure 1 to combine the biological treatment with mechanical processing steps to separate products from the waste prior or/and after the biological treatment. The configuration can comprise a wide range of technologies and a wide range of products. This is reflected in the mass flow diagram which shows a fairly high range for the products that can be separated.

A common approach is the front-end separation of a RDF fraction which will be utilised in industrial processes like cement kilns, coal power plants, purpose built combustion facilities (e.g. to feed the energy to an industrial process) or in a mass burn incineration.

In case of a front end separation the material left after the separation stage is enriched with easily degradable components like kitchen waste and “dirty” paper, like tissues, which are not suitable for recycling. This material is then treated through an aerobic process (composting) where aerobic (oxygen breathing) bacteria and other micro-organisms digest organic wastes. In the process the bacteria grow and reproduce by using some of the energy and material in the organic matter. This process yields carbon dioxide and heat. The time taken for composting is usually determined by the rate at which the feed can be hydrolysed. Higher temperatures accelerate the hydrolysis stage, but the number of micro-organisms that can survive these higher temperatures is reduced.

The continuation of the composting process requires the addition of water. Water is needed to hydrolyse the feeds and progress the other biochemical reactions. The stabilised waste can then be landfilled. An alternative discussed in some countries in Europe is a compost like product that can be produced through a post-refinement stage. At this stage other material, like RDF or aggregates can be separated as well if a market is available and the process is economically viable.

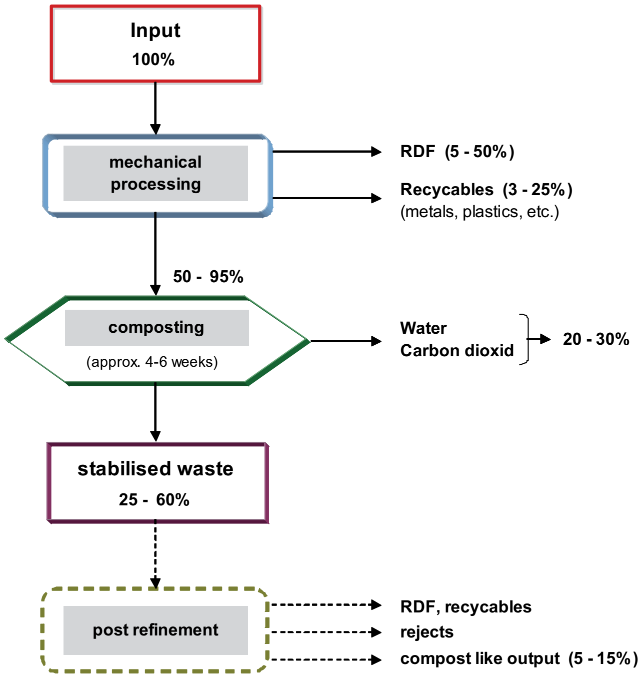


Figure 1: MBT for stabilisation

2.2 MBT with Anaerobic Digestion

Anaerobic Digestion is a biochemical process which takes place in a vessel in the absence of oxygen and results mainly in the formation of a carbon dioxide and methane gas mixture known as "biogas"

Anaerobic Digestion is very often referred to as a separate MBT approach. This might be justifiable for the aspect that renewable energy is produced. If looking at with respect to legal requirements for waste treatment AD is just one component of a MBT strategy. The most common approach where AD is involved is through the stabilisation approach. AD in such a context would then be used as the first stage of the biological treatment which focuses on the anaerobically easily degradable waste components. The "biogas" produced during digestion is used to provide internal electrical power generation and heating requirements. Surplus electrical power (and heat) can be sold as renewable energy.

The digestate is usually dewatered and treated aerobically (composted; often referred to as "maturation"). The purpose of the second stage is to further stabilise the waste, reduce the mass and reduce the odour of the material.

Figure 2 shows such an approach. The flow diagram looks very similar to the "stabilisation" approach. There is a significant impact in terms of process technology involved and the invest costs of such an approach are higher. On the other hand revenues from the biogas utilisation via CHP can be generated which might offset the higher investment costs.

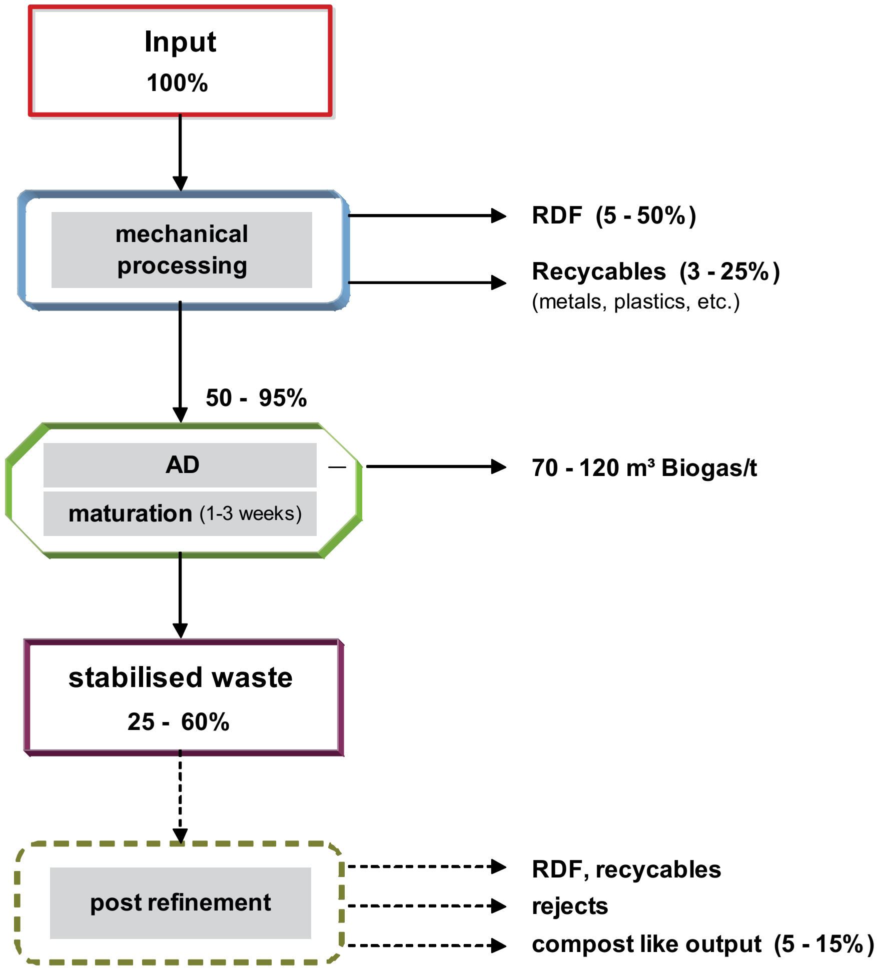


Figure 2: MBT with Anaerobic Digestion

An alternative to the approach of dewatering and further composting is the direct use of the digestate as a liquid fertiliser/soil conditioner. This is subject to meeting any legal requirements and conditions imposed. The key impact on the plant design will be in terms of achieving the sanitisation requirements imposed by the animal by-products legislation.

Figure 3 below shows the development of anaerobic digestion facilities in Europe for both biowaste (source separated kitchen and garden waste) and residual waste through

MBT. It can be seen that anaerobic digestion of residual waste has rapidly increased over the last 5 – 7 years.

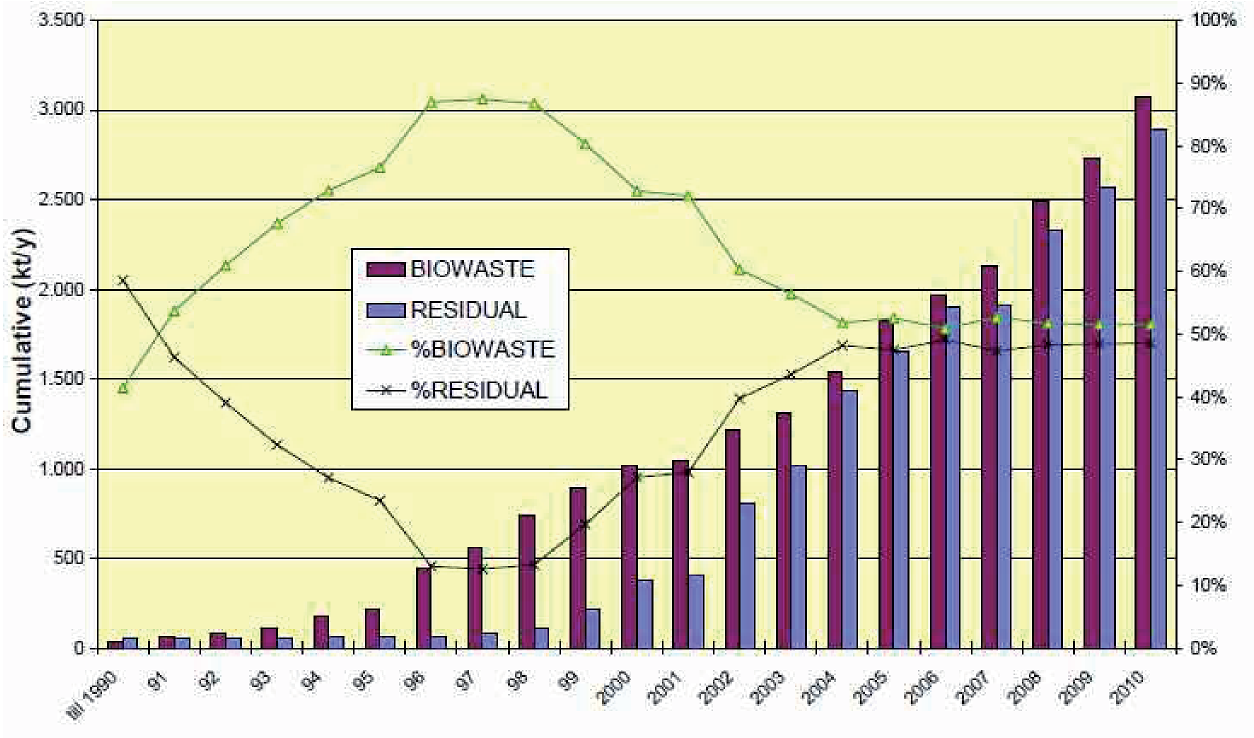


Figure 3: Development of MBT plants in Europe (Mattheeuws, 2010)

2.3 Biological Drying

"Biological Drying" is the other fundamentally different MBT approach. The scope of this approach is to make use of the energy content of the waste by means of the production of a (high quality) RDF which is the used for energy production.

The most well-known technology suppliers/developers of this approach are "Herhof" (Germany, now owned by the Greek civil construction company "Helector") and "Ecodeco (Italy)"

The main purpose of the biological part of the process is to produce the heat which is used to drive of the moisture from the waste in order to enable easier and more efficient mechanical separation. Hence the mechanical separation is performed after the biological treatment.

The waste is shredded and placed in enclosed bio-drying boxes for a pre determined period. Air is forced through the waste creating optimum conditions for microbial respiration, and hence drying of the waste. The warm air is extracted from the boxes and is passed over a heat exchanger. Air passed through the boxes is re-circulated, which is significantly reducing the volume of exhaust air.

Often associated with the biological drying approach is the production of a high quality RDF which can be burnt in industrial plants like cement kilns for a lower price than in a combustion facility or mass burn incineration.

Another benefit of the drying of the waste is the increase of the calorific value of the material. There are also a few examples of existing facilities where no biological system is used for the drying process but a physical drying is used instead using gas or oil to produce the heat for evaporating the moisture from the waste.

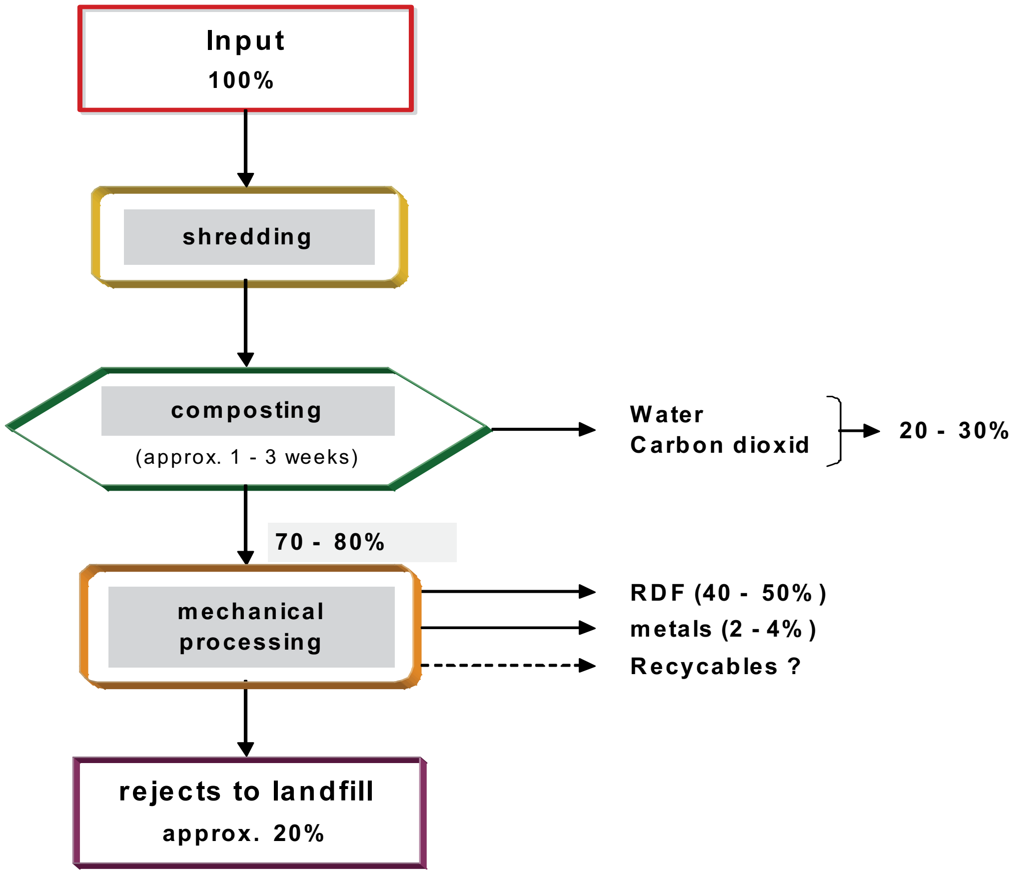


Figure 4: MBT – biological drying

3 Parameters to assess biodegradability

3.1 Background

The EU landfill directive requires a reduction of 65% in the amount of biodegradable waste which is landfilled (Art. 5). The main purpose of this requirement is a reduction in the adverse effect to the environment of the landfilling of untreated waste. The major problem with organic waste is that it degrades to the greenhouse gas methane in a landfill. Methane is a greenhouse gas that is 26 times more potent than Carbon Dioxide. Even with a state of the art landfill design incorporating methane capture, substantial amounts of methane will still escape to the atmosphere and contribute to global warming.

In Norway the government suggests the introduction of a threshold for biodegradable content in waste going to a landfill, defined by 10 % total organic carbon (TOC) or loss of ignition (LOI).

3.2 Parameters in different countries

While this general context is clear, the EU landfill directive does not give a clear guidance as to how to determine what is biodegradable. As methane is produced in landfills by a biological process, a suitable parameter to determine “organic waste” has to be established to measure it. In extensive research, predominantly in Germany, but also in Austria, Italy and other countries it has been demonstrated that several parameters may be used to determine the biodegradable content of waste. However, different biological tests measuring the aerobic (respiration) or anaerobic (gas formation) decomposition have been selected in individual countries and implemented in national regulations or guidelines (see Table 1).

Whilst in other European countries parameters to assess the organic content in waste have not yet been implemented in the national regulations, the parameters and limits proposed in the 2nd draft EU biowaste directive 2001 are often used on a regional level.

The limits applied in Germany and Austria are somewhat stricter than in the 2nd draft of the EU biowaste directive. This is because the limits have been derived from an existing technical guideline (“TASI”; TA Siedlungsabfall), where limits for LOI (<5%) and TOC (<3%) were specified. In a court case it has been successfully demonstrated that the 3% TOC could be fully degradable organic material like sugar. From one tonne of waste with a 3% sugar content about 55 m³ of landfill gas could be produced in a landfill. This sets the benchmark for stabilised waste. It can then be demonstrated from repeated landfill simulation tests with biologically stabilised waste that waste with a respiration rate AT4 of 5 mg O_2/g dm shows a gas potential of usually less than 55 m³ landfill gas. Furthermore the gas potential of waste with an AT4 <5 mg O2/g dm is reduced by over 90% compared to fresh, untreated waste. If assuming that the 65% reduction requirement in the EU landfill directive refers to a reduction of landfill gas production, then the limits set in Germany and Austria exceed the EU landfill directive requirements. A 65% reduction of the landfill gas production corresponds more closely with the limits set in the 2nd draft EU biowaste directive.

Table 1 : Parameters to assess MBT in different countries

Country	Parameter	Limits	Method/regulation
Germany	Static respiration index "AT4" Gas formation test "GB21"	< 5 mg O_2/g dm < 20 Nl/kg dm	Fixed in German landfill ordinance[[1]]
Austria	Static respiration index "AT4" Gas formation test "GB21" or "GS21"	< 7 mg/g O_2 dm < 20 Nl/kg dm	Fixed in Austrian landfill ordinance [2]
Italy	Dynamic respiration index (Adani method) DRI [[3]]	< 1,000 mg O_2/(kg VS x h)	Regional require-ments
England and Wales	Change of biodegradability in from beginning to end of a treatment process, biode-gradability parameters: - Biological methane potential in 100 days "BM100" - Dynamic respiration index "DR4"	No limits but de-termination of the reduction of the gas potential in a treatment plant	UK Envrionment Agency guidance[[4]]
Scotland	Change of organic content from beginning to end of a treatment process Assessment parameter pro-posed: - LOI (loss on ignition) Alternative approaches are possible	Equivalent to Eng-land/Wales	Scottish guidance [[5]]
EU	Static respiration index "AT4" Dynamic respiration index (Adani method) DRI	< 10 mg O_2/g dm < 1,000 mg O_2/(kg VS x h)	2nd draft EU bio-waste directive 2001, withdrawn [[6]]

1 German Ministry of Environment, 2001: Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and on Biological Waste-Treatment Facilities; 20 February 2001; http://www.bmu.de/files/pdfs/allgemein/application/pdf/ablagerungsverordnung.pdf

2 Verordnung des Bundesministers für Umwelt über die Ablagerung von Abfällen (Deponieverordnung); modified 23.01.2004 StF: BGBl. Nr. 49/2004; http://ris1.bka.gv.at/authentic/index.aspx?page=doc&docnr=1

3 Riffutti e combustibili rcavati da rifiuti, Determinazione della stabiliata biologica mediante l´indeice di Respirazione Dinamico (IRD); UNI/TS 11184, ottobre 2006; www.uni.com

4 Environment Agency (2005): Guidance on monitoring MBT and other pre-treatment processes for the landfill allowances schemes (England and Wales); http://www.environment-agency.gov.uk/commondata/acrobat/the_final_outputs_1096040.pdf

5 Landfill Allowance Scheme (Scotland) Regulations 2005: SEPA Guidance on Operational Procedures; http://www.scotland.gov.uk/Publications/2005/06/08111144/11463

6 EUROPEAN COMMISSION; Working document; Biological Treatment of Biowaste, 2nd draft; http://www.compost.it/www/pubblicazioni_on_line/biod.pdf

4 MBT Capacity in Europe

MBT is well established in many countries in Europe with major capacity in Italy (about 14 Mio t), Germany (5 Mio to); Spain (3 – 4 Mio t) and Austria (1 Mio t). Many other countries are introducing MBT and substantial plants are under development or proposed, for example, in the UK and France as well as in Eastern European countries .

Whilst in Germany, Austria and Italy the purpose of the biological process is to stabilise the waste prior to landfill, in other countries the production of low grade compost is a part of the MBT concept. Because of the higher content of pollutants compared to compost produced from source separated organic (kitchen and garden waste), the use of such compost can be very controversial. The major country to promote the use of mixed waste compost is France, but it is being discussed and used in several other countries.

4.1 Germany and Austria

The situation of MBT in Germany and Austria is laid down in other presentations.

4.2 Italien

Italy is the country with the highest number of MBT and the highest capacity.

Number of MBT:	133
Available capacity:	14 Mio Mg/a
Actual amount of waste treated in MBT:	5,6 Mio Mg/a

The difference between available capacity and actually used capactity is due to the fact that several plants are under revision or modifications are carried out. Another reason is that some plants are now treating source separated organic kitchen and garden waste (“biowaste”). In 2007 3.5 Mio Mg/a biowaste had been collected and treated.

With respect to the MBT concept the stabilisation approach (see Figure 1) is prevailing but more recently the biological drying became more relevant and some plants are modified to biological drying plants.

Similar to Germany and Austria the stabilized organics is predominantly landfilled. A land use of this material as “dirty compost” is seen as tabu in most cases and would require a special permit. The only relevant option for the use of this material are one-time application for recultivation purposes.

The current government favours waste incineration but there are reservation in the population and protests against the installations of incineration plants.

Therefore MBT is still seen as a relevant treatment option. The main reasons are that MBT it is capable to provide to the targets of the EU landfill directive and can be implemented quicker than incineration. Furthermore. it is seen as a flexible technology which can also be used for the treatment of biowaste.

4.3 Spain

MBT is also prevalent in Spain with a focus on anaerobic digestion plants (13).

Table 2: requirements on the quality of mixed waste compost („Real Decreto 824/2005“)

Organic content	> 35 %
Water content	30 – 40 %
C/N ratio	< 20
stones > 5 mm	< 5 %
Other contraries (glas, plastics)	< 3 %
Salmonella (in 25 g compost)	0
E. coli	< 1.000

Table 3: Vergärungsanlagen in Spanien; Stand 2006 (Krack, 2008)

Localisation	capacity (Mg/a)	MSW Mg/a)	waste (Mg/a)	Beginning of operation	Technologie
Barcelona -1 (Zona Franca)	600.000	120.000		2002	Linde (Humide)
Barcelona -2 (Montcada)	240.000	25.000	70.000	2005	Valorga
Barcelona -3 (Sant Adría Besós)		90.000		>2006	Ros Roca (Humide)
Barcelona		25.000			Dranco
Logroño	148.000	175.000		2005	Kompogas
Leon (San Román de la Vega)	195.000	50.000		2005	HAASE (Humide)
Valladolid	200.000	15.000		2002	Linde (Sec)
Coruña (Nostián)	185.000	120.000		2001	Valorga
Palma Mallorca (Can Canut)			20.000	2003	Ros Roca (Humide)
Madrid (Pinto)	140.000	75.000		Arrèté	Linde (Humide)
Madrid (La Paloma)	230.000			En construction	Valorga
Madrid (Las Dehesas)		100.000		En construction	Valorga
Avila	80.000	36.500		2003	Ros Roca (Humide)
Gran Canaria	80.000	36.500		2004	Ros Roca
Navarra (Tudela)	55.000	28.000		>2006	Ros Roca
Alicante	195.000	52.000		En construction	Ros Roca
Burgos		40.000		>2006	Linde (Humide)
Zaragoza		60.000		En construction	Valorga
Salamanca		50.000		En construction	HAASE
Vitoria	120.000	25.000		>2006	Dranco (OWS)
Gran Canaria (Salto del Negro)	150.000	60.000		En construction	Valorga
Cadiz (Bahía de Cadiz)		115.000		Arrèté	Valorga
	2.618.000	1.298.000			

Source separation of biowaste is only in Catalonia. In Barcelona 5 so-called “Ecoparcs“ have been build which show the flexibility of MBT. With increasing amount of source separated biowaste treatment capacity of the MBT is changed from MBT to biowaste-treatment.

In all other parts of Spain, agricultural use of the compost-like output (“CLO”) from MBT is possible. The requirements for compost from mixed waste are specified in „Real Decreto 824/2005“. According to available data only 5 to max. 10 % of the Input to MBT are utilised as compost.

4.4 France

France is very sceptical with respect to source separation of biowaste but favours compost production from mixed waste. There view is that compost with low content of contaminants can be achieved by using appropriate separation technologies and source separation of biowaste is therefore dispensable. Accordingly there are numerous plants in France that produce compost from mixed waste. But there are also a similar number of plants using the same technology where the stabilized organics is landfilled. It can be assumed that this is because of the lack of market for this low quality compost. Table 4 lists the plants for MSW and biowaste treatment.

Table 4: MBT and biowaste treatment plants in France (Fruteau, 2010)

		number	capacity (Mg/a)
MBT with compost production			
composting	in operation	12	430.000
	under construction	11	300.000
	planning stage	7	300.000
anaerobic digestion with composting	in operation	3	270.000
	under construction	5	750.000
	planning stage	6	800.000
MBT without compost production			
composting	in operation	4	180.000
	under construction		
	planning stage		
anaerobic digestion with composting	in operation	1	70.000
	under construction	0	
	planning stage	1	80.000
sum MBT	in operation	20	950.000
	under construction	16	1.050.000
	planning stage	14	1.180.000
Biowaste treatment			
composting	in operation	0	
	under construction	?	
	planning stage	?	
anaerobic digestion with composting	in operation	3	150.000
	under construction	1	40.000
	planning stage	?	

4.5 Portugal

Table 5 lists the plants for biological waste treatment in Portugal which are in operation or in planning stage.

Table 5: vorhandene und geplante Behandlungsanlagen in Portugal (Baptista, 2010)

	2009	2016 (14 plants in tangible planning stage)
Total number of plants for biological waste treatment	11	25
Plants for biowaste treatment	5 (4 composting + 1 AD)	10 (6 composting + 4 AD)
MBT plants	5 (composting)	9 (7 composting + 2 AD)
Combination plants (MBT and bio-waste treatment in different parts of the same plant)*	1 (AD + composting)	6 (AD + composting)
Treatment capacity of the plants	- all plants including MBT produce compost for agricultural use. - 2 MBT produce RDF	- the agricultural use of CLO depends on future legislations - an increase of RDF production to 400,000 Mg/a by 2016 is envisaged.
Total capacity	600 000 Mg/a	1.7 Mio

The figures in the represent the measures specified by the portugese government to meet the requirements of the EU landfill directive. To incentivize the implementation of the plants grants for 75 % of the invest costs are offered.

In 2003 MBT did not play a role in the national waste strategy. It focused on the implementation of source separation of biowaste. As this turned out to be difficult a new strategy was developed in 2007. In this new strategy MBT and RDF production plays a bigger role.

At the moment there are not guideline for the utilisation of compost. The CLO of all MBT is currently used in agriculture and vineyards. A corresponding guideline or regulation is announced by the government for several but it is remains open whether and when this law will be finalized.

4.6 Sweden, Norway

Because of the strict requirements (TOC solids < 10 %) there are currently no relevant activities with respect to MBT in Sweden and Norway.

4.7 United Kingdom

In the UK there are currently only a few MBT plants in operation but some major projects are currently und construction or commissioning (see Table 6). In addition at least 10 – 15 further projects have already received a commitment for financing grants by the government.

Table 6: MBA pkants in UK (DEFRA, 2009)

site	**Number/capacity**	**Beginning of operation**	**Technology supplier/ technology**
East London Waste Authority, Frog Island	2 MBT á 180,000 Mg/a	2006/7	Biodrying (Ecodeco)
Dorset	50.000 Mg/a	2003	New Earth windrow composting in closed hall
Western Isles MBT facility	21.000 Mg/a (MSW + bio-waste)	2008	Linde-dry digestion + HotRot composting
Lancashire	2 MBT á 175.000 Mg/a	2010/11	ISKA-Percolation + SCT composting
Greater Manchester	5 MBT´s: 550.000 Mg/a	2011	2 x BTA/Enpure 2 x Haase + AMB
Cambridge/Donarbon	1 MBT 240.000 Mg/a	2010	Table windrow with gantry turning system (KELAG-VKW)
Falkirk (Scotland)	1 MBT 100.000 Mg/a	??	ArrowBio /wet digestion
Wakefield	175.000 Mg	2010	VT Engineering autoclaving and AD
Essex County Council (with Southend-on-Sea Council)	1 MBT with AD 351,000 Mg/a, of which 148,000 Mg/a input AD	2013	Not fixed yet
South London Waste Partnership (SLWP)	2 MBT á 106,500 Mg/a 1 RDF combustion plant Kraftwerk 106,500 Mg/a	2016	Not fixed yet

In terms of MBT concepts autoclaving is widely promoted and discussed in the UK alongside to the other approaches explained in this paper. The idea of this approach is that the waste will be both sanitized and disaggregated by means of pressure and heat (autoclaving). The autocalved waste should then be better accessible to mechanical separation to produce clean recycling materials. A further product is a fibre fraction consisting of organic and paper which might be used for material recyling (e.g. insulation boards). Weiterhin wird in den meisten Konzepten eine Faserfraktion, die sich im wesentlichen aus Organik und Papierbestandteil zusammensetzt, gewonnen. Diese Faserfraktion wird teilweise als Rohstoff für eine stoffliche Verwertung gesehen (z.B. Faserdämmplatten). Another option is the utilisation of the organic fibre fraction in an anaerobic digestion plant. Currently one large-scale MBT with autoclaving and anaerobic digestion is under construction.

4.8 MBT worldwide

MBT is also discussed outside Europe.

MBT concepts are also considered for countries with no or less developed waste management using low-budget solutions. Hence MBT can provide to gradually develop a regular waste management infrastructure..

But also in other industry countries outside Europe MBT is considered but as there is no EU landfill directive or equivalent in place the concepts typically focus more on recyling and RDF production rather than stabilisation of the organic fraction prior to landfilling. This is the case e.g. for South Korea where MBT is heavily promoted by the government. Because of high requirements of the RDF (heat value, moisture content) sophisticated plant concepts are required.

5 Summary - key advantages of MBT

MBT is often perceived as a “greener” solution for the treatment of waste when compared with mass burn incineration. As a consequence, it is easier to obtain planning permission than it is for incineration.

MBT is based on existing and well known technology (mechanical treatment stages, composting)

MBT is a versatile and flexible concept which can be adapted to a wide range of conditions.

MBT can be economically viable for low waste quantities and be part of a wider waste infrastructure where, for example, several smaller plants which prepare the waste are combined with a bigger unit for producing fuel or recycled materials. This saves transport costs and adheres to the proximity principle.

Smaller scale plants built for a local community are often more acceptable to the public than bigger plants for a wider collection area. Hence planning consent can often be more easily achieved for such plants

MBT can be developed quicker than alternative treatment technologies and may be the quickest option for local authorities to legal requirement.

MBT is a fairly flexible system approach which can be adjusted to local conditions and treatment targets, it can be developed gradually through a /modular system and also cope with a wide range of waste quantities and waste types.

MBT can be developed to optimise the energy yield from waste, including the production of renewable energy via AD and heat and power via RDF combustion. With MBT a more uniform and homogenous fuel (RDF) can be produced which can be used more flexible and hence increase energy efficiency. As the energy production is decoupled from the waste treatment process the energy might be produced where it is needed and hence the overall efficiency is higher compared with a mass burn incineration.

MBT reduces the volume of residual waste due to the breakdown of the waste. This minimises the amount of landfill and therefore the landfill space taken for any residual waste, which maximises landfill resource.

Hazardous waste contaminants, such as batteries, solvents, paints, fluorescent light bulbs etc, can be separated through an MBT plant and it is a requirement that hazardous waste is not disposed of through municipal landfill sites and it is essential that it does not go through into the organic waste stream.

6 References

Mattheeuws, B	2010	ANAEROBIC DIGESTION - State of the art 2010 In: Lasaridi, Katia; Manios, Thrassyvoulos; Bidlingmair, Werner; Abeliotis, Konstantinos; De Bartoldi, Marco; Diaz, F.Luis; Stentiford, I. Edward: Organic Resources in the Carbon Economy. Proceedings of the 7th International Conference ORBIT 2010. Thessaloniki: Grafima, ISBN 978-960-6865-28-2
Krack, D.	2008	RETOUR D'EXPERIENCE PÖYRY "; presentation at Pollutec 2008 Lyon, not published
DEFRA	2009	http://www.defra.gov.uk/environment/waste/localauth/funding/pfi/projects.htm
Baptista, M.	2010	Verbal information
Fruteau, N.	2010	Verbal information

Author's addresses:

Dr.-Ing. Wolfgang Müller/Prof. Anke Bockreis
Universität Innsbruck
Institut für Infrastruktur
Lehrstuhl für Abfallbehandlung und Ressourcenmanagement/*Waste and Resource Management*
Technikerstraße 13
A-6020 Innsbruck
Telephone: (+43)512 507-6926
Fax: (+43)512 507-2911
E-Mail: Wolfgang.Mueller@uibk.ac.at
Web: http://www.uibk.ac.at/umwelttechnik

A Comparison of two Biological Treatment Processes for Residual Waste Management

Tony Yates

SLR Consulting Limited, Bath, England

Abstract

The paper presents a technology comparison of MBT Anaerobic Digestion and MBT biodrying for treatment of residual municipal waste.

Specifically the paper enables a strategic decision to be made on the optimal deliverable residual waste management solution for municipal waste contracts where the generation of an SRF, either as an element of the overall solution or as a contract output is required.

Both technologies have been proposed as precursors for SRF production in recent UK municipal waste management contracts.

The most important factors in the evaluation of municipal waste tenders are project cost followed by landfill diversion and deliverability. The analysis indicates that the AD solution offers the potential to achieve the highest landfill diversion performance however they tend to exhibit higher lifecycle project costs than biodrying solutions. Furthermore AD solutions suffer against deliverability primarily because of the lower calorific content of the SRF and the implications that this may have on securing long term markets.

MBT biodrying solutions do not exhibit the highest landfill diversion performance and the quality of recyclates can be problematic due to contamination issues. However where a concept can be developed based on only metals and dense plastics recycling and where the fines fraction can be incorporated with the SRF, then MBT biodrying would appear to offer a deliverable solution exhibiting a competitive cost and offering a high level of deliverability.

The paper concludes with the Author's overview of the preferred technology against a given range of parameters.

Keywords: MBT Biodrying, MBT Anaerobic Digestion, Life Cycle, Secondary Recovered Fuel, financial comparison

1 Introduction

Technologies involving the mechanical and biological treatment of waste, either for SRF production or as a precursor to thermal treatment are increasingly being specified by municipal authorities as a preferred method of waste treatment for municipal waste management contracts in thE UK.

Renewable energy potential and carbon footprint are also important factors and for this reason MBT solutions involving anaerobic treatment are sometimes specified/chosen as alternatives to the more conventional aerobic approach.

The primary purpose of the review is to compare two distinct biological technologies for treatment of residual municipal waste namely MBT biodrying and MBT anaerobic digestion.

The comparison is limited to these two technology forms although it is recognised by the Author that solutions involving in-vessel composting technology are also being specified by a number of market operators.

Whilst MBT and AD technologies can be configured to provide a range of outputs this review concentrates on the generation of secondary recovered fuel (SRF)

1.1 MBT – Biodrying

Biodrying technologies, in general, are based on a combination of biological treatment and dry mechanical separation processes, designed to separate the waste into recyclates, SRF and a non-recoverable landfill fraction according to the principal design intent.

Generally the quantity and quality of materials recovered from MBT for recycling is low. Although broadly similar, the actual design configuration of MBT plants can vary considerably, depending on the specific output(s) required. The general MBT concept is illustrated in Figure 1.

Key features of the technology are as follows:

- Technology relies on the drying of waste using heat generated by biological degradation
- Biogenic losses are in the form of CO_2 (from aerobic degradation) and water vapour
- Incoming waste undergoes initial mechanical separation to remove any large cardboard / plastic that can be directly processed into SRF without biodrying

- All waste is subjected to aerobic degradation over a period of 15 - 20 days utilising a combination of forced aeration and/or mechanical turning
- After biodrying all waste is subjected to mechanical processing to derive recyclates, SRF and up to two landfill fractions (fines and heavies)
- The landfill fraction quantity and composition is dependent on the required characteristics of the SRF
- Removal of moisture raises the net CV of the SRF. Losses are typically 15-25% depending on composition

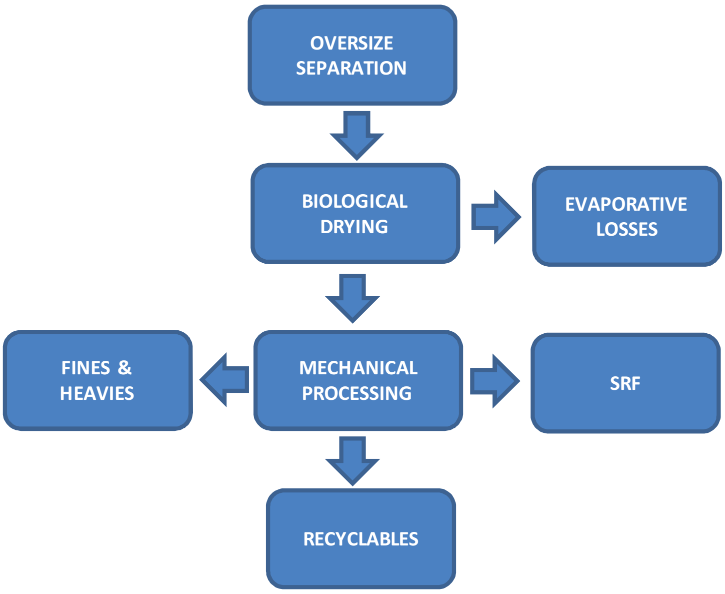


Figure 1: MBT- Biodrying Concept

1.2 MBT – Anaerobic Digestion

This technology utilises anaerobic biological treatment to biostabilise the waste and to create a methane rich biogas that can be converted into electrical energy and/or heat. The technology concept is illustrated in Figure 2.

Key features of the technology are as follows:

- Mechanical Separation into organic and non-organic fractions with the organic fraction consigned as feedstock to digestion plant following additional mechanical separation prior to AD to remove lights and heavy fractions
- Heavy fraction is generally consigned to landfill although further processing could be undertaken. Light fraction contains mainly paper, card and plastic and can therefore be combined with SRF

- Biogenic losses are in the form of biogas generation which is converted to exportable energy via CHP engines
- Resultant organics exit the digester as whole digestate at circa 6-9% solids concentration , and subsequently dewatered to circa 35% solids concentration

Management of solid digestate can follow a number of routes either disposal to landfill. beneficial use as a Compost Like Output (CLO), subject to permit restrictions or recombined with the SRF as a fuel. In the case of the latter use the digestate will require further drying to raise the CV. Waste heat can be provided from the AD gas engines or alternatively, where available, from an onsite SRF energy plant; this may result in a loss of electrical power.

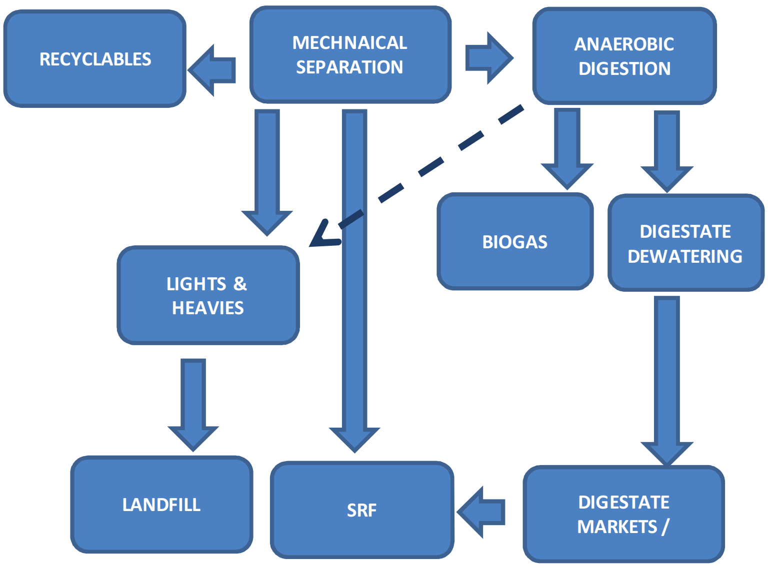


Figure 2 MBT-AD Concept

2 Quantitative Comparison

2.1 Mass Balances

Whilst the review concentrates on the two main technology types a number of sub scenarios have been modelled, to investigate the implications of different management routes for the process outputs, as follows.

- Scenario MBT (1): SRF excluding fine fraction
- Scenario MBT (2): SRF including fine fraction
- Scenario AD (1): Dewatered digestate to landfill
- Scenario AD (2): Dewatered digestate to SRF

- Scenario AD (3): Dried digestate to SRF

The models do not assume onsite management of SRF; instead the financial model a value is assigned to the SRF to reflect the likely disposal cost or gate fee charged by the receiving energy generation facility.

Table 1 Mass Balance for MBT-Biodrying

	Input	To Biostab	Losses	SRF	Fines	Heavies	Recycle (Metals)
Total %	100.0	89.8	24.8	35.7	14.3	20.5	3.2
BMW (%)	64.7	58.6	21.8	19.7	11.9	11.3	0.0

Table 2 Mass Balance for MBT-AD

		MT Separation			Anaerobic Digestion			
	Input to MT	Fines	Recy-cled	To SRF	Light Frac-tion	Bio-gas	Heavi es	Diges tate
Total %	100.0	45.9	8.0	46.1	4.9	11.5	7.2	36.2
BMW (%)	64.7	38.1	0.0	26.6	3.8	11.5	0.0	22.8

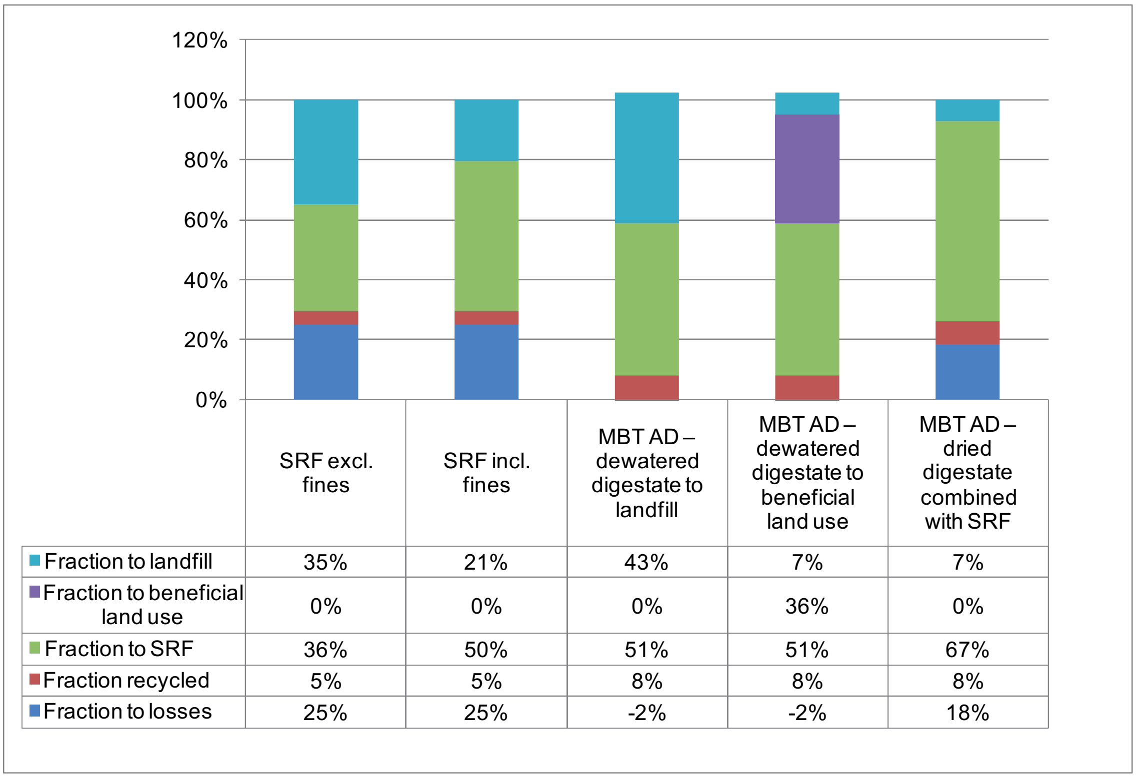


Figure 3 Scenario Mass Balance Performance

The results indicate that Scenario AD(3) – "Dried Digestate to SRF" in which digestate is thermally dried and combined with SRF achieves the highest landfill diversion performance. Scenario AD (1) – "Digestate to Landfill" in which dewatered digestate is consigned to landfill results in the lowest landfill diversion performance. Scenario AD (1) also results in the highest proportion of input BMW consigned to landfill.

Although both AD1 - "Digestate to Landfill" and AD2 – "Digestate to Beneficial Land Use" result in losses associated with biogas generation the net impact of water addition in the AD process is an overall increase in weight.

2.1.1 SRF Characteristics

Specific SRF characteristics calculated for each scenario are set out in Table 3.

Table 3: Calculated SRF Parameters

	MBT(1)	MBT(2)	AD(1)	AD(2)	AD(3)
NCV (MJ/kg)	16.4	14.8	11.6	11.6	10.8
Moisture content	15%	21%	29.0%	29.0%	29.2%
Ash content	23%	25%	24%	24%	37%
Biomass contribution to NCV	40%	45%	55%	55%	57%
Biomass Energy Content (MJ/kg)	6.53	6.62	6.29	6.29	6.60
SRF Energy content per kg of input waste (MJ)	5.85	7.40	5.93	5.93	7.22

The physical parameters of the SRF derived from the AD technologies (specifically CV and ash content) are at the lower end of what would be considered acceptable for treatment in an advanced thermal technology such as gasification. Furthermore this SRF may not be suitable as feedstock to other SRF consumers such as cement kilns or in co-firing installations, potentially limiting the markets for this material to a dedicated thermal treatment process based on combustion or gasification technology.

Despite the lower biomass percentage content there are only minor differences in the overall biomass energy content, being the proportion of fuel content that would qualify for Renewable Obligation Certificates (ROCs). MBT solutions perform marginally better due to the lower losses of biogenic carbon in the biological treatment process.

Finally, MBT (2) is marginally more efficient with respect to conversion of waste calorific value into SRF calorific value.

2.1.2 Electrical Energy Balance

The review has briefly considered the energy balance of the difference scenarios, again based upon the data provided by the technology suppliers. The energy balance considers the consumption and generation of electricity in operating the plant only.

Table 4 Electrical Energy Balance (based on waste input)

Energy (kWh/t)	**MBT(1)**	**MBT(2)**	**AD(1)**	**AD(2)**	**AD(3)**
Energy generated	0	0	80	80	80
Energy consumption	31	31	39	39	113
Net energy balance	-31	-31	41	41	-33

As would be expected the MBT solutions are net energy consumers due mainly to the energy required for aeration and ventilation, whilst the AD plants are net energy generators except for AD3 where energy is required to drive the SRF drying process. Without another form of energy on site (e.g. SRF utilisation) heat for the dryers would need to be provided by the combustion of biogas with a consequent loss of electrical generation. The resultant impact is that Scenario AD3 is a net electrical energy consumer. In reality it may be possible to reduce energy consumption through detailed balancing and cascading of heat however ultimately the solution will remain a net energy consumer.

Table 5 sets out net energy flow including utilisation of SRF and indicates that Option MBT(2) yields the highest electrical output due mainly to the increased net CV as a consequence of reduced moisture content. .

Table 5 Life Cycle Energy Balance (based on waste input)

Energy flow (kWh/t)	**MBT(1)**	**MBT(2)**	**AD(1)**	**AD(2)**	**AD(3)**
SRF electrical output,	324.8	411.2	329.4	329.4	401.0
Net Energy balance	-30.8	-30.8	40.9	40.9	-32.9
Net electrical output	294.0	380.3	370.4	370.4	368.1

3 Financial Comparison

The financial analysis uses data supplied by the technology suppliers to compare the costs of the five configurations identified above, on a total and NPV basis, over a 25yr period. The analysis is based upon a 200,000 tpa facility. This should not be considered to be a complete financial assessment as it excludes certain elements such as cost of finance and bidding costs.

Table 6 Financial Assumptions

	Mechanical treatment	Anaerobic Digestion	MBT
CAPEX (£/t capacity)	145	362	224
CAPEX (£,000,000)	34.7	52.8	53.7
Staff Costs (£/tpa)	8.3	2.0	5.0
OPEX costs (£/tpa)	11.8		6.0
Life Cycle Costs (£/t)	3.5	8.7	2.4
INCOME STREAMS			
Energy	£ 35.00		per MWh
ROCS & LECS	£ 40.00		per MWh
Electricity Purchase Price	£ 65.00		per MWh
Disposal to Landfill	£ 72.00		per tonne
SRF Gate Fee	£ 20.00		per tonne
Digestate to Land	£ 20.00		per tonne

Lifetime project costs are presented for a 200,000 tpa facility including error bars (set at 25%) to account for uncertainty in cost data. The following conclusions may be drawn from the analysis:

- All AD scenarios are more expensive over the project lifetime than the MBT-biostabilisation scenarios
- Scenario MBT2, whereby fines are combined with the SRF to reduce the quantity of material landfilled exhibits the lowest overall project cost
- The highest project cost is exhibited by Scenario MBT_AD1 due primarily to the cost of disposing of digestate to landfill. Based on this fact it is not sensible to adopt an AD solution if no guaranteed outlet for the digestate can be secured
- By adding error ranges to the 4 remaining scenarios an overlap of project costs occurs. Consequently it becomes less certain as to which scenario offers the most cost effective solution although Scenario MBT2 still remains the most cost effective solution

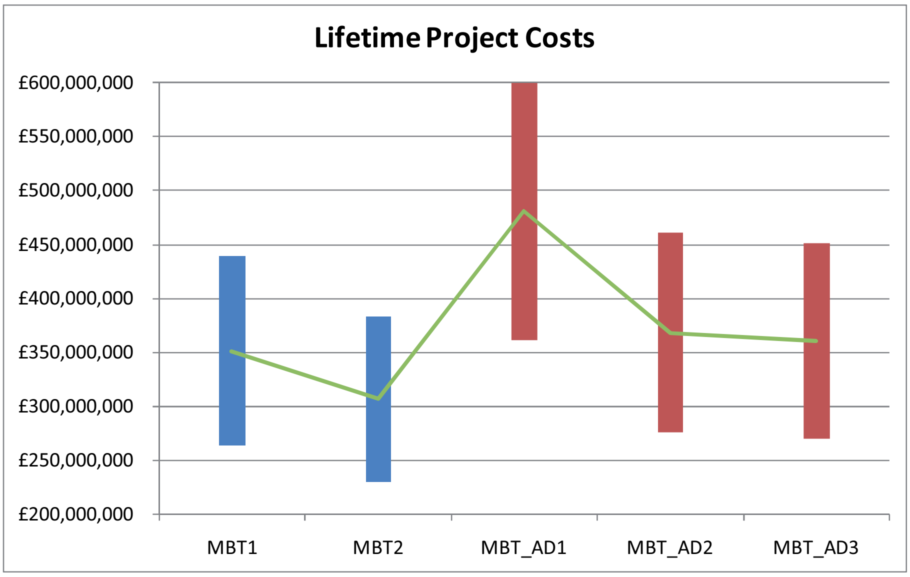


Figure 4 Predicted Lifetime Project Costs

4 Scenario Comparison

4.1 Quantitative Comparison

In order to provide an overall comparison each scenario has been ranked on its performance against a handful of key operational parameters including recycling and landfill diversion, SRF CV and biomass content and NPV cost. Weightings have also been applied to reflect relative importance. The results are shown below.

Table 7 Summary Performance Comparison

	MBT1	MBT2	AD1	AD2	AD3
Unweighted Total	13	15	10	14	16
Unweighted Rank	4	2	5	3	1
Weighted Total	44	51	24	43	46
Weighted Rank	3	1	5	4	2

Table 7 shows that AD3 performs marginally better than MBT2 based on the unweighted rankings scores. However when weightings are added Scenario MBT2 is shown to represent the highest performing option primarily due to the lowest NPV cost.

Whilst AD2 and AD3 achieve the highest landfill diversion performance it should be recognised that the SRF is of a relatively poor quality and only suitable for direct combustion or gasification using a grate technology such as Energos or KIV. This represents a significant risk to the project which may only be successfully mitigated by constructing a dedicated thermal facility to treat the SRF from the AD process. The implications of this are set out below.

4.2 Environmental analysis

The Environment Agency's Life Cycle Assessment software, WRATE, has been used to derive the life cycle environmental impacts of the two technical options with the results further compared to the impacts of landfill. Five key environmental criteria have been chosen to characterise environmental impacts; due to the different measurement units all results have been normalised to the common unit, Euro Persons Equivalent.

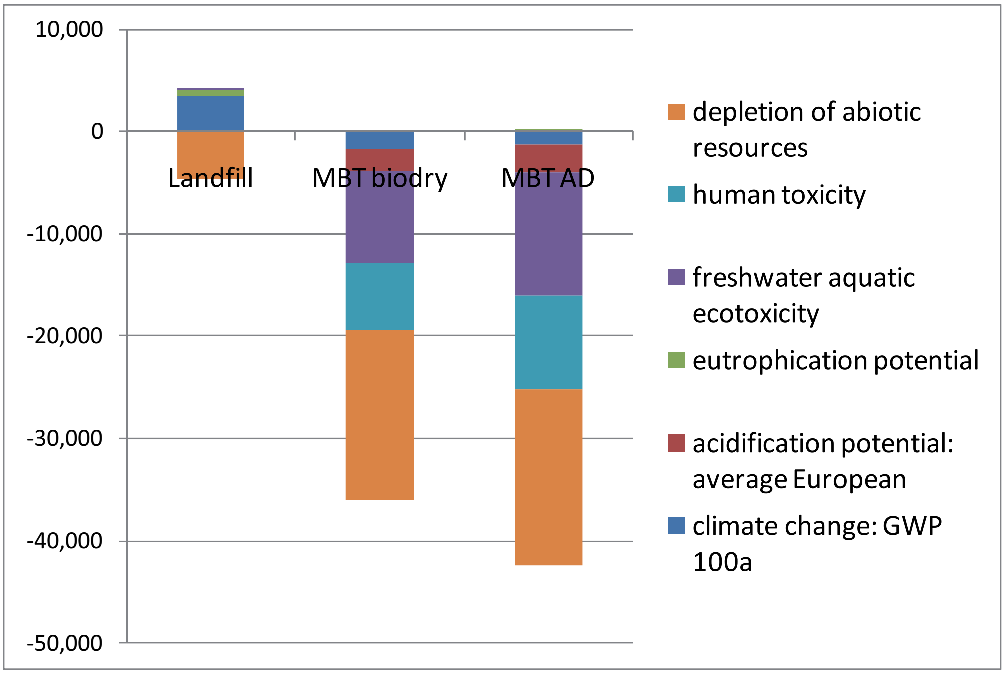


Figure 5 Lifecycle Environmental Impacts

The analysis indicates improved performance compared to landfill across all criteria, and for both technologies, with MBT AD showing a marginal benefit compared to the biodrying solution.

4.3 Other relevant considerations

A comparison against other key commercial criteria is set out below.

Constructability: Bio-drying offers a less complex construction process being essentially a single enclosed building of standard concrete, steel clad construction.

Operability: AD presents a greater degree of control complexity which is unlikely to be an issue on a day-to-day situation but could result in problems should inexperienced staff be made responsible for site operations or if waste inputs are highly variable in composition and throughput.
Scale and footprint: It is anticipated that AD would be more space efficient than biodrying. However, in reality, there is likely to be only minimal difference in footprint due to the need for other auxiliary equipment such as gas engines, gas bubbles and water treatment plant.
Odour management: General perception is that AD requires a lower level of odour management due to the enclosed nature of AD reactors and reaction kinetics involved in AD. Whereas bio-drying is specifically generating a high volume of air that specifically requires treatment and odour management. In general it is the quantum of exhaust air from the process rather than the concentration of odour species that creates a potential odour problem.,
Effluent management requirements: Most moisture from bio-drying is removed in an air stream and effluent management will relate to the specific APC systems employed. AD however, generates a liquor that may require significant management to enable disposal to drainage.
Robustness to changes in waste composition: Bio-drying is robust to changes in waste composition. AD, however will be susceptible to contaminants in the waste and requires contingencies for evacuating and cleaning plant on such occasions.
Adaptability to changes in throughput: Both processes can be set up to adapt to throughput changes. Reduction in throughput for AD can be an issue; eg lack of organic material reduces biogas output. Increases to capacity can be managed by reduced residence time or in the case of modular systems addition of modules. AD may be considered to offer greater modularity than biodrying processes
Markets for outputs: It is the marketing of digestate post digestion that creates the most significant problem. Existing waste legislation limits the use of organic outputs from mixed waste processes to certain non agricultural markets such as landfill and brownfield restoration and forestry. Biodrying produces a heavy fraction which is a combination of inert and active components. Where SRF quality is not an issue then the heavy fraction could be incorporated into the fuel product. However in most circumstances this fraction will either need to be disposed of to landfill or undergo further processing.

4.4 Preferred Solution

The analysis presented herein clearly demonstrates that it is possible to define a preferred technology based on consideration of a range of key performance criteria.

The most important factors in the evaluation of municipal waste tenders are project cost followed by deliverability and landfill diversion.

The analysis indicates that AD solutions offer the potential to achieve highest landfill diversion performance, however, they tend to exhibit lifecycle project costs in excess of those for MBT solutions.

Furthermore AD solutions suffer against deliverability primarily because of the poor quality of SRF and the implications that this may have on securing long term markets.

The market problem can be overcome if a dedicated EfW facility is provided as part of the solution. However, this in itself impacts on deliverability since the addition of a further treatment process involves additional complexity during project construction and operation.

MBT-biodrying solutions do not exhibit the highest landfill diversion performance and the quality of recyclates can be problematic due to contamination issues.

However where a concept can be developed based on only metals and dense plastics recycled and where the fines fraction can be incorporated with the SRF then MBT – biostabilistaion would appear to offer the most deliverable solution, exhibiting a competitive cost and offering a high level of deliverability.

Unlike AD technologies marketing of the SRF is not considered a problem, as witnessed by recent export agreements between UK SRF producers and EfW plants in mainland Europe.

In conclusion the following general positions hold true:

- Where the main purpose of the contract is to generate an SRF or to convert waste into energy then MBT- biodrying offers a more deliverable and cost effective solution than AD
- Where a viable, long term outlet for organic material can be secured, for example in landfill or brownfield restoration then AD could be considered as a viable alternative to MBT-biostabilisation

Author's address

Dr. Tony Yates

SLR Consulting

Treenwood House, Bradford on Avon, Wiltshire, BA15 2AU

tyates@slrconsulting.com

Composting of Municipal Solid Waste in the districts of Lomé (Togo): experimental process study and agronomic use potential

KOLEDZI Komi Edem [a], BABA Gnon[a], TCHANGBEDJI Gado[a], AGBEKO K.[a], MATEJKA Guy*[b], FEUILLADE Geneviève[b] and BOWEN Jim[c].

[a]Laboratory for Management, Treatment and Value of Waste (GTVD), University of Lomé

[b]Research Group for Water, Soil and Environment, University of Limoges

[c]Civil Engineering department, University of North Carolina at Charlotte

Abstract

This study concerns waste processing by composting in Lomé (Togo). It presents the composition of this waste, the treatment by composting of this waste recovered in the transfer sites and collected within individual households, an evaluation of its use as a fertilizer, and finally a market research to determine its economic value. The composition of the Municipal Solid Waste (MSW) shown that even though mineral components like sand and gravel represent the most important part of the waste arriving at the final dump location, organic material makes up a large part of households wastes. In order to determine the optimal conditions for composting biodegradable materials and for the overall process, a study was launched at a transfer site within a district of Lomé. Four types of compost were investigated, two with organics collected directly in households and two with raw waste stored at transfer sites that had been collected by a non-governmental organization (NGO) in charge of primary collection. Amendment of the compost with natural fertilizer, natural phosphate, and chicken manure was also tested. It was found that the quality of the four types of compost was quite similar except for the one in which natural phosphate and manure had been added. Studies on the toxicity of the four types of compost on their agricultural effectiveness, and their economic value were also carried out. The market research demonstrated that the production costs of the compost were low enough to make it an attractive and potentially profitable alternative to existing fertilizers such as manure.

Keywords:

Waste, composting, agricultural, economic, fertilizers

1 Introduction

Twenty years ago, Lomé, the capital of Togo, was a pleasant city that was considered to be an attractive destination for international tourists. Unfortunately, recent political and socio-economic turmoil within the country have affected Lomé negatively. Rural depopulation has occurred at a rate that is among the highest in African countries (Parrot and al., 2009). In addition, over the past twenty years Togo has experienced a reduced economic growth and a decline in the gross domestic product (GDP) per capita. There is an interest, therefore, in activities that might contribute to the economic development of newly urbanized areas within Togo. The creation of solid waste is unavoidable consequence of production and consumption activities of society. In developing countries the waste generation ratio of households varies between 0.4-0.7 Kg/cap/day, but seasonal variations can influence the amount of waste generation and its physical and chemical characteristics. For instance, high humidity during the rainy season or the consumption of vegetables and fruits can influence the moisture content and organic content of MSW (de Guardia and, al., 2010; Chitsan, 2008). Variations in these characteristics can in turn affect whether treatment processes such as recycling or composting can be effective (Tinoco and al., 2009). At the present time, recycling of materials collected door-by-door by either municipal or non-governmental organizations (NGOs) is not done on an organized basis but is instead done by individual scavengers and waste pickers. In Lomé issues related to Solid Waste Management (SWM) have been neglected for decades, and the economical stagnation of the country, with resulting low investment in the SWM sector is seen as a serious problem. As a result the inhabitants of Lomé are faced with the problem of uncontrolled disposal of solid wastes close to their households. Faced with similar problems in other developing nations, NGO members, gardeners and scientists in India or Bangladesh (Zurbrugg et al., 2005) have investigated the possibility that composting of MSW that can improve the functioning of the solid waste management system while producing a marketable product.

Here we investigate the efficacy of MSW composting in Lomé. The idea to be investigated is whether compost can be produced in Lomé in a sustainable and economical manner, and whether the compost produced could be of a quality that allows it to be used as an alternative fertilizer to animal manure. If so, then this compost produced in the urban zone could be transferred to agricultural areas adjoining Lomé. It is expected, based on local conditions, that composting would best be carried out in decentralized systems. If done properly, the use of compost could result in a variety of environmental benefits. Composting organic materials that have been diverted from landfills avoids the eventual production of methane (Domingo, 2009) and leachate (Kjeldsen and al., 2002) in the landfills while producing a product with economic value. Furthermore, using compost can reduce the agricultural demands for water, fertilizers, and pesticides (Hoitink and al., 1997). Composting also extends the life of the municipal landfill by diverting organic materials from landfills to agricultural lands.

To gather information on different parameters of the composting process, this study has been set up to control and analyse two boxes and two windrows of different compositions of compostable materials. Chemical analyses of the compost were followed during the time of the aerobic decomposition of the waste. The finished compost was then evaluated as a fertilizer by performing growth studies on carrots. In addition, the finished compost was evaluated to estimate its economic value and the potential that its production could be done profitably.

2 Materials and Methods

2.1 Origin of waste and sampling

Domestic waste samples were collected from 33 houses randomly identified in the middle district of Lomé after an investigation conducted by the NGO in charge of waste collection in the district. The 33 houses were selected in order to sample wastes from households having a range of economic standing. Two collection methods were utilized. In the first, only compostable wastes were collected from the household. In the second, raw waste was collected and then sorted to eliminate materials not suitable for composting (papers-cardboards, textiles, plastics, glasses, metals, miscellaneous, hazardous, etc.). The samples for physical characterization were obtained in both the dry season and in the wet season. For the selective collection of organic waste, a mass of 250 kg waste was characterized; for the raw waste, a mass of 500 kg was collected and characterized. One of the samples obtained by selective collection was amended with chicken manure and organic phosphate. Sorted wastes were obtained from two different districts within Lomé. The four types of composts to be evaluated were prepared according to the following combinations of raw materials (**Table 1**).

Table 1: Composition of Different Biodegradable Materials

	Composition of compostable materials				**Covered**	**Size**	
	MSW Organic fraction (Kg)	MSW raw (Kg)	Chicken manure (Kg)	Natural phosphate (Kg)		Volume (m3)	(LxWxH)
Box A	120		-	-	yes	0.72	*1.2x1.2x0.5*
Box B	120		24	8	yes	0.72	*1.2x1.2x0.5*
Windrow C		1650	-	-	no	4.25	*1 x2.5 x 1.7*
Windrow D		1420	-	-	no	4.25	*1 x2.5 x 1.7*

Manure being used by farmers, our goal is to compare the effect of manure, compost made from waste and manure and compost made from household waste alone. Very often, farmers use this kind of manure as organic fertilizer in agriculture without any preliminary treatment. Consequently, a considerable emission of harmful gases is released into atmosphere (greenhouse gases), nitrogen losses from manure are large, and contamination of soil with pathogens is possible. Manure handling, storage, and disposal continue to present major problems for poultry producers throughout the world (Petric et al., 2009*)*.

Compost C and D are drawn because of the waste composition of various neighbourhoods in terms of quality of fermentable matter. Waste of compost A and B are from the collection of neighbourhood Agbalépédogan. The compost activation process is performed by micro natural organisms.

2.2 Windrow and Box preparation

After the sorting of the waste to remove unsuitable materials (metals, glass, miscellaneous, and hazardous), the remaining organic waste was poured into buckets to build the compost pile. Two composting methods (box and windrow) were utilized. These two methods are described below.

Box composting method (or reactor composting method): In this method all the operations were conducted under a roof to protect the compost from excessive rain and sun. Compostable materials were placed in boxes that were 1,2 m long, 1,2 m wide, and 0,5 m high. The boxes made of cement were constructed to allow air penetration on their sides. The bottom of the reactor was designed with a slope to facilitate leachate drainage.

Windrow composting method: The organic wastes were piled on the ground after sorting and were protected from excessive sun and rain by a composting fleece, permeable to air but not to rain water (Zurbrugg et *al*., 2005). A drainage system collected leachate and rainwater, which was used for watering of the windrows. The dimensions of the windrow were 1 m long, 2.5 m wide and 1.7 m high. These methods are less costly than other composting technologies, such as in-vessel composting (van Haaren, 2009).
Turning frequency: The boxes and windrows were turned to allow the aeration of the pile, the homogenization and also the cooling of the waste during aerobic degradation. In normal windrow composting practice, oxygen may not penetrate throughout the body of the windrow. Therefore, some anaerobic reaction may take place, resulting in methane formation. However, with adequate turning, the amount of methane generated in windrows is very small (van Haaren et al., 2010).

2.3 Compost control parameters

Temperature: The temperature was determined every day with an alcohol thermometer at different points of the pile (deep, middle and bottom) (Unmar and al., 2008).

Moisture content, H%: The moisture content of sample was determined at 105°C in an oven (Yobouet and al., 2010). If no drops of water emerged, then the moisture content of the waste was considered to be too small. Moisture content in the field was adjusted by watering. $H\% = (M_0 – M_1). 100/M_0$

Where:

M_0 = weight of sample (100g)

M_1 = weight of sample after drying at 105°C

Organic matter content: To measure organic matter content, 25g of compost were burned at 550°C in an oven for 2 hours (Unmar and al., 2008). The content in organic matter or in volatile solid was obtained by the difference of weight between the mass of the dry waste and the mass of the burned waste.

pH measurement: Composts pH was measured in a 1:5 (w/v) composts ratio to distilled water. To measure pH, 20 g of dry matter were mixed with 100 ml of distilled water. The suspension was homogenized by magnetic stirring during 15 minutes. The pH was measured directly by reading using a pH-meter with a combined glass electrode (Yu and al, 2009).

Other compost quality criteria

Nutrient and Contaminant Analysis:

- Total Kjeldahl Nitrogen (TKN) was determined by the Kjeldahl method (Barrena and al, 2010).
- TOC was determined by wet digestion in $K_2Cr_2O_7$ and concentrated H_2SO_4, digested on a preheated block at 150°C for 30 min, left to cool and titrated for excess $Cr_2O_7^{2-}$ with ferrous ammonium sulphate (Tumuhairwe and al., 2009).
- Total phosphorus was determined by color spectrometry using ammonium molybdate and ascorbic acid (Bustamante and al., 2008).

The preparation of the sample for the analysis of all parameters except nitrogen and carbon contents consisted of a wet digestion in acidic conditions (HCl/HNO_3).

- Cationic species (Na, K, Mg and Ca) and heavy metals (Pb, Ni, Cd) were determined by Atomic Adsorption Spectrometry AAS (Bustamante and al, 2008).

Germination Index (GI) Test: The biomaturity test was conducted with a fresh water extract from the compost that was dropped into a plastic Petri dish with a filter paper. Ten ml of diluted compost extract was put on each Petri dish. Twenty corn (*Zea mays)* seeds and twenty bean (*Virgna unguiculata)* seeds as basis cultures in Togo and twenty cress (*Lepidium sativum L)* seeds were distributed on the filter paper, and incubated at ambient temperature (28°C) in the dark for 48h under cover (Chikae and al., 2006). The numbers of germinating seeds were counted and the lengths of the roots were measured. For the control, 10 ml of distilled water was used rather than compost extract. The GI was calculated by the formula of Zucconi (Bustamante and al., 2008):

GI = %G x (Mean total root length of treatment) / Mean root length of control),

%G is the percentage of germinated seeds in each extract with respect to control
%G = (Numbers of germinated seeds/ Numbers of germinated seeds of control) x100
Two treatment levels (GI50 and GI75) were used in which the compost extract made up either 50% or 75% of the sample. The same water used for the control was used for these dilutions. The germination index (GI) was defined as the arithmetic average of the 50% (GI50) and 75% (GI75) treatment levels: GI = (GI50 + GI 75)/2.

2.4 Agricultural Study: Field Test

The composts A, B and C were tested in comparison with chicken manure and artificial fertilizer (NPK). All the trials were conducted in the same field. For each test a plot size of 2.8 m x 1 m was used. Within the plot an area of 25 cm x 1 cm was sown with 3 or 4 carrot seeds. The following manure treatment levels were used:

T_0: natural soil with no application,

T_1: natural soil with chicken manure at a dose of 20 T/ha,

T_2: natural soil with inorganic fertilizer (N15P15K15)

T_3: natural soil with inorganic fertilizer (N30P30K30),

T_4: natural soil with inorganic fertilizer (N60P45K45),

A, B, C: natural soil with composts A, B, C at a dose of 20 T/ha.

The carrot seeds were allowed to germinate and grow for a period of 90 days in the field. The field was then harvested and the total mass of carrot tubers for each treatment level was calculated.

2.5 Statistical Analysis

Standard errors for the field tests were calculated using general statistical methods like the ones described by Rea, (1997).

3 Results and Discussion

3.1 Physical characterization of collected Waste

Not surprisingly, the composition of the wastes collected directly from the households was found to be significantly different from that of the non-sorted raw waste (Figures 1a and 1b). There were also some differences in composition observed between the dry and rainy seasons. For the waste collected directly from the homes, 66-75% was compostable, 20-30% was non-compostable, and less than 10% were fine grain (< 20 mm) material (**Figure 1a**). For the waste collected directly from the households, a high organic matter of 70 to 80% was found. Relative moistures of 50 to 70% were also observed. For the raw waste collected at the final discharge site, the results of the characterization of two seasons (wet and dry) revealed a rate of 15-22% of compostable fraction, 30-32% of non-compostable waste and a high proportion of fine fraction 46-56% (**Figure 1b**). The average humidity ranged from 15% in the dry season to 44% in the wet season. Organic matter represented an average of 24-25% of municipal waste with a rate of 8-9% organic matter in the fine fraction. This is not advantageous for composting of raw waste as it indicates a high percentage of non-compostable mineral materials (e.g. sand and gravel).

The results revealed that the waste composting closer to the households or in the neighborhoods could be more effective than on the centralized final disposal as a higher percentage of the material was compostable.

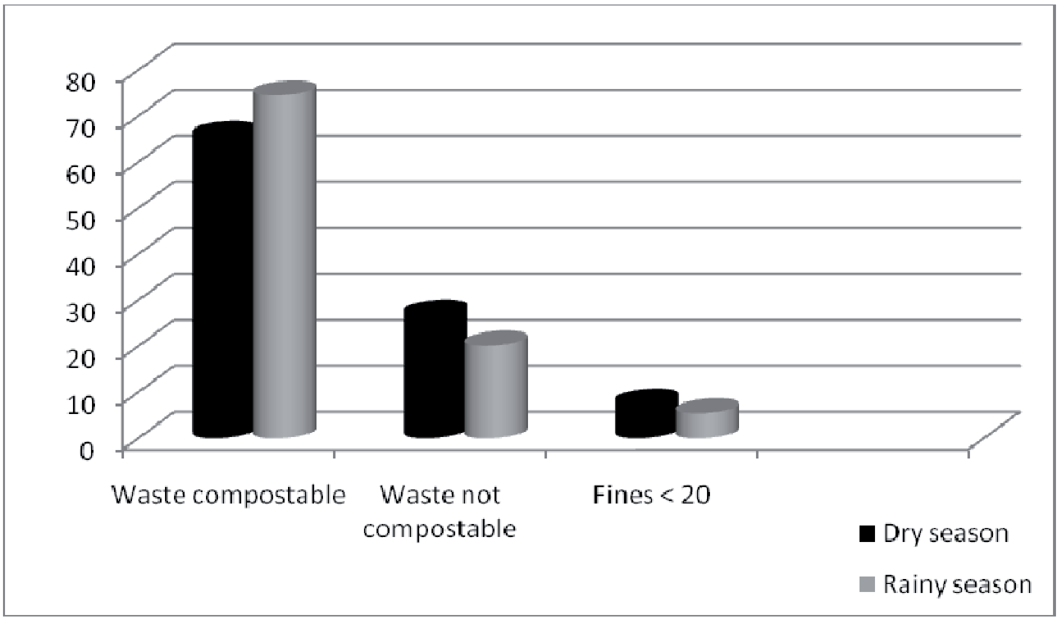


Figure 1a: Composition Of Waste After Collection Directly In Households

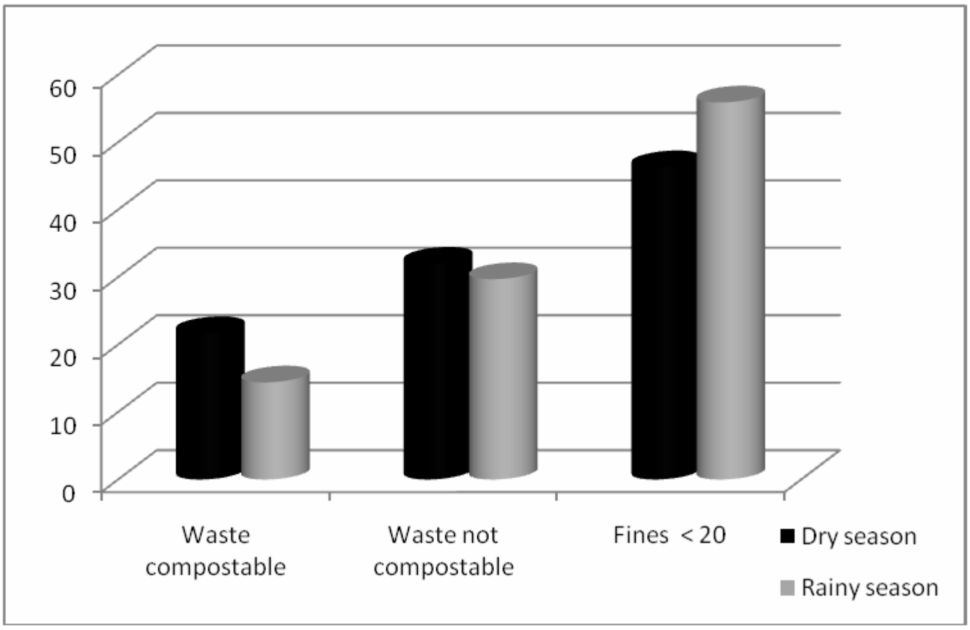


Figure 1b: Waste Composition in Final Discharge

3.2 Follow-up of process parameters

3.2.1. Moisture content, H%

All the substrates in boxes or in windrows were always controlled and the moisture content was maintained at 40-50% during the process. Less watering was needed during the rainy season to maintain the optimal water content. The **table 2** show water requirement in different seasons. Moisture between 30-40% in mature compost is the usual value established in reviewed regulations.

Table 2: Water requirement in different seasons

	predominant season	Total Volume of water added (m^3)	Initial tonnage of compost (T)	water requirement (m^3/ton)
Box A	Dry	0.17	0.120	1.4
Box B	Dry	0.18	0.152	1.2
Windrow C	Dry	1.84	1.148	1.6
Windrow D	Rainy	0.62	1.025	0.6

3.2.2. Temperature

Daily temperature recorded during the composting process clearly showed the two commonly-seen composting phases: the thermophilic phase (T>50°C) for the boxes (**Figures 2a and 2b**) and T>60°C for the windrows (**Figures 2c and 2d**), and the mesophilic phase (T<40°C) for the boxes (**Figures 2a and 2b**) and T=40-50°C for the windrows (**Figures 2c and 2d**). As expected, turning the compost generally had the effect of beginning a phase of temperature increase as fresh organic material and oxygen was mixed into the pile temperature with occasional turning (Hassen and al., 2001). The maximum temperature seen in the boxes was 50-60°C (**Figures 2a and 2b**). A maximal temperature of 60-70°C was observed in the windrows (**Figures 2c and 2d**). Composts C and D reached the ambient temperature after 65 days (**Figures 2c and 2d**).

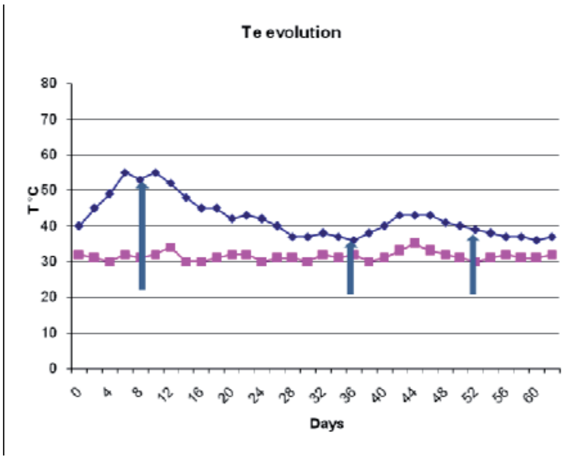


Fig 2a Compost A

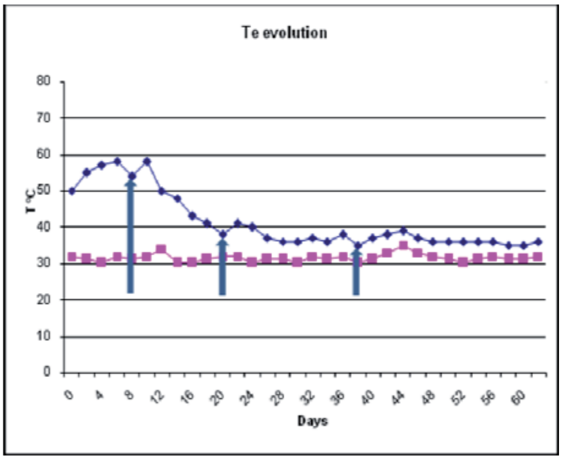


Fig 2b Compost B

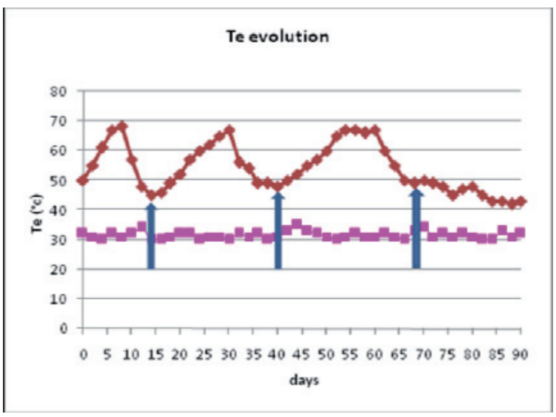


Fig 2c Compost C

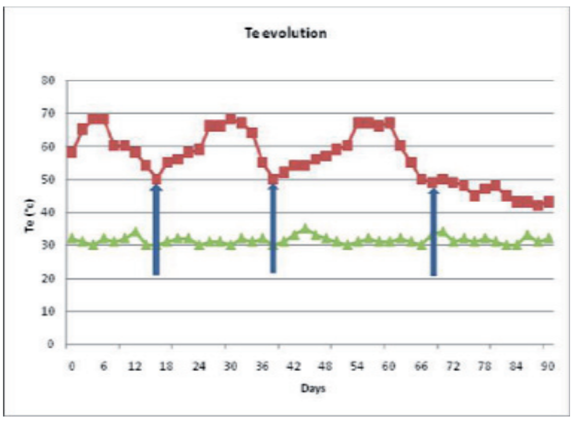


Fig 2d Compost D

Figure 2: Temperature versus Time In Boxes And Windrows

(Arrows Indicate The Turning Of Waste)

3.2.3. Evolution of pH according to the Organic Matter content

The pH values ranged from 8 to 9.6. Waste collected from the households (A and B, **Table 3**) contained a quantity of ashes from basic wood or coal representing almost all the sources of energy in households. Three of the four composts recorded a pH above 9 which can induce the volatilization loss of ammonia as the acid/base equilibrium shifts from NH_4^+ to NH_3 ($pK_a = 9.2$). Compost B was the only one in which the pH was below the ammonia pK_a, with a pH at 8.7 (Table 3). Changes in the pH through time are a function of the fluctuating alkalinity during the composting process (Komilis and al, 2006). A possible reason for this effect may be that a quantity of ashes from basic wood or coal increased the pH level in the composting, thus partly counteracting the toxic effect of low pH. Organic acids have been shown to be more toxic at an initial lower pH value (Yu and al, 2009). In mature compost pH levels were generally higher than the pH values measured in the Nan-Tzu District (Chitsan, 2008) and Bangladesh composts (**Table 4**).

During composting process, organic matter is oxidized and converted to carbon dioxide, water, ammonia and new microbial biomass. Organic matter is good indicator of how biological degradation occurred over time.

Table 3: Evolution of pH and organic matter (OM) in the boxes and in the windrows

Time	Week	2	3	4	5	6	7	8	9	10
Parameters	**Compost**									
	A	ND		ND		9.10		9.20		9.20
	B	ND		ND		8.75		8.85		8.90
pH (u.pH)	**C**		ND		9.30		9.60		9.60	
	D	8.00		9.45		9.45		9.45		
	A	ND		69.6		42.6		34.5		34.5
	B	ND		38.7		29.9		27.1		25.1
OM (%)	**C**		58.2		28.2		28.1		27.0	
	D	45.5		38.5		31.4		33.6		

ND: not determined

The organic matter decreases with increasing composting time (**table 3**), as expected. The decrease is related to the aerobic decomposition of organic matter into CO_2 and H_2O. In mature compost carbon and organic matter were similar to the corresponding values taken from the literature. The content of organic matter which was approximately 30% (**table 4**), would be very helpful for water retention in amended soils.

Table 4: *Chemical Composition And Ph Of Dry Matter Of 4 Composts A, B, C, D In Comparison With Others MSW Composts In Equatorial Areas.*

Parameters		**Com-post A**	**Com-post B**	**Com-post C**	**Com-post D**	**Com-post Labé ***	**Com-post ****
pH		9.3	8.7	9.3	9.4	8.2/8.8	7.8
N	%	0.8	0.9	0.8	0.7	1.4/0.88	1.0/2.0
OM	%	32	31	34	30	-	35/40
C	%	*19*	*18*	*20*	16	16.2/13.8	20.3/23.2
C/N		*24*	*20*	*25*	20	11/16	11.6/20.3
P	mgP_2O_5/g	13.6	44.7	8.0	11.8	10.9/10.2	9.4/91.5
Na	$mgNa_2O$/g	7.5	4.0	9.4	-	-	-
K	mgK_20/g	17.3	19.8	15.1	-	11.1/10.8	6.0/31.3
Mg	mgMgO/g	2.8	3.1	4.2	3.2	8.1/6.8	-
Ca	mgCaO/g	16.2	38.5	35.1	36.7	63.8/51.2	-

* Matejka.et al., 2001; **Waste Concern, 2002

3.2.4. Mass balance

Mass balances for the waste management processes were similar for composts A and B (69-71% of compost), where the compostable waste was taken from the households, and samples C and D (21-22%), in which waste was first sorted and then composted (shown schematically in Figure 3). Composts A and B used the box compost method while samples C and D were composted in windrows. In samples C and D, the collected material included recyclable materials like metals and plastics which could be further sorted. After what the remaining materials could be checked for some unwanted components and could be reintroduced in the process. In general the compost mass decreased in time as the moisture and organic matter contents decreased as a result of the composting process.

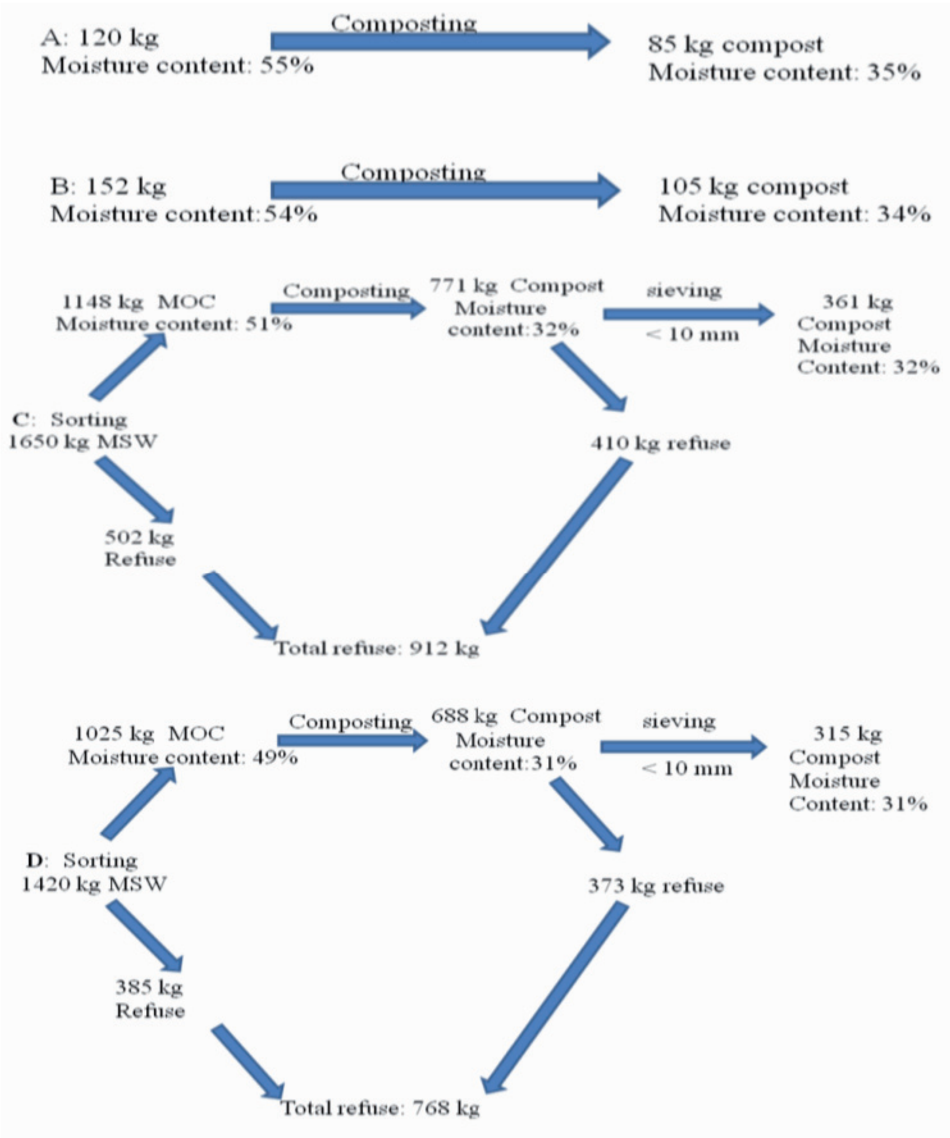


Figure 3: Solid Waste Mass Balance for the Four Compost Samples

3.2.1 Chemical compost quality

Chemical characteristics of the four compost samples were found to be similar to values available in the literature. The four compost samples A, B, C and D (**Table 4**) were compared to the chemical characteristics of compost from Nan-Tzu District in Taiwan and Bangladesh.

3.2.2 Nutrients

Quality parameters such as N, P and K, which make up the nutrient content of compost, are essential as they are indicative of future use of the compost. When the organic carbon in the compost is mineralised into CO_2, the carbon has a higher losing rate than that of N, P and K causing the concentration effect. The nitrogen content was slightly lower than the other composts, which as mentioned earlier could be the result of ammonia volatilization associated with pH values above the NH_4^+/NH_3 pK_a value (Chang and al, 2010). The elevated phosphate rate in compost B is due to the addition of natural phosphate to the organic fraction at the beginning of the process. The range of Fe in compost is 2040-3330 mg/kg. All the composts were found to have a high content of inorganic nutrient like phosphate, Na_2O, MgO, K_2O or CaO (**Table 4**) which is an advantage for the use in agriculture.

3.2.3 C/N ratio

The carbon to nitrogen ratio (C/N) because of the relatively low nitrogen content was therefore high (20-26) in comparison with other domestic waste composts (Chitsan, 2008; Chang and al., 2008; Chang and al, 2010). Authors pointed out that a mature compost C/N ratio should be less than 20 (Chen et al., 2005) or was between 13.7 and 32 (Aulinas Masó and Bonmati Blasi, 2008). Higher C/N ratio would cause nitrogen to evaporate thus reducing the nitrogen content in the soil while lower C/N ratio would release a large quantity of soluble basic salt thus making the soil reductive to affect the plant growth.

3.2.4 Heavy metals

Heavy metal (Pb, Ni, Cd) concentrations were measured in all four compost samples and compared to standard values for composts (**Table 5**). It can be observed that the lead contents are above the standards fixed by the French Norm NFT 44 051. It is troubling that lead in these concentrations was found in these composts. The heavy metal content in food products is low, especially for those heavy metals that are not essential to plant nutrients, such as Pb and Cd. The heavy metal content in the organic fraction most probably originates from the layer of humus that is found in the topsoil in the household gardens (Veeken and al, 2002).

Table 5: Concentration of Some Metallic Pollutants in the Different Composts

Elements (mg/kg)	Compost A	Compost B	Compost C	Compost D	Limits values*
Pb	460	380	480	290	140
Ni	40	14	20	18	50
Cd	1	1	2	2	3

* AFNOR, (2005)

The organic fraction contains 11 % of metals on dry weight of household waste with a concentration going to 154 mg / kg of Pb. Metal from compost is thought to vary with compost maturity. As compost matures, the humic material in compost tends to increase and is capable of binding many metals thus decreasing their availability (Hargreaves and al., 2008). Generally, whilst increasing the overall heavy metal burden of soil may be undesirable, application of composts poses little risk in terms of phytotoxicity or metal contents of crop tissue (Farrel and Jones, 2009). Whilst compost cannot remove metal from the soil the can stabilize or immobilize them on the solid phase.

3.3 Germination test

The mean values of ten replicate germination tests were calculated for each of the four, composts for three different plants (**Table 6**). The results of the germination tests indicate the maturity of the composts and the lack of any compounds that would be toxic to the plants or interfere with seed germination.

Table 6: Mean Values of Germination Index, GI

		Compost A	Compost B	Compost C	Compost D
GI (%)	*Zea mays (corn)*	76	78	81	87
	Virgna unguicula-ta (bean)	86	77	78	80
	Lepidium sativum l (cress)	79	75	86	82

A germination index (GI) of 50% has been used as indicator of phytotoxin-free composts (Zucconi and al., 1981). For the four composts and the three plants tested, the GI varied from 75% to 87%. The lowest GI occurred for compost B, which was the household waste sample amended with chicken manure. The relatively high observed GI values indicate a very low content of the toxic substances such as the acetic acid. The acetic acid can completely inhibit the germination of cress seeds starting from a concentration of 300 mg/kg (De Vleeschauwer and al., 1981). The reduction of the germination of seeds by the acetic acid was reported for cress and corn (Keeling and al., 1994). The high observed GI values for these composts indicate that the composts produced are stable and mature.

3.4 Agronomic value of the compost

The produced compost brought a significant improvement to the growth of carrot tubers (**Figure 4**). For instance, the field test without fertilizer produced 1500 kg/ha of carrot tubers, while composts A, B, C had carrot productions of 2699, 2998, and 2685 kg/ha respectively. No statistically significant difference was found between carrot tuber productions for fields treated with compost as compared with the field treated with chicken manure (**Figure 4**). Fields treated with artificial fertilizer (treatments T2, T3, and T4, **Figure 4**) produced higher carrot tuber production.

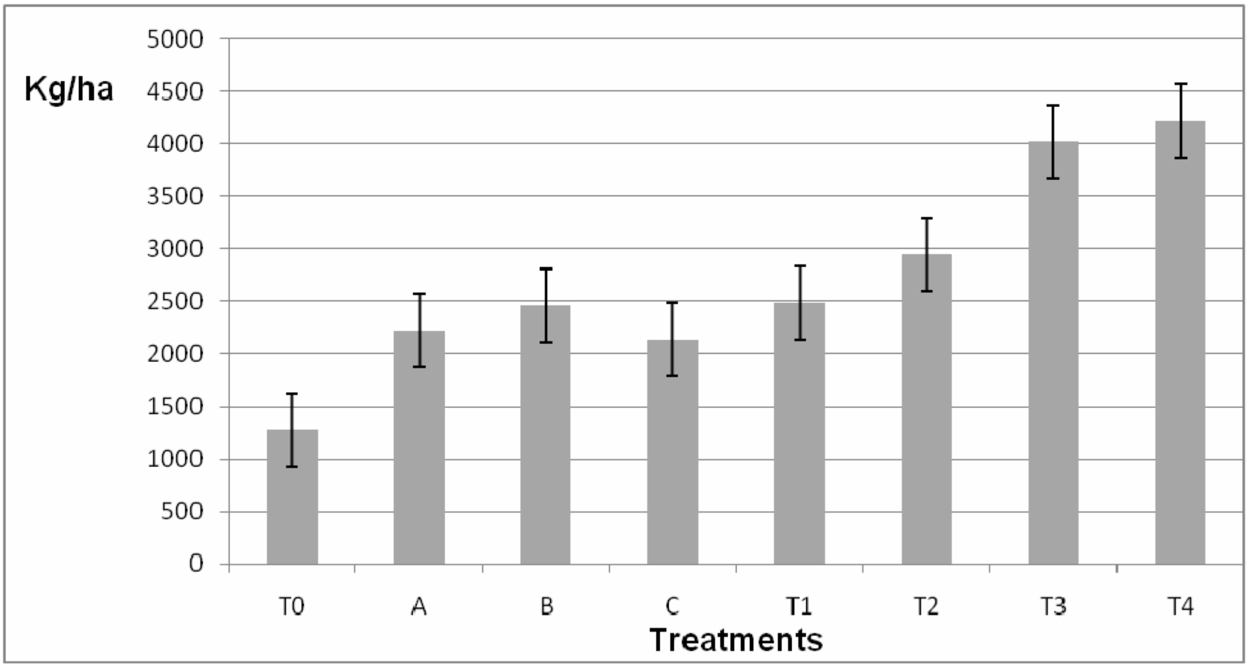


Figure 4: Yield of Carrot Tubers

3.5 Compost market

Studies conducted by Kessler (2004) and a market study showed that gardeners in Lomé and farmers in towns surrounding Lomé need fertilizer for their fields but find the cost of artificial fertilizers or natural fertilizers such as chicken manure to be too high. Given the agricultural value observed for compost, these farmers and gardeners represent a large potential market for the compost. To investigate whether compost could be produced profitably we assume that a 20 kg bag of compost could be sold for 700 FCFA (1.1 Euro) francs (the local currency abbreviated FCFA), which is approximately 40% less than the typical cost for 20 kg bag of chicken manure (1200 FCFA (1.8 Euro) francs per 20 kg bag). At this price for compost a ton of compost would fill 50 bags and produce an income of 35,000 FCFA/ton (53 Euros/ton). We estimate the potential compost production rate and associated costs as follows. Four composters working 6 hours per day and 6 days per week can sort 52 tons of raw waste and produce 11 tons of fine compost (< 10 mm) per month (132 tons per year). These 11 tons of compost would give a monthly income of 385,000 FCFA (588 Euros). Assuming that production can occur year-round, this gives an annual income for the sale of compost of 4,620,000 FCFA. Estimated costs (**Table 7**) for the composters and the associated support staff are 3,050,000 FCFA (4,656 Euros) per year.

Based upon these cost and revenue estimates, four full-time composters with their support staff could product an annual profit of 1,570,000 FCFA (2,397 Euros) through the sale of compost. Other possible revenues that might also result include the sale of recyclable materials, household participation in the collection, the grants of private vs. public, the environmental service to the community and potential carbon credits. On the other hand costs not considered in this analysis include maintenance of the site and facilities, purchase of consumables, expenses related to water and energy, wages and overhead management, taxation, marketing, sales, etc.) and costs investment, often involving the depreciation for depreciable property (site development, purchase of mobile equipment and transfer fees for feasibility studies and engineering). If these costs can be kept below 34% (1,570/4,620) of total costs, or if the additional revenues can offset some or all of these additional costs, then the compost could be produced profitably.

4 Conclusion

The physical characterization showed that a majority of wastes (70% on average) collected directly from the households was biodegradable. The composts produced using two different candidate collection and processing methods do not present risks, aside from lead concentrations which exceeded the French standard AFNOR for compost. Many researchers agree that bioavailability should be addressed in the guide line limits, in addition to metal loading. The earlier the sorting of waste occurs, such as at collection or before the composting process begins, the lower the heavy metal content in the mature compost. The results of an agricultural study indicated a good opportunity for the composting of urban waste directly collected in the households in different districts of Lomé. Previous studies demonstrated that a demand exists for an economical fertilizer in the area surrounding Lomé. The compost had a benefit that was equivalent to an alternative fertilizer (chicken manure), and could be produced profitably at an assumed price that would be significantly less than the manure. A variety of plant species should also be used in trials in order to identify Pb bio accumulators to ensure that plants are safe for human consumption. Composting of MSW has potential as a beneficial recycling tool. Its safe use by farmers in agriculture, however, depends on the production of good quality compost and it selling price.

Acknowledgements

The work presented in this paper was financially supported by the Service of the French Cooperation, with the CORUS research program.

References

AFNOR, 2005. Amendement organique et supports de culture. Pr NF U 44-051. http://wwww.afnor.fr

Aulinas Masó, M., Bonmati Blasi, A., 2008. Evaluation of composting as a strategy for managing organic wastes from a municipal market in Nicaragua. Bioresource Technology 99 (2008) 5120-5124.

Barrena, R., Turet, J., Busquets, A., Farrés, M., Font, X., Sánchez, A., 2010. Respirometric screening of several types of manure and mixtures intended for composting. Bioresource Technology. doi:10.1016/j.biortech.2010.09.011.

Bustamante, M.A., C. Paredes, F.C. Marhuenda-Egea, A., Perez-Espinosa, M.P. Bernal, R., Moral, 2008. Co-composting of distillery wastes with animal manures: Carbon and nitrogen transformations in the evaluation of compost stability. Chemosphere, 72: 551–557.

Chang, J.I., Hsu, T.E., 2008. Effects of composition on food waste composting. Bioresour. Technol., 99: 8068–8074.

Chang, J.I., Chen, Y.J., 2010. Effects of bulking agents on food waste composting. Bioresource Technology 101 (2010) 5917–5924.

Chen, M.J., Liao, C.Z., Tsai, Y.F., 2005. Manual and Case Studies of Composting Technology and Equipment. Issued by the Taiwan Green Productivity Foundation, Prepared for the Industrial Development Bureau, Ministry of Economic Affairs, Taiwan.

Chikae, M., Ikeda, R., Kerman, K., Morita Y., Tamiya, E., 2006. Estimation of maturity of compost from food wastes and agro-residues by multiple regression analysis. Bioresour. Technol., 97: 1979-1985

Chitsan, L., 2008. A negative-pressure aeration system for composting food wastes. Bioresource Technology 99 (2008) 7651–7656

de Guardia, A., Mallard P., Teglia C., Marin A., Le Pape C., Launay M., Benoist J.C., Petiot C., 2010. Comparison of five organic wastes regarding their behaviour during composting: Part 1, biodegradability, stabilization kinetics and temperature rise. Waste Management 30 (2010) 402–414.

DeVleeschauwer, D.O., Verdonock, P., Van Assche, P., 1981. Phytotoxicity of refuse compost. *BioCycle,* **2**2: 44-46.

Domingo, J. L., Nadal, M., 2009. Domestic waste composting facilities: A review of human health risks. Environment International 35 (2009) 382–389.

Farrel, M., Jones, D.L., 2009. Critical evaluation of municipal solid waste composting and potential compost markets. Bioresource Technology 100 (2009) 4301-4310.

Hargreaves, J.C., Adl, M.S., Warman, P.R., 2008. A review of the use of composted municipal solid waste in agriculture. Agriculture, Ecosystems and Environment 123 (2008) 1-14.

Hassen, A., Belguith, K., Jedidi, N., Cherif, A., Cherif, M., Boudabou, A., 2001. Microbial characterization during composting of municipal solid waste. Bioresource Technology 80: 217-225.

Hoitink, H.A.J., Stone, A.G., Han D.Y., 1997. Suppression of plant diseases by composts. Hortscience 32: 184-187.

Keeling, A. A., Paton, I. K., Mullet, J. A., 1994. Germination and growth of plants in media containing unstable refuse derived compost. Soil Biol. Biochem., 26, 767-772.

Kessler, 2004. Socio-economic aspects of a plant health compost resulting from waste applied in urban agriculture in West Africa. A comparative analysis in five cities. Thesis of University of Humboldt in Berlin. Faculty of Agriculture and Horticulture. Department of Phytopathology. edoc.hu-berlin.de/dissertationen/kessler...2004.../Kessler.pdf

Kjeldsen, Peter, Barlaz, Morton, A. , Rooker, Alix, P. , Baun, Anders , Ledin, Anna, Christensen, Thomas, H., 2002 'Present and Long-Term Composition of MSW Landfill Leachate: A Review', Critical Reviews in Environmental Science and Technology, 32: 4,297-336.DOI:10.1080/10643380290813462. URL:http://dx.doi.org/10.1080/10643380290813462

Komilis, D.P., Ham, R.K., 2006. Carbon dioxide and ammonia emissions during composting of mixed paper, yard waste and food waste. Waste Management, 26: 62-70.

Parrot, L., Sotamenou, J., Kamgnia, B.D., Nantchouang, A., 2009. Determinants of domestic waste input use in urban agriculture lowland systems in Africa: The case of Yahounde in Cameroon. Habitat Int., 33: 357-364. DOI: 10.1016/j.habitatint.2008.08.002

Petric, I., Sestan, A., Sestan, I., 2009. Influence of wheat straw addition on composting of poultry manure. Process Safety Environ. Protection, 87: 206–212.

Rea, L.M., Parker, R.A., 1997. Designing and Conducting Survey Research: A Comprehensive Guide. 2nd Sub Edn., Josse-Bass Inc. Publishers, San Francisco; 1997.

Tinoco, A.A.P., Azevedo, I.C.D., Azevedo, R., Marques, E.A.G., 2009. Separation and composting plant in small cities of Zona Da Mata Minas Gerais, Brazil. Sardinia 2009 Symposium. XII International WM and Landfill Symposium. Page109. www.sardiniasymposium.it/sardinia2009/

Tumuhairwe, J.B., Tenywa, J.S., Otabbong, E., Ledin, S., 2009. Comparison of four low-technology composting methods for market crop wastes. Waste Management 29 (2009) 2274–2281

Unmar, G., Mohee, R., 2008. Assessing the effect of biodegradable and degradable plastics on the composting of green wastes and compost quality Bioresource Technology 99 (2008) 6738–6744

Van Haaren, R., 2009. Large scale aerobic composting of source separated organic wastes: A comparative study of environmental impacts, costs and contextual effects. MS Thesis, Columbia University, New York. Unpublished Results. www.seas.columbia.edu/earth/wtert/sofos/haaren_thesis.pdf

Van Haaren, R., Themelis, N.J., Barlaz, M., 2010. LCA comparison of windrow composting of yard wastes with use as alternative daily cover (ADC). Waste Management, 30: 2649–2656

Veeken, A., Bert, H., 2002. Sources of Cd, Cu, Pb and Zn in biowaste. Sci. Total Environ., 300: 87-98.

Waste Concern, 2001. Research report on application of compost on soils of Bengladesh. Field Experiment Report Prepared for the Sustainable Environment Management Programme (SEMP) of the Ministry of Environment and Forest and UNDP.

Yobouet, Y. A., Adouby, K., Trokourey, A., Yao, B., 2010. Cadmium, Copper, Lead and Zinc speciation in contaminated soils. International Journal of Engineering Science and Technology. Vol. 2(5), 2010, 802-812.

Yu, H., Huang, G.H., 2009. Effects of sodium acetate as a pH control amendment on the composting of food waste. Bioresour. Technol., 100: 2005–2011

Zucconi, F., Forte, M., Monaco, A., de Bertoldi, M., 1981. Biological evaluation of compost maturity. BioCycle 22 (2), 27-29.

Zurbrugg, C., Drescher, S., Rytz, I., Sinha, A.H.M., Enayetullah, I., 2005. Decentralized composting in Bangladesh, a win-win situation for all stakeholders. Resour. Conserv. Recycling, 43: 281-292.

Author’s addresses:

KOLEDZI Komi Edem, BABA Gnon, TCHANGBEDJI Gado and AGBEKO K.
Laboratory for Management, Treatment and Value of Waste (GTVD)
University of Lomé
BP 1515 Lomé, Togo

MATEJKA Guy*, FEUILLADE Geneviève
Research Group for Water, Soil and Environment
University of Limoges
16 rue Atlantis Parc
ESTER Technopole
87068 Limoges, France
*Corresponding author:
E-mail address: matejka@ensil.unilim.fr
Telephone: 0033555423679
Fax: 0033555423662

BOWEN Jim
Civil Engineering department
University of North Carolina at Charlotte
Charlotte NC 28223-0001, USA

Biological mechanical treatment of municipal solid waste in China: lab and field application

LU Fan, YANG Na, SHAO Liming, HE Pinjing

Institute of Waste Treatment and Reclamation, State Key Laboratory of Pollution Control and Resources Reuse, College of Environmental Science and Engineering

Abstract

High water content and the putrescible property of municipal solid waste (MSW) could greatly deteriorate the sorting efficiency, deactivate the operations of aerobic treatment and incineration, as well as aggravate the landfill pollutions. A hydrolysis-aerobic combined process was designed and investigated to improve the bio-drying efficiency of MSW with high water content. The process was found to be preferable for water elimination and energy reservation. The water content reduction led to a direct increment of sorting efficiency and heat value, and a reduction of volume and landfill pollution potential. The environmental and economic assessment was done on the bio-drying-centric waste management framework. Demonstration plant was then established based on the optimized process.

Keywords

High Water Content, Municipal Solid Waste, Bio-drying

1 Background

Municipal solid waste (MSW) in many developing countries, such as China, is characterized by high water content (usually more than 60%) due to a relatively high proportion of food waste (ZHANG ET AL., 2008A). The high water content and the putrescible property greatly deteriorate the sorting efficiency of MSW or even deactivate the operations. In addition, the waste-to-energy process is also limited for its low lower heating value (LHV, 3−6.7 MJ/kg), and the landfill process is interfered by large amounts of generated leachate with high organic loading. Therefore, bio-drying pretreatment is proposed to decrease the water content and subsequently increase the sorting efficiency of the waste in China. After mechanical sorting, the fractions with high recovery value can be recovered from the waste flow, the fractions with better combustibility can be subjected to incineration or pyrolysis and the residues of high stabilization are left for landfill disposal. As a whole, the biological-mechanical treatment (BMT) can increase the recovery amount of material and energy, and save land for landfill. Herein, a lab-scale simulation was done to optimize the bio-drying process for MSW with high water content, considering sorting efficiency, heating value, gaseous emissions, water and organic reductions. Based on the proposed optimal bio-drying parameters, the environmental and economic effect of BMT on the subsequent management processes, i.e.

material recovery or composting, incineration or pyrolysis and landfilling, were researched compared with raw waste disposal.

2 Lab-scale Simulation of the Bio-drying Process

2.1 Hydrolysis-aerobic combined process

Considering the high water content and high organic content of the mixed collected MSW, hydrolysis-aerobic combined process was proposed as a specific bio-drying method, which can remove more water per unit of organic loss compared with the conventional aerobic process (ZHANG ET AL., 2008B; ZHANG ET AL., 2008C).

As shown in Figure 1, during the hydrolysis stage, no or less external oxygen was supplied, resultantly, leading to an anoxic or anaerobic condition, which could facilitate the hydrolysis of polymers. The disruption of external cell membrane would further accelerate the release of internal cytoplasme. As a result, the water retained in the solid matrix came out in the form of leachate, and produced a dryer materials which were more favorable for aerobic reaction. Furthermore, the majority of organic matters would still be kept in the solid matrix, so as to reduce the ratio of water to organics of substrate, indicating higher vaporization potential. Comparatively, during the subsequent aerobic stage with air ventilation, the system took use of the heat and high temperature generated from aerobic degradation of organics, and made the water release out mainly in the form of vapor. It was indicated that the combined process was more suitable to bio-drying this type of waste.

Compared with the aerobic processes, the combined processes had a higher bio-drying index (4.20 vs. 3.40). Moreover, the lowest final water content occurred in the combined process (51.5% decreased from an initial 78.7%). It suggested that the combined process was more suitable for water elimination and energy reservation.

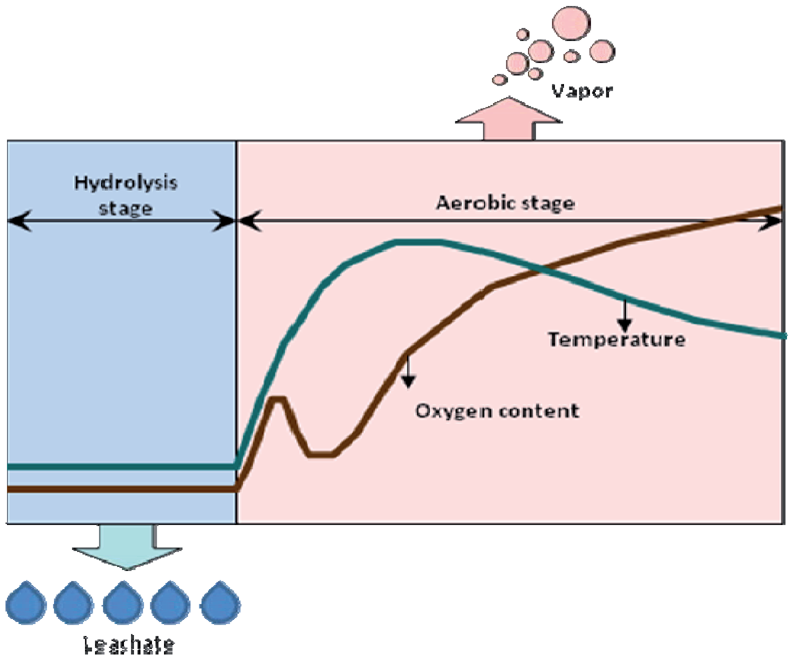


Figure 1 Temporal scheme of hydrolysis-aerobic combined process

2.2 Benefit from bio-drying process

During the hydrolysis-aerobic combined bio-drying process, mechanical sorting efficiency of MSW increased from 34% to 71% (ZHANG ET AL., 2009A), and the sorting efficiency was negatively correlated with water content (r = − 0.89) and positively correlated with the organic degradation (r = − 0.92).

After bio-drying, the food and paper (FP) was manually sorted from the residues, and the combustion properties of the mixed-residues (MR) and FP were investigated, which revealed that MR had higher LHVs and ratios of volatile matter to fixed carbon and FP had higher final burnout values. With regard to the gas emissions from combustion (ZHANG ET AL., 2009B), bio-drying resulted in the increase of the HCl and SO_2 emissions and potential for PCDD formation but the decrease of NOx emissions, and MR was more favorable for combustion than FP.

The heavy metal concentrations increased by around 60% due to the loss of dry materials mainly resulting from biodegradation of food residues. The bio-dried waste fractions with particle size higher than 45 mm were mainly composed of plastics and papers, and were preferable for the production of refuse derived fuel (RDF) in view of higher LHVs as well as lower heavy metal concentrations and emissions. However, due to the higher chlorine content and HCl emission potential, attention should be paid to acid gas and dioxin pollution control. Although LHVs of the waste fractions with size <45 mm increased by around 2× after bio-drying, they were still below the quality standards for

RDF and much higher heavy metal pollution potential was observed. Different incineration strategies could be adopted for different particle size fractions of MSW, regarding to their combustibilities and pollution properties (SHAO ET AL., 2010).

2.3 Environmental and Economic Assessment

Based on the lab-scale simulation, the environmental and economic impacts of two combined processes, active stage bio-drying + sanitary landfill (AL), and active and curing biological treatment (ACL) were compared with the direct sanitary landfill (SL). The results indicated that land requirement, leachate generation and CH_4 emission from ACL process was significantly (69, 89 and 88 % respectively) decreased from SL.

The total costs for the three scenarios were calculated and shown in Table 1. The total costs for AL and ACL were 88.5% and 75.8% of that for SL, respectively, indicating that the combinations of bio-drying and subsequent landfill were more economically advantageous than the conventional landfill and the ACL was the optimal combination.

Sensitivity analysis revealed that the land price was the dominate factor in determining the cost of treatment and disposal when the price was greater than 100 USD m^{-2} and the total costs of ACL were reduced to less than 40% of those of SL.

Table 1 Economic assessment

Scenarios	Costs (×10^6USD)		Benefits (×10^6USD)	Total Cost (×10^6USD)
	Bio-stabilization	Landfill		
CL	--	15.97	6.39	9.58
AL	4.15	5.74	3.20	8.48
ACL	4.66	1.41	0.59	7.26

By contrast with “direct sanitary landfill” process, the combined “active bio-drying + sanitary landfill” process could not only substantially save land, minimize landfill pollutions regarding leachate generation and methane emission, but also reduce the total cost. Therefore, the combined MSW bio-drying followed by landfill process was suggested as an environmental friendly technology for substituting the sanitary landfill of raw MSW.

3 Demonstration Application

Based on the above mentioned BMT process on the background of this paper, a MSW treatment plant with the daily capacity of 1000 tons of raw waste is under construction in Shanghai. The flowchart of treatment technologies is shown in Figure 2.

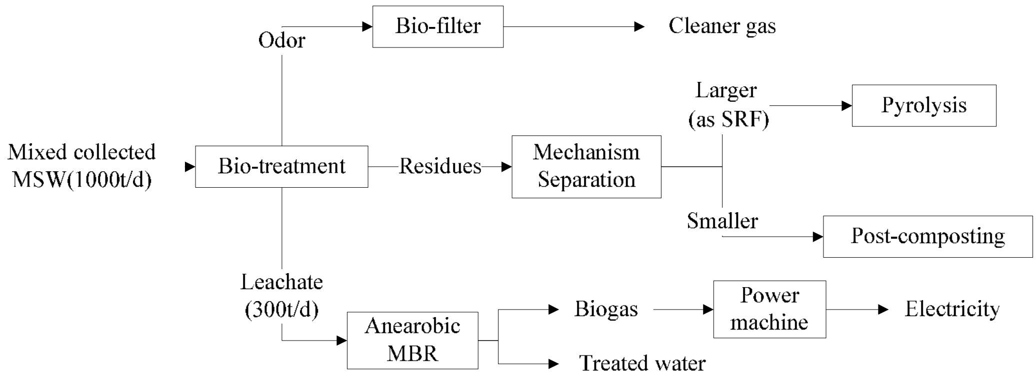


Figure 2 Flowchart of treatment technologies in the abuilding BMT plant in Shanghai

4 Conclusion

Bio-drying is preferable for sorting and then subsequent landfilling or incineration of high-water content MSW. Nevertheless, the outlet of bio-dried products should depend on the further analysis of it's characteristics. Furthermore, the arguing pro and con on the bio-drying should be established upon a global assessment of the bio-drying-centric waste management framework.

5 Acknowledgement

This work was financially supported by National Key Technology R&D Program of China (No. 2006BAC06B04) and the Key Special Program on the S&T for the Pollution Control and Treatment of Water Bodies (No. 2008ZX07101-006).

6 Literature

Shao, L.M., Ma, Z.H., Zhang, H., Zhang D.Q., and He P.J.	2010	Bio-drying and size sorting of municipal solid waste with high water content for improving energy recovery. Waste Management 30: 1165-1170
Zhang, D.Q., He, P.J., Shao, L.M., Jin, T.F., and Han, J.Y.	2008a	Biodrying of municipal solid waste with high water content by combined hydrolytic-aerobic technology. Journal of Environmental Sciences-

		China 20: 1534-1540.
Zhang, D.Q., He, P.J., Jin, T.F., and Shao, L.M.	2008b	Bio-drying of municipal solid waste with high water content by aeration procedures regulation and inoculation. Bioresource Technology 99: 8796-8802.
Zhang, D.Q., He, P.J., Shao, L.M., Jin, T.F., and Han, J.Y.	2008c	Biodrying of municipal solid waste with high water content by combined hydrolytic-aerobic technology. Journal of Environmental Sciences-China 20: 1534-1540.
Zhang, D.Q., He, P.J., and Shao, L.M.	2009a	Sorting efficiency and combustion properties of municipal solid waste during bio-drying. Waste Management 29: 2816-2823.
Zhang, D.Q., He, P.J., and Shao, L.M.	2009b	Potential gases emissions from the combustion of municipal solid waste by bio-drying. Journal of Hazardous Materials 168: 1497-1503.

Author's address:

*Corresponding to : Prof. Dr. Pining He
Institute of Waste Treatment and Reclamation
College of Environmental Science and Engineering, Tongji University
1239 Siping Road, Shanghai 200092, P.R. China
Tel/Fax: +86 21 65981383
Email: solidwaste@tongji.edu.cn

Role of MBT in increasing the number of composting facilities in Iran

Nader Mokhtarani[1*], Manigeh Khaleghi Sarnamy[2], Babak Mokhtarani[3]

1-Civil & Environmental Engineering Faculty

2-Jahesh Kimia Company

3-Chemistry and Chemical Eng. Research Centre

Abstract

In I.R. Iran with respect to 0.64 Kg/Cap.day garbage, near 48,000 ton of solid waste is produced daily. Regarding to high percentage of biodegradable material in this waste, production of 10,000 ton/day of fine compost is possible. At this time, only 15 active composting plants are available in Iran and if all of them act with nominal capacity, only 12% of the total produced municipal solid waste will be processed and reminder will be disposed with the other methods. Unfortunately, as the solid waste in Iran collected without any source segregation, the quality of produced compost is poor. The Presence of glass may be the main reason for poor quality of this compost. Refused batteries are also other sources that reduced the Desirability of compost for the consumers. In order to increase the quantity and quality of produced compost, development of mechanical and biological treatment (MBT) systems are strongly recommended. Developing of MBT systems in solid waste managing facilities not only increase the quality of compost but also reduce the reject elements which remains after processing and will be sent for disposal to landfill. By taking advantage of these systems, it is expected that the production of compost will increase up to 10%. It is also causes the composting plant to be profitable. Therefore, it is anticipated that the number of composting facilities increase dramatically in the near future.

Keywords

Composting, Disposal, Iran, MBT, Recycling, Solid waste

1 Introduction

Solid waste is a serious environmental problem in both developed and developing countries. In recent years, most developing countries have started to improve their municipal solid waste management practices. The increasing amount of wastes generated by rapid urbanization in these countries is usually not properly managed. Solid waste management (SWM) systems in developing countries must deal with many difficulties, including low technical experience and low financial resources which often cover only collection and transfer costs, leaving no resources for safe final disposal (COLLIVIGNARELLI, ET AL., 2004). Improper management of solid waste has been reported by several researchers in different cities of developing countries (BERKUN, ET AL., 2005; CHUNG AND CARLOS, 2008; IMAM, ET AL., 2008; SHARHOLY, ET AL., 2008). Inadequate management of solid waste in most cities of developing countries leads to problems that impair human and animal health and ultimately result in economic, environmental and biological losses (ALAVIMOGHADAM, ET AL., 2009).

Generations of a huge amount of MSW have produced a lot of environmental problem in all over the world. In order to overcome of these environmental problems, an appropriate and integrated solid waste management is essential. An integrated solid waste management system is composed of several functional elements including Generation & storage; Pollution prevention & waste minimization; Recycling & reusing; Collection & transfer; and Treatment & Disposal. In such a system, all functional elements from the generation of waste to the final disposal are considered carefully (TCHOBANOGLOUS, ET AL., 1993). The reason for this classification is identification and separation of the duty of each step (LAGREGA, ET AL., 2001; TCHOBANOGLOUS, ET AL., 1993).

Environmental impact of improper SWM is becoming a global problem in all over the world. In recent years, the international policy on management of organic wastes has been increasingly directed towards recycling and reuse. Recycling not only reduces the environmental impact of waste but also decreases the costs of disposal facilities. There are different technologies to reduce wastes in the disposal site and mechanical biological treatment (MBT) is often presented as a suitable system for this propose.

Use of MBT is one of the attractive topics raised in recent years in solid waste management. A mechanical biological treatment system is a form of waste processing facility that combines a sorting facility with a form of biological treatment such as composting or anaerobic digestion. MBT plants are designed to process mixed household waste as well as commercial and industrial wastes.

MBT system reduces the volume of residual waste and therefore the landfill space taken. It is also reduces the biodegradability of the waste, thus reducing the methane and leachate production once the residue is landfilled. MBT can enable recovery of items that may not otherwise be collected in household systems (e.g. steel coat hangers, etc.) Potential hazardous waste contaminants of the waste stream, such as batteries, solvents, paints, fluorescent light bulbs etc, will not reach municipal landfill sites due to the sorting of the waste prior to treatment. Stabilization of the waste reduces side-effects at the landfill site such as odor, dust and windblown paper and plastics are other Potential advantages of MBT (DAMIECKI R., 2002). The capacity of MBT plants can range from 10,000 tpa to large scale facilities of 250,000 tpa.

So far this system has been experienced in different countries such as Germany, France, Britain, Belgium, Poland, Spain, Finland, Switzerland, Hungary, Iran and Turkey. From 70 MBT plants operating in Europe in 2007 more than 40 plants were in

Germany (HEERMAN, C., 2002). In recent years several MBT plant has been used to manage municipal solid wastes in some big cities of Iran.

Regarding to high percentage of biodegradable constituent in MSW of Iran, as well as the lack of source segregation scheme and with regard to national and international environmental laws and regulations, applying of MBT systems could be a good candidate to improve the performance of different stages of SWM in this country.

The main objectives of this study was to reviews the current status of composting plants in Iran and provide practical solutions for increasing the number of production facilities and also raising the quality of produced compost in this country.

2 Materials and methods

The research reported here focuses on Iran Solid waste composting program and provide practical solutions for increasing the number of production facilities and also raising the quality of produced compost in this country. Specifically, this paper addresses the following research questions:

What should be the focus for increasing performance of SWM in Iran?

What is the most effective medium for increasing the number of composting plant?

What strategies should be adopted to effectively enhance the quality of compost?

The collected data were based on the data from the visual observations by the authors, available reports and several interviews and meetings with responsible persons, including engineers working in the municipality and composting plant.

3 Results and discussion

In this section, the current situation regarding MSW management in Iran, including the quantity and quality of waste, recovery and recycling of organic materials and strategies to enhance the compost quality is discussed.

3.1 Solid waste generation and characteristics

Data regarding solid waste generation and its individual components are important in the selection and operation of equipment and facilities, in assessing the feasibility of resources and energy recovery, and in the analysis and design of the final disposal facilities. Waste production and composition depends on many factors such as the stage of development, the socioeconomic, climatic and geographical conditions and collection frequency (TCHOBANOGLOUS, ET AL., 1993; COLLIVIGNARELLI, ET AL., 2004).

As the quantity of solid waste generated is of critical importance for proper management of solid wastes, it is discuses firstly in this paper. According to the collected data, the waste generation rate in Iran is about 0.64 Kg/Cap.Day. This generation rate is lower than that of Tehran city, which is about 0.84 Kg/Cap.Day (CSMRMO, 2004; OWRC, 2005; NABIZADEH, ET AL., 2008). In Iran with respect to 75 million populations, near 48,000 ton of solid waste is produced daily. The quantity of municipal solid wastes production in several big cities of this country is shown in table 1 (NABIZADEH, ET AL., 2008; POPULATION REPORTS, 2011).

Table 1 quantity of MSW produced in several important cities of Iran (2010)

Location (City)	**Quantity** (Ton/day)	**Population** (Cap)	**Generation rate** (Kg/Cap.day)
Ahvaz	1200	1,400,000	0.86
Ardabil	350	540,000	0.65
Arak	400	580,000	0.69
Bandarabas	400	600,000	0.67
Bojnourd	140	340,000	0.41
Birjand	160	260,000	0.62
Esfahan	1100	2,100,000	0.52
Orumieh	450	920,000	0.49
Hamadan	310	600,000	0.52
Gorgan	220	420,000	0.52
Ghazvin	350	580,000	0.60
Ghom	600	1,150,000	0.52
Ilam	140	210,000	0.67
Kerman	400	760,000	0.53
Kermanshah	600	990,000	0.61
Karaj	1200	1,900,000	0.63
Khoramabad	300	590,000	0.51
Mashhad	1750	3,000,000	0.58
Rasht	560	880,000	0.64
Semnan	90	165,000	0.55
Sari	300	520,000	0.58
Sanandaj	250	430,000	0.58
Shiraz	1000	1,800,000	0.56
Tehran	7500	9,000,000	0.84
Tabriz	1100	1,650,000	0.67
Yazd	270	570,000	0.47
yasuj	120	230,000	0.52
Zahedan	350	780,000	0.45
Zanjan	280	470,000	0.60

The average weight percentages of different components of Iran's MSW are also shown in figure 1 (NABIZADEH, ET AL., 2008). As shown more than 70% of this waste is biodegradable (food) materials which make it difficult to manage. The main reasons for the high percentages of food wastes in Iran MSW are: consumption of raw and unprocessed foods such as different types of vegetables and high rate of fruit consumption.

3.2 Recycling and reuse of organic materials

In recent years, the international policy on management of organic wastes has been increasingly directed towards recycling and reuse. There are different technologies to recycle organic wastes and composting is often presented as a low-investment process to convert organic wastes to an organic fertilizer known as compost (HAUG, 1993).

Regarding to high percentage of biodegradable constituent in the MSW, and also compiled of new standards by Iran Environmental protection agency, as well as existence of native technology for manufacturing of many composting equipments, the composting process will be a superior option for disposal of organic materials in this area.

At this time, production of more than 10,000 ton/day of fine compost from MSW is possible in Iran. This compost can be used in farms, agricultural soils and also as soil conditioner in unproductive and brackish areas. But marketing and sales issue is the major obstacle in establish of new composting facilities and production of compost in this country.

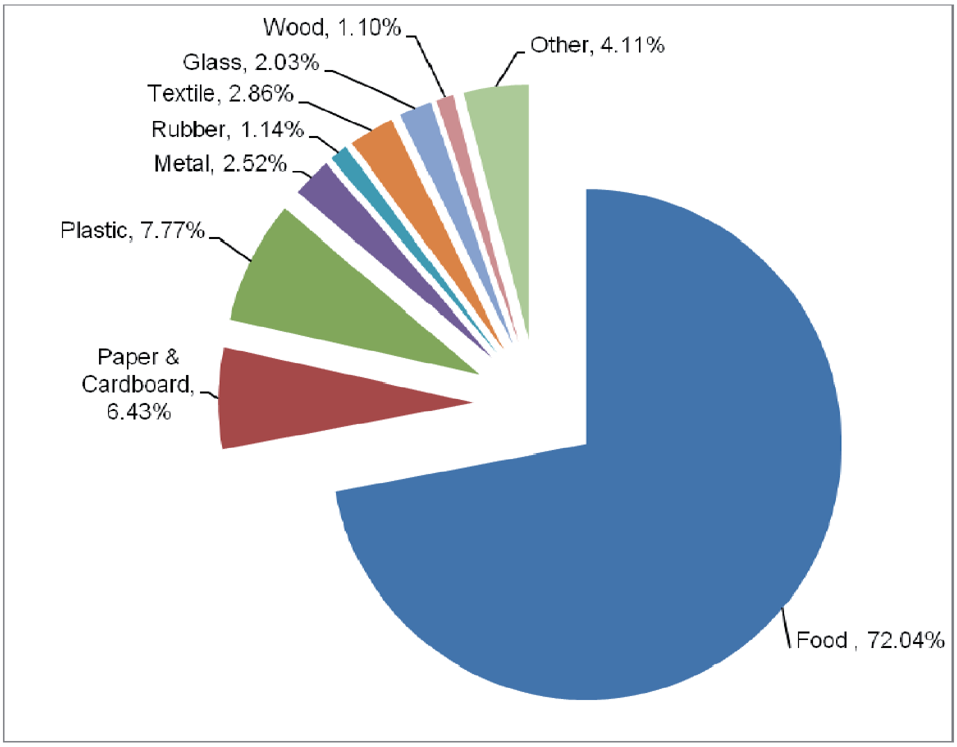


Figure 1 Average composition of MSW of Iran (% of weight)

At present (winter 2011), only 15 active composting plants are available in Iran, and if all of them act with nominal capacity, only 12% of the total produced solid waste will be processed and the reminder (88%) will be disposed by anther methods. The characteristics of active composting facilities are summarized in table-2.

Table 2 The characteristics of active composting plant in Iran (2011)

Location (City)	**Nominal Capacity** (Ton/Day)	**Date of Operation**	**Method**
Tehran	2000	1992-2009	OWC*
Rasht	500	2004	OWC
Tabriz	250	1998	OWC
Karaj	500	1999	OWC
Gorgan	250	2007	OWC
Amole	200	2006	OWC
Kerman	200	2008	OWC
Kermanshah	300	2000	OWC
Mashhad	500	1997	OWC
Esfahan	500	1970	OWC
Yazd	200	2009	OWC
Sanandaj	100	2006	OWC
Anzali	50	2007	OWC
Roudsar	200	2010	OWC
Lenjan	50	2009	OWC

*Open Windrow Composting

As shown, in this 15 active composting plant near 1200 tons of compost has been produces daily which cover a small percentage of fertilizer needed in agriculture. Nevertheless, due to relatively low-quality, the product of these units has not been welcomed by farmers and despite of government support, already establishment of new composting units are not economically justified.

Different conventional stages of composting process used in Iran are shown in Figure 2. Although in all of the composting plants hand sorting has been predicted, however, the lack of source segregation programs is considered as the main factor in poor quality of produced compost.

Presence of glass particles was the most important impurities of compost that make it unwillingness for consumers. Most of glass residue in municipal solid waste Crush during collection and transportation process and therefore, it is impossible to segregate all of them from compostable part of waste in composting facilities. Although in the recent years with the replacement of plastic compounds such as PET instead of glass containers, glass percentage significantly dropped in the MSW, but this small quantity also makes dissatisfaction of consumers.

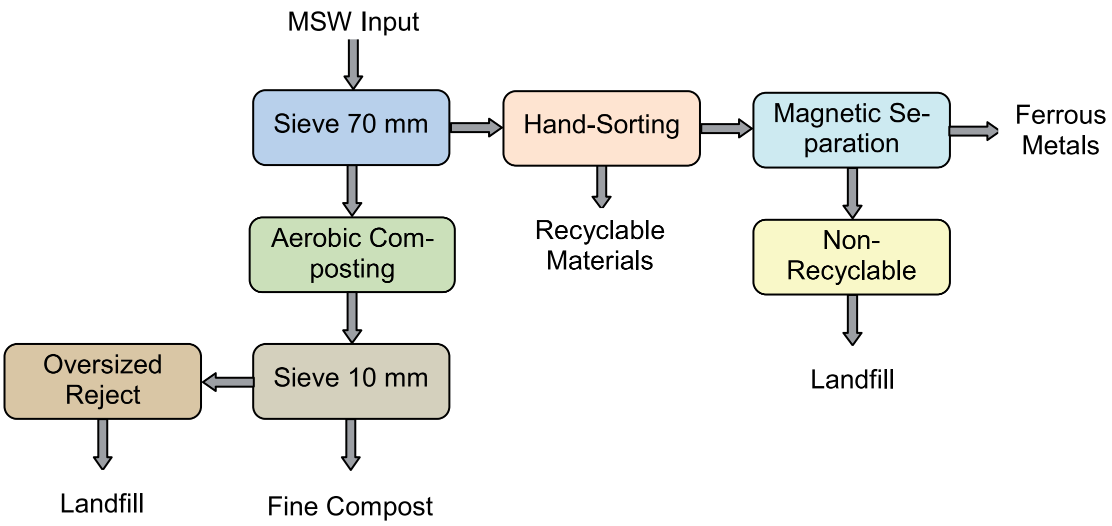


Figure 2 Different conventional stages of composting process in Iran

Refused batteries are also other sources that reduced the Desirability of compost for the consumers. Due to impossibility of complete separation of batteries from organic waste the presence of these compounds in the fermentation hall was inevitable that increases the amount of heavy metals, and reduces the quality of compost.

Different Types of plastic bags are other impurities that found in the fermentation Hall. They not only reduce the quality of product but also due to coverage on organic materials and isolating part of them from surroundings, causing abort compost or longer process time.

3.3 Strategies to enhance the compost quality

There are different ways to enhance the quality of compost and create customer satisfaction. In this way waste segregation from the origin is one of the most efficient and most important options. But according to the situation of waste management in Iran and lack of suitable infrastructures this should be considered as a long-term option and an appropriate solution should also consider for short term. It should be considered that the source separation schemes in most cases do not have 100% efficiency and For example, for glass particles inside the compost may not be instrumental. Regarding to above mentioned subjects and according to studies undertaken on social, economical and geographical situation of Iran, the following are suggested to enhance the composting performance.

3.3.1 Segregation in transfer station

In most cities of Iran the collected MSW are transmitted to disposal sites through transfer stations. Separation of recyclable fraction by using mechanical equipment in transfer station is one of the most effective methods to increase recycling efficiency as well as compost quality. In this case different types of mechanical equipment such as belts conveyor, rotating screen, magnet, bags splitter and other mechanical separation equipments could be useful.

3.3.2 Segregation in composting plants

Although most of composting plants in Iran equipped with hand sorting conveyor to separate valuable compounds but since some fractions of waste such as plastic bags, glass and batteries are not economically valuable; not separated from organic materials and a high percentage of them remind along with organic materials which will be goes to fermentation site. In order to separate plastic bags and other light elements from the compostable materials air classifiers systems should be used. For glass, batteries and other impurities site management should be taken and required mechanical equipment must be provided. Because in Iran the MSW is collected in Plastic bags package and transfer of closed bags (not opened bags) as rejects to the landfill reduces the efficiency of recycling centers, installation of bag splitter is also recommended. It should be noted that recently an Iranian company (Jahesh Kimia) Succeed to build a kind of bag opener consistent with the Iran MSW and Three of them have been installed and are successfully tested in Gorgan and Rasht composting plants. Data showed that by installing of these devices, not only compost production efficiency increased but also the percentage of rejected waste that should be transferred to the landfill dropped significantly. Therefore the use of an enhanced mechanical biological treatment system (EMBT) in composting facilities could be useful in this regard.

3.3.3 Improvement of fine compost

Although EMBT during different stages of SWM will help greatly to increase the compost quality, but Improvement of fine compost by using mechanical equipments will cause a significant added value and customer satisfaction.

In this regard, the use of grinder, followed by compression to make the powder into Pellet or granule is one of the profitable strategies. In this process hard particles such as glass and gravel completely pulverized into very fine particles which will not be sharp and cutting. In This method additives can also be supplemented to compost to prepared specified properties and formula. It should be mentioned that wind withstand of particles and minimum loss due to wind dispersal (windblown) during transport and handling as well as Fertilization of land is another benefits of this technique. So, with applying of these mechanical systems not only the quality of compost can be changed according to customer requirements, but also different goods can be produce.

4 Proposed Process

With regard to quality and quantity of waste produced in Iran and with considering the national and international laws and regulations, an enhanced mechanical biological treatment system as shown in figure 3 was recommended for better SWM in Iran. This system will increase the quality of compost and also reduce the reject elements which remains after processing and will be send for disposal to landfill. By applying this system, it is expected that the production of existing composting plant increase up to 10%. It is also causes the composting industry to be profitable. Therefore, it is anticipated that the number of composting facilities increase dramatically in the near future.

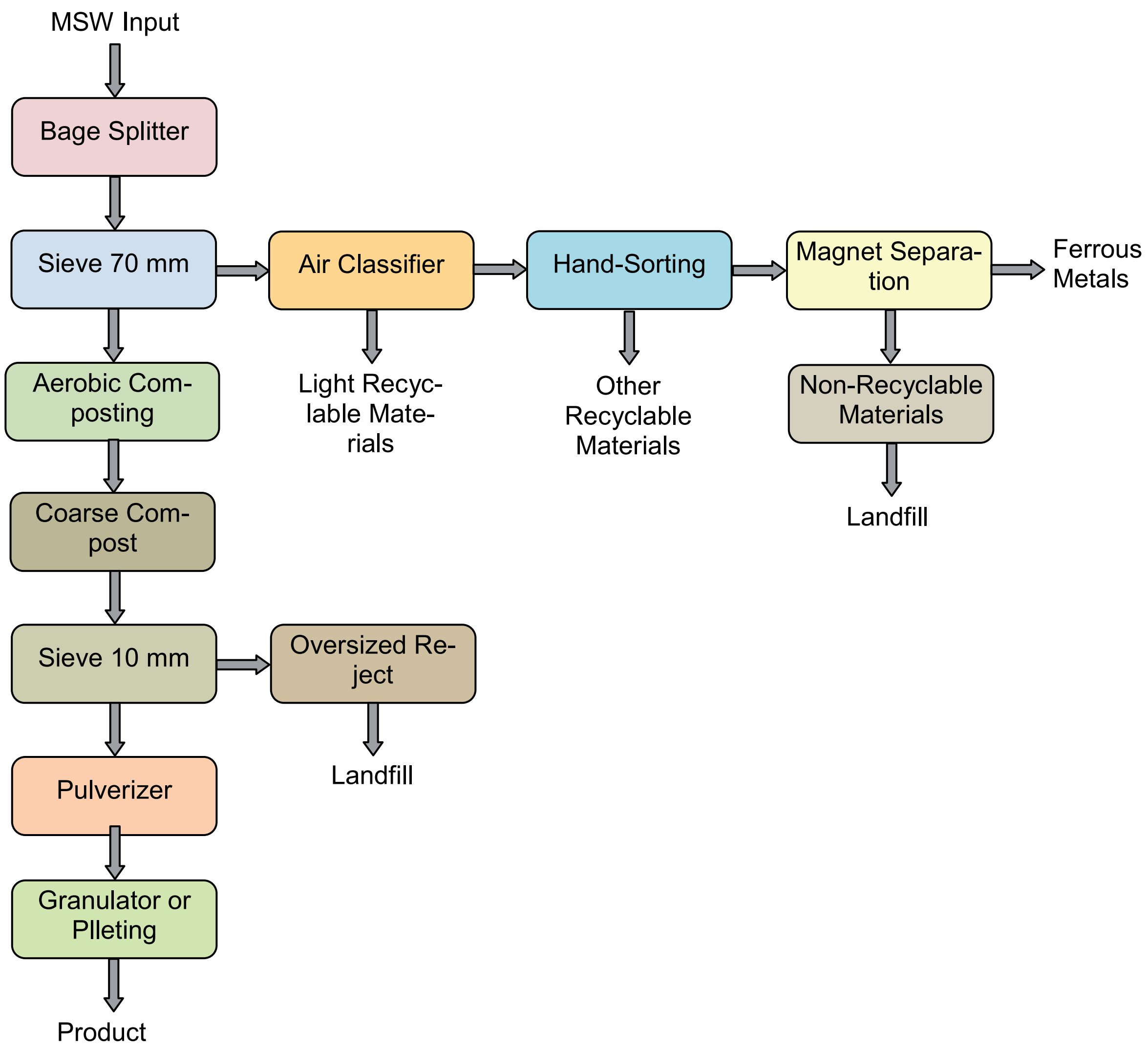


Figure 3 Recommended EMBT systems for composting plant

5 Summary and conclusions

In Iran more than 48000 ton per day garbage is produced daily. With considering 70% organic fraction in this waste, production of 10000 ton per day fine compost would be possible. At this time, only 12% of the total produced municipal solid waste will be processed to compost. Unfortunately, as the solid waste in Iran collected without any source segregation, the quality of produced compost is poor. Waste segregation from the origin is one of the most efficient and most important strategies to increasing the compost quality and recycling performance.

Separation of recyclable fraction by using MBT systems in transfer station and also in composting plant is another effective method to increase recycling efficiency as well as compost quality. In this case different types of mechanical separation equipment such as belts conveyor, rotating screen, magnet, bags splitter, could be useful. Improvement of fine compost by using again mechanical equipments such as grinder, rotary screen and granulator which cause a significant added value to compost is also another method for customer satisfaction.

Considering the Iran's environmental policies and with regard to agricultural, climate and geographical conditions and also poverty of soil, it is forecasted that by development of MBT and EMBT systems the quality of the produced compost and Demand for organic fertilizer significantly increased and establishment of new composting facilities will become profitable. In this case, it is anticipated that the number of composting facilities increase dramatically in a short period of time.

6 Acknowledgements

The authors would like to thank all responsible people in the municipality and the Organization for Waste Recovery and Composting of the Municipalities for their kind help with this research.

7 References

Alavimoghadam, M. R., Mokhtarani,N.,Mokhtarani,B	2009	Municipal solid waste management in Rasht City, Iran, Waste Management, 29, 485–489
Berkun, M., Aras, E., Nemlioglu, S.;	2005	Disposal of solid waste in Istanbul and along the Black Sea coast of Turkey, Waste Management 25, 847–855.
Chung, S.S., Carlos, W.H.Lo.;	2008	Local waste management constraints and waste administrators in China, Waste Management 28 (2), 272–281

Collivignarelli, C., Sorlini, S., Vaccari, M.;	2004	Solid Wastes Management in Developing Countries, CD-ROM of ISWA 2004 World Congress, October 17–21, Rome, Italy
CSMRMO;	2004	Quantitative and qualitative study of MSW in ten regions of Iran, Center of studies of Municipalities and Rural Management Organization, Ministry of interior, Iran
Damiecki, R.;	2002	Mechanical-biological pretreatment of MSW, Bioprocessing of solid waste and sludge, 2, 31-36
Haug, R.T.;	1993	The Practical Handbook of Compost Engineering, Lewis Publishers, Boca Raton, FL.
Heerman, C.,	2002	MBT – applicability to household waste, Warmer Bulletin
Imam, A., Mohammed, B., Wilson, D.C., Cheeseman, C.R.;	2008	Solid waste management in Abuja, Nigeria. Waste Management 28 (2), 468–472
LaGrega, M.D., Buckingham, P.L., Evans, J.C.;	2001	Hazardous waste management, 2nd edition, Mc Graw Hill publication, New York
Nabizadeh R., Heidari M., and Hassanvand M.S.;	2008	Municipal Solid Waste Analysis in Iran, Iran J. Health & Environ., 2008, Vol. 1, N0. 1
OWRC;	2005	Statistical report on 2002-2005, Organization for Waste Recycling and Composting, Tehran Municipality, Iran
Population Reports;	2011	Statistical Centre of Iran, http://www.amar.org.ir
Sharholy, M., Ahmad, K., Mahmood, G., Trivedi, R.C.;	2008	Municipal solid waste management in Indian cities – A review, Waste Management 28 (2), 459–467
Tchobanoglous G., Theison H. and Vigil A. S.;	1993	Integrated Solid Waste Management, McGraw-Hill International Edition

Author’s addresses:

Nader Mokhtarani, Assistant Professor

Civil & Environmental Engineering Faculty

Tarbiat Modares University, Tehran, Iran

Tel. (98-21) 82884921; fax: (98-21) 82883381

E-mail address: mokhtarani@modares.ac.ir

Manigeh Khaleghi Sarnamy

Jahesh Kimia Company

P.O. Box 13445-1381

Tehran, Iran

Babak Mokhtarani

Chemistry and Chemical Eng. Research Centre

Tehran, Iran

German GHG Mitigation Lighthouse Project MBT Plant Gaobeidian (PR China)

Florian Kölsch, Mathias Ginter, Klaus Fricke

Technical University Braunschweig, AWN Umwelt GmbH, Buchen, Germany

Abstract

In June 2009, the German Federal Ministry of Environment granted a fund to the German company AWN Umwelt GmbH (Buchen) to establish a mechanical biological treatment plant in the City of Gaobeidian (PR China). The facility is seen as a lighthouse project for GHG mitigation. In July 2009 the project work was launched. Detailed engineering design has been finalized by Pöyry Environment by October 2009 and the construction works were tendered. The site clearing and the construction of provision infrastructure was finalized by December 2009. In January 2010 the construction of the facility was started and will be finalized by April 2010. It is expected that the facility will run on full operation in summer 2011. Emission reductions of approximately 8.000-25.000 t CO_2eq per year are expected.

Keywords

MBT, CDM, waste treatment, emission reduction, China, MSW

1 Introduction

Experts estimate that 8 to 12 % of greenhouse gas (GHG) emissions in developing and emerging market countries are due to waste management activities. The major sources are methane emissions from disposal of untreated municipal solid waste, which in those countries contains a large portion of degradable organics. Biological waste treatment is an effective technology to stabilize organics and to minimize decay processes in landfills. The MBT plant in Gaobeidian (Hebei province, PR China) is a pilot waste management project to demonstrate this technology in China.

The project is administered by AWN Umwelt GmbH, a German waste management company partly public owned by AWN (Abfallwirtschaftsgesellschaft Neckar-Odenwald-Kreis) based in Buchen. AWN Umwelt has already established a joint venture for the construction of a sewage treatment plant in Gaobeidian The project was recently finalized and started operation. In the summer 2006 AWN Umwelt and the Municipality of Gaobeidian decided to prepare a similar project for the improvement of the waste disposal in Gaobeidian. The treatment facility is under construction and will open in Summer 2011.

Figure 1: Location of Gaobeidian

The project aims on reducing emissions from waste disposal activities, particularly emissions of methane to reduce the GHG release to the atmosphere by means of biological treatment. With an annual treatment capacity of 40.000 t municipal solid waste the total emission reduction is expected to amount to 80.000 – 250.000 t CO_2equivalents during a 10 years period.

2 Methodology

In a first step the technical, economic and legal conditions were investigated in a feasibility study funded by the PPP facility of KfW development bank, an endowment fund for the support of public private partnership projects financed by the German Ministry of Economic Cooperation and Development (BMZ). The technical and organisational execution of the study was assigned to the department of Waste and Resource Management of the Technical University Braunschweig. The study was prepared between September 2006 and February 2008. Based on the study AWN Umwelt applied for funding from the International Climate Initiative (IKI) of the German Ministry of Environment, Nature Conservation and Nuclear Safety. In June 2009 the German Government approved the grant. The implementation of the project was launched in July 2009. Detailed engineering and the approval process was finalized in December 2009. The facility is currently under construction, which is expected to be finalized by April 2011.

3 Technical investigations

During the feasibility study several technical investigations were carried out by experts from Technical University Braunschweig, AWN Umwelt and Pöyry Environment Witzenhausen. Data on waste generation and waste composition were examined. The department of waste management of Gaobeidian municipality collects annually approximately 50.000-60.000 t municipal solid waste. The collection is carried out by different collection systems, predominantly by underground drop-off containers and multi-chamber containers that are located at the roadside. The waste disposal site was located near to the city in an exploited clay pit, but has been shifted to a new site next to the future MBT plant located about 10 km outside Gaobeidian. The old disposal site had no technical barriers and was operated on the poorest technical level as a dumpsite. Dozens of waste pickers are irregularly active on the site (figure 2).

Figure 2: Waste pickers at Gaobeidian city landfill

The composition of the waste was determined by means of hand assorting a 250 kg waste sample. The sample was screened by 40 mm and 10 mm sieves. The sieve overflows were sorted by hand into groups of materials. The material that passed the 10 mm filter has been analysed in the laboratory. Table 1 shows the waste composition distinguished by material groups, which constitutes approximately 55 % of the waste weight.

Table 1: Waste composition

Material group	Portion [dry mass %]
Organic	28 %
Plastic foils	8,5 %
Coal	8,5 %
Stones	5 %
Paper	3 %
Textiles	1,5 %
< 10 mm	45,5 %

Plastic bottles, metals, rag paper, glass bottles and wood were not found. Regarding to a biological waste treatment there is a particular interest for the portion of the organic group as well as possible disturbing materials. In the fraction < 10 mm the organic fraction is 16%, measured as loss on ignition. Thus the entire organic portion amounts to approximately 35 mass-%, significantly less than the common value for developing countries (usually: 50-70 mass-%). Disturbing materials were not found in the waste. The high ash portion, which originates from burned out coal elements from simple cook places, showed up to be slight in pollutants.

Figure 3: Actively aerated windrow for MSW

The suitability of the potential biological treatment procedures under the given boundary conditions (local situation, climate, waste composition) was examined in three different pilot plants:

- Passively aerated heaps (so called chimney effect system)
- Actively aerated windrow heaps for MSW
- Actively aerated composting windrows for biowaste

The results of the biochemical stability of the fraction < 40 mm before, during, and after the actively aerated windrow treatment are listed in table 2. The respiration activity of the input material measured as AT_4 (respiration during 4 days) amounts to 25 mg O_2/kg, the loss on ignition amounts to 18%, the TOC to 8%. Table 2 illustrates the development of the parameters over the treatment period. The respiration activity dropped significantly down to 1,9 mg O_2/kg after two weeks of treatment reflecting the comprehensive stabilization of the organics. The output material meets the German standards for waste disposal.

Table 2: Evaluation of the biochemical properties – actively aerated window for MSW

	Input	**after 14 days (active)**	**after 6 weeks (active)**
	13.10.06	2.11.06	13.12.06
AT_4 [mg O_2/kg]	25,2	1,9	0,9
oDS [mass %]	18,1	14,2	14,3
TOC [mass %]	8,2	5,1	5,2
TOC in the eluate [mg/l]	639	160	270

The results were not fully satisfying. Though the quality of output material was welcomed, the total mass of converted organics was small due to low input concentration. For the large scale application it was anticipated to increase the portion of organics in the input material by either segregating non-organic waste or by separation of organic waste before treatment. Since a separate source collection is not feasible in Gaobeidian a test was carried out for hand assorting of organic materials. A biowaste acquisition campaign was launched at the dumpsite. During a period of 5 weeks biowaste was accepted against incentives. The collected organics were placed immediately on the composting heap. Larger quantities of biowaste were delivered by both waste pickers and residents at a rate of 6 €/t. Thus there is an economical bench mark for the separate source collection for biowaste available.

Figure 4: Delivery of market waste by local resident

4 Design

Based on the technical investigations a design for the MBT plant was prepared by Pöyry Environment Witzenhausen. The MBT plant consists of a mechanical and a biological treatment step. The mechanical treatment aims on segregating of valuable goods (paper, synthetics) and on enrichment of the organic fraction. The waste stream is split into three fractions (fine, medium, coarse). Middle and coarse fraction are being directed to hand assorting stations. Based on the waste analysis it is expected, that the medium fraction after assorting consists mainly of slightly clean organic. This portion may be converted into compost. The fine fraction will undergo biological treatment as well prior to final disposal. This fraction may be also useful as amendment for landfill cover, where it acts as methane oxidation layer. The coarse fraction will be either crushed and fed to the waste stream again or directly disposed at the landfill site. The design of the delivery and pretreatment plant is shown in figure 5.

The biological treatment will be carried out as an aerobic, actively ventilated stabilization. The process will run partly under roof and partly in open air areas. The triangular windrow heaps will be frequently turned by means of mobile equipment as shown by example in figure 6. The output material will be disposed at the adjacent new landfill, which recently started operation.

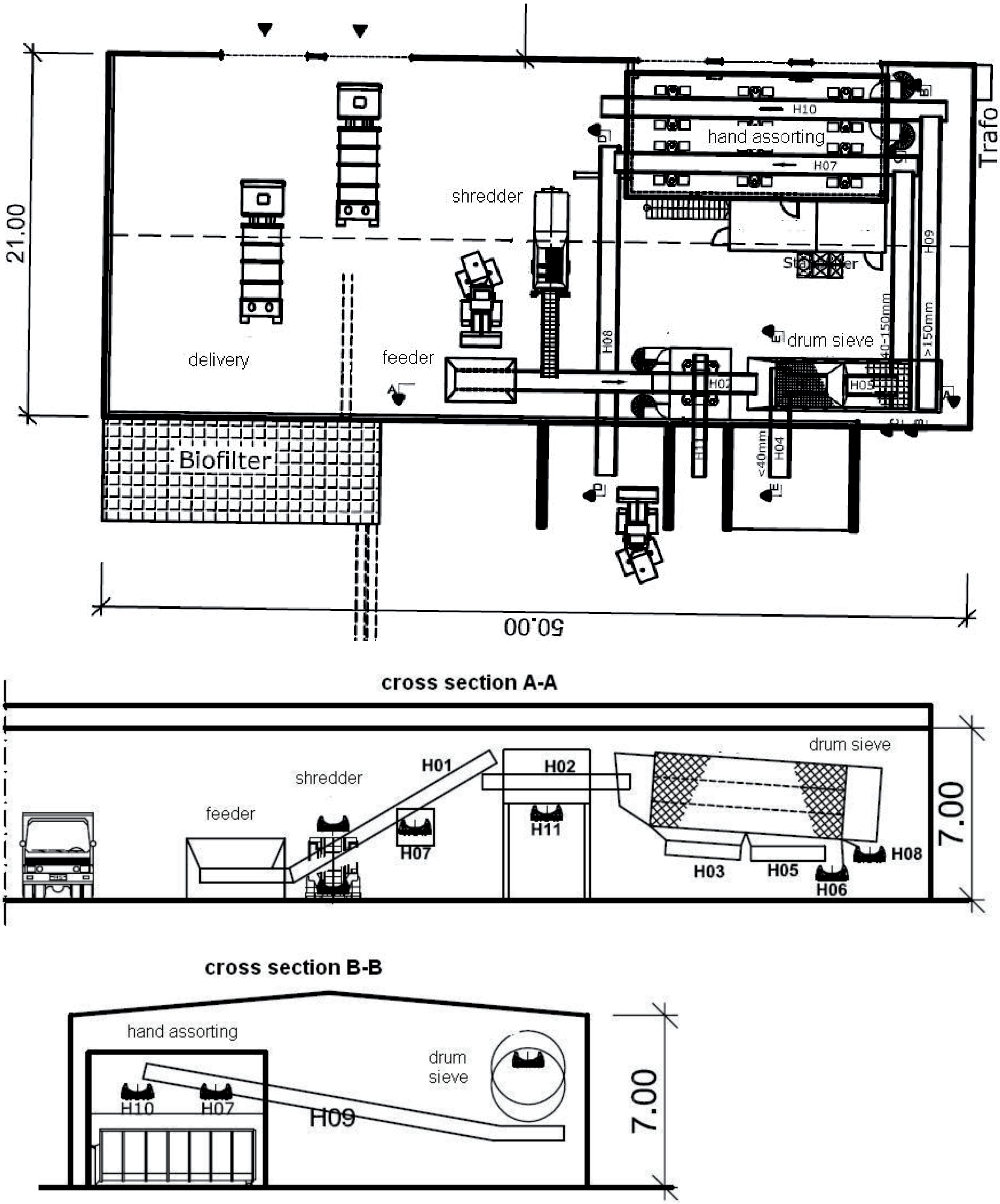


Figure 5: Delivery and mechanical treatment

On a longer view the economic benefits of the plant will be increased particularly by means of reutilization of the stabilized biomass for methane oxidation layer (special landfill cover), as soil amendment, or as fertilizer in agriculture, if possible. To achieve this goal the waste flux management needs to be refined in order to minimize pollutants and harming matters in the organic waste fraction.

Figure 6: Windrow heap under roof with revolving machine (example)

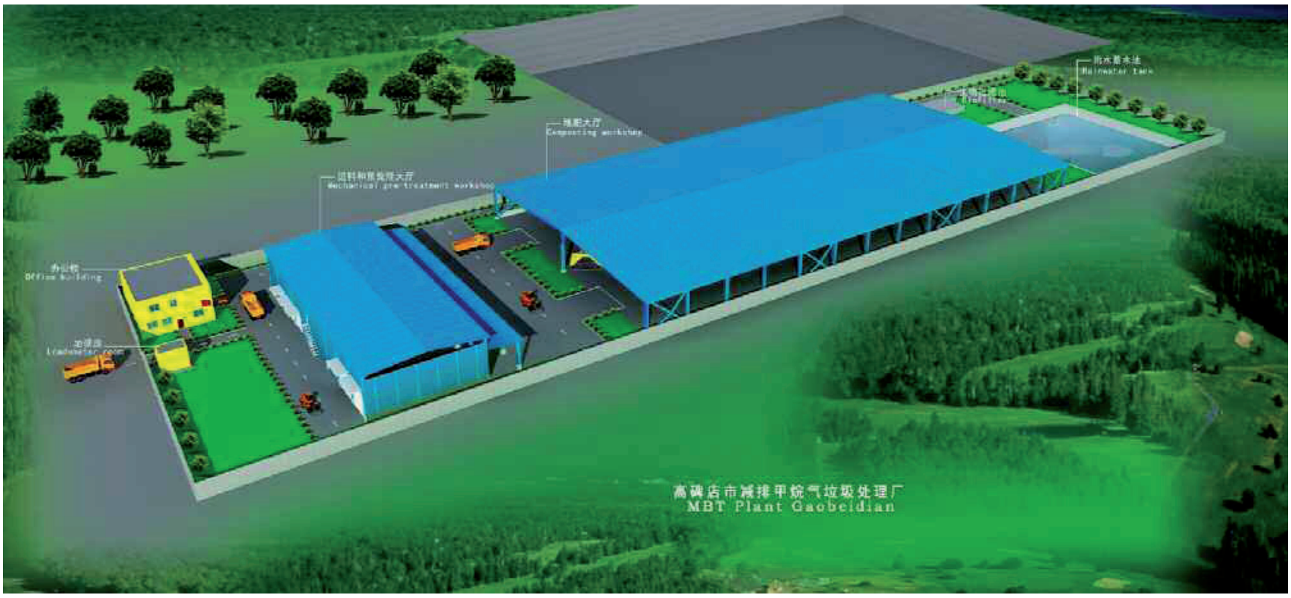


Figure 7: Lay out of the MBT plant Gaobeidian

The annual treatment capacity amounts to 40.000 t. If necessary, the capacity can be significantly increased by introducing two working shifts. The location still provides contingency area for an expansion of the biological treatment. Figure 7 illustrates the lay out of the facility.

5 Climate mitigation

The generation of methane in the landfill will be dramatically reduced by disposing stabilized biomass instead of untreated waste. The emission reductions were calculated using the methodologies of UNFCCC, which are relevant for CDM projects. Since the facility has been financed by national revenues from carbon trade a registration as CDM project is not permitted. Nevertheless, it is anticipated to verify the emission reductions in a similar procedure. Thus, the calculation of the baseline as well as the monitoring of project emissions is required.

The methodology AMS III.F (Avoidance of methane production from decay of biomass through composting) serves as the base of the baseline study and the monitoring concept for the Gaobeidian MBT project. For calculations an specific tool is available, the „ Tool to determine methane emissions avoided from dumping waste at a solid waste disposal site".

In the greenhouse gas balance of the whole project, the emissions which result from the project itself must be considered as a negative influence. Therefore all CO_2 emissions from power or fuel consumption of motor vehicles and electric machines are considered. The calculation algorithms for both scenarios - baseline and project – are, as far as possible, given by the existing methodologies and tools. For the calculation of the methane emissions by the disposed waste, a biological decay of the deposited waste is modelled over several years by a layer model. With this model the highest methane emissions in a layer emerge during the first years and show in the subsequent years a regressive behaviour. Table 3 shows the ex ante calculated emission balance for the project Gaobeidian during one period of 10 years. The projected amount of emission reductions result in 83,812 t CO_2-equivalentes for the project period of 2011-2020. The calculation does not include any of the planned measures to increase the organic fraction prior to the biotreatment. The baseline calculations represent only a prognosis, the amount of real reductions can diverge strongly. It depends on the plant capacity, the waste composition, the resource input, and other factors. In fact, the amount of emission reductions may even become three times higher resulting in approximately 250.000 t CO_2-equivalents.

Regarding the monitoring process, all data that were used for the determination of the emissions, have to be determined ex-post, if not constant. Based on the monitored data the real emissions during the lifetime of the project will be recorded. To these data belong e.g. the power or fuel consumption, as well as the waste composition, which has to be examined several times in the year. Table 3 provides the breakdown of expected emission reductions over the first ten years of operation.

Table 3: Ex ante emission calculations for the MBT Gaobeidian

Year	Baseline emissions [Mg CO_2eq]	Project emissions [Mg CO_2eq]	Emission reductions [Mg CO_2eq]
2011	2339	497	1842
2012	4376	537	3839
2013	6156	577	5579
2014	7714	616	7097
2015	9081	655	8426
2016	10284	694	9590
2017	11345	732	10613
2018	12283	770	11513
2019	13114	807	12306
2020	13852	845	13007
Total	**90541**	**6729**	**83812**

6 State of implementation

On 3rd of July 2009 the establishment of the MBT was officially launched in a ceremony by laying the first stone. After the clearing of the construction site the local counterpart had turned the area into a festival zone with stage, flowers, dragons, balloons and red carpets. On a 3 x 15 m sign the future plant was visualized. German and Chinese stakeholders from the municipality, province and national government, project developers and the donor joined the event. Several hundred spectators from the region gathered as audience. Finally fire works crowned the opening.

The execution of the project proceeds quickly. In accordance with the Chinese regulations a feasibility study and an environmental impact assessment was carried out and finalized by the end of October 2009. The official permit was granted by November 2009. Site clearance and construction of access and supply infrastructure was launched immediately but suffered from harsh weather conditions in January/February 2010. The main construction works of the facilities started in April 2010.

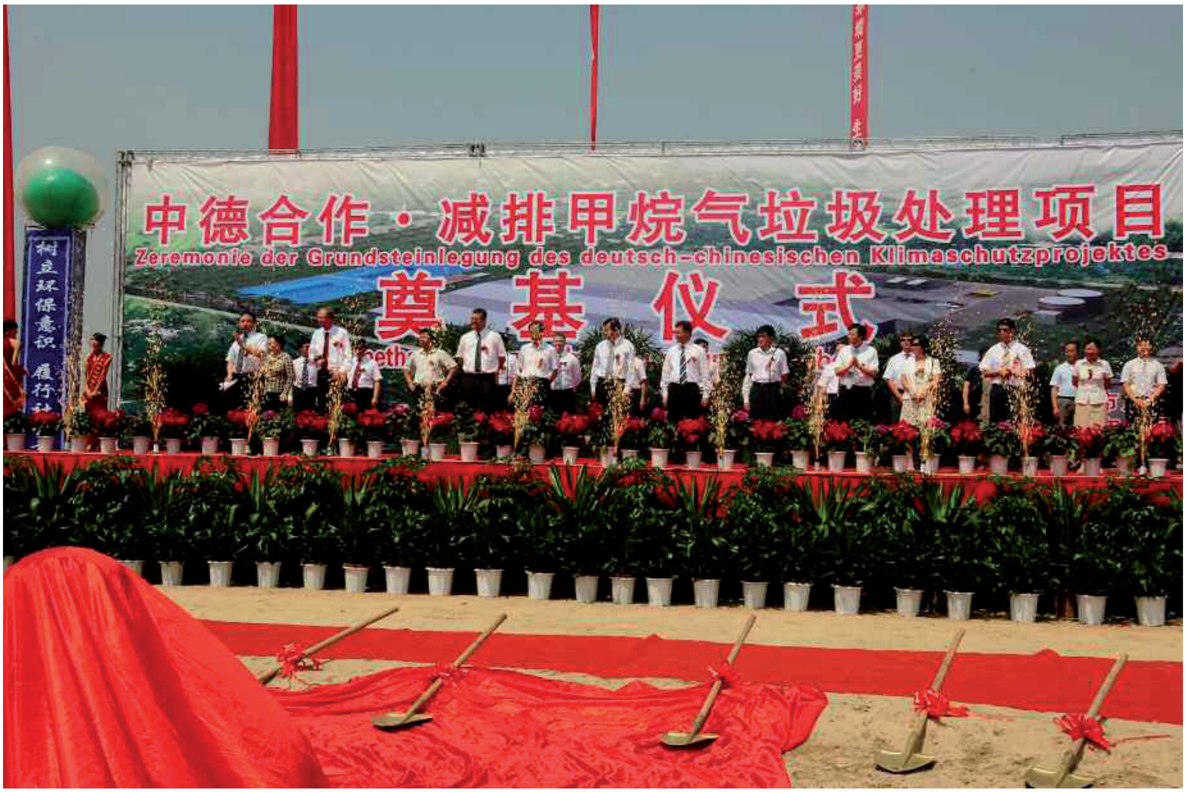


Figure 8: Opening ceremony

Figure 9: Facility compounds - biological treatment (in front), delivery (background)

All major civil constructions of the plant (delivery/mechanical treatment, biological treatment, administration, entrance) are nearly finalized. Figure 9 shows the current situation on site. The construction works are expected to be completed by April 2011, pilot operation shall subsequently.

7 Acknowledgements

The project developers appreciate the funding from the International Climate Imitative (IKI) by German Federal Ministry of Environment, Nature Conservation and Nuclear Safety. The International Climate Initiative is financing climate protection projects in developing and newly industrialising countries and in transition countries in Central and Eastern Europe since 2008. Through this, the Federal Environment Ministry is making an effective contribution to emission reductions and adaptation to climate change. This new form of environmental cooperation complements the government's existing development cooperation. Funding of 120 million euro per year is available for the International Climate Initiative from the revenues of the sale of emission allowances. A decision by the German Bundestag (parliament) forms the basis of this worldwide investment in climate protection. When selecting projects, the Federal Environment Ministry attaches great importance to the development of innovative and multipliable approaches that impact beyond the individual project itself and are transferable. Through targeted cooperation with partner countries the Climate Initiative provides important momentum for negotiations on an international climate agreement for the post-2012 period. One focus of the International Climate Initiative lies in the areas of promoting a climate-friendly economy. In this field the goal is to support partner countries in establishing a climate-friendly economic structure that prevents climate-damaging greenhouse gas emissions where possible. This support covers areas such as increasing energy efficiency, expanding renewable energies, reducing environmentally harmful greenhouse gases and investment-related measures, know-how transfer and policy advice in the partner country.

Author’s address:

Dr.-Ing. Florian Kölsch
Dr. Kölsch Geo- und Umwelttechnik GmbH
Gliesmaroder Straße 100
D-38106 Braunschweig
Telefon +49 531 2094133
Email: office@dr-koelsch.de
Website: www.dr-koelsch.de

Practice of Waste Management in the Arab Region

Abdallah Nassour, Mohamad Al-Ahmad, Ayman Naas, Michael Nelles

Department of Waste Management, University of Rostock

Abstract

Almost in all Arab countries general waste management concepts are still in the initial stage. Partly suitable laws were passed and some administrative structures have been established, but technical implementation, management, monitoring and financing of appropriate waste management systems are still considered to be a major challenge. Most Arab countries have had bad experiences in the sorting plants and MBT, caused by some organizational, technical and financial factors. The target of sorting plant and MBT technology in the Arab countries is not clear until now. MBT is only pre-treatment and it is not a complete solution, it cannot expect to produce high quality compost from mixed waste and sorting of all recyclable material. The produced fractions must be utilized in recycling facilities or disposed of, high calorific fractions can be used as fuel in the cement industry or power station plant while the organic fractions can be used for cultivation and land reclamation works. Tunisia and Jordan are in the preparation phase of pilot projects for sorting and MBT. Kuwait is a good potential market for MBT-Technologies now.

Zusammenfassung

Die Abfallwirtschaft – insbesondere was die Abfallbehandlung – steht in fast allen arabischen Ländern noch am Anfang. Es wurden diesbezüglich teilweise Gesetze verabschiedet und einige administrative Strukturen geschaffen. Die praktische Umsetzung im technischen Bereich, in der Verwaltung, Überwachung und Finanzierung sind nach wie vor noch eine große Herausforderung. Die meisten arabischen Länder haben schlechte Erfahrungen mit Sortieranlagen und MBA gemacht. Unzureichende Organisation, technische Probleme und finanzielle Schwierigkeiten sind hier als Ursachen zu sehen. Die Ziele der Sortieranlagen und der MBA-Technologie in den arabischen Ländern ist bis heute nicht klar. Es kann kein hochwertiger Kompost aus gemischten Abfällen produziert werden. Es können nicht alle Wertstoffe in einer MBA sortiert werden. Die MBA ist nur zur Vorbehandlung und nicht als komplette Lösung geeignet. Die erzeugten Fraktionen müssen in speziellen Anlagen verwertet oder entsorgt werden. Hochkalorische Fraktionen können als Brennstoff in der Zementindustrie oder in Kraftwerksanlagen verwertet werden. Organische Fraktionen können für Rekultivierung und Landgewinnung verwendet werden. Die Länder Tunesien und Jordanien sind in der Vorbereitungsphase zur Realisierung von Pilotvorhaben für Sortierung und MBA. Kuwait ist ein potentieller Markt für MBA-Technologien.

Keywords
MBA, Arabischer Raum, Sortieranlagen, Kompostierung, Abfallbehandlung

MBT, Arab Region, Sorting plant, Composting, Solid Waste Treatment

1 The present situation of waste management in the Arab region

The Arab region is now facing a turning point, which will have a positive effect on the overall development and waste management. The Arab countries have a total population approximately 300 million people and most of the countries are to be classified as developing countries, exceptions are the gulf countries (Kuwait, Saudi Arabia, United Arab Emirates, Qatar, Bahrain and Oman). However, in almost all Arab countries waste management concept still in the initial phase, most governments had recognized their waste management issues and they seek to implement legal, organizational and technical solutions for these problems. The lack of know-how in practicing the organization of waste management and the inadequate provision of the necessary funds for investment and operation of the plants are considered the main weaknesses of waste management in the region. Implementation of waste management varies according to the different standards of living in the countries, and the role of policies and international cooperation. Most countries have established technical systems for collection, transport and disposal of waste which are adapted to local conditions, the collection and transport of waste will be implemented by municipal or private companies, while the landfill remains the main disposal option.

In most Arab countries waste charges are very low and the funding system for waste management is not based on the principle of cost recovery. In the Gulf States it is the responsibility of the relevant ministries and local authorities, the fees are generally collected with the electricity bill, trade taxes, property or building taxes etc., the collected waste fees can often cover max 30% of the cost, another problem is that the fees go to a treasury centre, and there is not always a clear criteria on how it has been distributed.

There is no recycling management in most countries. The informal sector sorts the economically usable material PET, other plastics, metals and paper from the refuse bins on the streets. These materials are marketed nationally (metals, paper and plastic) and internationally (PET). Old paper, metals and partial plastics are recovered in local structures. The recycling materials sorted by the informal sector are about max. 1 - 3% of the total amount of waste.

There is no waste separation by households, while small quantities of recyclable materials are separated from commercial and industrial wastes. The implementation of the separate collection is still a great challenge, there are different test projects implemented to a introduce the separate collection in Jordan, Lebanon, Saudi Arabia, etc. so far, no scientific, long-term test projects planned and carried out. International Engineering for such projects with long-term experience should be integrated in such plans.

Ministries, municipal administrative structure or waste authorities are responsible for the implementation of collection and transport of waste. Tunisia is the only country which has a waste authority (ANGED) since 2004. Municipal and private companies are responsible for the implementation of waste collection and transport, however, the trend goes in the direction of private waste management (Gulf States, Egypt, etc.).

Depending on the finances available steel or plastic containers are used, which are locally or internationally produced. There is a trend towards supplying the market with plastic containers with volumes of 240 and 1,100 l by German and other European manufacturers. In most countries the number of containers is not sufficient, for this reason waste is often dumped alongside the provided containers on the street, the collection frequencies of the containers is one of the weakest points of waste management in the region. The waste containers are emptied in most cities at least once, sometimes three times, per day. German companies have established containers production facilities in UAE to supply the markets. Depending on available finances different techniques have been used (modern refuse collection vehicles, trucks, tractors, etc.). the modern waste collection vehicles in countries such as Syria, Jordan, Lebanon and Egypt are from Germany, Western Europe and Japan and are mostly financed through development assistance programs, while Turkey, Saudi Arabia and Jordan have their own production and they supply their neighbouring countries.

Persons employed in waste management are mainly from low wage countries and not trained for these tasks. The monthly income of the employees is between 50 and 200 € depending on the task, because of the low social acceptance for dealing with waste a common bonus or premium is paid. The finance provided by the responsible local authorities for the disposal logistics, according to the Level of development, is between 10-50 € / Mg

Treatment, recovery and disposal of waste accumulating in the Arab countries represent a major challenge. All types of waste are simply deposited in landfills. Depending on the level of development, available finances and support from the international aid organization waste treatment plants and landfills were built and implemented. Tunisia is a leader in the Arab world, it has 9 central waste landfills funded with EU and KfW and a test project for MBT is in the planning phase. Until now, the region is living a bad experience with sorting. For sorting the recyclable materials and processing of the separated organic fractions, there are no facilities for composting of organic fractions. In particular the need is very large for organic fractions from animal husbandry. Currently, there are some activities for the construction and operation of mechanical-biological waste treatment plants and in the field of energy recovery of the calorific value rich fractions in the cement industry.

2 Development trends of sorting and MBT in the Arab region

The theoretical ideas and concepts of waste sorting and MBT are in the minds of decision-makers of waste management in the Arab countries. Political, administrative and waste management companies are very confident of it. The problem still lies in the implementation and collection of practical experiences, because it is difficult in the Arab countries to build and operate pilot and test projects in order to get practical experience and propose adapted large-scale solutions.

There are still six obstacles to the sorting and MBT in the Arab world listed below:

1. It is expected that a clean organic fraction of compost with high quality will be produced and can be marketed at high prices.
2. Sorting of almost all saleable fractions (paper, plastic, metals, PET, etc.) and the sale of recycled material to cover most of the costs.
3. Only projects in large cities such as 500 - 1500 Mg / d are planned, and it is difficult for decision makers to consider decentralized projects for 100 - 200 Mg/d.
4. Decision makers and waste staff think less on the operation of the system and providing trained personnel and finance.
5. Saving is often made in the planning phase and investments. There were some plants which did not operate after they have been built.
6. There are no recycling and recovery utilities available for products such as alternative fuels, glass, organic fractions after treatment, etc

The current and future situation of waste treatment is different from country to country. The following table shows the potential for sorting and MBT estimated according to each country.

Table 1 Assessment of situation and the need for sorting and MBT in selected Arab countries

Country	Assessment of the situation and the need for sorting and MBT
Egypt (80 million in-habitants)	• There are local facilities for simple sorting and compost production, but most of them have not been proved in practice • International and national private companies exist in the country. • Interest exists in M(B)T-Systems. Foreign suppliers have a chance but only with high developed technical solutions, because the market is controlled by national companies with simple techniques. • This also applies to the field of producing of high-calorific fractions for energy recovery in cement plants, where technological advanced solu-tions are required.
Jordan (6 million inhabitants)	• There is only one open composting plant for organic waste from ani-mal husbandry and agriculture. The compost has a very high eco-nomic value (about 50 € / Mg). Therefore, it should be continued to build more plants. • There is no investment in Jordan for the residual waste treatment. Waste management is a key issue in the context of cooperation with the World Bank. Therefore landfills, transfer stations and waste treat-ment plants are financed. • The recovery of valuable materials, production and utilisation of alter-native fuels in the cement industry and biological waste treatment are current issues. European engineering companies are responsible for the initial concepts and feasibility studies. • A pilot project "simple MBT" in the city of Amman is in the preparation phase. Based on this, MBT projects can be developed in the next years. Therefore technical simple mechanical treatment and aerobic treatment are required.
Tunisia 10 million inhabitants	• Tunisia has established a waste disposal authority. • The Eco-Lef, similar to "green dot " is established in Tunisia since 1997 • There are still no large-scale treatment facilities for municipal wastes. • There are 9 Standard landfills and the dumping is the main method of disposal. In 2010 a biogas plant was build in the area of Tunis for the waste market, which is still under trial operation. • In 2005 a pilot project was carried out for the separation of organics for further processing and recyclable materials. • The chances for MBT are good. A pilot project is currently tendered by ANGED and KfW.

	• Concepts for the utilization of alternative fuels in the cement industry are available.
Kuwait (2.5 million inhabitants)	• There are no facilities for household waste treatment. • Two plants were built for the processing of construction waste. • International companies have good market opportunities with appropriate technologies for the planned projects (eg, landfill remediation, remediation of contaminated sites "war damage"). • Kuwait has also gained a bad experience with MBT, there is an MBT plant in Kuwait, which is barely running, and the decision makers understood the MBT technology critically. • There are 3 large special treatment plants to be build as MBT plants 1,500 Mg/d. Local and international companies are trying to enter those projects.
Saudi Arabia (2.5 million inhabitants)	• The dumping is also the most common disposal method. Therefore, some modern landfills are available. • Recyclable materials are collected from the streets or landfills and marketed nationally and internationally. • International companies hardly exist, mainly the work obtained by five established national companies. German and European companies have a good business opportunity but mainly in the phase of preparation work for a project. • The city of Jeddah, Riyadh and other cities have had bad experiences with MBT plants. The reasons are bad planning of the construction and the process technology of the plants and poor operation of the plants, which were then shut down after short time. • From today's perspective local companies are not in a position to design, build and operate reasonable MBT plants. • Legislation does not force to treat the waste, so it is difficult to implement environmentally sound MBT concepts. • Plans In the area of environmental law is improved but it is impossible to predict, when it will take place. • Currently an advanced MBT technology has only one realistic chance, if major projects are awarded to foreign contractor. • GIZ consults Saudi Arabia in the waste management and it is good in consultation and preparation of projects.
Syria (20 million in-	• A master plan for waste management created was in 2004. There are more than 40 landfills, 200 transfer stations and 100 treatment plants.

habitants)	• The Government has provided finance to projects but so far no projects have been implemented, because of the lack of the necessary know-how by the decision-makers. • It is expected that in the next few years, many waste treatment plants, including a number of MBT plants will be build but they will not function. After that the government will try to improve the facilities and will work with experienced international Companies. At that time it is possible to integrate the "European" MBT technology.
Lebanon (4 million inhabitants)	• A number of small waste treatment plants (sorting and composting) are under construction. Local engineering companies are responsible for planning but often overwhelmed. There is a great need for know-how transfer • Lebanon has little space for landfills or solutions that require large areas, so that the trend towards incineration options (e.g. in cement plants) is preferable. • A modern MBT plant with an integrated wet-fermentation stage was built in the city of Saida in 2005, and the plant does not operate till now.
Qatar (1.5 million inhabitants)	• A modern waste management system (MBT and incinerators) has been established by various international companies. The systems are not yet in operation and there is no practical experience.
UAE (4.7 million inhabitants)	• A waste management centre was built in Al-Ain and has been operating for more than 3 years. There is interest intended to use the practical experience in the region. • A sorting system is currently in the tendering phase
Libya (6.5 million inhabitants)	• The old MBT facilities in Tripoli and Benghazi were closed in February 2011. • After the political situation stable, it is a potential market for modern MBT and composting plants.

3 Experiences with sorting and MBT in the Arab region

There are no good practical experiences for the sorting and MBT in most Arab countries. The reasons are the lack of know-how, inappropriate technology concepts, poor conditions for the operation, lack of skilled personnel, etc.

As part of the activities of the Department of waste and material flow management of the University of Rostock, compost in Egypt was examined from household waste (Table 2).

Table 2 Analysis of two samples of compost from mixed waste from Egypt

Parameter	Wet weight		Dry wieght		organic waste regulation (BioAbfV)	
Water [%]	22,3	28,0	-	-	-	
Dry mass [%]	77,7	72,0	-	-	-	
pH-value [-log(H)]	8,2	8,4	-	-	-	
Organic matter [%]	-	-	53,4	n.u.	-	
Salt content (als KCl) [mg/100g]	1949	n.u.	-	-	-	
Impurities > 2 mm [%]	-	-	21,2	n.u.	0,5	
Stones > 5 mm [%]	-	-	1,6	n.u.	5	
					§ 4 (3) Satz 1	§ 4(3) Satz 2
Lead [mg/kg]	-	-	33,8	57,7	150	100
Cadmium [mg/kg]	-	-	0,61	0,51	1,5	1,0
Chromium [mg/kg]	-	-	48,0	101	100	70
Copper [mg/kg]	-	-	141	309	100	70
Nickel [mg/kg]	-	-	15,8	18,8	50	35
Mercury [mg/kg]	-	-	0,39	0,33	1	0,7
Zinc [mg/kg]	-	-	455	379	400	300
Total Nf**) [%]	2,36	0,83	3,04	1,15	-	
Total phosphorus**) (P2O5) [%]	0,92	0,42	1,18	0,58	-	
Potassium, total**) (K2O) [%]	0,77	0,69	0,99	0,96	-	
Magnesium total**) (MgO) [%]	0,32	0,50	0,41	0,69	-	

The German and European standards can be achieved in most cases and problems of the impurities and contaminants will always remain. The Arab region urgently needs functioning adapted pilot projects in order to regain confidence in the sorting and MBT plants.

The company Grüschow GmbH has implemented a pilot project in the town of Korba in Tunisia, funded by German Investment and Development Company DEG. The University of Rostock was responsible for the scientific monitoring. The main findings are:

- About 68% of the waste could be classified by the screening drum
- Fraction of 0-40 mm contained only a few impurities (5%)
- Fraction of 40-80 mm is about 88% organics, about 11% impurities and about 01% recyclable material
- The material from the manual sorting was 20-25% consist of foil , packaging, textiles, etc., metals were approximately 6%

Following the classification and sorting composting was carried out of the fractions 0-40 mm and 40-80 mm. The quality of the compost produced is shown in figure 1.

Table 3 provides a comparison with previous waste compost produced in Germany, bio-compost from Germany and standards of organic waste regulation

Heavy metals in [mg / kg]	waste compost (earlier)	Separate collection Result of the UBA / BGK	organic waste regulation (Bio-AbfV)		Korba / Tunisia
			20 t/h	30 t/h	
Lead	51,3	46,4	150	100	24,4
Cadmium	5,5	0,47	1,5	1	<0,6
Chrome	71,4	25,3	100	70	72,5
Copper	274	57,7	100	70	64,25
Nickel	44,9	16,3	50	35	7,51
Mercury		0,16	1	0,7	0,07
Zinc	1570	203	400	300	173

Figure 1 Comparison waste compost from Korba / Tunis, waste compost from Germany (earlier), compost from separate collection of organic waste and standards of organic waste regulation (BioAbfV)

Such approaches and solutions may be suitable for small towns and pilot projects. Large cities need other solutions. MBS and MPS technologies have great opportunities because of the global energy situation, the construction and operation of the adapted plants should be guaranteed through the cooperation of national and international companies and partners.

In the Arab region large quantities of organic waste are produced in the food industry, this can be treated biologically. As part of a doctoral thesis at the University of Rostock, the situation in the industrial city of Aleppo in Syria has been studied. There accrue various organic wastes, they are mainly wheat mud, grain residues, wheat sludge and biowaste. Anaerobic and aerobic experiments were carried out in Syria. A part of this review, the composting experiments which have taken place in Syria shown figure 2

The compost samples were analyzed by LUFA-Rostock. The analysis provides insight into the heavy metal concentration, plant nutrients, dry matter and salt content, pH, organic matter content and Salmonella. The analysis results are summarized in table 3.

Table 3 Analysis results of the compost samples

Parameter		**Class. 1**		**Class. 2**		**Class. 3**		**Class. 4**		**BioAbfV**	
		FM	TM	FM	TM	FM	TM	FM	TM	TM	TM
Water content	%	16		15		17		28			
Dry matter	%	84		85		83		72			
pH	log (H)	7,5		7,2		7,3		7,3			
NH4-N	mg/l	20		128		161		81			
Salinity	g/l	3,9		6,5		4,5		7,7		< 2	
Org. substance	%		9,5		16		23		23		
Density	g/l	1000		750		720		740			
Nitrogen-saturated	%	0,6	0,7	1	1,2	1,4	1,7	1,1	1,5		
P_2O_5	%	0,3	0,4	0,4	0,4	0,4	0,5	0,5	0,7		
K_2O	%	0,4	0,5	0,6	0,7	0,4	0,5	0,7	0,9		
MgO	%	0,6	0,7	0,8	0,9	0,6	0,7	0,7	0,9		
Pb	mg/kg		55		9		9		11	**150**	**100**
Cd	mg/kg		0,63		0,67		0,59		0,66	**1,5**	**1**
Cr	mg/kg		31		44		28		43	**100**	**70**
Cu	mg/kg		32		53		**472**		**771**	**100**	**70**
Ni	mg/kg		**36**		**50**		35		**82**	**50**	**35**
Hg	mg/kg		0,02		0,03		0,02		0,03	**1**	**0,7**
Zn	mg/kg		126		98		124		211	**400**	**300**

Heavy metals are harmful to the compost, according to biowaste regulations, the elements lead (Pb), cadmium (Cd) and chromium (Cr) are potentially harmful heavy metals. The heavy metal concentration in compost samples was investigated and compared with the requirements of organic waste regulation (Table 3). In comparison to the requirements of class A and class B, the results show that there is an excess in the two main elements (in the copper and nickel content).

The heavy metal concentration is compared only with the requirements of class A compost, the experiments 1 and 2 meet the conditions and exceed the copper content in experiments 3 and 4. the nickel content in experiment 4 exceeds the standards. In Experiment 2 and 3, it was found that the use of sludge in the composting of wheat can cause an increase in copper content. Perhaps it is because the copper can be solved by cooking of the wheat manufactured in a copper cauldron (a boiler has a capacity of 5,000 kg of wheat has), through this process, the cooking water is contaminated with copper, which then can remain as sludge after wastewater treatment. Fertilizer types for secondary raw fertilizer e.g. Compost in the fertilizer regulation set out (at least 0.5% N, 0.3% P_2O_5, 0.5% K_2O, a total of at least 2% by dry mass, below these levels is referred to as soil additives)

4 Literatur

Nassour, A;	2005	Ansätze zur Reform der Abfallwirtschaft in Entwicklungsländern, Lehrstuhl Abfall- und Stoffstromwirtschaft, Universität Rostock, Habilitationsschrift
Nelles, M.; Nassour, A.; Majanny, A.; Al-Ahmad, M.;	2010	"Internationale Abfallwirtschaft im Wandel – Aktuelle Entwicklungen im arabischen Raum", Depotech 2010 – ISBN 978-3-200-02018-4, S. 99-104
Mahn, M.:	2006	Integration der Abfalltrennung/Hausmülltrennung und Kompostierung in ein nachhaltiges Abfallwirtschaftssystem in Tunesien am Beispiel des Pilotprojekts in Korba, Lehrstuhl Abfall- und Stoffstromwirtschaft, Universität Rostock, Diplomarbeit.
Majanny, A;	2010	Clean Produktion unter dem Gesichtspunkt der Abfallwirtschaft für Industrie-city in Aleppo/Syrien, Lehrstuhl Abfall- und Stoffstromwirtschaft, Universität Rostock Promotionsschrift

Author's address:

PD Dr.-Ing. habil. Abdallah Nassour
Universität Rostock, Lehrstuhl Abfall- und Stoffstromwirtschaft
Justus von Liebig Weg 6
D-18051 Rostock
Telefon +49 381 498 3403
Email: abdallah.nassour@uni-rostock.de
Website: www.uni-rostock.de

Integrated Management of Municipal Solid Waste in Santiago de Chile – Recycling Treatment and Final Disposal

Klaus-Rainer Bräutigam and Tahnee Gonzalez

Karlsruher Institut für Technologie

Abstract

A detailed analysis of Municipal Solid Waste (MSW) management in the Metropolitan Region of Santiago de Chile has been carried out within the framework of a research initiative of the German Helmholtz-Association. The following paper gives an overview of the current situation of the management of MSW in Santiago de Chile (amount of MSW generation, MSW collection, MSW composition, recycling activities, MSW final disposal). Afterwards different waste management scenarios will be presented, which have been developed in close cooperation with stakeholders and scientists in Chile. These scenarios take into consideration different technical options for the management of MSW, including separate collection of biowaste, mechanical biological treatment as well as the production of Refuse Derived Fuels.

Inhaltsangabe

Im Rahmen einer Forschungsinitiative der Helmholtz-Gemeinschaft Deutscher Forschungszentren wurde das Management von Siedlungsabfällen in der Metropolregion von Santiago de Chile analysiert. In diesem Beitrag wird zunächst ein Überblick über den aktuellen Stand des Managements von Siedlungsabfällen in Santiago de Chile gegeben (Abfallaufkommen, Abfallzusammensetzung, Abfallsammlung, Recyclingaktivitäten, Abfalldeponierung). Anschließend werden unterschiedliche Szenarien für das Management von Siedlungsabfällen für das Jahr 2030 vorgestellt. In diesen Szenarien, die gemeinsam mit Wissenschaftlern und für das Abfallmanagement Verantwortlichen aus Chile entwickelt wurden, werden unterschiedliche technische Möglichkeiten der Behandlung von Siedlungsabfällen berücksichtigt. Hierzu gehören u.a. die Getrenntsammlung von Bioabfällen, die mechanisch-biologische Abfallbehandlung sowie die Herstellung von Sekundärbrennstoffen zum Einsatz in Zementwerken.

Keywords

Abfallmanagement, Santiago de Chile, Recycling, Vorbehandlung, Szenarios

Waste management, Santiago de Chile, recycling, pre-treatment, scenarios

1 Introduction

1.1 The Risk Habitat Megacity Project

Within a research initiative of the German Helmholtz-Association the Metropolitan Region of Santiago de Chile (MRS) has been analyzed under the aspect of sustainability and associated risks. This has been done for different fields of application (energy, air quality, land use management, socio-spatial differentiation, transportation, water resources and services, and waste management). For the management of Municipal Solid Waste (MSW), which is the focus of this paper, the analysis started with an evaluation of the current situation on the basis of selected sustainability indicators. Then scenarios for the year 2030 were developed (Business as Usual – BAU, Collective Responsibility – CR and Market Individualism – MI), taking into consideration different technical options for the management of MSW in MRS in the year 2030. These scenarios were evaluated on the basis of the above mentioned sustainability indicators. A more detailed description of the “Risk Habitat Megacity Project” is given in (KRELLENBERG et al. 2010). The methodology as well as the results of the work within the field of “Management of MSW” is fully described in a doctoral thesis (GONZALEZ, 2011).

1.2 Waste Management in Santiago de Chile

MRS consists of an area of 16,000 km^2 (2% of the total area of Chile) with about 6.7 million inhabitants (for the year 2007), which is approximately 40% of Chile’s population. Total generation of MSW in 2007 was roughly 2.9 million Mg or 1.2 kg/(cap*day). In 1995 the corresponding value was 0.8 kg/(cap*day) (SZANTO, 2006; BRÄUTIGAM et. al., 2008). The organic fraction decreased from 68% in 1990 to 50% in 2007 (SZANTO, 2006). Therefore the share of other fractions increased, e.g. paper and cardboards from 15% to 18% and plastics from 6% to 10%. These changes are mainly correlated with the rising income levels in Chile during this time. These – steadily increasing – amounts of MSW have to be managed properly in order to avoid negative impacts on health and environment and thus present a challenge for stakeholders involved in waste management, who should develop adequate strategies for waste reduction and waste treatment under current social and financial regulations.

Figure 1 shows the waste streams in MRS for 2007. Currently, MSW management in MRS focuses on final disposal: about 86% of almost 3 million Mg generated were disposed of in the three existing sanitary landfills. Usually, MSW is left in bags or containers at the streets, where the major part is collected by the formal sector. The frequency of collection varies from three times a week to daily. Regarding recycling, about 400,000 Mg of waste, mainly paper, cardboard and metals are collected and separated by the informal sector. A recycling rate of nearly 14% has only been achieved due to the high contribution of the informal sector. Formal recycling is less than 1% (about 25,000 Mg/a). In addition separate collection of biowaste amounts to about 10,000 Mg/a, from which about 3,300 Mg of compost are produced. So far there is no mechanical-biological treatment (MBT) for collected MSW; however one of the landfill operators is about to start a mechanical pre-treatment for up to 100.000 Mg/a (03/2011), which is nevertheless only a small fraction of approximately 1.5 million Mg/a of MSW disposed of at the “Lomas Los Colorados” landfill.

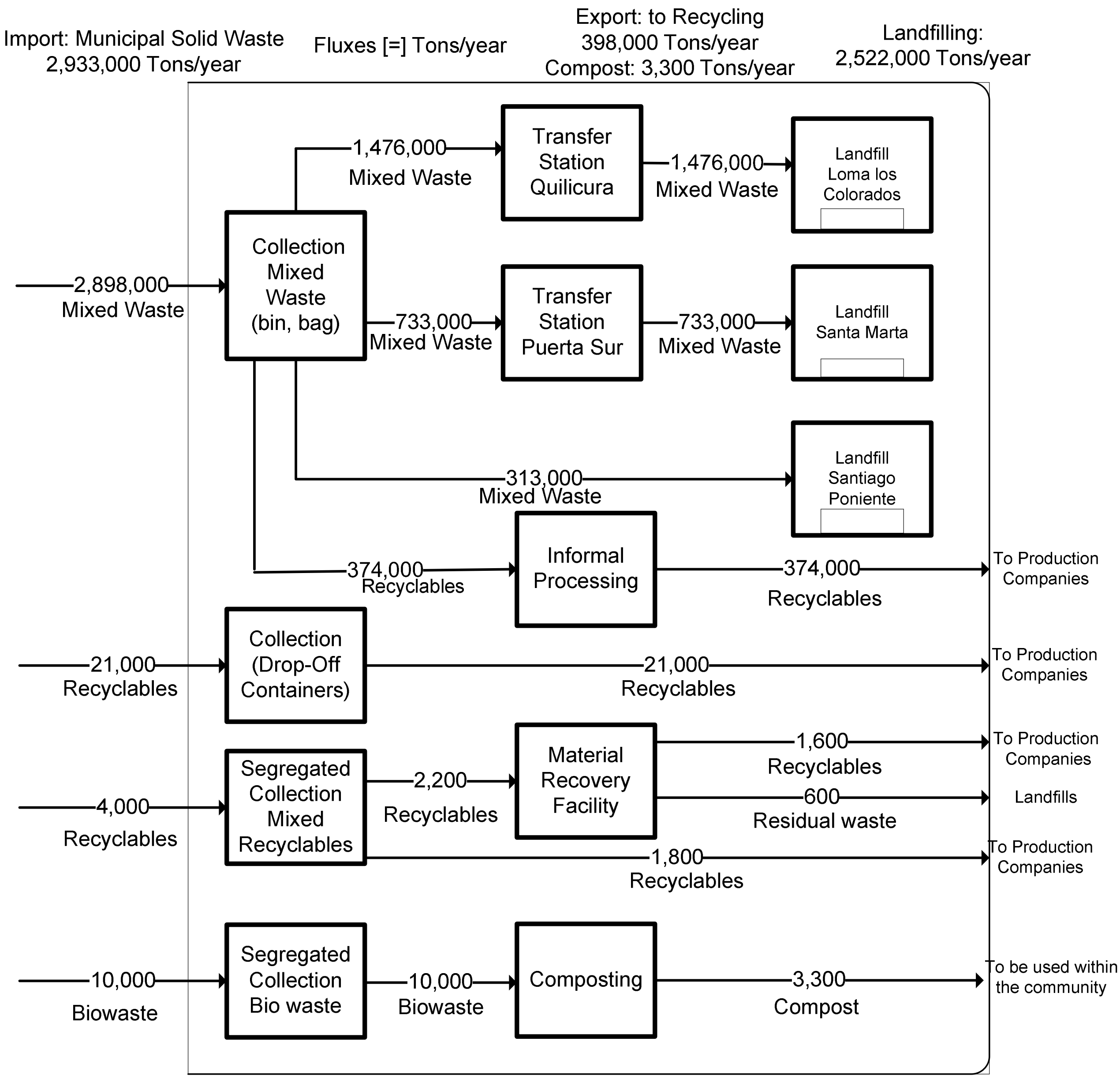


Figure 1: Mass flow of MSW in MRS for the year 2007 (Source: own elaboration)

The three operating landfills are relatively new: one started in 1996, the other two in 2002. They are equipped with a bottom liner and a collection system for leachate. The gas produced by landfills is partly captured and flared. These processes are financed by Clean Development Mechanisms (CDM) projects, which results in an extra income for the operating companies of the landfills. In November 2009, a plant equipped with gas engines and two generators, each with 1 MW power capacity, started operation in the Lomas los Colorados landfill. The electricity generated is sold to the national grid. The unused landfill gas is still being flared, but the extension of generation capacity to 14 MW is planned by the end of 2011. Moreover, it has been decided to gradually extend the total capacity in order to generate 28 MW by 2024 (KELLER, 2010, KDM, 2010). The characteristics of MSW in MRS (composition, TOC as well as water-content) are given in Table 1. This data was obtained on the basis of a sorting analysis carried out at the transfer station of “Quilicura” (ODDOU 2008) by using published data of Total Organic Carbon (TOC) and water content of single waste fractions (Loll 2002).

Due to the fact that informal activities only focus on commercially attractive recycling materials (scrap, paper & cardboard) and municipal recycling activities are restricted by costs, a significant volume of packaging material and biomass is disposed of in landfills, with negative effects on social and environmental areas (traffic, odours, greenhouse gas emissions).

Table 1: Calculated characteristics of MSW in MRS

	Composition MSW[1]	**TOC$_{MSW}$**	**Water content$_{MSW}$**
	[%]	[g/kg]	[%]
Organic food	53.6	273.3	29.5
Yard waste	1.8	8.8	1
Cardboard	3.2	14.8	0.5
Paper	12.2	56.1	4
Plastics	10.2	3.2	1.5
Tetra Pak	0.8	2.1	0.2
Hygienic articles	6.5	25.2	3.3
Glass	3.2	0	
Metals	1.1	0	
Leather	0.2	0.4	0.1
Wood	0.5	1.1	0.1
Textiles	3.2	6.3	1
Dust/Ash	1.2	0	
TOTAL		391.7	41.3

1: based on ODDOU, 2008

After a general description of recycling activities in MRS (Chapter 2), future development of the management of MSW in MRS will be analyzed in Chapter 3 on the basis of different scenarios for the year 2030, which include mechanical-biological treatment (MBT) and the generation of Refused Derived Fuel (RDF) for energy production. Some ideas for the implementation of MBT plants in MRS will be given in the following paper with the title “Mechanical-Biological Treatment of Municipal Solid Waste as a component of the Integrated Waste Management Concept for Santiago de Chile”

2 Recycling in Santiago de Chile

2.1 Introduction

Recycling activities do not only contribute to a reduction in the total quantity of waste to be disposed of in sanitary landfills; they also facilitate operation of and gas recovery at landfills and lead to a reduction in transport. In addition recyclable materials can be used for the production of several goods, which contributes to saving renewable and non-renewable primary materials. Hence a high recycling rate is desirable. In order to improve these rates, it is necessary to analyze the entire recycling system of MRS, including the informal sector. The latter is comprised of a vulnerable group of people confronted with numerous problems, including inadequate or lack of labor legislation and social security, and limited bargaining power to increase the price of materials they sell (FLODMAN BECKER, 2004).

2.2 Formal recycling activities

Formal recycling activities have been introduced in some municipalities including recycling programs to cover composting of biomass, separate collection and drop-off systems for recyclable materials. Other activities include education and campaigns to enhance awareness for the environmental benefits of recycling practices among the residents of these communities.

The schemes differ for the most part on how waste is collected and divided into "drop-off systems" (containers located in public places), operated mostly by private companies in cooperation with charity foundations, and, to a much lesser extent, "differentiated curbside collection" by some municipalities. Even though curbside collection requires the separation of only recyclable materials at home followed by a collection taken by special trucks and sorting in a centralized facility (thereby avoiding the need for several containers), the latter system meets several obstacles: 1) High frequency of MSW collection (3 to 5 times per week), 2) lack of container system, 3) direct competition with the informal sector. Participation in both systems is voluntary; motivation of charity campaigns is mainly social, while municipal programs emphasize aspects such as community identity and environmental benefits.

For the year 2007, collection from drop-off containers, a less expensive option than separate collection systems, amounted to about 21,000 Mg of recyclable materials (mainly glass), whereas the differentiated collection of mixed recyclables produced roughly 4,000 Mg. Approximately 10,000 Mg of biowaste was collected separately (s. also figure 1). This data is based on literature studies, surveys in MRS communes with recycling programs, interviews with people from the informal sector and own estimations (CONAMA 2005a, CONAMA 2005b).

2.3 The informal sector

The informal sector is a key component of the economy and the labor market in many low and middle-income countries, and instrumental in the creation of employment, production and income (HUSSMANNS, FARHAD, 1999). The collecting, sorting, trading and recycling of disposed materials provides income to thousands of people. As a general rule, these people work parallel to the formal waste management system, which means on their own and not contracted by the municipalities or any other entities associated with the waste sector; they do not pay tax and are excluded from social welfare and insurance schemes (WILSON et al., 2006).

Unofficial estimates indicate that between 4,000 and 15,000 people work as primary collectors in MRS (ASTORGA 2008, MNRCH 2009) or even 7.000 to 10.000 (IASA 2010). Primary collectors collect valuable materials from the streets of residential and commercial zones with the use of tricycles as means of transportation and working tools. They separate and classify the materials, improving their monetary value in the process, and sell them to middlemen who deliver them to production companies as secondary raw materials.

Figure 2 shows the total recycling rate for different materials, as well as the contribution from formal and informal systems. The contribution from the formal sector (drop-off) is almost negligible. The exception is glass, since quite a number of containers for glass collection have been in operation in MRS for more than ten years.

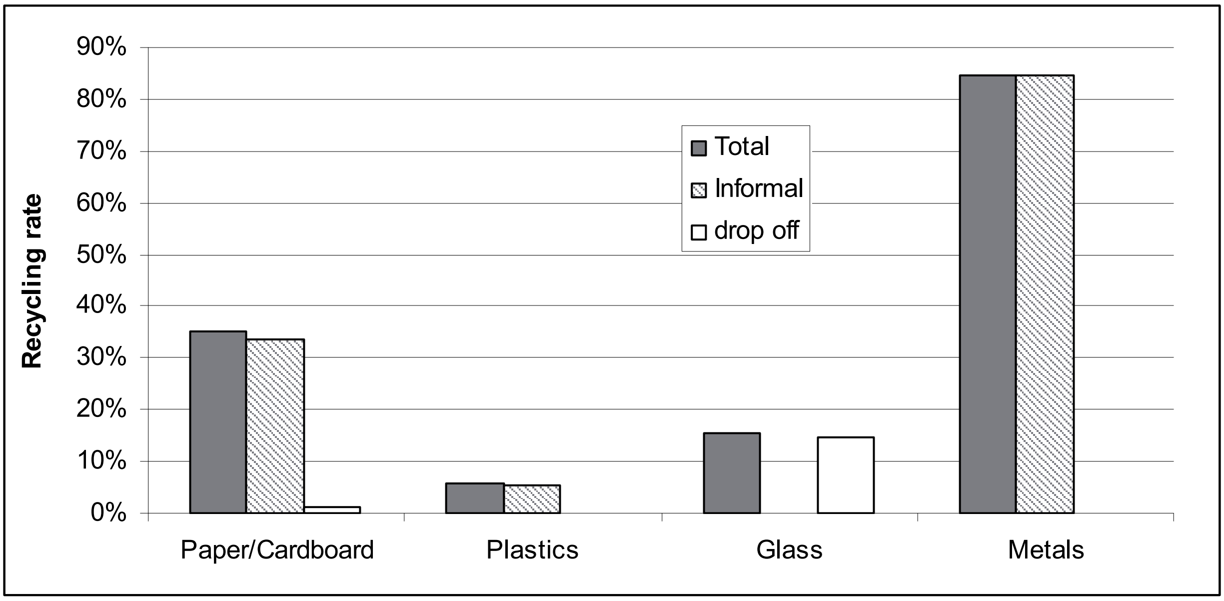


Figure 2: Recycling rates for different materials – formal and informal contributions, 2007 (Own calculations)

It has to be noted that the official statistics for ferrous metal recycling (180.000 Mg/a) includes approximately 50% of materials, which are not MSW (auto parts, construction materials and demolition waste); the major part of the remaining 90.000 Mg/a corresponds to bulky domestic waste (IASA, 2010). The global (official) recycling rate has to be corrected therefore to approx. 11%; the rate of metal recycling is close to 40%.

2.4 “Santiago Recicla“ Action Plan

As part of the recycling program “Santiago Recicla” currently 37 of the total 52 municipalities of the region have associated in order to meet the proposed recycling rate through the implementation of at least 10 recycling centres and approximately 1.000 drop-off points (“puntos limpios”). The program is currently in the feasibility stage, including not only the technical, economical and environmental evaluation of future waste management installations, their location, technology, transport logistics, but also educational and social aspects. In fact one of the main focuses of feasibility studies is the inclusion of informal recyclers. The investment for the program will be partially funded by a credit from the Interamerican Development Bank and Chilean government, as well as private investments. This program will be described in more detail in the following paper with the title “Integrated Solid Waste Management in Santiago de Chile – Potential for Mechanical-Biological Treatment of Mixed Municipal Solid Waste”

3 Scenarios for the Management of MSW in Santiago de Chile for the year 2030

3.1 Introduction

Within the “Risk Habitat Megacity” project different explorative framework scenarios have been set up. The aim of these framework scenarios was to give a general description of the political, social and economical conditions for a specific year in the future, in this case 2030. For the three framework scenarios, taken into consideration (Business as Usual – BAU, Collective responsibility - CR and Market Individualism – MI) qualitative and as far as possible quantitative descriptions of factors, which have an influence on the political and social general conditions in the country and especially in MRS were given (so called driving factors). Driving factors taken into consideration for the MSW management analysis were: economic development, institutional framework/governance, demographics, technological development, societal value systems and education. Based on these driving factors their influence on the management of MSW in MRS in 2030 is described by so-called qualitative storylines. On the basis of these storylines quantitative data for waste generation, waste composition and amount of different waste fractions to be recycled, recovered or treated were set up. This work was carried out in close cooperation with Chilean investigators, consultants and government experts, in order to develop technically and economically feasible alternatives for the MRS until 2030.

3.1.1 Storyline scenario "Business As Usual (BAU)"

This scenario is characterized by a material consuming culture. Environmental laws and regulations are weak and flexible. The political aim is to achieve waste recovery targets by improving recycling and biological treatment. Increase of climate change prevention policies promotes the use of landfill gas as renewable energy source.

With help of the civil society and NGOs, new recycling programs with participation of the informal recyclers are developed, creating a favourable framework for acceptance of the informal workers. However, the informal waste sector, even if continuingly playing an important role in recycling, is only partially integrated into the formal waste system.

The technological advancements promote application of biological treatment technologies, which helps to achieve recovery targets. Technology developments have also improved collection efficiency of landfill gas, contributing to increase the share of renewable energies into the energetic grid.

3.1.2 Storyline scenario "Collective Responsibility (CR)"

This scenario is characterized by high emphasis on social values. Environmental laws and regulations are established. Recovery gains in importance by improving recycling and biological treatment and increasing the amount of waste pre-treated. Increase of climate change prevention policies has promoted the collection and use of landfill gas as renewable energy source.

The influence of NGOs on waste management is relevant, in particular promoting recycling, source separation and acceptance of the informal sector. The organization and efficiency of the informal sector has improved noticeably. Community organizations play an important role in the collection of recyclables. The informal sector has decreased in number, due to poverty reduction. However, the quality of their work has increased. They have formed strong groups and work in collection of separate materials and further processing in stock centres. Public investment in environmental campaigns has contributed to create more participation and acceptance by civil society.

Technology development is not a priority in this scenario, but a tool used to achieve environmental goals. Landfills accomplish with international standards and collection and treatment of leachate and landfill gas.

3.1.3 Storyline scenario "Market Individualism (MI)

This scenario is characterized by a consuming and materialistic culture. Environmental laws and regulations are weak and flexible and are influenced by private interests and markets. The driving factor to recover valuable materials and energy from waste is given only by the economical profit. There is a large interest in technological development, thus, alternative technologies for recovery of MSW are only developed if costs and profitability are favourable.

Publicly organized recycling systems, including biological treatment are almost non existent. Recycling takes place only voluntarily by drop-off systems. The role of the public sector in recycling is inexistent, and they do not have any interest in working together with the informal sector. Private production companies might show some interest in working together with the informal sector, as a way to recover secondary raw materials at low costs.

3.2 Waste generation and waste management in the year 2030

Table 2 illustrates the results for waste generation and waste management for the three scenarios. This data is the result of the quantitative implementation of the three storylines. Data for waste generation are mainly based on a correlation between the Gross Domestic Product (GDP) and waste produced per capita, therefore the increase of waste generation (from about 3.0 million Mg in 2007 to 5.6 million Mg in the BAU scenario, 5.0 million Mg in the CR-scenario and 6.1 million Mg in the MI-scenario) results from both, an increase of the GDP (and the corresponding increase of the specific waste production) and an increase of the population, living in MRS. For a further description of the methodology see (GONZALEZ, 2011).

3.2.1 Specific waste generation

Compared to the year 2007 specific generation of MSW is much higher in all scenarios for the year 2030, with the highest value of 2.0 kg/(cap*day) in the MI-scenario and the lowest value of 1.8 kg/(cap*day) in the CR-scenario. The differences between the values for specific waste production are mainly the result of different GDP in the three scenarios for 2030.

3.2.2 Waste collection

The relevance of waste collection by the informal sector (bin, bag and separate collection by organized collectors) is highest in the CR-scenario (17.5% of total generation of MSW) compared to 12.8% for the year 2007, 10.5% in the BAU-scenario and 9% in the MI-scenario. The contribution from drop-off containers is 7.5% in the BAU and the CR-scenario and 3% in the MI-scenario (compared to 0.7% for 2007). Separate collection of biowaste, which is nearly negligible in 2007 (0.34%) is 5% in the BAU-scenario (which means about 17% of total biowaste) and 8% (25% of total biowaste) in the CR-scenario. This biowaste is sent to biological treatment plants. In the MI-scenario no separate collection of biowaste is taken into consideration.

Table 2: Waste Management data for different scenarios

		Scenario		
	Current Situation (2007)	**Business as Usual**	**Collective Responsibility**	**Market Individualism**
Population (million)	6.7	8.0	7.6	8.3
MSW generation(million Mg)	2.9	5.7	5.0	6.1
Specific MSW generation (kg/(cap*day))	1.20	1.93	1.78	2.02
Collection (%)				
bin,bag formal	86.06	75.66	66.80	87.68
bin,bag informal	12.75	4.90	2.28	9.04
separate by municipality	0.14	1.33		
separate by organized collectors	---	5.61	15.19	---
drop-off containers	0.72	7.50	7.48	2.99
segragated biowaste	0.34	5.00	7.98	---
Treatment (%)				
mechanical	---	19.67	13.36	21.92
mechanical biological (RDF)	---	---	13.36	---
biological (anaerobic digestion)	0.34	5.00	7.98	---
energy from landfill gas	yes	yes	yes	yes
Recycling (%)				
informal processing	12.75	4.90	2.28	9.04
mechanical treatment	---	6.51	10.01	7.72
separate collection by municipalities	0.12	1.19	15.19	---
separate collection by organized collectors	---	5.61		---
drop-off containers	0.72	7.50	7.48	2.99
biowaste	---	4.89	7.80	---
Sum Recycling (%)	13.58	30.60	42.76	19.76

3.2.3 Waste treatment

Treatment technologies, which are nearly non-existent in 2007, gain in importance in the different scenarios. Within the **BAU-scenario** a fraction of the mixed waste collected is diverted to mechanical sorting plants, with the aim of recovering materials or energy before landfilling. Currently, two of the three private companies, which are running landfills in MRS, are planning to build such plants with a capacity of 15% of the MSW sent to landfills. The value assumed for 2030 is 20% of total MSW generation. In addition, as already mentioned in chapter 3.2.2 the biowaste collected separately (17% of total biowaste) is sent to biological treatment plants.

As has been shown by model calculations for MRS for the time period 2001 to 2022, which are described in detail in (BRÄUTIGAM et al., 2009), separate collection of different fractions of biowaste, which then can be used for the production of compost, will reduce greenhouse gas emissions from landfills considerably (s. figure 3). If e.g. 65 % of landfill gas is captured and flared (an optimistic assumption), CO2 equivalents can be reduced from 35 million Mg (no separate collection of organic waste) to 17.9 million Mg when 90 % of the organic fraction (food and garden waste) is composted. If 30 % of landfill gas is captured and flared, CO_2 equivalents can be reduced from 70 million Mg (no separate collection of organic waste) to 36 million Mg when 90 % of the organic fraction is composted. If 10 % of landfill gas is captured and flared, CO_2 equivalents can be reduced from 90 million Mg (no separate collection of organic waste) to 46 million Mg when 90 % of the organic fraction is composted.

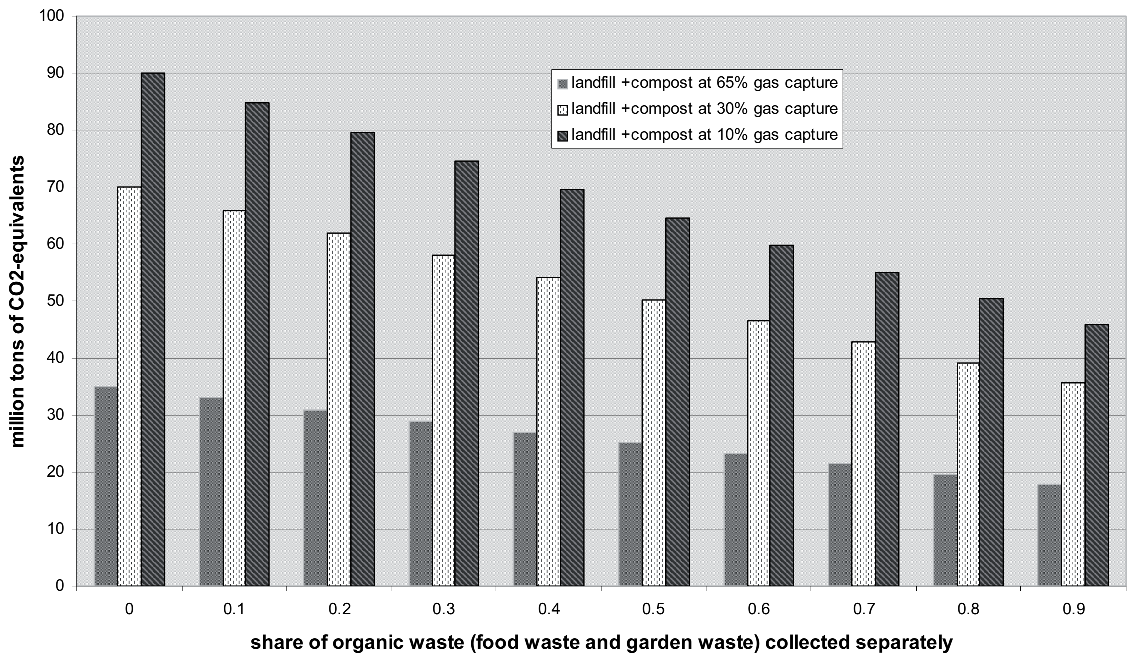


Figure 3: Calculated emissions of CO_2 equivalents for MRS for different shares of organic waste collected separately and different capture rates of landfill gas (source: BRÄUTIGAM et.al. 2009)

Within the **CR-scenario** a fraction of the mixed waste collected is diverted to mechanical sorting plants (13% of total MSW) to obtain valuable materials for recycling. Another 13% of mixed waste collected is diverted for waste pre-treatment and the production of "Refuse Derived Fuels (RDF)" which can be used e.g. in cement plants as an energy source. These measures result in a reduction of total amount of waste (and especially in the amount of the organic fraction) which has to be disposed of. Again, the biowaste collected separately (8% of total MSW, 25% of total biowaste) is sent to biological treatment plants.

Within the **MI-scenario** a fraction of the mixed waste collected is diverted to mechanical sorting plants to recover materials or energy. Because technology and innovation plays an important role in this scenario, the waste fraction sent to these plants corresponds to 22% of collected mixed waste. Publicly organized collection of biowaste or recyclables is not introduced within this scenario.

3.2.4 Recycling activities

A recycling strategy for MRS was developed at the national level by CONAMA (CONAMA 2005), the goal of which was to achieve a recycling rate of 20 % in 2006, a value that has not been achieved so far. In 2009, within the program Santiago Recicla, a new target was set at 25 %, to be fulfilled by 2020. The recycling rate, which amounts to 14% in 2007, increases to 30.6% in the **BAU-scenario**. Within this scenario a fraction of 7.5% of the MSW generated is collected through drop-off systems and a small fraction of 1.2% is recycled due to separate collection by the municipalities. Most of the informal collectors are organized and are called "organized primary collectors". These people now contribute with a share of 5.6% to total recycling, whereas the "old" informal sector has a share of 4.9%. In addition 6.5% are due to materials resulting from mechanical treatment and 4.9% from the separate collection of biowaste.

In the **CR-scenario** a fraction of 7.5% of the MSW generated is collected through drop-off systems. As in the BAU-scenario most of the informal collectors are much more structured and the collected materials (with a share of 15.2% to the total recycling rate) are further processed in improved material recovery facilities. The "old" informal sector has a share of 2.3%. In addition 10% are due to materials resulting from mechanical treatment and 7.8% from the separate collection of biowaste. The overall recycling rate in this scenario is 42.8%.

The recycling-rate in the **MI-scenario** is the lowest (19.8%). Within this scenario there is no publicly organized collection of biowaste or of recyclable materials. Therefore the informal waste sector plays an important role in recycling, contributing 9% to the recycling rate. Drop-off containers result in 3% and 7.7% are due to materials resulting from mechanical treatment.

3.2.5 Energy Production

Energy production from landfill gas is included in all scenarios. In table 3 values for energy recovery from waste are given. In the **BAU scenario** energy recovery from MSW is achieved by the installation of anaerobic digestion plants to produce about 54,000 Mg of biogas per year, corresponding to 63 GWh of electricity generation. Additionally, landfill gas is captured and used as an energetic renewable source. The total amount of landfill gas recovered is 440 Mio m³ of landfill gas per year, corresponding to 890 GWh.

Within the **CR-scenario** the installation of anaerobic digestion plants together with the anaerobic treatment taking place at the mechanical biological plant allows producing about 118,000 Mg of biogas per year, corresponding to 133 GWh of electricity generation. Furthermore an alternative combustible is obtained and co-combusted in cement plants, the energy recovery in this case corresponds to 1,057 GWh. Additionally, landfill gas is captured and used as an energetic renewable source. The total of landfill recovered gas is 380 million m³ per year from which 768 GWh of electricity can be produced.

In the **MI scenario** there is lack of incentives promoting alternative waste treatments. Therefore energy recovery takes place only from landfill gas. A total of 491 Mio. m³ of landfill gas per year is collected and energetically recovered (992 GWh). There are no additional plants generating biogas in this scenario.

Total electricity consumption in Chile is about 57,000 GWh, the energy consumption of MRS is about 17,000 GWh. Therefore, the production of energy from the use of landfill gas is only of minor importance (6% in the case of MRS). On the other side the production of RDF and its use as a secondary fuel in cement kilns might contribute about 25% to total energy consumption for cement production in MRS.

Table 3: Production of energy from landfill gas and from different treatment technologies in 2030

	Scenario		
	BAU	**CR**	**MI**
	values given in GWh		
anaerobic digestion	63	89	0
MBT		44	0
landfill gas	890	768	992
Sum	953	901	992
Refused dirived fuel (RDF)	0	1,057	0
electricity consumption Chile	57,000		
electricity consumption MRS	17,000		
energy consumption for cement production in MRS	4,400		
RDF-production	1,057		

3.2.6 Evaluation of MSW-management in MRS on the basis of sustainability indicators

The management of MSW in MRS in 2007 as well as in the different scenarios for 2030 has been evaluated on the basis of different sustainability indicators and on their associated target values (BRAEUTIGAM, GONZALEZ, 2010). These “target values” represent a socially agreed “target”, which should be achieved in the future in order to fulfill sustainability. Indicators as well as target values were set up together with Chilean investigators, consultants and government experts during several workshops. Table 4 clarifies the results of the evaluation of MSW management in MRS. Specific arising of MSW increases in the three scenarios, exceeding the maximum target value proposed for 2030. The main deficits result from the absence (BAU and MI) or relatively small amount (CR) of pre-treatment of MSW before final disposal in landfills and from high emissions of greenhouse gases from landfills.

The BAU-scenario shows improvements in the amount of waste recovered, attributable to the installation of mechanical sorting plants and segregated collection of biowaste and recyclables through organized informal workers, in addition to energy recovery from landfill gas and biogas. The organization of the informal workers is also reflected in an improvement of their income level.

***Table 4**: Sustainability indicators for the different scenarios*

Indicator	2007	Target	BAU	CR	MI
Specific waste generation [kg/(cap*day)]	1.20	1.6	1.93	1.78	2.02
Waste fraction recovered as material or energy [%]	13.9	36	31	43	20
Income level of informal workers in relation with individual household income [%]	76	100	113	154	-
Amount of mixed waste pre-treated to reduce organic carbon content in relation to total mixed waste [%]	0	50	0	19	0
Greenhouse gases emitted during waste management [kg. CO_{2eq}/(cap*year)]	143	71	235	153	296
Costs of MSW-management in relation to GDP [%]	0.22	0.30	0.16	0.17	0.16

The lowest value for specific waste generation is achieved in the CR-scenario, which is attributed to changes in economical and social factors. The CR-scenario reaches the target values for the recovered amount of MSW and the income level of the informal workers, but it shows little progress in the pre-treatment of waste. Nevertheless, the released greenhouse gases are still far away from the target value. This fact can be attributed, among other reasons, to the still large amount of organics being disposed of at landfill sites.

The MI-scenario shows large deficits in almost all the indicators. Of special importance is the income level of informal waste workers, which does not improve in comparison with current values.

4 Summary

Within this paper the current situation of the management of municipal solid waste in Santiago de Chile has been described. Specific waste generation increased from 0.8 kg/(cap*day) in 1995 to 1.2 kg/(cap*day) in 2007, resulting in a total amount of MSW generation of 2.9 million Mg in 2007. The official recycling rate is nearly 14%, a value which includes also materials, which are not MSW (autoparts, construction materials and demolition waste) and should therefore be corrected to about 11%. MSW which is not recycled is disposed of in one of the three existing sanitary landfills, currently without any further treatment. Separate collection of biowaste is negligible. In landfills the decomposition of the organic fraction results in the production of greenhouse gases, a part of which is captured and mainly flared. Only a small fraction is used for energy production.

In order to get an idea about future development of the management of MSW in MRS, different scenarios, together with Chilean investigators, consultants and government experts, have been set up for 2030. Depending on the scenario taken into consideration generation of MSW in MRS will increase from 2.9 million Mg in 2007 to values between 5.0 and 6.1 Mg in 2030 (resp. from 1.2 kg/(cap*day) in 2007 to values between 1.8 and 2.0 kg/(cap*day) in 2030). Especially in the CR-scenario mechanical, mechanical biological (13% of total waste generation in both cases) as well as biological (8% of total waste generation) will gain in importance. The recycling rate will increase from nearly 14% (official rate) in 2007 to 20% in the MI-scenario, 31% in the BAU-scenario and 43% in the CR-scenario.

Separate collection and treatment of the organic fraction will reduce greenhouse gas emissions from landfills. Part of the landfill gas will be used to produce energy. In addition in the CR-scenario the production of RDF which can be used as a secondary fuels in cement kilns is taken into consideration.

In all three scenarios incineration of MSW is not taken into consideration because in conformity with experts from Chile this will not be an option for Chile for the next 20 years due to high costs of incineration compared with actual costs of waste management in Santiago de Chile.

5 Literature

Astorga, A.	2008	Personal interview with Andrés Astorga, national consultant in the scrap and metal area, May 2008, Santiago de Chile, Chile
Bräutigam, K.-R., Gonzalez, T	2010	Evaluation of municipal solid waste management in Santiago de Chile regarding sustainability. In: International Solid Waste Association-World Congress (ISWA) 2010 (Hrsg.): Urban development and sustainability - a major challenge for waste management in the 21st century. Hamburg: 2010
Bräutigam, K.-R.; Gonzalez, T.; Seifert, H	2009	Landfill gas emissions from landfills in Santiago de Chile - Strategies to reduce impact on local environment as well as on global climate. In: Escudero de Fonseca, A. et al. (Hrsg.): La gestión sostenible de los residuos. II Simposio Iberoamericano de Ingeniería de Residuos. Barranquilla, Colombia: Ediciones Uninorte 2009, S. 76
Bräutigam, K.-R., Gonzalez, T., Seifert, H., Szanto M., Vogdt J.	2008	Risk Habitat Megacity – Waste Management in Santiago de Chile – I. Simposio Iberoamericano de Ingeniería de Residuos - Castellón, 23-24 de julio de 2008
CONAMA (Comisión Nacional de Medio Ambiente)	2005a	Estrategia de Reciclaje de Residuos Sólidos Domiciliarios de la Región Metropolitana. Area de Gestión de Residuos y Materiales Peligrosos. Santiago de Chile, Chile. June 2005
CONAMA (Comisión Nacional de Medio Ambiente)	2005b	Metropolitana de Santiago. “Sistemas de Reciclaje, Estudio de Casos en la Región Metropolitana”. Santiago de Chile, Chile. January 2005
Flodman Becker, K.	2004	The Informal Economy. Published by Sida, Department for Infrastructure and Economic Co-operation
Gonzalez, T.	2011	Analysis of Different Municipal Solid Waste Management Systems for Santiago de Chile, Doctoral Thesis an der Fakultät 4 Energie-, Verfahrens- und Biotechnik der Universität Stuttgart (to be published)

Hussmanns, R.; Farhad, M.	1999	Statistical definition of the informal sector, international standards and national practices. International Labour Office (ILO), Bureau of Statistics, Geneva, Switzerland
IASA	2010	Estudio de Factibilidad Técnico, Ambiental, Social Y Económica para la Implementación del Plan de Acción "Santiago Recicla" – Informe de Avance Nº1, Ingeniería Alemana S.A. (IASA)
KDM Santiago de Chile	2010	KDM inauguró su planta de generación eléctrica con bio-gas" (KDM starts its biogas power generation plant), Grupo URBASER-DANNER. http://www.kdm.cl/index.php/escondidos/46-noticiasportada/272-kdminaguraplatageneracionelectrica.html (June 30, 2010).
Keller, A.	2010	Personal interview with A. Keller, project manager, KDM Energía y Servicios S.A. (Energy and Services), Transfer Station of Quilicura, Santiago de Chile
Krellenberg, K., Kopfmüller, J., Barton, J. (eds.)	2010	How sustainable is Santiago de Chile? Current Perform-ance – Future Trends – Potential Measures. Synthesis report of the Risk Habitat Megacity research initiative (2007-2011) UFZ-Report 04/2010 (http://www.ufz.de/data/Synthesis%20report%20Megacities%20eng14131.pdf)
Loll, U.	2002	Mechanische und biologische Verfahren der Abfallbe-handlung; Ernst and Sohn: Darmstadt, Germany. 2002
MNRCH (Movimiento Nacional de Recicladores de Chile)	2009	Personal interview with Alvaro Alaniz, Director from "Fundación Avina", July 2009
Oddou, M.	2008	Caracterización por comunas en la estación de transferencia de Quilicura. (Characterization by munici-palities at the Quilicura Transfer Station); KDM-Grupo Urbaser Kiasa: Santiago de Chile, 2008.

Szanto Narea, M.	2006	Gestion de Residuos Solidos Domiciliarios en Santiago de Chile. Valparaíso: Pontificia Universidad Católica de Valparaíso, Facultad de Ingenieria, Escuela de Ingenieria en Construccion, Grupo de Residuos Solidos
Szanto Narea, M.	2006	Caracterization de residuos solidos domiciliarios en la region metropolitan: Pontificia Universidad Católica de Valparaíso, Facultad de Ingenieria, Escuela de Ingenieria en Construccion, Grupo de Residuos Solidos
Wilson, D., Velis, C., Cheeseman, C.	2006	Role of informal sector recycling in waste management in developing countries. Habitat International, Volume 30, 797 – 808

Author's addresses:

Dipl.-Phys. Klaus-Rainer Bräutigam
Karlsruher Institut für Technologie
Institut für Technikfolgenabschätzung und Systemanalyse (ITAS)
POB 3640
76021 Karlsruhe
Telephone.: +49-0721-6082-4873
E-mail: Braeutigam@kit.edu

Dipl.-Ing. Tahnee Gonzalez
Linde AG
Engineering Division
Dr.-Carl-von-Linde-Str. 6 - 14
82049 Pullach, Germany
Telephone +49 89 7445 2687
E-Mail: tahnee.gonzalez.martinez@linde-le.com

Mechanisch-Biologische Siedlungsabfallbehandlung im Rahmen eines Integrieren Abfallmanagementkonzeptes für Santiago de Chile

Joachim Vogdt, Bastian Wens

IASA, Santiago de Chile; IAR-RWTH-Aachen

Mechanical-Biological Treatment of Municipal Solid Waste as a component of the Integrated Waste Management Concept for Santiago de Chile

Abstract:

Based on the results of pre-feasibility analysis for the recycling program "Santiago Recicla", the following paper gives an overview of the potentials of mechanical and mechanical-biological pre-treatment options for integrated MSW management in Santiago de Chile (MSW quantities, MSW composition, current recycling activities, proposed recycling measures and mechanical pre-treatment). Also different logistical alternatives for the collection of recyclable materials, drop-off systems or curbside collection of bio-waste, as well as the production of Refuse Derived Fuels are discussed.

Inhaltsangabe:

Basierend auf den Ergebnissen der „Santiago Recicla" Machbarkeitsstudie wird im vorliegenden Beitrag ein Überblick über das Potential mechanischer oder mechanisch-biologischer Abfallbehandlungsoptionen gegeben (Siedlungsabfallmengen, -zusammensetzung, Recyclingaktivitäten und Vorbehandlung deponierter Abfälle). Außerdem werden logistische Alternativen zur Erfassung von Wertstoffen, Bringsystem oder getrennte Haus-zu-Haus Sammlung ebenso wie die Produktion von EBS erörtert.

Keywords:

Municipal Solid Waste (MSW), mechanical biological pre-treatment, integrated waste management, recycling, refuse derived fuel (RDF), sustainability, "Santiago Recicla"

Siedlungsabfälle, integriertes Abfallmanagement, mechanisch-biologische Vorbehandlung, Recycling, Ersatzbrennstoff (EBS), Nachhaltigkeit, "Santiago Recicla".

1 Introduction

The management of municipal solid waste (MSW) in the Metropolitan Region of Santiago de Chile (MRS), a city of 6.7 million inhabitants which equals approximately 40% of the country´s population, is based predominantly on final disposal in landfills. Less than 2% of the waste is recycled through formal programs (mainly glass, and to a lesser extend paper and cardboard), and there is nearly no recovery of the organic fraction, which accounts for about 50% of the total quantity disposed in landfills (SZANTO, 2006; IASA, 2010).

Although co-combustion in cement kilns is state of the art in the case of commercial and industrial waste (e.g. used lubricants, solvents, tires and packaging material), an energetic recovery of MSW in Chile is currently not feasible neither from the economical nor the technical standpoint. Incineration plants are too costly in comparison to landfilling, and other furnaces such as those from conventional coal power plants are not suitable for the combustion of mixed MSW (MMSW). In order to allow co-combustion in existing facilities the MMSW has to be pre-treated at a cost compatible to current disposal practices.

Furthermore, the Santiago Waste Recycling program ("Santiago Recicla") sets out the priorities of enhanced materials recycling and inclusion of primary collectors has to be considered. Therefore a mechanical processing as pre-treatment of MMSW before landfilling, considering the recovery of recycling materials and production of refuse derived fuel (RDF) was evaluated.

2 The "Santiago Recicla" Plan

2.1 Objectives

The "Santiago Recicla" Plan (SRP) intends to reach a recycling rate of 25% w/w of regional MSW production by the year 2020. The objective of the SRP pre-feasibility study was to evaluate different MSW recycling alternatives for the MRS, not only from a technical and economical, but also social and environmental standpoint, specifically considering the inclusion of primary collectors.

2.2 Current Status of the Project

Practically coinciding with the end of "Risk Habitat Megacity" (RHM), in July 2010 the pre-feasibility study for recycling measures to be implemented in the frame of SRP action plan was initiated. The following activities have been carried out up to date:

- Description and analysis of current waste management practices, including interviews and data collection in 37 municipalities (out of a total of 52);
- Waste quantities and prognosis, considering RHM scenarios and current waste production of each municipality;
- Waste characterization in more than thirty urban sectors, stratified based on socio-economic groups and population density, according to national census (INE, 2002);
- Interviews with a total of 350 collectors and five workshops with representatives of the informal sector were carried out;

- Technical-economic analysis of different logistical alternatives: A) “Drop-off” system (so called ”puntos limpios“), B) Separate collection of mixed recyclables, and C) Mechanical (biological) treatment of MMSW;
- Siting for installations, prioritizing the investment in public sites, abandoned landfills;
- Basic engineering design and pre-feasibility of 11 waste management installations for storage of recyclables, sorting and/or treatment of MMSW;
- Management model and inclusion of primary informal collectors; and
- Conceptual design of educational programs

In parallel to this regional initiative, the national government is elaborating a general waste law, defining producers responsibility for certain products, and a green label initiative by industry was created (“Ecoenvases”); both were taken into account in the design of an integrated MSW management concept.

2.3 Municipal Solid Waste (MSW) Generation

Including the estimated quantities for recycling materials of 400.000 Mg/a, the total MSW generation of the MRS amounts to approximately 3.1 million Mg/a.

2.3.1 Production Per Capita (PPC)

Figure 2.1 shows current per capita MSW generation for each community, based on global waste management statistics. These values include bulky domestic, commercial and public waste (public parks, street cleaning); however in this case the quantities of recycled materials are not included, since they are mostly being collected by the informal sector and cannot be assigned to any particular community. The municipality of Santiago, which concentrates commercial activities, offices, financial and public services, attracts about 1.8 million commuters per day (MUNICIPALIDAD DE SANTIAGO, 2010). It not only produces more than twice the average waste production per capita (PPC= 1.3 kg/day), but also accounts for roughly 30% of the informal recycling effort (IASA, 2010), i.e. approx. 125,000 Mg/a of the 420,000 Mg/a of recyclables are collected in the city center.

Only about 75% of the global MSW per capita generation (470 kg/a) is domestic; the rest corresponds to commercial and communal green waste (approx. 10% and 15% respectively). Only five municipalities (Santiago, Vitacura, Las Condes, Providence and Maipú) concentrate more than 80% of the commercial waste generated, up to now collected together with MMSW (WENS, 2008; IASA, 2010).

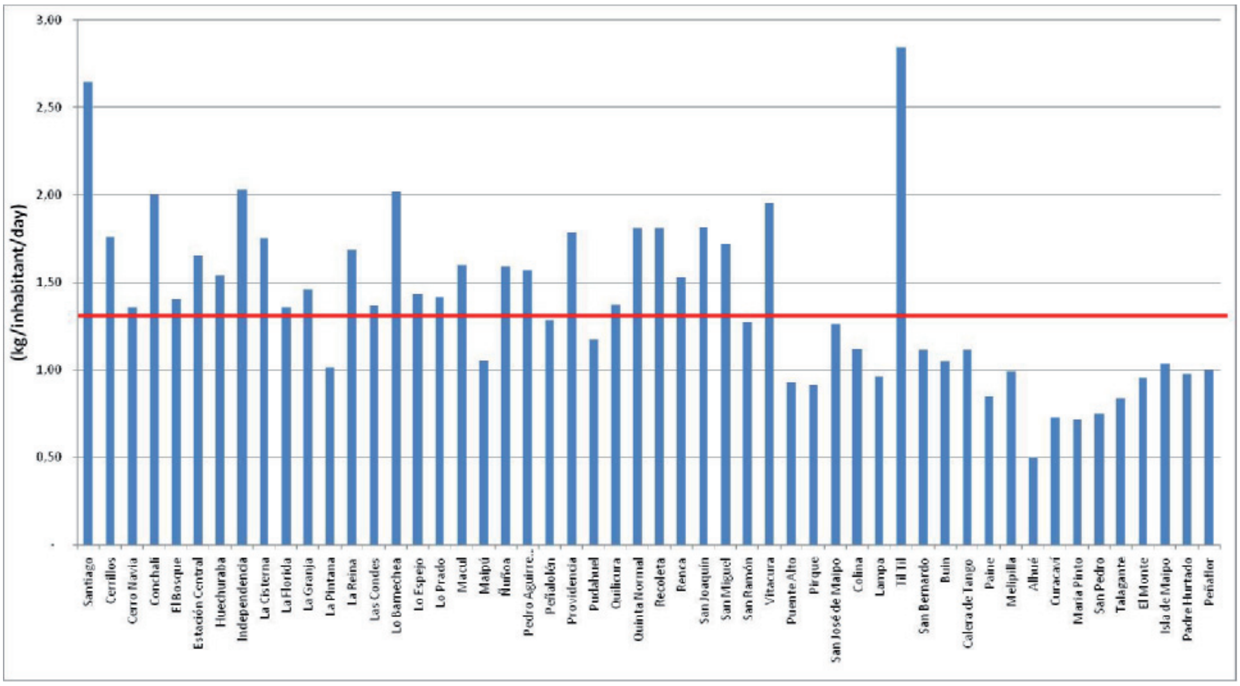


Figure 2.1: Current MSW Production Per capita for different communities (IASA, 2010)

The following per capita waste generation was estimated, differentiated according to the collection system (s. Figure 2.2):

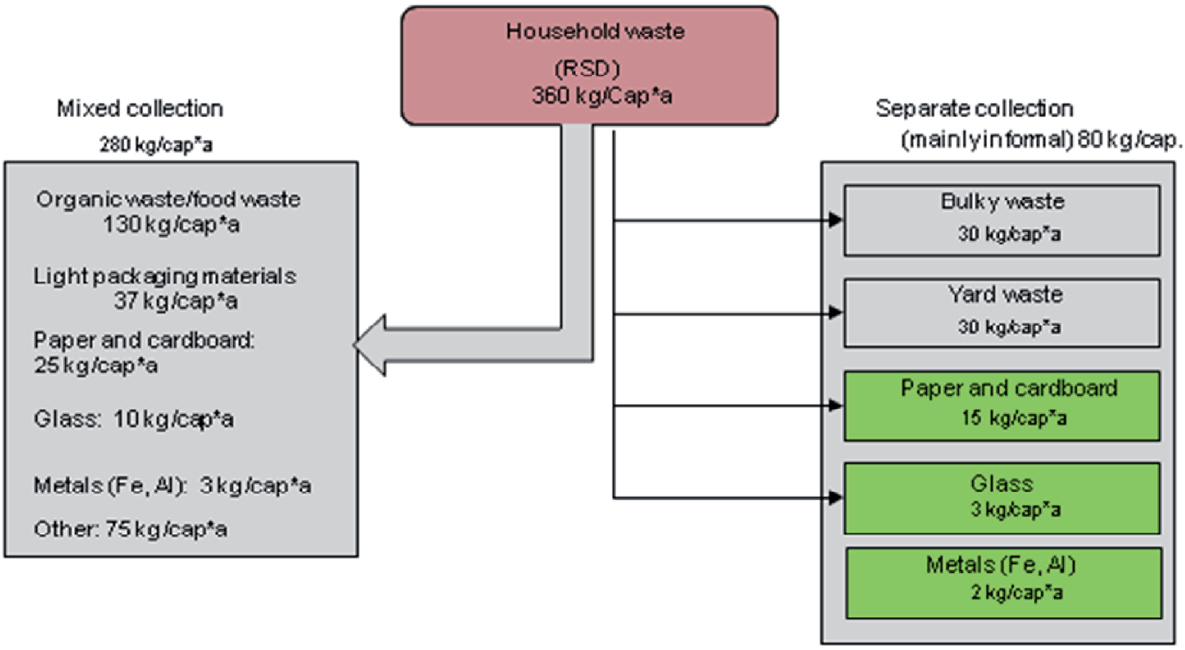


Figure 2.2: Estimated Annual Household Waste Production per Capita versus Collection Method (IASA, 2011)

2.3.2 Projection of Future Quantities

Based on different scenarios developed within the frame of the Risk Habitat Megacity investigation (RHM), the total waste generation for the year 2020 was estimated in at least 4 million Mg/a of MSW, reaching a total generation of between 5 and 6 million Mg/a in 2030, depending on scenarios (s. Figure 2.3). The SRP target value of 25% w/w therefore implies at least 1 million Mg/a of recycling in the year 2020, roughly two and a half times of current figures (see section 2.5).

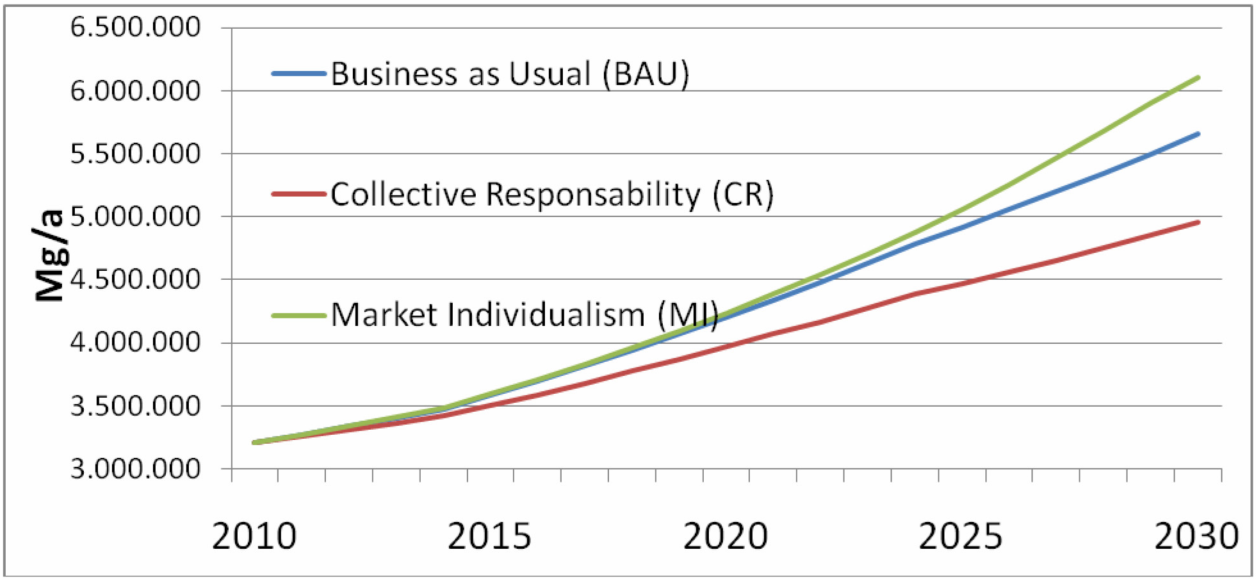


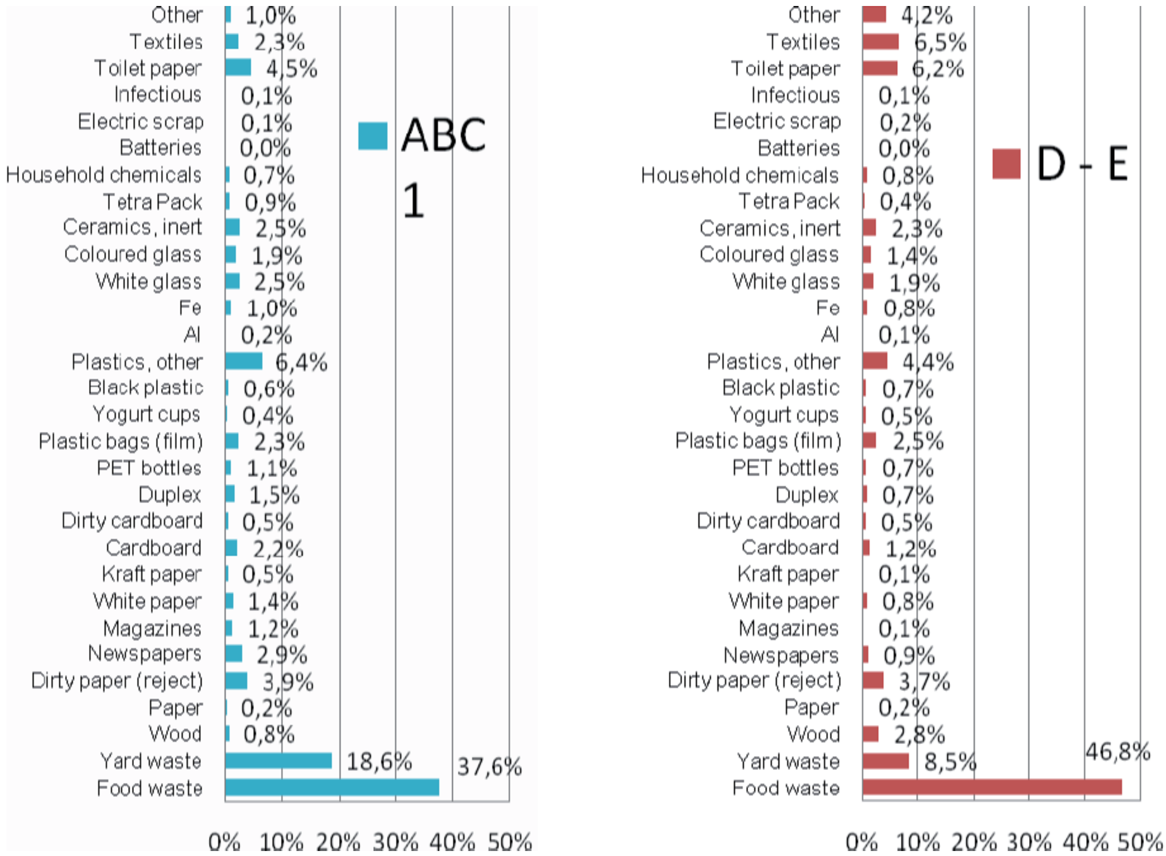
Figure 2.3: Total MSW Quantity Projection for MRS (GONZALEZ, T., 2010)

2.4 Waste Composition and Characteristics

Figure 2.4 shows MSW of two different socio-economic groups, high (ABC1) and low-income households (D). Figure 2.5 shows per capita production of different fractions of domestic waste (excluding bulky, yard and commercial waste), considering different socio-economic groups (SEG):

Although the percentage of waste fractions of different socio-economical groups tends to be similar, absolute per capita waste production varies significantly (between approx. 0,6 kg/day in low and nearly 1 kg/day in higher income SEG) (s. Figure 2.6):

Although the organic waste fraction in household waste decreased from 68% in 1990 to 50% in 2007 (SZANTO, 2006), it still accounts for nearly 60 % if yard waste is included (IASA, 2010).



a) High income socio-economic group (ABC1) b) Low income socio-economic group (D)

Figure 2.4: MSW Composition of different Socio-economic Groups (IASA, 2010)

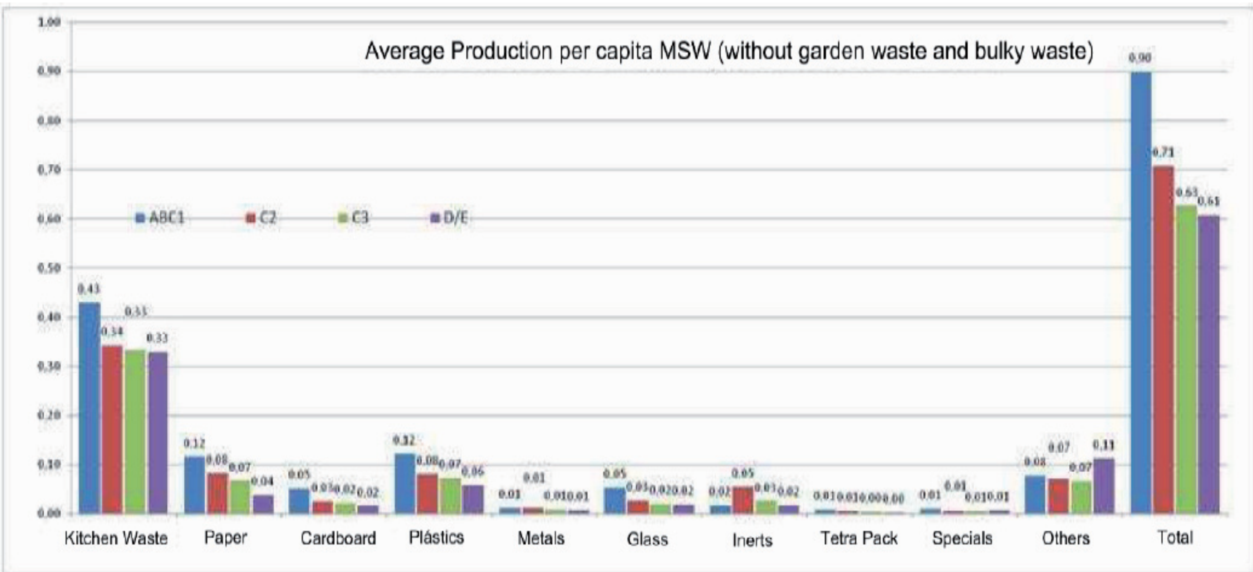
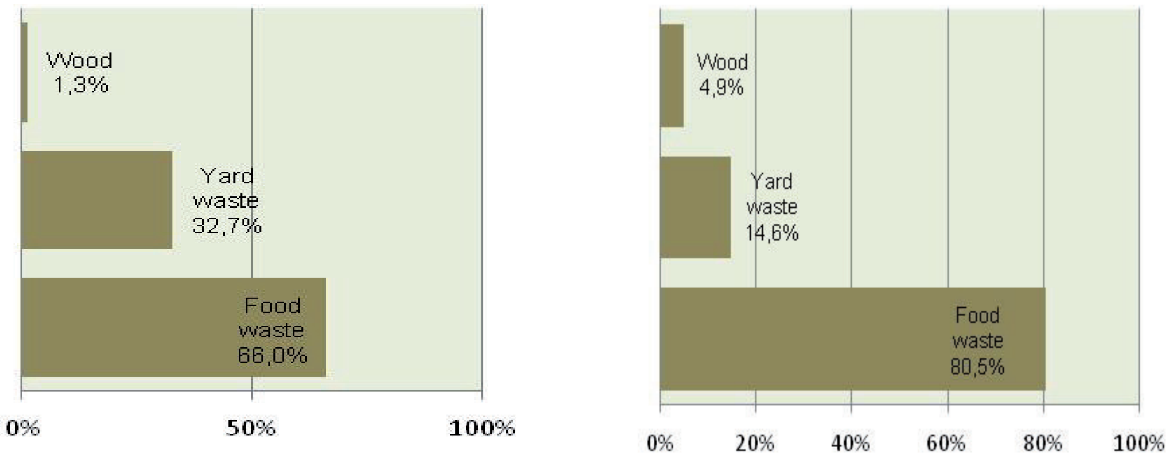


Figure 2.5: Waste Production Per Capita of different SEG`s (IASA, 2010)



a) High income socio-economic group (ABC1) b) Low income socio-economic group (D-E)

Figure 2.6: Composition of Bio-Waste fraction for different SEG`s (IASA, 2010)

2.4.1 Particle Size Distribution

Particle size distribution of the household waste is shown in Figure 2.7:

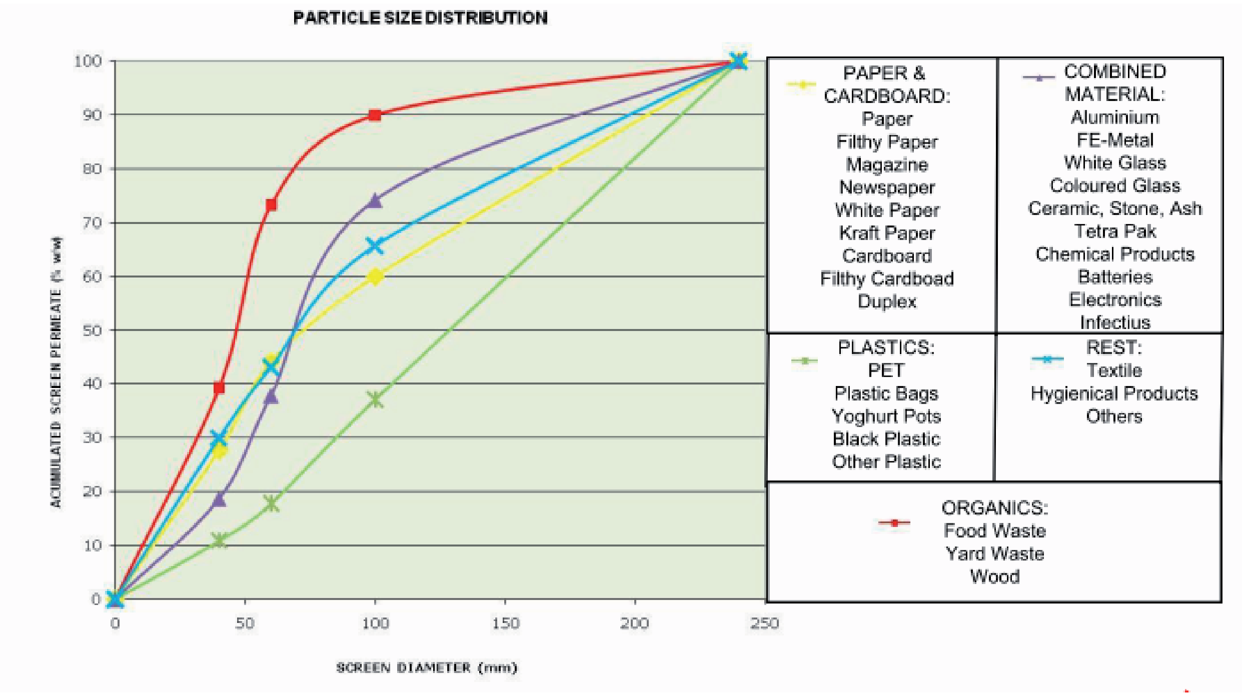


Figure 2.7: Particle Size Distribution of Household waste in the MRS (IASA, 2010)

2.4.2 Calorific Value

Table 2.1 shows the results of laboratory analysis of different particle size fractions of household waste:

Table 2.1: Calorific Value of different Particle Size fractions of Household Waste in Santiago (IASA & Fuentes, M. 2010)

Screen Size	Calorific Value [kJ/kg]				
	SEG: ABC1	C2	D	E	Plastics
< 40 mm	5,991	7,796	13,544	6,699	37,788
40 mm - 65 mm	16,479	6,004	12,037	10,212	
65 mm - 100 mm	8,386	9,738	16,086	8,411	
> 100mm	22,584	17,991	18,707	23,877	

Total calorific value of the household waste in the MRS was estimated in 10,000 kJ/kg; other parameters analyzed include moisture content, ash, total chlorine and sulfur.

2.5 Current Recycling Rates

According to official statistics approximately 420,000 Mg/a are recycled (14%), more than 90% of this quantity by informal or primary collectors; only 20,000 Mg/a formal glass recycling by private charity campaigns (drop-off system), and less than 2% by municipal campaigns (curbside collection or drop-off systems).

Example "Drop-off" system

There is only one municipal sorting installation in the MRS, which processes less than 2,000 Mg/a of mixed recyclables (paper, cardboard, PET, PE, Tetra-pack, Fe) from separate collection in the community.

A more detailed analysis of the informal recycling market (questionnaires of 350 primary informal collectors, interviews with intermediate buyers) shows however, that approx. 50% of paper&cardboard considered in the regional statistics comes from commercial sources (100,000 Mg/a); more than 90% of scrap material, declared as "domestic" (90,000 Mg/a) is from bulky waste, auto-parts or demolition waste, captured by the informal sector. Therefore, only little more than 5% of domestic waste is recycled; the estimated capture rates are shown in Figure 2.8:

Certain materials such as plastics (including PET) or Tetra-pack are recycled but only to an insignificant extend. Others, e.g. aluminum have to be exported in order to be recycled. With the exception of glass, the contribution of charity and municipal recycling programs to the recycling rate is relatively insignificant.

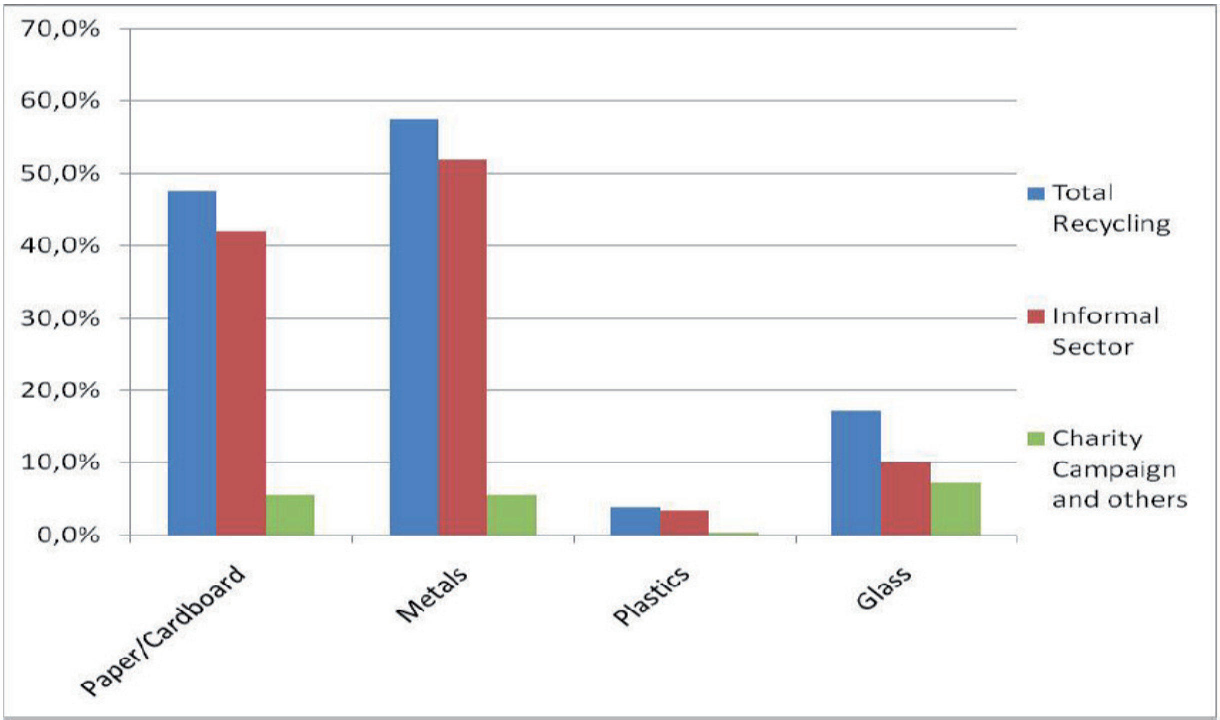


Figure 2.8: Current Recovery rates for different materials (IASA, 2010)

2.6 Proposed Recycling Measures

2.6.1 Location of future Installations

According to zoning regulations of the "Plan Regulador Metropolitano de Santiago" (PRMS) decentralized collection points (<20 m^3/day) can be installed throughout the MRS; simple storage of recycling materials is restricted to industrial (mixed or exclusive) areas and sorting facilities are restricted to exclusive industrial areas, outside the inner city areas. Figure 2.9 shows the suitable industrial areas within the Santiago area, whereas the areas marked in green qualify for exclusive waste storage and yellow for storage and sorting of recyclable materials.

With respect to installations for the treatment of MMSW (including mechanical and biological processing), the PRMS is not explicit; however, according to own experience with the environmental permitting of comparable solid waste handling facilities locations for MBA will most probably be limited to rural areas.

2.6.2 Technical-Economical Evaluation of Collection Logistics

Based on a conceptual model of waste generation for the region and scenarios for participation of households in the provided collection of recyclables three different logistic alternatives were evaluated:

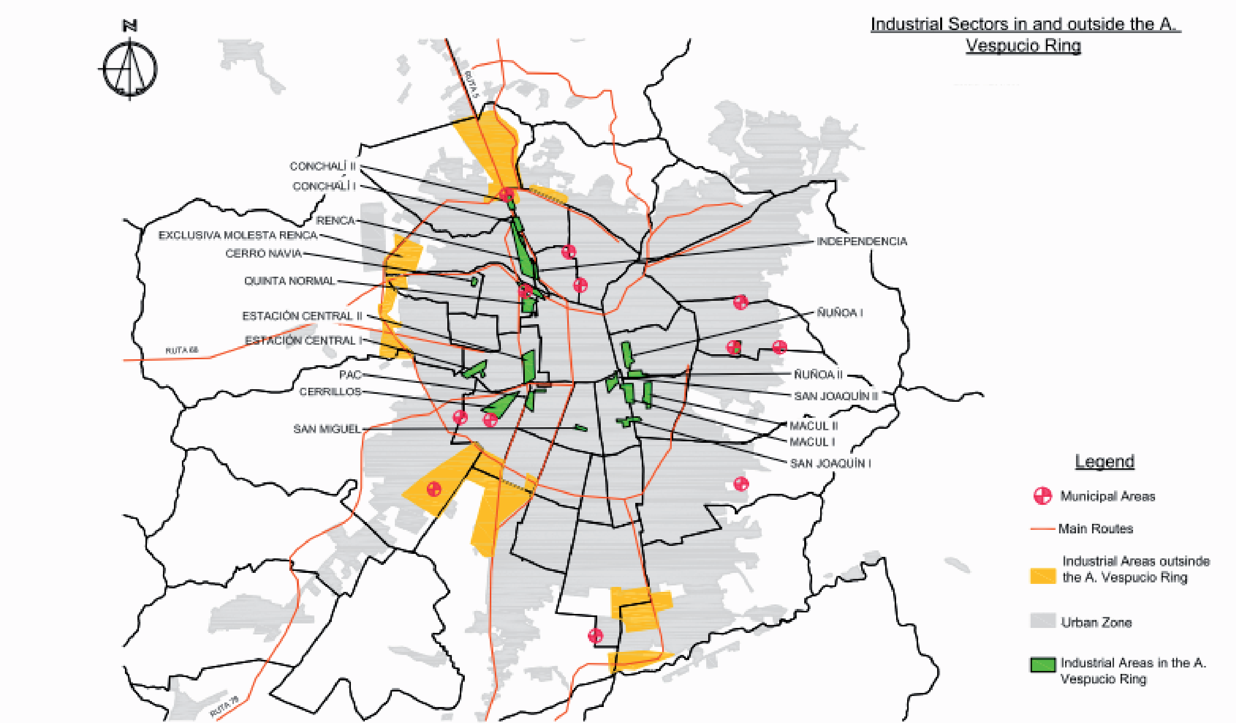


Figure 2.9: Zoning of Industrial Areas (PRMS), suitable for the location of storage and sorting facilities (IASA, 2011)

A. "Drop-off" system: Generally the most economical alternative in terms of collection effort, especially in the case of dense materials like glass; although different materials (PET, Tetra-pack) require a greater logistical effort, but little posterior processing. Costs for collection were estimated at €30 per Mg (even with a low 10% of participation of households);

B. "House by house" curbside collection: Implies not only a more expensive collection system, but also posterior sorting of mixed recyclables, in comparison to A) lesser quality of materials and 30 % of "rest"); Costs were estimated at over €80 per Mg (considering 40% participation of households);

C. Mechanical Pre-treatment: Intermediate costs of € 65 per Mg of recovered material (approx. €15 per Mg of MMSW treated); additional transport and disposal costs were not considered, therefore a location close to current transfer stations or landfills has to be chosen.

Figure 2.10 shows total collection and treatment costs versus participation of households, as well as impact of density of the material:

Only alternative A is completely compatible with inclusion of primary collectors, always assuming that primary collectors can be integrated as operators of collection points, thereby combining advantages of "Bring system" with "house to house" collection.

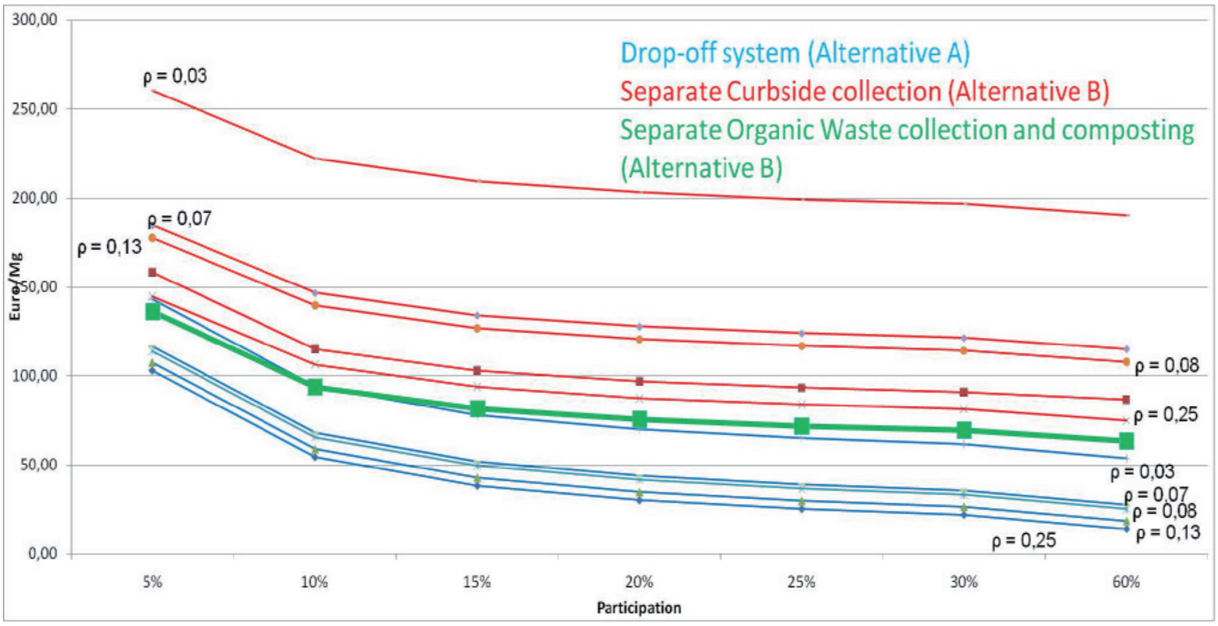


Figure 2.10: Combined Collection and Treatment costs (IASA, 2011)

Separate curbside collection ("house by house") is only feasible for the organic fraction, and/or in commercial areas. A complete separate collection of recyclable materials is not realistic, due to the current frequency of mixed collection (3 per week) and lack of discipline of users (waste is put on the curb on a daily basis). Only very few municipal collection systems of mixed recyclables and posterior separation have been successful up to date, however high costs are the disadvantages disqualifying this model under market conditions and making it unsuitable for the region as a whole. Motivation for these campaigns rises mostly from "ecological consciousness" of the generally high income population and positive image for the local government.

Alternative C is feasible including the extraction of certain recyclable materials, such as low quality paper, plastics, ferrous and non-ferrous metals and RDF (see section 3). An optimized concept not only from the technical and economic standpoint, but also inclusion of primary collectors is the following:

- Drop-off system ("puntos limpios"): Glass, paper&cardboard from domestic sources (aided by "house by house" collection of formalized, but independent collectors)
- Specialized recycling centers for the storage, compaction of PET and other low density materials (operated by collectors, small companies, etc.) to minimize costs for transport
- Separate collection of biomass (replacing one of three hauls per week)
- Mechanical treatment of remaining MMSW in order to recover PET, Tetra-pack, metals (Fe, No-Fe) and RDF.

In the final report (05/2011) minimal cost alternatives for each municipality will be presented in order to obtain financing for detailed engineering design studies, environmental permits and/or execution (Initial Investment for 2011 approximately US$ 8 millions).

3 Potential of Mechanical Pre-treatment in Santiago

3.1 Objectives

MBT of MMSW aims at separating the biodegradable waste fractions while fractions with higher calorific values are concentrated to an RDF product that enables an energetic recycling in existing plants (e.g. cement kilns). Table 3.1 shows average, minimum and maximum requirements for the co-combustion of solid waste in existing cement kilns in the MRS:

Table 3.1: Required Waste Characteristics (Fuentes, M., 2010)

Parameter	Units	Promedium	Standard Dev. (%)	Min.	Max.
Calorific value	kJ/kg	15,910	15	9,462	20,684
Moisture	%	22	15	n/a	28,6
Chlorine	%	0.42	10	n/a	0,4
Sulfur	%	0.6	8	n/a	0,7
Ash	%	15	10	n/a	18

Furthermore, the mechanical processing allows the material recovery of valuable materials; fractions considered to be potentially interesting secondary raw materials for the national industry are the following:

- PET bottles
- PE/PP
- Paper and cardboard
- Wood (“biomass”)
- Metals (ferrous and non-ferrous)

When evaluating valuable materials it has to be differentiated between metals and organic fractions such as paper and plastic. Metals are chemically stable during treatment and exhibit positive market values. Ferrous metals can be recovered by simple magnetic separators whereas nonferrous metals can be recovered using eddy-current separators. In the latter case, subsequent purification before reutilization as secondary raw materials is required in order to divide the different metals (e.g. aluminum, copper or zinc).

Based upon waste analyses carried out in the frame of SRP, process simulation was carried out in order to develop the plant design. The key aim was the production of RDF with a chlorine content below 0.4% and a heating value above 14,500 kJ/kg.

The material recovery of organic valuable materials is more complicated and requires sensor-based sorting, most importantly machines equipped with near-infrared sensors (NIR). Between the moment where citizens actually dispose of their waste at home and the collection potentially valuable materials are mixed with bio waste. This decreases the quality of valuable materials, most notably of paper and plastics. The longer this time span, the more the quality decreases so that the materials often do not qualify as input for the German recycling industry. In contrary to Germany, the collection intervals for household waste are considerably shorter in Chile, between three and up to five times per week. Hence, the preconditions for the recovery of valuable materials from MMSW are more favorable in Chile than in Germany. Of course, the extraction of valuable materials for material recycling depends on local market conditions. Even if technically possible, the economic feasibility may not be given due to lacking demand.

3.2 Conceptual Design

The concept chosen in order to test and evaluate the MBT of MMSW in Chile is displayed in Figure 3.1:

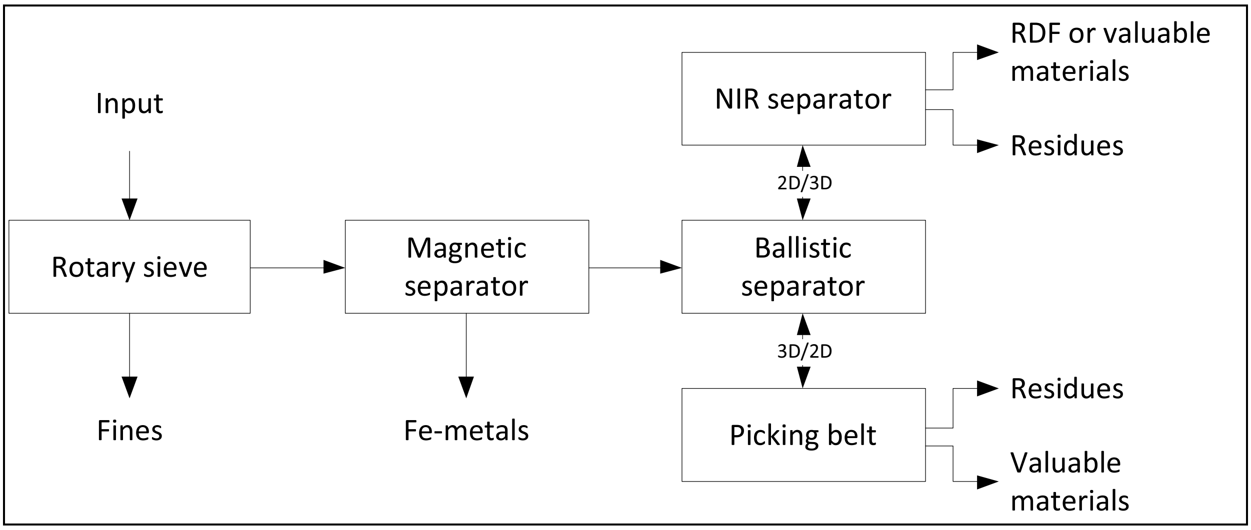
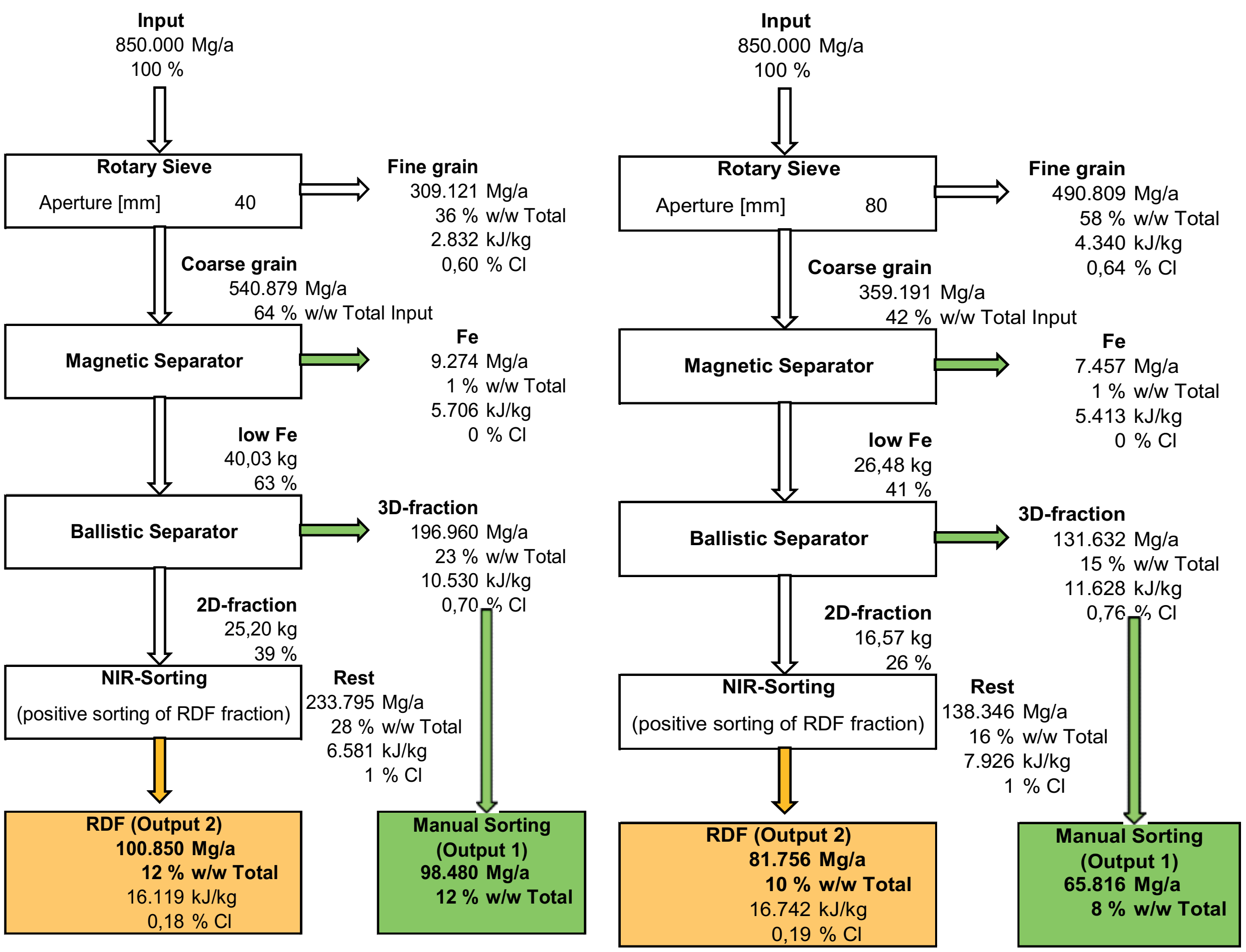


Figure 3.1: Concept of the demonstration mechanical treatment plant

At the beginning of the process, a fine fraction mainly consisting of biodegradable material and minerals is separated using a rotary sieve. In contrary to many MBT concepts realized in Germany, subsequent to initial screening no light fraction is produced from the coarse fraction. Instead, sensor sorting was chosen. A ballistic separator was chosen in order to separate two-dimensional and three-dimensional particles. Using reversible conveyor belts, both output streams can be led either to a picking belt or to a NIR sorter. Both, the automated as well as manual sorting can be operated in different modes or with different aims respectively to evaluate possible options for enhanced material recovery from household waste in Chile.

3.3 Simulation and Mass Balance

Considering typical extraction efficiencies for magnetic, ballistic separator and the NIR sorter, as well as waste characterization presented in section 2.4 a process simulation and mass balance for two different screen sizes was carried out (see Figure 3.2): Screening at 40 mm and 80 mm both RDF products theoretically meet the requirements of the cement kiln with chlorine contents of 0.18% and 0.19% respectively. However at a sieve size of 40 mm, 12% of the input can be converted into RDF, whereas at 80 mm it is only 10%.



a) Screen size 40 mm b) Screen Size 80 mm

Figure 3.2: Mass Balance for Mechanical Pre-treatment with different Screen sizes

Without the ballistic separator and materials recovery, up to 28% of the input can be converted into RDF by screening at 40 mm, 18% in the case of 80 mm screens. Of course the heating value of the latter is higher due to a lower share of organic fractions that can be found in the fraction < 80 mm.

If, as supposed in the Collective Responsibility (CR) scenario of RHM project, up to 21% of the MSW receive mechanical or mechanical-biological pre-treatment before landfilling, up to 100.000 Mg/a of recycling materials and 100.000 Mg/a of RDF could be recovered.

3.4 Pilot Experience

During 2011 a pilot experience of separate biomass collection is planned; the “rest” will be processed in the mechanical-biological treatment plant (2012). Besides an assessment of the quantities of valuable materials, the operation of the demonstration plant also offers the possibility of assessing the quality of the products after a mechanical processing.

4 Summary

The objective of the „Santiago Recicla“ Program, which initiated in 2010 a series of pre-feasibility studies, the site evaluation and engineering design for a modern drop-off, intermediate storage and sorting facilities, is to recycle 25% of MSW until 2020 (approximately 1 million Mg/a). The proposed measures include the following:

- Inclusion of primary informal collectors (as administrators of collection points);
- Intermediate storage, compaction for packaging materials (PET, Tetra-pack, paper and card-board), considering at least 10 storage and/or processing facilities;
- Separate collection of biomass (in order to facilitate mechanical treatment of MSW);
- Three or four integrated treatment and sorting plants for the processing of MSW, bulky waste and commercial waste;
- Educational campaigns in schools, training of collectors and the general public.

Participation in drop-off system and activity of primary collectors is believed to have a potential of up to 750.000 Mg/a of materials recovery (considering household participation of over 60%), while curbside collection of light packaging materials in commercial areas might contribute another 200.000 Mg/a of recyclable materials.

However in order to meet the proposed recycling rate of 25% by the year 2020, mechanical pre-treatment in one of the transfer stations and/or landfills has the potential of 100.000 Mg/a of recycling material (PET, Fe and non-Fe metals). Since MMSW treatment does not require additional collection logistics, it appears to be a competitive alternative especially in the case of light packaging materials. Other potential benefits of MSW pre-treatment include the following:

- Production of refuse derived fuel (RDF);
- Social acceptance of waste management facilities;
- Reduction of CO_2 emissions, due to materials recovery and biological pre-treatment;
- Longer lifetime of landfills (reduction of MSW quantities and volume, also due to a better compaction).

Based on the indicators developed in the RHM Project (BRÄUTIGAM ET AL., 2008), mechanical or mechanical-biological pre-treatment is considered as an important contribution to the overall sustainability of MSW management of MRS.

Separate bio-waste collection in combination with mechanical processing of the "rest" should be considered in order to improve recovery rates, quality of the separated materials; these aspects will be evaluated based on the operational results of the pilot plant.

5 Literature

Bräutigam K.-R., Gonzalez T., Seifert H., Szanto M., Vogdt J.	2008	Risk Habitat Megacity – Waste Management in Santiago de Chile – I. Simposio Iberoamericano de Ingeniería de Residuos - Castellón, 23-24 de julio de 2008
Bräutigam, K.-R.; Gonzalez, T.; Seifert, H	2009	Landfill gas emissions from landfills in Santiago de Chile - Strategies to reduce impact on local environment as well as on global climate. In: Escudero de Fonseca, A. et al. (Hrsg.): La gestión sostenible de los residuos. II Simposio Iberoamericano de Ingeniería de Residuos. Barranquilla, Colombia: Ediciones Uninorte 2009, S. 76
Fuentes, M.	2010	Resultados de Análisis Físico y Químico a RSD
Gonzalez, T.	2011	Analysis of Different Municipal Solid Waste Management Systems for Santiago de Chile, Doctoral Thesis an der Fakultät 4 Energie-, Verfahrens- und Biotechnik der Universität Stuttgart (to be published)
IASA	2010	Estudio de Factibilidad Técnico, Ambiental, Social Y Económica para la Implementación del Plan de Acción "Santiago Recicla" – Informe de Avance Nº1, Ingeniería Alemana S.A. (IASA)

IASA	2010	Estudio de Factibilidad Técnico, Ambiental, Social Y Económica para la Implementación del Plan de Acción “Santiago Recicla” – Informe de Avance Nº2, Ingeniería Alemana S.A. (IASA)
INE	2002	Censo 2002: Instituto Nacional de Estadísticas (INE)
Leiva, R.	2011	“Ecoenvases” - Sistema Integrado de Gestión de Envases Post-Consumo
Municipalidad de Santiago	2011	http://www.municipalidaddesantiago.cl/comuna/comuna_caracteristicas.php (Letzter Zugriff, 31.03.2011)
Szanto Narea, M.	2006	Gestión de Residuos Sólidos Domiciliarios en Santiago de Chile. Valparaíso: Pontificia Universidad Católica de Valparaíso, Facultad de Ingeniería, Escuela de Ingeniería en Construcción, Grupo de Residuos Sólidos
Szanto Narea, M.	2006	Caracterización de Residuos Sólidos Domiciliarios en la Región Metropolitana: Pontificia Universidad Católica de Valparaíso, Facultad de Ingenieria, Escuela de Ingeniería en Construcción, Grupo de Residuos Sólidos
Wens	2008	Einsparungspotenzial von Deponiegasemissionen durch die getrennte Erfassung organischer, häuslicher Abfälle in der Región Metropolitana in Chile: Institut für Aufbereitung fester Abfallstoffe (IAR), RWTH Aachen, Studienarbeit

Author’s addresses:

Joachim Vogdt, Env. Eng. (M.Sc.)
Ingeniería Alemana S.A.
Ñuñoa, Santiago de Chile
Telephone.: +56-2-269 8158
Email: jv@iasa.cl

Bastian Wens, Dipl.-Ing.
Department of Processing and Recycling (I.A.R.) - RWTH Aachen University
Wüllnerstraße 2
52062 Aachen
Telephone: +492418095710
Email: wens@ifa.rwth-aachen.de

Municipal solid waste treatment in Poland – facts and myths

Magdalena Rybaczewska-Błażejowska

University of Applied Sciences in Ciechanow, Poland

Abstract

The experience shows that there are still numerous misunderstandings about the municipal waste sector in Poland and thus the intension of this paper is to present analytically the current state of MSW treatment in Poland. The optimal solution to the transformation of the waste sector (towards cyclical production/consumption processes) cannot be found without its thorough self-assessment at the first-place. The SWOT analysis proved that the key strengths and opportunities of municipal waste management in Poland are relatively low and stable level of MSW generation, high economic potential of MSW composition and the growing use of materials and energy recovery. On the other hand, amidst its greatest weaknesses can be enumerated an ineffective system of MSW collection, still poor application of the waste hierarchy measures and significant delays in the establishment of regional structure for municipal waste management.

Keywords

Municipal solid waste, integrated waste management, Polish waste sector, SWOT analysis

1 The future of MSW treatment in Poland

The priorities and objectives as regards the management of MSW are stated in the Waste Management Strategy for Poland 2014. Pursuant to this planning document, published by the Ministry of the Environment in 2010, the following goals are expected to be achieved:

- covering the whole population of Poland by the MSW collection system by 2015;
- covering the whole population of Poland by the separate collection system of at least bio-waste from gardens and parks, metal, plastic and glass by 2015;
- reduction of the landfilling levels of biodegradable waste to 50% of the 1995* level in 2013 and 75% of the 1995 level in 2020;

  (* 4 380 thousand tonnes of biodegradable municipal waste was produced in Poland in 1995)
- reduction of the level of municipal solid waste landfilling to maximum 60% by 2014;
- reuse and recycling of at least 50% of household waste by 2020.

To fulfil the above specified objectives, it will be necessary to develop the regional systems for municipal waste management that offer integrated waste treatment methods. Consequently, according to the Waste Management Strategy for Poland 2014, the foundation of the municipal waste management in Poland ought to be regional municipal waste treatment facilities serving minimum 150 thousand of dwellers. In case of agglomerations or regions inhabited by more than 300 thousand citizens, the preferred method for mixed municipal waste treatment is their processing with energy recovery in incinerators. Therefore, the target plan is the construction of 11 incineration plants throughout Poland in the following cities: Lodz, Cracow, Warsaw (the extension of the existing plant), Bialystok, Gdansk, Upper Silesia Metropolitan Area, Poznan, Szczecin, Bydgoszcz-Torun Metropolitan Area, Olsztyn, Koszalin. Regarding MSW landfilling, each province ought to have 5 up to 15 regional landfill sites for non-hazardous waste. Their total disposable capacity in each region has to be sufficient for at least 15 years of exploration.

2 The present of MSW treatment in Poland – SWOT analysis

Despite the fact that there are different states of advancement of municipal solid waste management amidst members of the European Union, all have to fulfil the requirements of the Landfill Directive 1999/31/EC and the Waste Framework Directive 2008/98/EC. In some countries, as in case of Poland, where there are considerable delays in materials and energy recovery from municipal solid waste, this requires considerable acceleration of action. The first step forward is the thorough self-assessment of the current state of the MSW sector. To address its key strengths, weaknesses, opportunities and threats to reach legal obligations, a SWOT analysis will be carried out. By using this strategic tool, the authors of the article will present the ongoing transformation of MSW sector from waste towards product management. Unfortunately, due to the limitations of paper length, only chosen aspects can be discussed. The authors are very happy to answer all remaining questions via email.

2.1 Strengths and opportunities – MSW generation and composition

The results of the SWOT analysis confirmed that the sector of municipal waste management in Poland has a certain potential to follow the road of sustainable development. Its unquestionable strengths embodies, among others,:

- relatively low and stable level of MSW generation;

In comparison with other EU countries, there is a relatively low level of MSW generation in Poland. According to the Polish Central Statistical Office, 12 053 thousand tonnes of municipal waste was produced in Poland in 2009 (see figure 1). This gives, on average, 316 kg per capita per year. Contrary to many prognosis done in the early 90ties, there is no increasing trend in the quantities of waste generated in the last 10 years in Poland. This might be a result of relatively stable consumption patterns, economic growth rates and recessions as well as the enhancement of public environmental awareness.

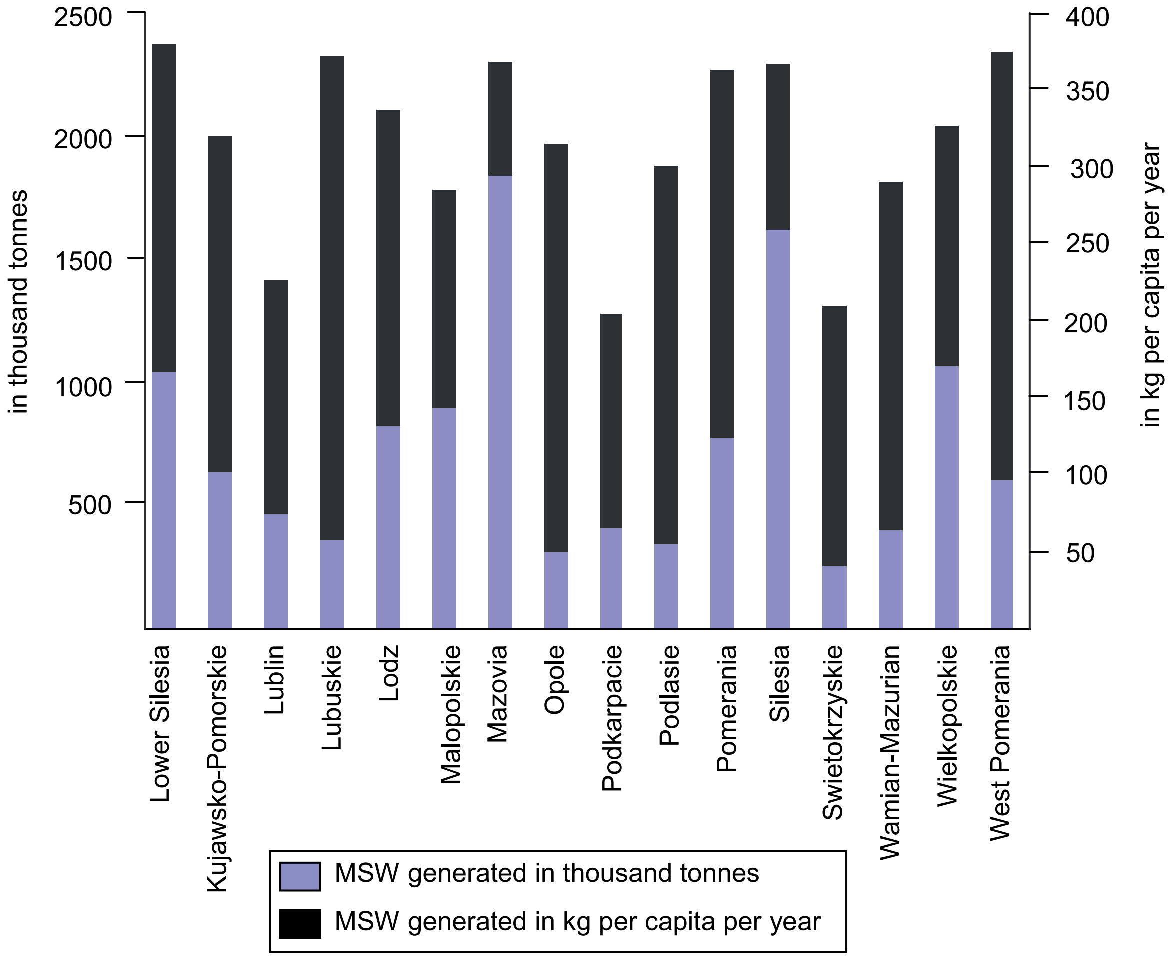
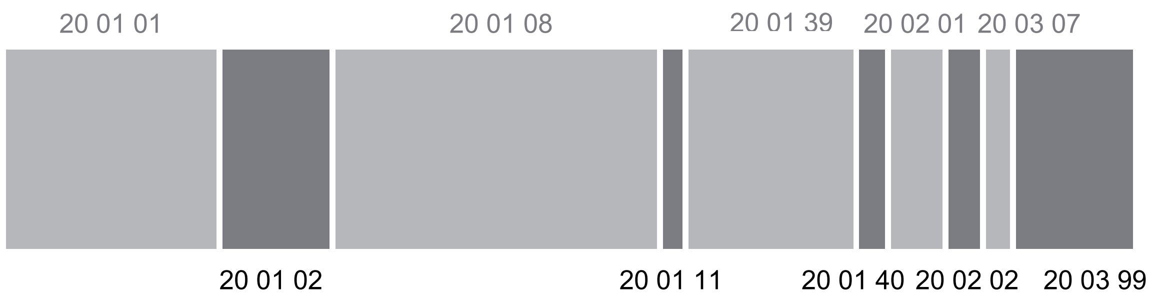


Figure 1 Generation of municipal solid waste by province in 2009

– high economic potential of MSW composition;

The analysis of morphological composition of municipal solid waste in Poland proved that they can be a source of many valuable materials for the processes of re-use and recovery (see figure 2). Although the content of MSW is very dependent on local conditions (large differences between rural and urban areas), on average biodegradable waste (approx. 34%), followed by paper and cardboard (approx. 19%), plastics (approx. 15%), and glass (approx. 10%) have the biggest percentage contribution to the domestic waste composition. The latter three reflect the increase use of packaging in Poland.



20 01 01 Paper and cardboard – 19,1%

20 01 02 Glass – 10%

20 01 08 Biodegradable kitchen and canteen waste – 28,9%

20 01 11 Textiles – 2,3%

20 01 39 Plastics – 15,1%

20 01 40 Metals – 2,6%

20 02 01 Biodegradable waste – 5,3%

20 02 02 Soil and stones – 3,2%

20 03 07 Bulky waste – 2,6%

20 03 99 Municipal wastes not otherwise specified – 10,9%

Figure 2 Composition of municipal solid waste in Poland in 2008

– the growing use of materials and energy recovery.

According to the data of the Polish Central Statistical Office, over the last 10 years a regular increase in re-use and recovery processes has occurred in Poland. As in the 90-ties the options for MSW management were practically confined to landfilling, currently physical, biological and chemical transformation encompasses more than 20% (see figure 3). If this trend continuous, it might be expected the transformation from the linear consumption processes (raw materials → production processes → product → use of product → disposal) to cyclical consumption processes (raw materials → production processes → product → use of product → reprocessing (or composting) → secondary raw materials (or compost)).

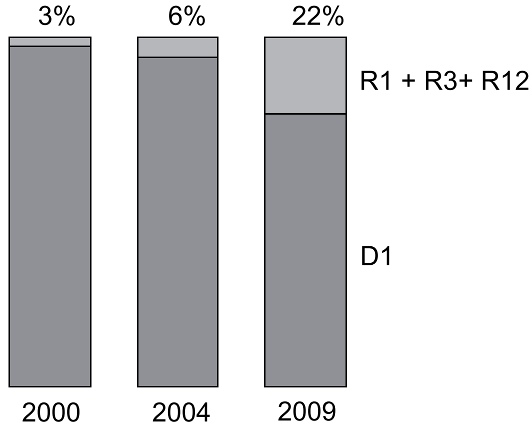


Figure 3 Management of municipal solid waste in Poland from 2000 to 2009

2.2 Weaknesses and threads – MSW collection and treatment

Besides indisputable efforts of the sector of municipal waste management in Poland to comply with the challenges of modern (integrated) waste management, it has still faced many difficulties. Amongst the greatest weaknesses of MSW treatment in Poland can be enumerated:

– ineffective system of MSW collection;

Notwithstanding the fact that there has been a considerable progress in the collection of municipal solid waste over the last few years in Poland, in 2009 MSW was collected just from 79% of Polish population. The situation is even worse at the rural areas where the large dispersion of households makes the waste collection very difficult. As a result, in many areas occur the negative phenomena of "illegal dumping". The collection of source-separated municipal solid waste also remains at the relatively low level. In 2009, solely 7.8% of municipal solid waste in Poland was source-separated via drop-off schemes (offered in blocks' estates) or kerbside systems (offered in detached-houses' estates). The highest amounts of glass (4.6 kg par capita per year), paper and cardboard (3.8 kg par capita per year) and plastics (3.6 kg par capita per year) were collected in 2009.

– poor application of the waste hierarchy measures;

Despite the growing use of materials and energy recovery from municipal solid waste, recycling and incineration are still much under-utilised options of MSW management in Poland. In 2009, only 2 211 thousand tonnes of municipal solid waste was recovered, giving a level of 22% (see figure 4). Consequently, disposal at landfill sites remains a predominant form of MSW management, largely because of its ready availability and applicability for a wide range of MSW components. The alternative methods, which are, among others, the production of refuse derived fuel, material recycling, composting or incineration are mostly at the investment stage. Therefore, one of the crucial problems of MSW management in Poland is the insufficient infrastructure for materials and energy recovery, including the one for mechanical-biological treatment as well as thermal transformation (see table 1).

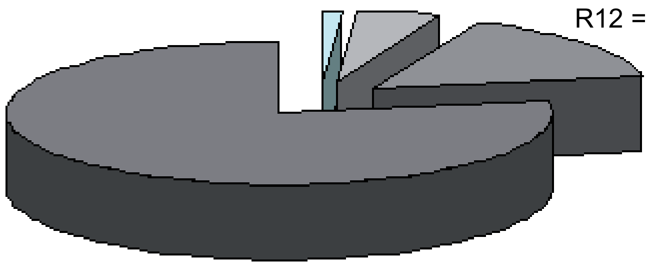


Figure 4 Management of municipal solid waste in Poland in 2009

Table 1 Municipal waste treatment plants in Poland in 2009 (according to their owners' declarations)

Division of plants	Number of installation	Total capacity [in thousand tonnes]
Composting plants for selectively collected biodegradable waste	90	602.3
Municipal solid waste sorting plants	173	2227.1
Municipal solid waste incineration plants	1	42
Mechanical-biological treatment plants for mixed municipal solid waste	11	411.7

– significant delays in the establishment of regional structures for municipal waste management.

One of the causes of too slow pace of the municipal waste sector modernisation are substantial delays in the establishment of regional structures for municipal waste management. In consequence, many communes are unable to commence the construction of regional municipal waste treatment facilities offering comprehensive solutions for MSW and thus benefit from the EU funding. There are many reasons for such situation. One of the crucial seems to be the instability of environmental regulations. The constantly changing legal rules, followed by not taking the consequences from organisations that do not comply with these regulations, influence the activity of many regions very negatively. As a result, they, instead of taking actions, observe the MSW sector in terms of the future situation.

3 Final thoughts

Summarising the above enumerated findings, the sector of municipal solid waste in Poland is on the path to reach the goals of the Waste Management Strategy for Poland 2014. Experts together with practitioners are slowly coming to general agreement that the successful change can only be achieved if:

- communes share the common infrastructure for municipal waste management (cost savings),
- the investments in modern MSW reuse and recovery treatment methods take into consideration local circumstances (e.g. available quantity and composition of municipal solid waste) and finally
- domestic waste are collected selectively at source (to improve the quality of secondary raw materials and compost), which requires widespread environmental education of the public.

4 Basic literature

Główny Urząd Statystyczny	2010	Environmental Protection 2010 – statistical yearbook, Zakład Wydawnictw Statystycznych, Warszawa
Marcinkowski, T	2009	Kompleksowe zarządzanie gospodarką odpadami – Integrated waste management, Polskie Zrzeszenie Inżynierów i Techników Sanitarnych, Poznań
Uchwała nr 217 Rady Ministrów	2010	Waste Management Strategy for Poland 2014

Author's address*:*

PhD Magdalena Rybaczewska-Blazejowska

University of Applied Sciences in Ciechanow
The Chair of Environmental Engineering
Narutowicza Street 9
06-400 Ciechanow, Poland
Email: magdalena.blazejowska@pwszciechanow.edu.pl

MBT/MRF state of art and possible development in Norway

M.Sc. Frode Syversen

Mepex Consult AS, Lier, Norway

Abstract

Norway has implemented a modern waste management system in compliance with European directives. But there is potential for improvements. In 2010 the amount of mixed household waste disposed via landfilling amounted to about 5-6% of waste generated, due to a new landfill ban for waste containing 10% TOC or more. Source separation, recycling, biological treatment and incineration are common solutions. MBT facilities are not a part of the system so far.

Mixed residual waste after source segregation is mostly sent directly to incineration, even though this waste contains a lot of materials suitable for recycling. Mixed waste contains also inert fractions that give high bottom ash amount and food waste with low calorific value. MBT represents a potential solution that can optimize the environmental aspects for waste management in Norway, according to EUs waste hierarchy.

Keywords

Municipal Solid Waste, Mechanical and Biological treatment systems, Technology, Legal framework, Market situation, Norway

1 Introduction

1.1 National research project

Background for hereby document is an on-going national research project about MBT technologies and relevant framework within national regulation in Norway. A report from part 1 of this project has been published and includes an international survey of solutions and the possibilities to adapt them under Norwegian conditions. The report has identified potential environmental benefits. Part 2 has started with focus on a practical test programme. The aim is to demonstrate if MBT can be justified in future integrated waste management solution in Norway. The project can then lead to changes in legal framework, including a possibility to landfill biological stabilized residual products (CLO) with low risk for methane production in long term.

1.2 Historical review

In Norway MBT has not been a common expression used in the waste management vocabulary. There is no specific waste treatment facility in operation in Norway that is classified as a real MBT-plant. MBT is looked upon as a complex and costly solution for central parts of Europe with high waste amounts and limited incineration capacity.

In Norway we had some negative experiences with mechanical sorting of mixed waste from early 1980's. This gave mechanical sorting of mixed waste a bad reputation;

- Composting of waste fractions rich in organic content sorted out from mixed waste was developed, but it soon appeared that the poor product quality and content of heavy metals became a problem. Thus this treatment method was stopped.

- A sorting plant for material recycling of mixed waste was build up in Oslo in 1985 based on an Italian technology. However this plant was never put in regular operation. Mainly because of the quality requirements for recyclables were not achieved in practice. Low quality of paper and plastic was not demanded by the market.

MBT still has the same challenges but the situation has anyway changed a lot. On one side requirements for soil products have become stricter. At the other sorting technology has been developed and the focus is now more on plastic recycling from residual waste.

In the hereby document we describe and analyze the Norwegian situation and try to answer if MBT can represent a potential for development. Several barriers are discussed and the research program is presented.

2 Waste management systems in Norway

2.1 Norway – the land of source separation

Source separation has been developed during the last 2 decades and is implemented in almost all Norwegian municipalities step by step since 1992. There are a lot of different systems and almost no municipalities/regions have similar solutions. About 60% of waste from households is source separated. The official number for waste generation from households is about 420 kg/capita per year in 2009, and this represents more than 100% increasing over 17 years. Figure 1 show this development based on Statistics Norway (SSB). Numbers for 2010 is not complete.

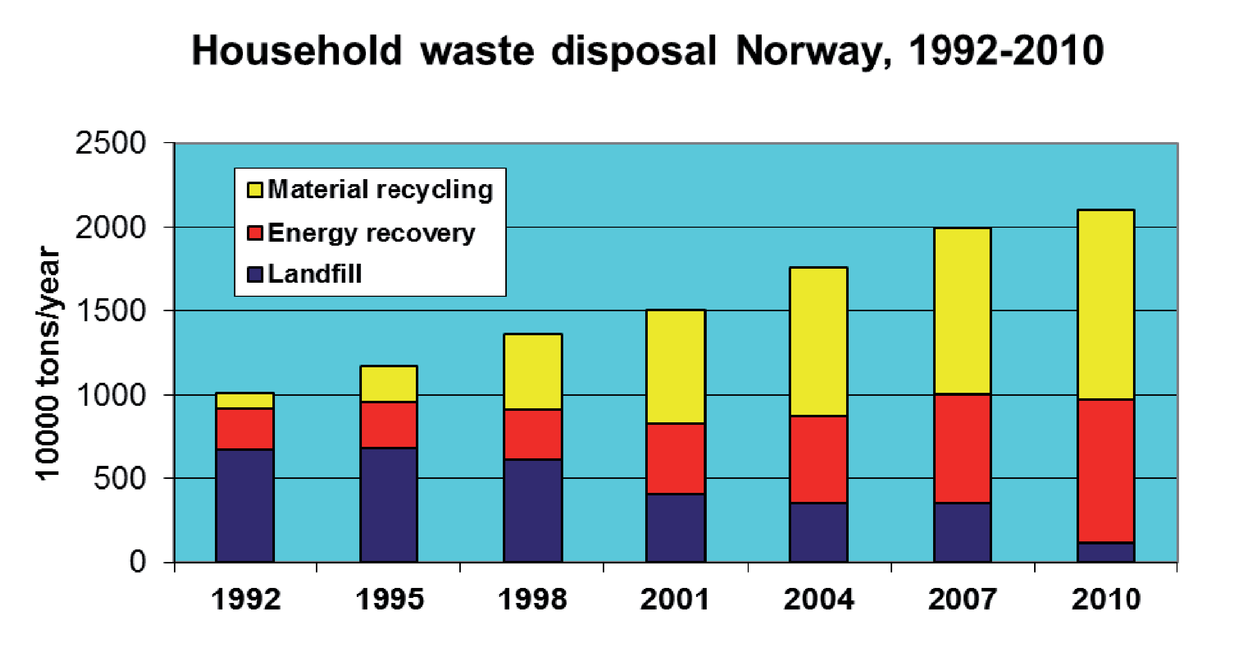


Figure 1 Household waste disposal Norway (SSB)

Material recycling includes biological treatment of source separated biological waste.

2.2 Incineration – the leading solution for residual waste

Norway has now totally 20 Waste to Energy plants and about 5 RDF production plants. The capacity has been doubled over the last 5 year. In 2010 about 1,9 mill tons of municipal waste was sent to incineration with energy recover with an average 83% degree of utilization of produced energy. Mostly it is mixed waste without any pretreatment. Only 8% is derives from RDF production appointed for cement kilns and 2 CBF-plants.

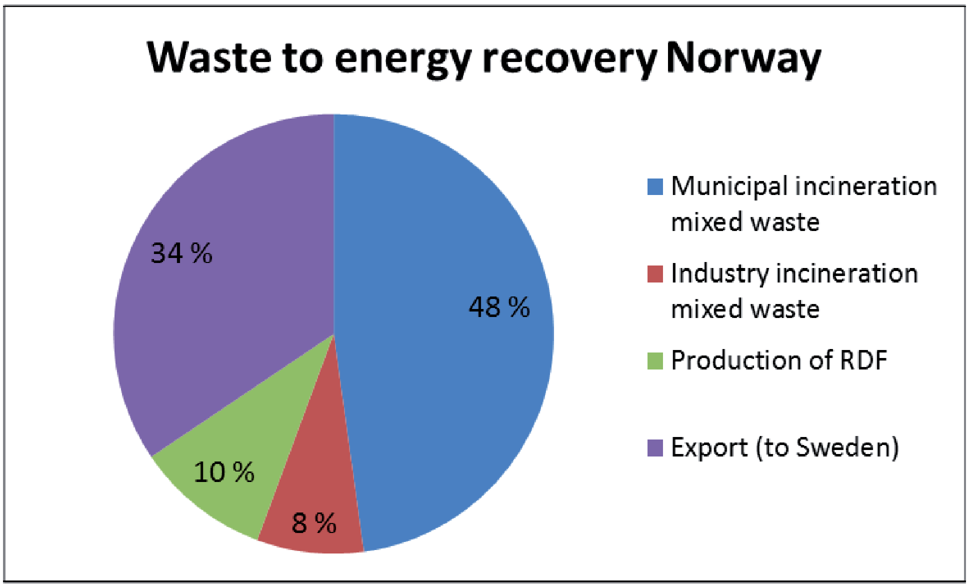


Figure 2 Waste to energy recovery Norway (SKOGESAL 2011)

Content of all waste generated in Norway and sent to incineration was investigated in 2010. Figure 3 shows national figures. About 20% of waste by weight was inert and 20% of waste fossil, while 60% was renewable organic.

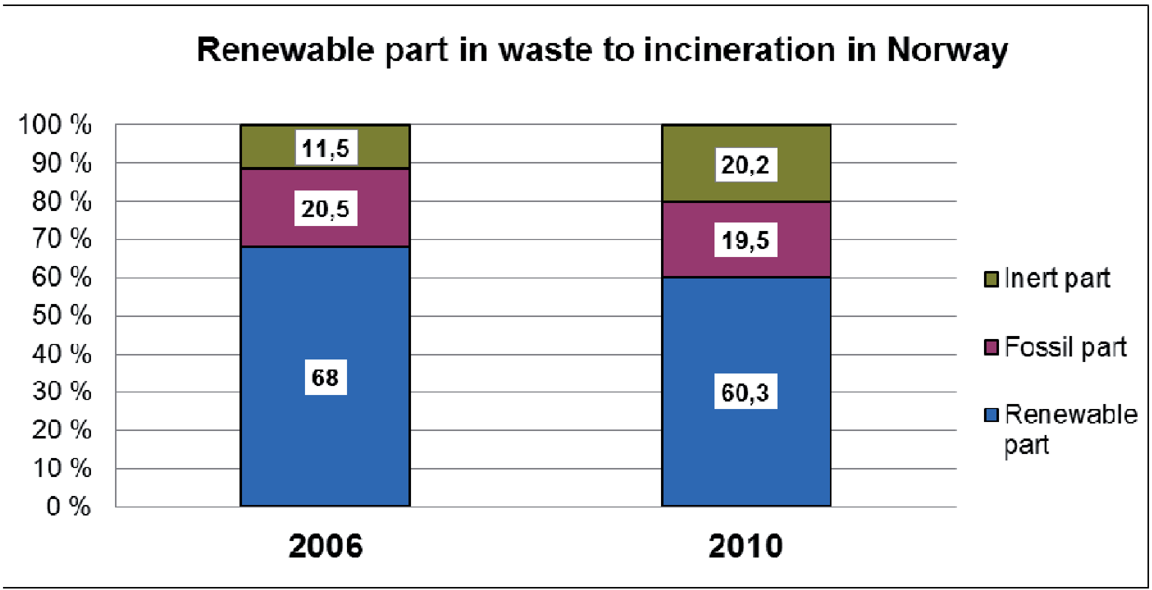


Figure 3 Composition of waste to incineration in Norway. (MARTHINSEN 2011)

Inert part has been increasing and this is connected to landfill ban. Waste with high degree of inert material has to be mixed into other waste and sent to incineration. In general higher amount of bottom ash has also been registered in most of the plants.

Waste morphology analysis documents that 60-70% of residual waste from household still represents a potential for material recycling or production of biogas/fertilizer.

2.3 Biological treatment

About 200.000 tons organic waste was sent to biological treatment in Norway in 2009 and about 75% came from households. There are a few biogas plants in operation, but main biological treatment is mostly small or medium scale composting plant. Some export to Sweden and Denmark is developed.

2.4 Optical bag-sorting plants

In Norway there are about 10 plants based on source separation in colored bags and optical bag sorting system, mostly from Optibag. Number of fractions is between 2 and 5.

Oslo is now building 2 optical bag sorting plants with total capacity of 150.000 tons for organic waste, plastic packaging and residual waste. About 30.000 tons is predicted to be sorted for organic waste for biogas production and fertilizer.

2.5 Plastic packaging collection and recycling

In 2010 about 21.000 tons of plastic packaging was collected from Norwegian households and source separation covered about 70% of all household. Still there is a lot remaining in residual waste and the system efficiency is quite low – about 25% of potential is collected. Mixed plastic is today sent to Germany for separation and recycling.

3 Regulations for landfills

3.1 Landfill tax from 1999.

In Norway in 1999 landfill tax was introduced alongside with a tax on incineration. The landfill tax has been increased and reached in 2009 the level of almost 60 EUR/ton. After landfill ban of waste with organic content the tax is reduced to 35 EUR/ton.

3.2 Landfill Ban from 2009

In 2003 started the process to plan a general landfill ban on organic biodegradable waste in Norway. Before that landfills in Norway had restrictions for household residual waste from a municipality without any system for source separation of food waste.

Sweden had already decided to implement a general ban from 2005. So Norwegian authorities was looking to Sweden and was driven upon the wrong information that landfill first represented 16% of the national climate gas emission, that later was adjusted to 7%. Landfill ban was pointed out to be one of the most cost-effective incentives to reduce emissions. New calculations show that the level of emission is more 3%.

So quite early it came up a proposal that waste to landfill should contain maximum 5% TOC in accordance with Swedish regulation. During the following process the scientific institutions and different organizations claimed that this regulation was not based on scientific research results and that TOC was not an appropriate indicator for biological stabilization. Other biological parameters should be connected to the stabilization of organic matter and that TOC is not usable because it will include fossil elements like plastic and so on.

The final result was a regulation with 10% TOC and 20% LOI finally decided in 2007 and put in force from 1.07.2009. The consequences for total integrated waste management system were not investigated At this time incineration was pointed out to be the only solution to meet the general landfill ban. The planning of new incinerators was speeding up and soon new projects where decided. This happened parallel with increasing export to Sweden that already had built out their incineration capacity. During the financial crises in 2009 the waste amount dropped especially in Sweden and increased the demand for waste to energy. In Sweden the requirements for the incineration tax was withdrawn and shortly did it happen in Norway.

In general the gate fee for incineration was over 1-2 year reduced to half price comparing with level in 2007-2008. Increasing energy prices has also had an effect on gate fee.

Landfill ban came after a period with environmental improvement and investments in landfills to meet national and EU-requirements. The ban has big consequences for municipal landfill owners. Many have closed down and structure has changed. Waste reduction causes economic challenges, especially for those who have high capital costs.

In general the regulations on landfilling have not given any incentives to develop MBT as a method. In the preparation of the new act of law the authorities stated that the landfill ban should not be an obstacle for introduction of new technologies.

4 Relevant experience and projects

4.1 RDF production lines

Mechanical treatment of waste to produce RDF has been developed during the last 15 years, but still the market for RDF in Norway is limited. These RDF facilities are mainly based on waste from Industrial and Commercial and just to some degree household waste. In general the fuel specifications have not been that strict and often allowed the producer to keep fine fraction as a part of the RDF, for example for use in cement kilns when feeding in pre – calcinatory

Today only 1 of 5 plants is removing fine fraction under 20 mm. At least 2 plants are sorting out a heavy fraction 0-100 mm with wind swifter. Both the fine and heavy material are then mixed into other waste fraction to be sent to waste incineration. Today there is no other legal solution, because this material can contain for example 20-30% TOC. Before the landfill ban was introduced in 2009 the high landfill tax gave no incentives to treat this on local landfill or to introduce a biological stabilization.

4.2 Plans for sorting lines/MBT

Several Norwegian municipal companies are planning to build out mechanical sorting lines and biological treatment that can be classified as MBT plants. We have shortly presented 3 projects that are close to final decision for realizing the investments.

4.3 FolloRen

This is a waste company for 5 municipalities just south of Oslo that has been planning a new waste system based on central sorting and utilization of organic waste for biogas and fertilizer and recycling of plastic. The sorting concept is based on experience from Ludvika in Sweden. Planned capacity is 25.000-50.000 mixed household waste. First step includes a biological drying for 2 days before drum sorting. The plan is to build a dry biogas plant where organic fraction from household waste would be mixed with crushed garden waste. However, most critical parameter is the quality of the end product and risk to produce compost not fulfilling legal requirements.

4.4 ROAF

This is a waste company for 8 municipalities just North from Oslo that is planning to invest in a sorting system that is a combination of NIR sorting of organic waste in green plastic bags and NIR sorting of different plastic fractions from the rest fraction. Metal sorting with sensors is also included. The Near Infra Red technology is well developed for identifying and sort different plastic or metal material. The new element is to use the same system to sort green bags with organic waste. Capacity is 50.000 tons/year. The plan includes a possible plant for washing and produce plastic granules from PELD, PEHD, PP and PET. The plastic sorting line has possibility to also receive source separated plastic packaging.

4.5 IVAR

This is a waste company for 10 municipalities including Stavanger city that is planning to invest in a sensor based sorting system mainly for taking out different plastic fractions from residual waste. The region already has source separation of food waste from households. The region has built out a lot of underground solutions and finds it difficult and expensive to include plastic packaging in source separation. Total sorting plant capacity is planned for 50.000 tons including some bulky waste and commercial waste.

The Norwegian supplier Titech Vision-sort with relevant sensor technology has been involved in different tests for ROAF and IVAR.

4.6 Biological treatment

In Norway there is also interesting experiences with different solutions for biological treatment with mechanical pretreatment. This represents a potential for MBT development in future. We have mentioned some of the most relevant solutions

4.7 BioSep

The core technology - given the name BioSep® is built on an invention which makes it possible to separate packaged food waste into pure biomass and undesired components, especially plastic, from collected wet organic waste. This technology has recently received an international price at EPP in Lyon.

The pretreatment process has been operating on packed food waste from industry with good results. The product is bio slurry for wet anaerobic digestion. In step one plastic is removed and in the second part also glass, stones and particles over 4 mm. The loss of organic substances in process reject is low and can give maximum biogas potential and lower costs in reject treatment This process is so far built in full scale at one biogas plant in Verdal and will be the solution for a new plant for Oslo with capacity 50.000 tons of biowaste. This solution can also have a potential for organic fraction from MBT plant.

4.8 Cambi technology

Cambi is today a leading provider of advanced digestion systems based on its patented thermal hydrolysis processes (THP). The biomass is treated under pressure at 130-160 degrees for a short period to break up cell structure. Two plants for biowaste are in operation in Norway and a new contract for Oslo Municipality is closed. The experience from sewage sludge is much broader.

In combination with BioSep pretreatment this can give significantly high biogas output. Use of biogas as fuel for city transportation is an important part of Oslo Municipal carbon-dioxide emission reduction plan.

4.9 Ag-bag treatment

In Norway in vessel composting of organic waste in Ag-Bag technology has been tested with mixed results. The same method is now being tested as an anaerobic process and biogas production. This is identified as one possible method for stabilizing organic residuals in an integrated MBT concept.

4.10 Biocell treatment Lindum

In Norway reactor biocell treatment is developed as a low cost technology for organic waste fractions treatment. This kind of treatment of organic waste represents a stabilization of organic substances and production of biogas in a controlled and closed biocell reactor. The anaerobic degradation will typically take about 5-7 years. After this, the residual will be removed, and if necessary processed for final utilisation.

The final residual may be used as soil products, SRF (solid recovered fuel) or stabilized material for landfills, depending on the quality. If the input material is source segregated food waste, the end product most probably can be used as a soil fertilizer. If the input is based on mixed municipal waste, the residual will be more contaminated with heavy metals and organic pollutants.

5 Waste Norway - MBT-project 2009

Background for the project was to investigate the possibilities to introduce more MBT technology in Norway. The aim has been to identify the challenges and search for solutions that can be adapted under Norwegian conditions, especially for the landfill owners that often also have experience with biological treatment of food waste and garden waste. The capacities should be cover the range from 10.000 to 50.000 tons/year.

An international survey is carried out in order to evaluate technologies and the possible products at their quality and markets. In general the report states:

- The most countries have regulations that open up for MBT as a method based on possible landfilling of stabile organic residuals after biological treatment.
- Stricter regulation for using CLO for agriculture purposes is put into force in the countries where CLO-production has been an important part of the solution.
- It is difficult to find complete reference plants in relevant scale for possible plants in Norway. Most of them are too big and too expensive.
- We have identified different interesting technical elements and parts in solutions and described possible Norwegian concepts for small scale solutions.
- Mechanical sorting can be considered as a separate unit that can produce fuel, organic rich fraction, metals and possible mixed plastic for further sorting.
- Organic rich fraction can be treated in reactor biocell solution with biogas production. Alternative is different composting technology available in Norway. End product can not be sent to landfill within present regulation, and probably does not represent a quality for soil/fertilizer.

6 Waste Norway - MBT-project 2011

The aim for phase two is to demonstrate MBT solutions under Norwegian conditions and develop scientific research results that can be used in developing new regulations together with international research results. This will also give possible decision makers in municipalities a better platform for further planning.

Test program is developed and will be implemented before end of June 2011. The practical testes at 3 different regions in Norway will cover following main elements:

- Mechanical sorting with different equipment
- Biological stabilization with aerobic and anaerobic methods
- Incineration with measuring emissions and ash production

The waste amount in each region test will be 200-300 tons. The waste will be strictly from households and we will have waste content data. In general there will be developed a system to ensure mass balance in all process steps. Table gives a brief overview over the planned test.

Table 1 Full scale tests for MBT in Norway 2011

Parameter	Oslo-area	In countryside	West-coast
Waste source	Household, Bærum 50% food	Household HIAS 25% food	Household, IHM and SIMAS
Waste morphology	2009/2011	2010	New analysis
Mechanical shredding and sorting	NG (former Veolia) at Tønsberg, incl. wind swifter.	HRR, pretreatment plant Hamar	Temporary mobile shredding and sort-ing
Fuel fractions size	0-100 mm (Hafslund Bio-El)	65-250 mm (Hafslund BWtE)	80-250 mm (Hafslund BWtE)
Residual fraction for stabilization	Heavy fraction 0-100 mm	Fine fraction 0-65mm	Fraction 0-80 mm
Biological stabili-zation	AgBag anaerobic (Lindum)	Not finally decided (Lindum)	Closed in vessel composting (Bioplan Florø)

There will also be performed biological testing in small scale with reactors of 150 liters with good process control and relevant measuring of the biodegradation. This will be used for parallel treatment of the same waste in full scale testing.

Samples of end products after bio stabilization in full scale will be placed into the same small reactors after adding fertilizer and a biodegrading process will be tried. This will represent the final proof if stabilization has been succeeded.

One important part is to perform a test program for biological parameters together with relevant physical and chemical parameters. We have so far decided to include follow-ing direct and indirect methods for measure potential biological activity:

- BMP_{100} and BOD_{28}
- DOC and TOC
- LOI

7 Potential for MBT in Norway

MBT has a potential for development in Norway based on following registrations:

MBT can optimize the utilization of resources in residual waste.

- Higher degree of recycling of plastic

- Higher degree of recycling of metals
- Possible biogas production from organic waste

MBT can also have positive impact on incineration

- Lower amount of sand, stones, glass, so will reduce the need for maintenance
- MBT represents a pretreatment of waste that will give more homogenous incineration condition and lower amount of bottom ash. The bottom ash will contain less unburned carbon
- Reduce the transportation of waste and ash. Mixed residual waste is today transported up to 2000 km for incineration.

MBT can give more local activity at landfills

- Landfill need to be post – operated 30 years after closing down. There is need for improvements in landfill gas extraction and leachate water.
- In many places it is anyway necessary to have a shredder and bailing system for waste to incineration

Landfilling of stabile organic substances, not suitable as a fertilizer, can be considered as a carbon capture system.

8 Barriers for MBT in Norway

Both national framework and market situation has big impact on the possible development of MBT solutions. The project has identified the most important barriers such as:

- The landfill ban of waste containing 10% TOC or more is the most crucial element today. This has to be changed so landfilling of stabilized organic material can be allowed like in Germany and Austria that also have similar landfill bans.
- Landfill tax is still based on emission of methane gas and global warming potential, even though there should be no landfill gas potential from the waste put to landfill now. There is no good environmental reason to keep landfill tax that reduce the economic benefits with MBT.
- There is a limited market for RDF in Norway, but now there are proposals to require pretreatment of all waste sent to incineration. This is also to avoid today situation with limited control of incoming waste streams.
- Overcapacity for incineration of waste in Sweden and Norway has reduced the prices in market and together with removal of tax on incineration this has made all MBT solutions less competitive in market.

- There are few incentives to sort out packaging from residual waste. Green dot Norway is giving financial contributions for source segregation in municipalities and not for packaging sorted/recycled out of residual waste.

- Lack of incentives to biogas production and usage from biomass. Norway is not in line with Denmark and Sweden.

9 Final remarks

MBT has a potential in Norway to optimize the environmental aspects in waste management, mainly with focus on recycling of plastic and metals and biogas production. MBT will represent a supplementary solution for source separation. MBT systems can be useful to meet goals within national climate reduction plan 2020, including 40% plastic recycling. In Norway we can expect a structure of local pretreatment and biological stabilization, and a few central plants for plastic sorting and RDF production. The development of solutions will provide new regulations and incentives by national authorities.

10 Literature

Syversen F., Marthinsen J. , Fredriksen K.	2010	MBT-project 2009. International situation and possible solutions in Norway. Waste Norway report 5/2010, ISBN 82-8034-086-1
Marthinsen, Jarle	2011	Renewable part in solid waste to Norwegian waste incinerators. NVE and Waste Norway, ISSB 1503-0318.
Marthinsen, Jarle	2011	Food waste prevention. Report to Norwegian Climate and Pollution Agency (KLIF) 2011
Skogesal, Olav	2011	Energy recovery in Norway 2010. Report to Green Dot Norway for national reports to KLIF. 2011
SSB (Statistic Norway)	2011	Official waste statistics at web-side.

Author's address

M.Sc. Frode Syversen

Mepex Consult AS
Teglverksveien 9A
N-3400 Lier
Telefon +47 900 83 661
Email frode@mepex.no
Website: www.mepex.no

Comparing the Life Cycle Assessment (LCA) Performance of Residual Waste Treatment Solutions

Nick Cawthorne and Sarah Trevers

Golder Associates (UK) Ltd

Abstract:

Materials Recovery Facilities (MRF) and Mechanical Biological Treatment (MBT) take a fundamentally different approach to the management of residual waste as compared to Waste to Energy (WtE). MRF/MBT recovers the maximum amount of material and then uses the remainder for energy recovery, whereas WtE typically takes a reverse approach. Life Cycle Assessment can demonstrate the carbon benefit of different waste management solutions and recognises that the benefit of recovering different materials can vary greatly and that the recovery of materials is very often more beneficial than energy recovery. From this assessment the appropriateness of taking a “Materials Recovery First” approach to residual waste treatment is discussed.

Keywords

Life Cycle Assessment, WRATE, LCA, Recycling, Energy recovery, Residual Waste, MRF, MBT, WtE.

1 Introduction

Life Cycle Assessment (LCA) is an objective process to evaluate the environmental burdens associated with a product, process, service, or life style choice by identifying energy and materials used and emissions released to the environment. LCA is therefore a tool that can be used to assess the environmental impacts of an overall waste management solution across its entire life cycle, a so called cradle to grave approach. The impacts on the environment may be beneficial or adverse.

Waste Resource Assessment Tool for the Environment (WRATE) is the primary LCA tool used in the UK specifically for waste management applications. WRATE allows users to track the environmental impacts from kerbside collection, through advanced waste treatment processes to ultimate recycling, recovery or disposal. WRATE includes databases identifying a range of environmental burdens, for specific waste treatment technologies, which can be combined with transport impacts and benefits from energy and material recovery, to identify the full life cycle impact of the solution.

Varied waste management solutions have been implemented across Europe to comply with the national strategies to achieve landfill diversion. The pressures upon these solutions have mainly been limited to diversion targets, recycling rates, environmental emission standards and cost and has not considered off site emissions, e.g. transport or the full life cycle emission of the waste management scheme.

This paper uses LCA to compare the environmental performance of different residual waste treatment solutions. The solutions have been selected from the WRATE processes reflecting different approaches with respect to recycling, energy recovery and disposal of residues. From the results and assessment fundamental conclusions are drawn and recommendations made regarding the approach to solution design.

2 Modelling

WRATE has been used to produce seven scenarios for the management of waste. The information relating to the assumptions and limitations of the modelling, the data inputs, detail on the modelled scenarios and the results are presented below.

2.1 Assumptions and Limitations

In undertaking this modelling a number of assumptions have been made and there are also a number of limitations associated with the modelling. The system boundary of the modelling is between the point of residual waste being delivered to a treatment facility and when the waste is fully recovered or disposed.

Table 1 Assumed Composition of Residual Waste

Waste Category	**Tonnes/yr**	**Percentage (%)**
Paper/card	53,600	21.4%
Plastic film	15,850	6.3%
Dense Plastic	22,125	8.9%
Textiles	9,175	3.7%
Sanitary	8,725	3.5%
Wood	4,000	1.6%
Misc. combustibles	11,650	4.7%
Misc. non-combustibles	19,925	8.0%
Glass	15,025	6.0%
Ferrous metal	8,425	3.4%
Non-ferrous metal	2,300	0.9%
WEEE	2,400	1.0%
Garden waste	19,450	7.8%
Food waste	55,400	22.2%
Household Hazardous	1,950	0.8%
Total	250,000	100.0%

The waste composition data which has been used within the modelling is based upon experience of UK projects and the composition of kerbside municipal residual waste following the separate collection of municipal recyclables and green waste. Each of the models created assume 250,000 tonnes/year input of residual municipal waste having the composition identified in Table 1 above.

All vehicles moving waste and recovered materials from the treatment facility are assumed to be ‘Intermodal Road Transport’, vehicles which are capable of transporting containers in bulk. It is considered that this method of transport most closely represents the transport that would be used in practice. Each vehicle within the model is assumed to travel 25 km to third party facilities and end users and the road type split is 80% urban and 20% rural. The electricity mix is taken as that applicable to the UK in 2011.

All landfills included within the model have been defined as landfills with an HDPE composite liner and an HDPE cap.

The models produced are considered to represent realistic interpretations of the identified solutions utilising the processes within the WRATE LCA model. However, the results must be read taking into account the above assumptions and also that the properties of each of the processes in WRATE may not be fully accurate and that apparently similar processes may in practice vary significantly in terms of detailed design and consequently the magnitude of environmental burdens.

3 Detail of WRATE Scenarios

A total of seven scenarios have been built within WRATE to enable the comparison of the different options for managing waste. A description of each scenario is presented below, with an associated scenario number.

Scenario 1 – Waste to Energy (Power)

The model assumes that all the waste is input to a moving grate Waste to Energy (WtE) facility. 29% (gross) of the energy value of the waste is recovered as electricity and no heat is recovered. 90% of the input ferrous metal and 50% of the input non ferrous metal is recovered from the bottom ash. Bottom ash is additionally recovered as secondary aggregate with residues going to landfill. The electricity and material recovery rates assumed are in accordance with the latest best performing plants.

Scenario 2 – Mechanical Biological Treatment (RDF)

The model assumes that the waste is input to a Mechanical Biological Treatment facility. The waste is biodried to produce a Refuse Derived Fuel (RDF), ferrous and non ferrous metals are recovered and residues are sent to a moving grate combined heat and power plant. The RDF is utilised within an off site cement kiln. The respective recovery rates are defined by a default MBT plant system process within WRATE.

Scenario 3 – Materials Recycling Facility, MRF (Recycling and RDF)

The model assumes that the waste is treated by a Materials Recycling Facility (MRF) designed for the treatment or residual waste. Ferrous and non ferrous metals, glass and dense plastic are recovered at rates defined by a default process within WRATE. The remaining material is then used to create a paper based RDF and the residues are sent to a moving grate combined heat and power WtE plant. The RDF is again utilised within an off site cement kiln.

Scenario 4 – Mechanical Biological Treatment (Stabilisation)

This model assumes the waste is treated within an MBT plant which recycles metals and glass, produces an RDF by mechanical recovery and the remaining waste is then treated within a composting hall to stabilise the waste prior to landfilling.

Scenario 5 – Mechanical Biological Treatment (Anerobic Digestion)

In this solution paper and card, dense plastic, plastic foil, glass, and ferrous and non ferrous metal are recycled by mechanical treatment. The remaining waste is treated by anaerobic digestion with the subsequent digestate being landfilled as a stabilised waste. Some residue is also sent to a moving grate combined heat and power plant. The performance of the MBT and AD system is defined by an existing system process within WRATE.

Scenario 6 – Waste to Energy (Combined Heat and Power, CHP)

This model assumes that all the waste is treated within a moving grate combined heat and power WtE plant. 26% of the energy value of the waste is recovered as gross electricity and 12% as heat, total gross energy recovery is 38%. 90% of the input ferrous metal and 50% of the input non ferrous metal is recovered from the bottom ash. Bottom ash is additionally recovered as secondary aggregate with residues going to landfill. The electricity and heat recovery rates and material recovery rates assumed are in accordance with the latest best performing plants. The heat is assumed to be utilised within a nearby industrial process substituting natural gas.

2.5.7 Scenario 7 - Landfill

To provide a benchmark, this scenario assumes that all the waste is deposited within a geomembrane lined and capped landfill site.

4 Results

4.1 Material Recovery

The following table presents the quantities of the respective materials which were identified as recovered in the respective models. The figures were determined by the default processes in WRATE and the composition and quantity of the assumed input waste.

Table 2 Recovered Materials (Tonnes)

Scenario number and Treatment solution		Paper & Card	Plastic Film	Dense Plastic	Glass	Ferrous	Non Ferrous	RDF	IBA	Total
1	WtE (Power)					7,566	1,150		54,956	63,672
2	MBT (RDF)					6,734	1,769	110,277	28,552	147,333
3	MRF (Recycling, RDF)			5,497	11,269	8,384	2,243	17,964	39,303	84,659
4	MBT (Stabilisat'n)				3,723	7,258	1,986	18,988		31,955
5	MBT (AD)	41,324	1,984	2,977	5,580	8,339	2,070		4,925	67,198
6	WtE (CHP)					7,566	1,150		54,956	63,672
7	Landfill									

4.2 LCA Impacts

The WRATE model produces results in terms of six default impact assessments and can produce a wider range of assessments if required. The six default assessments are identified in the following table with the units of measurement identified.

Table 3. Impact assessment full name, short name and unit

Impact Assessment Full Name	Short Name Term	Unit
Climate Change: GWP 100a	GWP	kg CO_2- Eq
Acidification potential: average European	Acidification	kg SO_2- Eq
Eutrophication potential: generic	Europhication	kg PO_2- Eq
Freshwater aquatic ecotoxicity: FAETP infinite	Freshwater Aquatic Ecotoxicity	kg 1,4-DCB-Eq
Human toxicity: HTP infinite	Human Toxicity	kg 1,4-DCB-Eq
Resources: depletion of abiotic resources	Resource Depletion	kg antimony-Eq

WRATE presents the LCA results in both the above 'characterisation' data form and also as 'normalisation' data. The normalised unit is 'European Persons Equivalent' (EPE), this presents the magnitude of impact in terms of the overall impact of an average European Person for the respective impact category.

4.3 LCA Results

The following table presents the LCA model results for the seven solutions for each of the six default impact assessments. It should be noted that a negative result, i.e. a negative emission of CO2 (equivalent), is "environmentally good" whereas a positive result is "environmentally bad".

Table 4 LCA Summary Results

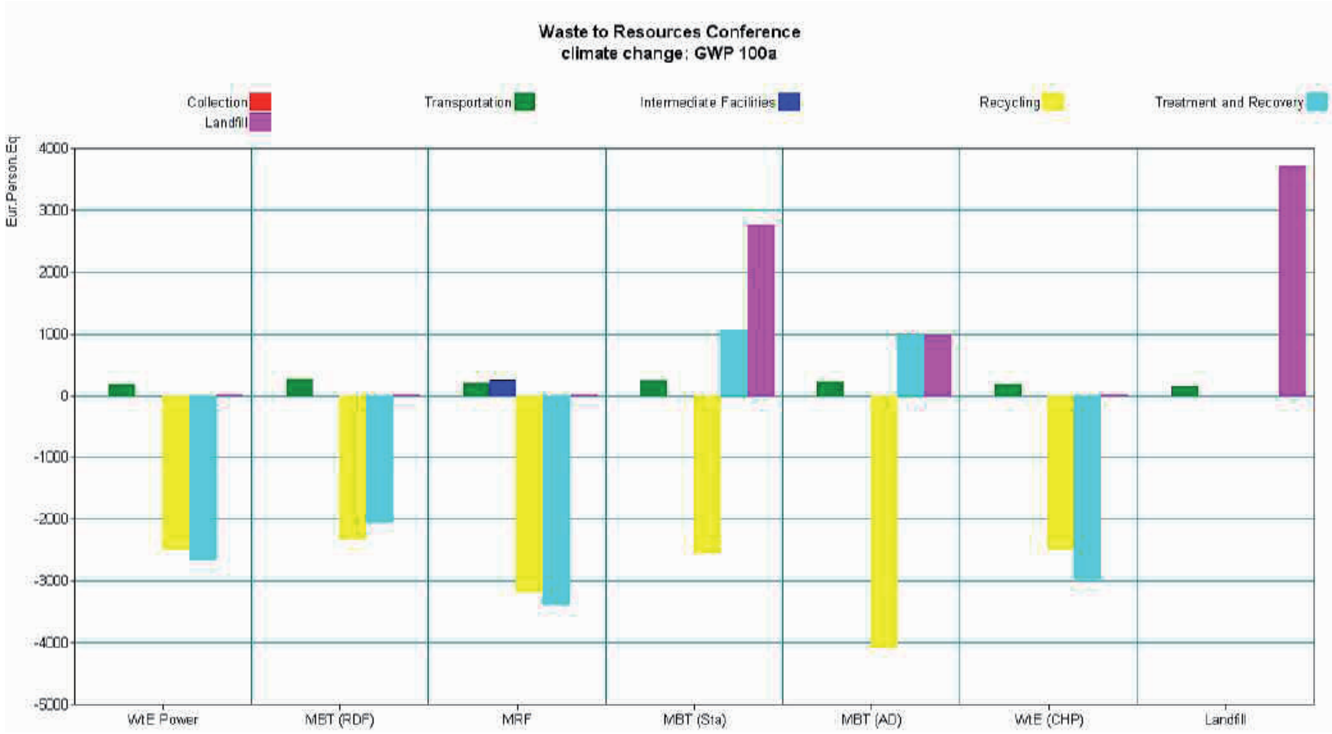
	Scenario	Climate change: kg CO2-Eq	Acidification potential: kg SO2-Eq	Eutrophication potential: kg PO4-Eq	Freshwater aquatic ecotoxicity: kg 1,4-DCB-Eq	Human toxicity: kg 1,4-DCB-Eq	Resources depletion kg antimony-Eq
1	WtE (Power)	-64,320,695	-150,957	5,486	-10,521,317	-117,459,746	-1,236,796
2	MBT (RDF)	-53,308,936	-226,445	34,567	-9,036,036	-107,274,204	-1,953,113
3	MRF (Recycle,	-79,535,636	-204,239	9,068	-11,842,172	-138,699,164	-1,487,811

	RDF)						
4	MBT (Stabil'n)	19,273,785	-130,999	46,952	-9,815,583	-110,526,805	-614,158
5	MBT (AD)	-24,655,559	-173,339	33,801	-9,290,146	-123,254,742	-56,166
6	WtE (CHP)	-68,241,512	-149,670	5,770	-10,487,149	-118,401,673	-1,276,609
7	Landfill	49,924,886	10,150	25,198	314,834	35,198	-167,029

The significance of the results for each of the impacts identified is variable depending upon the importance of the impact and also upon the degree to which local pathways are in place to connect with the receptors. Climate change, Global Warming Potential (GWP) has both a very high degree of importance and a high degree of connectivity. i.e. carbon entering the atmosphere at any location globally will contribute directly to the global effect. In consideration of this, for the purpose of the detailed assessment of the results, Global Warming Potential is exclusively used to compare the results between the different treatment solutions.

In the following figure the Global Warming Potential impacts associated with each solution are broken down into the following elements of the modelling:

- Transportation;
- Intermediate Facilities (for example MRF);
- Recycling;
- Treatment and Recovery (of energy) (for example incineration, MBT);
- Landfill.



Scenario 1 Scenario 2 Scenario 3 Scenario 4 Scenario 5 Scenario 6 Scenario 7

Figure 1: Climate Change Results for Different Elements of the Models (EPE)

Collection, delivery of waste to the facility, is not included in the model and thus is zero in all cases.

As shown the negative (good) impacts are associated with recycling (yellow) and treatment and recovery of energy (light blue). The latter burden comprises the benefit of energy recovery less the burden of waste treatment.

Scenario 3 (MRF) and Scenario 5 (MBT(AD)) solution have the best performance in terms of recycling, reflecting the recycling of plastic, paper and glass etc and the higher recovery efficiency of non ferrous metal, see Table 2.

The treatment and recovery results are similar for the WtE (power only, Scenario 1 and CHP, Scenario 2) and for the RDF based solutions, Scenarios 2 and 3. In the latter case residual materials are sent to external WtE plants. The respective WtE results are similar in that although energy recovery is significantly higher in the WtE (CHP) solution, Scenario 6 as compared to the WtE (Power only) solution, Scenario 1, this is partially balanced by the carbon benefit of electricity being greater than heat where gas is substituted.

Scenario 3, (MRF) has the best treatment and recovery result as the mechanical treatment process is relatively simple, is a low energy consumer, the recovery of energy from RDF is high due to direct utilisation within a cement kiln and unsuitable residues are sent to WtE rather than landfilled. Scenario 2, MBT (RDF) solution is less beneficial due to the more complex treatment equipment and higher energy consumption associated with the biological treatment element.

Scenario 4, MBT (Stabilisation) and Scenario 5, MBT(AD) solutions have positive (bad) treatment and recovery results due to the complex and energy consuming treatments and because residues are landfilled rather than utilised for additional energy recovery. Landfilling of these materials also has the additional affect of the direct landfilling impacts, as shown, which further reduce the performance of these solutions.

The following figure identifies the overall Global Warming Potential results presented graphically in terms of European Persons Equivalent. These overall impacts are the summation of the different elements shown in Figure 1 above and take into consideration the combined direct and indirect burdens associated with the building and operation of the solution and the benefits associated with material and energy recovery as identified.

Figure 2: Climate Change Results (EPE)

The order of the overall solution performance based upon this assessment is as follows:

1. Scenario 3 – Materials Recycling Facility, MRF (Recycling and RDF);
2. Scenario 6 – Waste to Energy (Combined Heat and Power, CHP)
3. Scenario 1 – Waste to Energy (Power)

4. Scenario 2 – Mechanical Biological Treatment (RDF)
5. Scenario 5 – Mechanical Biological Treatment (Anerobic Digestion)
6. Scenario 4 – Mechanical Biological Treatment (Stabilisation)
7. Scenario 7 – Landfill.

Scenario 3 was the best performing due to having a high degree of recycling followed by energy recovery, RDF and WtE with no waste going to landfill. More carbon benefit is achieved by recycling a given amount of plastic or paper than can be achieved by combusting for energy recovery in a WtE plant or in a cement kiln as RDF. In addition recycling of non ferrous metal prior to, rather than after, combustion will give a higher collection efficiency.

Scenario 6 – WtE (CHP), Scenario 1 – WtE (Power) and Scenario 2 – MBT (RDF) were next in terms of performance. These can be characterised by having no recycling other than metals but with all other waste being used for energy recovery, RDF and WtE and no significant landfill disposal.

Scenario 5 – MBT (AD) and Scenario 4 – MBT (Stabilisation) were next in performance. These can be characterised by having significant recycling but having low energy recovery, net of energy consumption, in addition to significant landfill disposal.

The last solution in terms of performance was Scenario 7 (landfill). No recovery of materials or energy is undertaken, other than via landfill gas utilisation, and all wastes are landfilled resulting in significant burdens.

Conclusions

The study undertaken has identified that the best performing solutions include a high degree of recycling prior to combustion of other materials. The recycling prior to combustion allows for the recovery of plastic and paper etc which achieves a higher carbon benefit than is achieved by combustion of the same materials to recover energy. In addition recovery of metals, particularly non ferrous metals, prior to combustion of mixed waste is likely to be at a higher rate than can be achieved from bottom ash following energy recovery. Carbon benefit is particularly sensitive to non ferrous metal recovery due to the very high energy consumption associated with the manufacture of first generation aluminium.

The study has also identified that solutions where materials which cannot be recycled are combusted to recover energy rather than landfilled also perform well. This relates to both the carbon benefit of energy recovery and the carbon burden associated with landfilling. It should be considered therefore that the environmental performance of solutions which recycle materials and where energy is recovered may be very substantially impacted if residue materials are then landfilled.

The findings of the study undertaken would suggest that the Global Warming potential performance of residual waste treatment solutions is enhanced where the maximum amount of materials are recycled and then all residual materials are combusted to achieve energy recovery rather than being landfilled. Energy recovery could be as an RDF within a cement kiln etc or within a WtE facility. The carbon benefit of energy recovered by combustion is dependent upon both the amount of energy recovered and the type of energy being substituted. The carbon benefit of increased total energy recovery in the form of heat may be less than expected, if this is also associated with a reduced amount of electricity generation. The primary fuels being used for electricity and heat production which are substituted are a key consideration in undertaking such an evaluation.

The financial incentives to encourage increased recovery from residual waste in the UK are focused entirely upon energy rather than material recovery. In consideration of the improved LCA performance associated with recycling, in contrast to energy recovery, the balance in this regard with respect to treatment of residual waste could perhaps be reconsidered.

Author's addresses

Nick Cawthorne and Sarah Trevers

Golder Associates (UK) Ltd.

Attenborough House

Browns Lane Business Park

Stanton-on-the-Wolds

Nottinghamshire NG12 5BL, UK

Telephone: +44 (0) 1159371111

Fax: +44 (0) 1159371100

Email: strevers@golder.com

Website: www.golder.com

Municipal Solid Waste sorting and treatment in Romania: strategies of energy recovery from two pilot case studies

Gabriela Ionescu*, Elena Cristina Rada, Adrian Badea*, Marco Ragazzi**, Tiberiu Apostol***

* Department of Energy Production and Use, Politehnica University of Bucharest, Romania

** Department of Civil and Environmental Engineering, Trento, Italy

Abstract

In the past decade, one of the main topics analyzed in the waste management area is how to dispose of the large quantities of municipal solid waste (MSW). Romania has to implement the European Union regulation regarding the recovery and recycle of the waste decreasing landfill as primary destination of MSW products. In this paper, possible evolutions of two preliminary scenarios, according to EU criteria, are analyzed. After the MSW sorting process, the waste to energy concept will be based on the bio-drying and pyrolysis treatment of the residual MSW and residual packaging waste. Considerations on consequence of increasing efficiency of selective collection complete the paper.

Keywords

Bio-drying, MSW, selective collection, packaging waste, PET, pyrolysis, SRF

1 Introduction Deadlines and formalities

The Sixth Environment Action Program (2002–2012) sets out the EU key environmental targets. This program aims to the overall reduction in the volumes of waste generated through waste prevention and reduction of the waste going to disposal until 2020: at least 50% of waste materials such as paper, glass, metals and plastics from households and possibly from other origins must be recycled or prepared for reuse. Romania entered into the EU during the implementation of this Program.

Since the 1st of January 2007 Romania is one of the European countries that have to implement and comply with all the European Directives regarding waste management. In Romania, as well as in other countries, the impact of municipal solid waste (MSW) on the environment has increased at an alarming rate during the past 20 years. The dual influences of the resource supply and environment protection required by EU, impose a significant challenge to sustainable development. Solid waste management offers opportunities to improve profits by conserving resources and improving environmental performance.

Romania has the possibility to postpone of 4 years the achievement of targets to reduce the biodegradable waste that will be landfill by 25% until 2010 and 50% before 2013 taking into account the quantity produced in 1995. In case of absence of incinerators, the target for MSW biological treatments (composting and mechanical-biological treatment) must reach a ratio of 70% in the year 2017. By the year 2013 it is foreseen a recovery degree of useful materials from waste packaging for recycling or incineration with energy recovery of 60% for paper or cardboard, 22.5% for plastics, 60% for glass, 50% for metals and 15% for wood. Unfortunately a significant delay is expected.

Generally, the composition of Romanian MSW (Figure 1) has a high organic content (about 50%) and a medium light packaging content (about 20%). The MSW selective collection at national level is not yet developed but in some regions at local level some pilot selective collection strategies (generally only for valuable materials) are adopted.

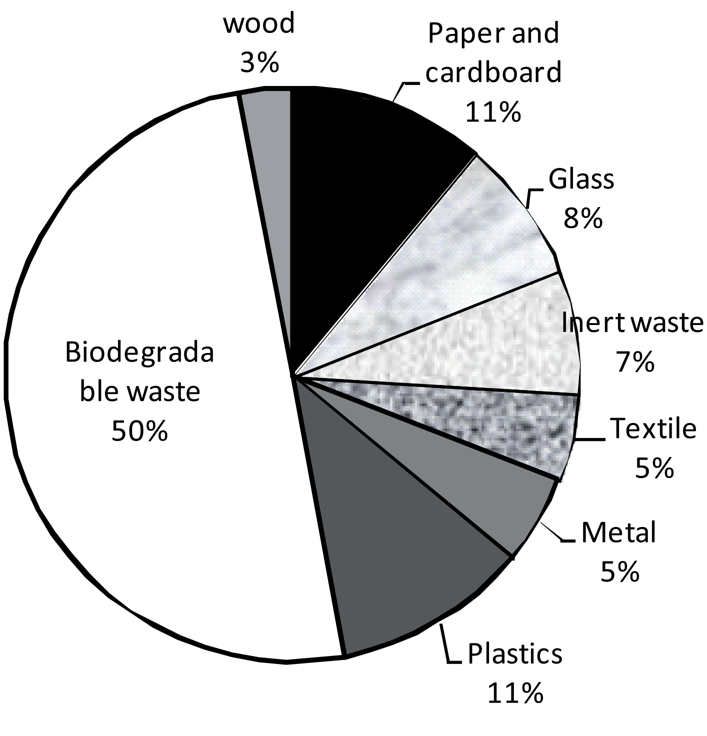


Figure 1 Romanian MSW composition

In this paper two case studies are presented and discussed in order to evaluate the use of the residual MSW (RMSW) and residual packaging waste (after sorting of source selected materials) for energy purposes, taking into the EU regulation requests and the effect of an extreme delay in the development of selective collection. Some considerations on the consequences.

2 Material and methods

In this paragraph the case studies proposed for the MSW management in Romania are presented. Taking into account the EU target in terms of reducing the quantity of biodegradable waste that will be landfilled and also the fact that in Romania, at the moment, there is a lack of MSW treatment plants, the processes proposed are: bio- drying and pyrolysis.

These two processes were chosen because in the last years two PhD researches co-supervised between Romania and Italy were developed. The first one, achieved in 2005, regarded a research about the bio-drying process (Rada, 2005) and the other one is a developing research study on integrated pyrolisis/gasification treatments with energy recovery. (Ionescu, 2009-2013). Thus data on viability of these processes in Romania are available.

The reference location for both scenarios is the Romanian Valcea region having 410,000 habitants that generate 151,200 t_{MSW}/year (PJGD,2009).

2.1 First case study

The first scenario focus on the implementation of selective collection supported by pilot projects (by EU funds) for the MSW separation in two flows: combustible light packaging (plastics, paper and cardboard waste) and the rest (residual MSW). According to Romanian National Statistic Institute in 2008, 20.54% of packaging waste could be valorized and 15.48% could be recycled, instead the paper and cardboard percentage that could be valorized or recycled are 68.79% respectively 61.63 % (ANPM-DDSCP, 2008).

The first flow (a part of plastics, paper and cardboard waste) is sent to a pyrolysis thermal treatment. The second flow, residual municipal solid waste (RMSW), is send to a bio-drying plant in order to obtain solid recovery fuel that will be sent in a cement work for energy purpose.

2.2 Second case study

The second scenario refers to a pilot PET collection implemented at regional level in buildings. Each block collects the waste in two flows: PET and the rest. The PET is valorized from the economical point of view. At the moment, the remaining plastic waste (packaging) and the residual waste are generally sent to a landfill without any pre-treatment.

For the current scenario it is assumed that one block has 160 apartments with an average of 3 persons each. Taking into account the methods used for determination of PET percentage in the plastic waste, the value 21 % was used in the current balances (EPR, 2010).

In this scenario the RMSW containing also the remaining packaging waste will be sent to a bio-drying plant. The obtained solid refused fuel (SRF) will be then co-combusted in a thermal power plant. This strategy was chosen in order to maximize the energy recovery with un-conventional approaches.

3 Results and discussion

3.1 First case study

The overall composition of RMSW that is sent in the bio-drying plant is presented in Table 1. The chosen bio-drying process is the one with unique flow: all RMSW is sent to the biological process. Energy consumption for SRF production can be assumed as 80kWh/t_{RMSW} (Rada, 2005). The overall mass balance is 53% as SRF/RMSW as resulted from the adaptation of an experimental run to the case study.

Table 1 RMSW composition

	RMSW %	C %TS	H %TS	O %TS	N %TS	W %
Paper and cardboard	9.69	42.5	5.936	41.6	0.13	18
Plastics	3.80	66.4	9.1	9.5	1	6
Glass	8.87	0.52	0.07	0.36	0.03	2
Inert waste	7.76	0.52	0.07	0.36	0.03	7
Biodegradable waste	55.44	45	6.43	28.5	2.7	79.2
Textile	5.54	49.6	6.7	36.1	4.1	25
Wood	3.32	49	5.1	41.1	0.3	16
Metal	5.54	2	0.6	4.3	0.05	2

Taking into account the bio-chemical model of the bio-drying process developed by Rada et.al., 2007, the dynamics of the LHV during the process is presented in Figure 2.

The initial LHV of residual waste was 4,926 kJ/kg_{RMSW}. After the bio-drying treatment and the separation of inert, glass and metal materials the final SRF has a LHV of 7,872 kJ/kg_{SRF}. Taking into account this value and the new EU regulation (UNI

CEN/TR_15508) this SRF can go for energetic purposes in a cement factory supposing that the request for Chlorine and Mercury are complied with.

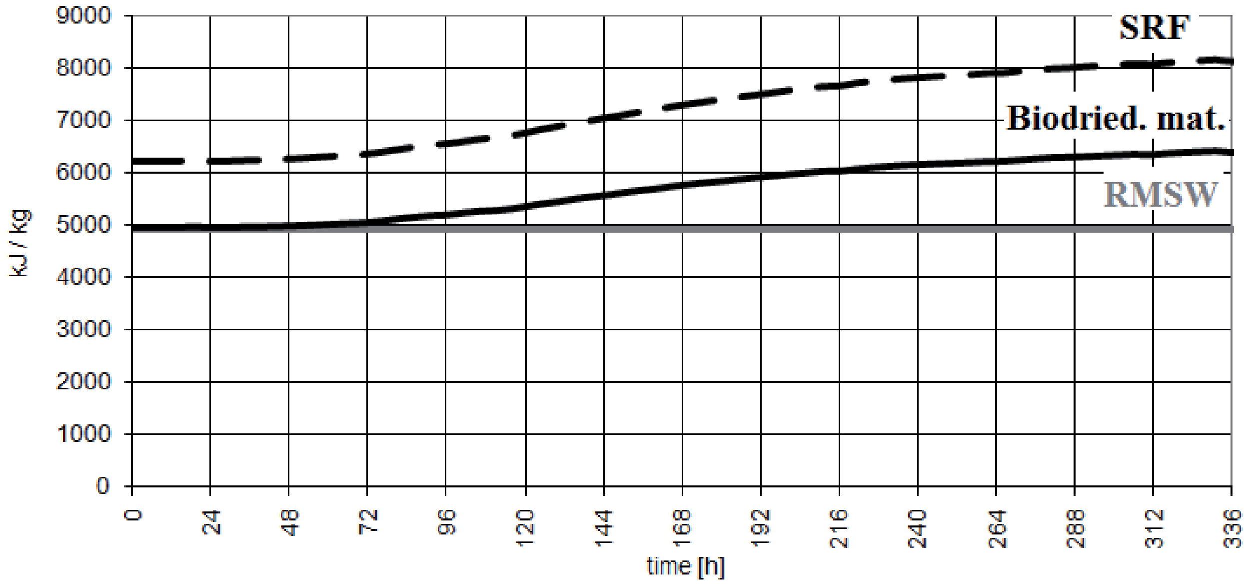


Figure 2 Romanian MSW composition

Considering the Valcea region in one year the quantity of SRF are about 80,547 t_{SRF}/year. This quantity is suitable for construction of a regional bio-drying plant.

For the second flow of waste, using the data from Romanian National Statistic Institute for our case study the results are presented in table 2. Taking into these data and also EU indications, for our case study it was chosen to send to the pyrolysis plant 50% of recyclable and non-recyclable material, therefore from 100 kg of plastic only 5 kg could be sent to the pyrolysis plant.

Table 2 Percentage of packaging waste

	Recyclable %	**Non- Recyclable %**
Paper and cardboard	6.77	0.78
Plastics	1.7	0.55

For our case study the LHV for plastics and paper- cardboard mixture are 33,992 kJ/$kg_{plastics}$ and 16,589 kJ/$kg_{p\&c}$ respectively; LHV of the input material will be 20,155kJ/kg_{mix}. In the current paper the treatment plant will operate 325 days/year, giving a power at the input of about 5.5 MW.

3.2 Second case study

Considering the Valcea region with its quantity of MSW, the PET produced is 3,510 t_{PET}/year. Each inhabitant generates 8.5 kg_{PET}/year. Hence, one block generates 4 t_{PET}/year. In Romania generally one ton of PET costs in a range of 200-250 Euros (BD, 2010). From the total income, the manager of the buildings could cover some administrative operations as renovation works.

The RMSW (Figure 3) is sent into a bio-drying plant. The initial LHV of residual waste was 6,779 kJ_{RMSW}/kg. After the bio-drying treatment and the separation of inert, glass and metal materials the final SRF has a LHV of 10,774 kJ_{SRF}/kg. Taking into account this value and the new EU regulation (UNI CEN/TR_15508) this SRF can go for energetic purposes in a fluid bed combustion plant or in the cement industry.

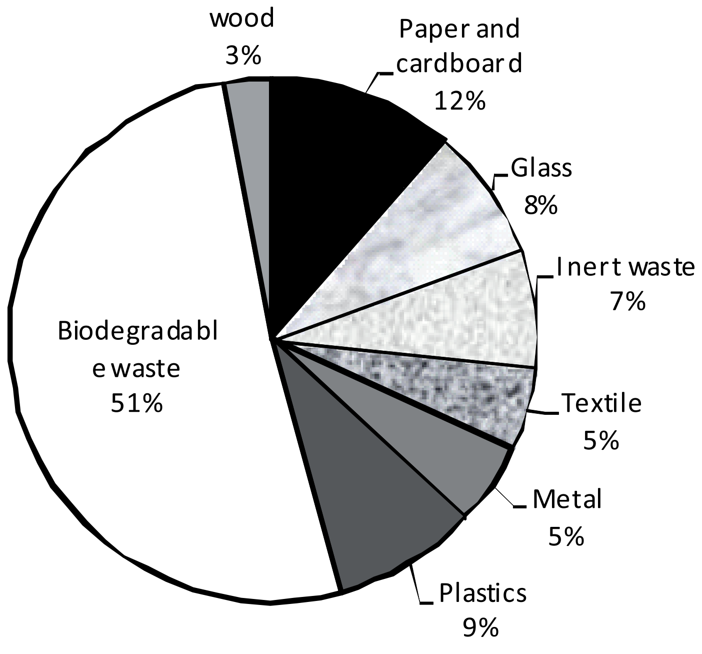


Figure 3 Romanian MSW composition

The energy consumption is the same as in the first scenario, and dynamics of LHV for the RMSW, bio-dried materials and SRF are presented Figure 4. Also the mass balance is similar the one the first scenario being 55% SRF/RMSW. In this case the quantity produced by Valcea region is about 83,586 tSRF/year adequate for a bio-drying regional plant.

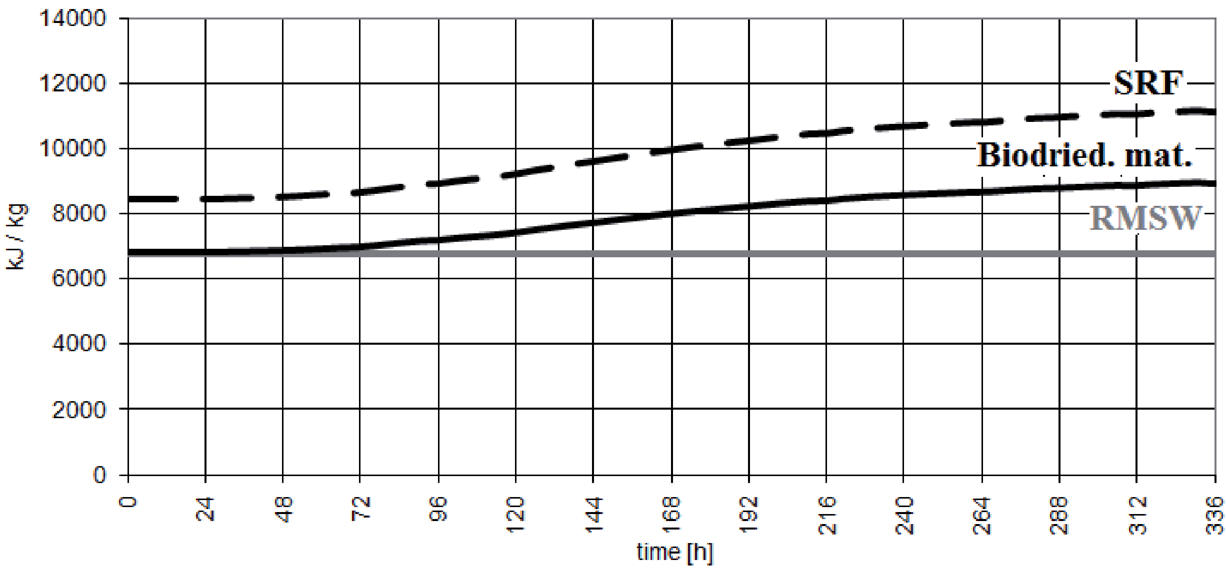


Figure 4 Romanian MSW composition

The development of selective collection of other fraction can change the scenarios. The following considerations are useful for understanding the effects:

- The implementation of selective collection of inert fractions (glass, metal inert) decreases the non combustible amount of materials entering the bio-dryer without effects on the final characteristics of SRF.
- The implementation of selective collection of organic fraction can affect bio-drying as food waste is the engine of the process. Anyway only an extreme efficiency of source separation of food waste can decrease the percentage of the organic fraction in the residual MSW to critical levels.
- The improvement of selective collection of light packaging waste increases the input into the pyrolyzer. Anyway this process is suitable for adoption of small modules that could be added according to the needs.

4 Literature

E.C. Rada	2002-2005	Municipal solid waste bio-drying before energy recovery, PhD, University of Trento, Italy and University ,,Politehnica'' of Bucharest, Romania
G. Ionescu	2009-2013	Treatments for plastics and cellulose from municipal waste selective collection
ANPM-DDSCP	2008	***http://www.anpm.ro/
EPR	2010	www.epr-italia.com

E.C.Rada, A. Franzinelli, M. Taiss, M. Ragazzi, V. Panaitescu, T. Apostol	2007	Heating Value Dynamics during Municipal Solid Waste Bio-Drying, in ENVIRONMENTAL TECHNOLOGY, v.28, n. 4 (2007), p. 463-470.
UNI CEN/TR_15508	2008	Key properties on solid recovered fuels to be used for establishing a classification system
PJGD	2009	http://apmvl.anpm.ro
BD	2010	http://www.bursa-deseuri.ro

Author's address(es) :

Ing. Gabriela Ionescu
Department of Energy Production and Use, Politehnica University of Bucharest, Bucharest, Romania
Spl. Independentei 313
RO-060042, Bucharest 6, Romania
Telephone: +40 21 402 96 75
Email: gabriela_ionescu@ymail.com

Dr.-Ing. Elena Cristina Rada
Department of Civil and Environmental Engineering, University of Trento
via Mesiano 77
IT-38122 Trento
Telephone: +39 0461 28 26 13
Email : Elena.Rada@ing.unitn.it
Website: http://www4.unitn.it/People/it/Web/Persona/PER0038284

Dr.-Ing. Adrian Badea
Department of Energy Production and Use, Politehnica University of Bucharest
Spl. Independentei 313
RO-060042, Bucharest 6, Romania
Telephone: +40 21 402 96 75
Email: adrian.badea@energ.pub.ro

Dr.-Ing. Marco Ragazzi
Department of Civil and Environmental Engineering, University of Trento
via Mesiano 77

IT-38122 Trento
Telephone: +39 0461 28 26 09
Email : Marco.Ragazzi@ing.unitn.it
Website: http://www4.unitn.it/People/it/Web/Persona/PER0003630

Dr.-Ing. Tiberiu Apostol
Department of Energy Production and Use, Politehnica University of Bucharest
Spl. Independentei 313
RO-060042, Bucharest 6, Romania
Telephone: +40 21 402 96 75
Email: tiberiuapostol80@gmail.com

Municipal Solid Waste Management Policies and Problems in Naples

Stefania Romano

The Regional Environmental Center for Central and Eastern Europe, Szentendre, Hungary

Abstract

Waste management is gaining importance in today's decision-makers' agenda; the effectiveness of political actions on waste management directly affects the daily life of citizens, who are more and more sensitive to how waste plans are implemented and waste processes take place. Over the last decades waste started to be associated with management because of the need for plans and methodologies for its disposal; a procedure which requires specific and well-tailored policies. In order to look into the whole process one single case will be depicted: the case of Naples which, in 2008, became infamous for its patent poor waste management. This case study will highlight the different phases of waste cycle, the involvement of different stakeholders, whether from the governmental - central and local – or the private sector, as well as the citizens themselves, and, last but not least, an examination of the legal framework regulating waste management. Leading topics of this paper will be the underlying and specific causes of such ecological disruption; the extent to which these are due to political negligence; and the solutions suggested for repairing the damage.

Keywords

Municipal solid waste management and policies; waste cycle; prevention; recycling; incinerator; landfill; participatory democracy.

1 INTRODUCTION

In our current globalised world consumption patterns have significantly increased resulting in huge quantities of waste produced, impacting our environment (OECD, 2002,A). If the initial phase of a good - production - has mainly an economic driver, followed by consumption - which mainly reflects the social pursuit for comfort - the final phase has a significant environmental impact, besides the social and economic ones.

The concept of waste management has therefore entered the current vocabulary not only of the environmentalists, experts, politicians, but also of common people, increasingly affected by efficient or poor waste management. When did waste emerge as a problem in our society? At the end of the 19th century, at the beginning of the industrial revolution, the whole society in Europe was still sober in consumption, and waste minimization was a natural lifestyle, with the reuse and recycle of materials. Society was naturally sustainable. Taking Italy as an example within Europe, it was after World War II that the industrial economic development exploded, for which new man-made products appeared bringing in not only plastics and different kinds of packaging, but above all the “throw-away” model, which nowadays dominates our societies, repressing the habit of recycling, reusing and recovering. Already in the First Report of the Italian Ministry of the Environment (May 1989), the then Minister, Giorgio Ruffolo conveyed the 1987 waste production data which totally amounted to 97 million tons, out of which only 16% was treated appropriately. The 80s witness an increase of public concern over waste disposal (PINNA, 2009).

In order to better understand the waste management process, the actors involved, and what is needed to make the system efficient and effective, this paper will consider one single case, that of Naples, which, in terms of poor waste management caused a sensation in 2008. The analysis will start from an overall European scale, narrowing down to one single EU country – Italy - and focusing on one single city - Naples - the capital of the Region Campania, in Southern Italy.

It has to be pointed out that the subject of this paper is not waste in its totality, but only municipal solid waste (MSW).

2 WASTE MANAGEMENT: DEFINITION AND PROCESSES

In order to understand why MSWM failed in Naples, it should be clear how waste is processed once it is collected, and how it is disposed. MSW is defined as waste collected by a municipality. It is waste from households, small businesses, office buildings and institutions such as schools, hospitals, government buildings, waste from parks and street cleaning (EUROSTAT, 2003). Ronchi Decree (22/1997) first and the Single Act on the Environment later define waste, in line with the European regulation (Directive 91/156/CEE), any substance or object that the holder throws away or is obliged to throw away. According to law 152/2006 waste is classified according to four main categories: no hazardous municipal waste; hazardous municipal waste; no hazardous special waste; hazardous special waste.

In our daily life hundreds of objects pass through our hands but we rarely think of the processes preceding their production and following their use. Being aware and knowing what to buy and how to recycle and/or dispose of them has a tremendous impact on our environment (WORLDWATCH INSTITUTE, 2004).

Waste management is regulated by a set hierarchy which stretches from a least favored option to a most favored option: disposal, energy recovery, recycling, reuse, minimization, and prevention represent the six procedures utilized.

In 1975 the Waste Framework Directive stressed the importance of waste minimization for the protection of the environment and human health. Since then the basic principles of reducing, re-using and recycling (the 3 R) gradually but increasingly have taken hold in waste legislations and policies. In 1992 Agenda 21 encouraged the commitment from the member states in “promoting waste prevention and minimization as the principal objective of national waste management programs […] giving priority to waste reuse and recycling”. Agenda 21 introduced the waste hierarchy by indicating precise steps to be undertaken.

OECD (2000) defines “strict avoidance” the prevention of waste generation by reducing material or energy intensity in production, consumption and distribution. As suggested by EPA (2006) waste can be prevented by: (1) using the least or reusable packaging; (2) using and keeping durable equipment and supplies; (3) using supplies and materials more efficiently; (4) reducing the use of hazardous components, replacing them with substitutes easily recyclable or recoverable.

The so-called 3 R include reducing, re-using and recycling. Reducing at source involves minimizing material or energy consumption (OECD, 2000) can be attained by developing a more efficient technology for production, for example reducing the weight of the product while it is functioning (REPORT ON WASTE PREVENTION, 2006). Therefore by maximizing the use of available resources environmental impacts are reduced.

Product reuse involves the multiple use of a product in its original form, for its original purpose or for an alternative, with or without reconditioning (OECD, 2000). Reusing, compared to recycling, saves consumption resources, while recycling implies processing (re-manufacturing or conversion into raw materials). Re-using reduces the need for new objects, consequently decreases the cost of production. Moreover reuse creates new jobs in service and repair industries.

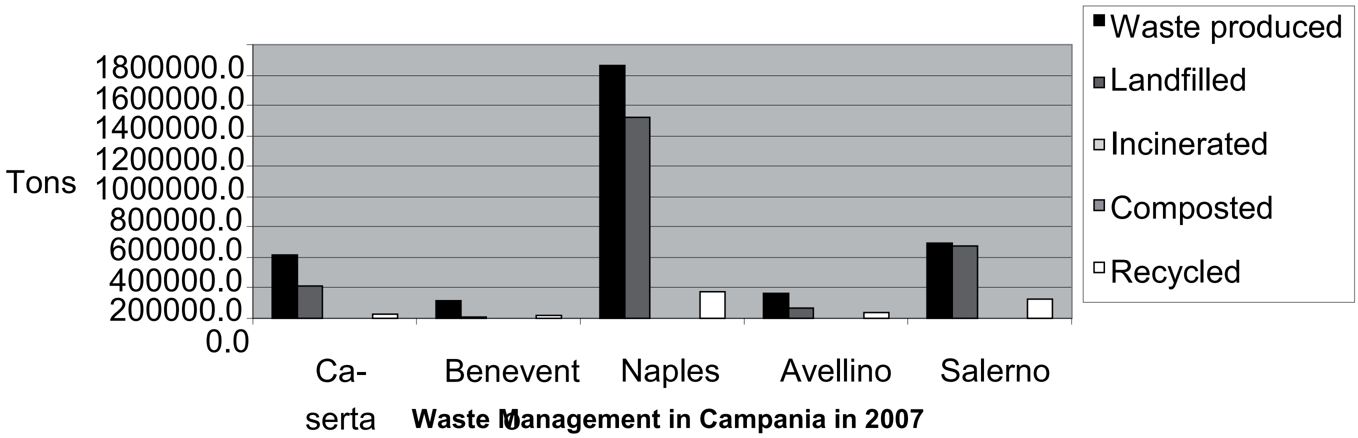
Recycling means to use collected waste materials for other purposes than originally intended with reconditioning (OECD, 2000). Recycling is an approach which saves resources by diminishing the amount of products ending up in landfills. The used product is pulled into different pieces which are reprocessed for their original use or a new one; the phases of this process include collection, sorting, reprocessing and manufacture (WASTE MANAGEMENT BOARD, 2004). Besides the fact that many materials can be recycled, nowadays technological progress advances significantly in the design of recyclable materials. For a better modality of recycling, when waste is collected, the humid part should be separated from the dry ones (plastic, paper, etc.); the humid part can therefore be composted, for which the natural processes of decomposition can be accelerated with an aerobic treatment, transforming the organic waste in compost; if the aerobic treatment is applied with undifferentiated waste the result is stabilized organic fraction (SOF); compost can be used for agricultural purposes as a fertilizer, SOF can be used for other purposes - i.e. daily cover of landfills (ISTAT, 2007).

Incineration is the most used method to recover energy from waste; as it is explained in EEA glossary (2009), incinerators imply the process of burning solid waste under controlled conditions to reduce its weight and volume; through this methodology garbage is destroyed through burning, gasification and pyrolysis. Gases and ashes produced may be toxic but the original waste is reduced by 95-96 %. The incinerator produces steam which through a turbine can generate electricity with high efficiency. In Italy, since 1st January 1999, only plants with energy recovery have been allowed to be built.

Another interesting energy recovery method is the mechanical/biologic treatment plant (MBT) which includes a mechanical separation of the waste and biological treatment (anaerobic and/or aerobic digestion). MBT plants are very flexible and can be built on a modular basis (IPPC, 2006B). The mechanical process can be configured to further separate the non-biodegradables into clean fractions for recycling. The remaining material can be combusted and so is referred to as Refuse Derived Fuel - RDF - (JUNIPER CONSULTANCY SERVICES, 2005).

Landfill is the site where waste is disposed; controlled landfills - areas subjected to a permit system and to technical control procedures in compliance with the national legislation in force (OECD/EUROSTAT, 2000) – have to be distinguished from illegal landfills - areas where dumping is not authorized, causing severe environmental and health problems.

3 WASTE MANAGEMENT IN CAMPANIA IN 2007



Source: adapted from APAT/EEA 2007

In 2007 Naples produced 1.700 thousand tons of waste out of which 1.300 thousand was landfilled and only 172 thousand tons were recycled. The weak facilities and equipment might be one of the causes for which landfills were overfilled.

It is interesting to point out that Salerno, where in 2007 almost all waste was landfilled - now stands out as a case of excellence. Recycling patterns are in fact improving considerably since the mayor has strongly fought for a separate collection plan with the involvement of citizens, using a widespread awareness-raising campaign ("Salerno differenzia") and severe fines for illegal dumping; the interview to the assessor to the environment Gerardo Calabrese - reported by De Santo (2009) - shows that in Salerno separate collection is currently 45%, and in the three districts where it started is as high as 80%. The overall analysis of the table shows how the waste problem in Naples is probably not due to the quantity of waste produced but to other elements.

4 HOW WASTE MANAGEMENT IS IMPLEMENTED IN CAMPANIA

Decree 22/97 set the criteria for the waste management cycle, for which the relevant plans had to be developed at regional and provincial level. According to the Decree a regional self-sufficient management had to be attained, for which the ATO (Optimal Management Area) was established - made up of a set number of municipalities, usually coinciding with the province's territory.

The responsibilities among the bodies are distributed as follows: (1) the regions issue the regulations on waste according to the national laws. They elaborate regional waste management plans for which waste collection, treatment and disposal are to be carried out within the ATO. They set the guidelines for the separate collection - and the relevant financial tool - and for reducing the use of landfills. They grant permissions for the treatment, management and disposal facilities to be built; (2) the provinces elaborate their waste management plan according to the regional laws. They coordinate municipalities in complying and harmonizing with waste management programs. They can help in the implementation of separate collection practices; (3) municipalities deal with municipal collection and disposal; they set municipal regulations and targets.

In principle this is the structural system which assigns tasks and functions among the bodies; but the waste emergency in Campania of 1994 resulted in the establishment of an Extraordinary Commission, coping with the severe situation; but, instead of being a short and targeted interlude, the commission has lasted up until today and presents major flaws. Another important element of the structure in charge of waste management worth explaining, is the so-called "consorzio di bacino" responsible for the following services: street sweeping, separate and not separate waste collection, transport to the plants. They were later absorbed in the structure of the Extraordinary Commission. The employees of these consortia were recruited from lists of unemployed and the so called "workers socially useful" (mainly composed of ex convicts) whose temporary contract became permanent after a given period.

5 CHRONOLOGY OF EVENTS

In 1994 the waste emergency in Campania officially began on the 11th of February, when the then President of the Council of Ministers, Carlo Azeglio Ciampi, issued a Decree taking cognizance of the environmental emergency in various cities of the region. The problem was that the regional plan, issued the previous year, did not work; waste ended up in landfills which were close to the exhaustion. The government appointed the prefect of Naples as the Extraordinary Commissioner to the emergency of the waste; the offer of a contract for tender was called in 1998 and ended in 2000; the then president of the region and Extraordinary Commissioner, Antonio Bassolino, signed the contract with the winning company, FIBE - a consortium made up of different companies, among them Impregilo. Technically the project of FIBE scored only 4.2 - less than half of the competing company, Elettroambiente – owned by ENEL - which scored 8.6.

But the low prices and the short timeframe offered were the winning factors, therefore the emergency was read in time-terms rather than in quality terms. The integrated disposal plan of the MSW consisted of two incinerators producing energy - where RDF should have been burnt - and seven plants for the production of RDF and SOF. The incinerator proposed was outdated and did not offer good energy outputs; these plants would receive urban waste (undifferentiated); the biologic stabilization would separate the humid fraction from the dry fraction; the latter would be processed through a rotating shredder unit for chopping and grinding.

FIBE was supposed to deliver the incinerator by 31st December 2000. But by that date there was neither plant nor the permissions to build. The timing proposed was indeed not workable. A series of clauses were later added allowing - for reasons beyond the ordinary control - extensions to the delivery without penalties. One of the clauses provided that the site would be chosen by the winner, without any consultation with the local institutions or with the citizens; without therefore taking into consideration the problems and the characteristics of the territory. The two incinerators were planned in two places next to each other (Acerra – recently opened - and Santa Maria La Fossa – only planned) with a high impact on the environment; and because of the powers of derogation of the Extraordinary Commission EIA was not requested. As a result, this area which produces 70% the of the famous cheese mozzarella di bufala, would be invaded by trucks arriving from hundreds of kilometers away bringing the waste of the whole region.

The seven plants planned for producing RDF should have given out a product to be afterwards burnt into the incinerator; but those plants, which grind and package waste, do not differentiate the product and do not produce RDF or SOF; the components resulting from the process are such as they enter the plant; The incinerator of Acerra has been recently inaugurated (27th March 2009) but the eco-balls – which are against regulations - cannot be burnt there (PARLIAMENTARY REPORT, 2006). Traces of arsenic - exceeding the allowed limits - have been found, as well as whole pieces of products. The calorific value of this product is lower than it should be and the rate of humidity is too high to be processed in an incinerator. The volume of the outgoing garbage is bigger than the one at the entry, because of the additives. Hence the need to find new caves to dispose waste; additional million Euros needed to ship the balls to North of Italy or abroad. In this context, speculations and criminal infiltration could easily find their way.

6 ANALYSIS OF THE HYPOTHESES

Different hypotheses have been advanced and consequently inquired into in order to unravel the reasons of Naples' problems concerning waste management: (1) the lack of the political will to properly enforce and comply with waste management regulations; (2) the lack of clarity and overlapping of competences of different public organs jeopardize the efficiency of environmental management in Naples; (3) the lack of controlling and monitoring of entities in charge of waste collection facilitates corruption in waste management at public and private levels; (4) the lack of involvement of citizens in the waste management decision-making process at public levels deters the identification of community concerns and needs regarding life conditions.

By combining these four hypotheses one can extrapolate the factors that determined the waste problem in Naples, which are the lack of political will, overlapping of competences and confusion of roles, scarce monitoring and controlling, limited involvement of citizens in the political processes of waste management. The complex analysis originates the waste crisis in Naples to one key concept: political inefficiency. The literature dealing with political efficiency is quite abundant, specially dealing with democratic deficits and democratic revitalization (at national and EU levels), on institutional reforms, on local empowerment, new public management or on capacity building in civil society (ECPR, 2006).

7 RECOMMENDATIONS

The lack of political will undermined the implementation and therefore the overall efficiency of waste regulations in Naples, allowing private interests to gain ground in the public arena. In order to achieve real results, a strategic plan should be developed targeting both the short and the long term, both at political and technical level. The short term solutions should be introduced to immediately start the process of correcting and repairing the damage produced by years of waste mismanagement. But long term measures are necessary to address the problem at its core. Solutions should be aimed at improving the performance of the political class - primarily the actions of local administrators - and at devising technical measures to improve waste management.

The short term plan should be structured with outputs and outcomes: local administrators should be committed to these steps. Moreover, incentives and punitive actions should be set, considering meritocracy as the core element of a functioning system; bonuses should be given for good performances, but rather as awards granted to individuals (which might create resentment and obsession to attain the goal) team bonuses should be designed to reward therefore groups, promote cooperation and encourage exchange of information (Osborne 1993). In this framework, it should be guaranteed that the private interests do not push and influence the decisions of political administrators.

The long term solutions revolve around the concept of an anticipatory government, acting rather than reacting and presenting rather than responding. The government should invest in the new generations, therefore pupils should be made aware of the respect for the environment, and should be taught how to comply with regulations. Educational campaigns for children should be promoted as follows: introducing at primary and secondary schools one/two classes per week on sustainable development - waste management would be one topic; the local government should organize training modules - free of charge - delivered by scholars and experts for graduates and undergraduates of technical universities, who in their turn should teach to school children, achieving cascading effect. At the same time cartoons for children and scientific documentaries for adults should be broadcast in the evenings.

8 CONCLUSIONS

In conclusion we may say that the lack of political will, combined with different elements, as neglecting the monitoring phase, creating confusion with installing external organs, caused the waste disruption in Naples. Recommendations aim at improving waste management in Naples, emphasizing the concept for which governance should be redefined according to the needs of our society. For this reasons institutions need to be more flexible and adaptable. The political class dealing with waste management needs to be driven by experts adopting a holistic approach; inspecting schemes have to be regularly implemented within a user-friendly system, empowering citizens through a participatory democracy steered by an anticipatory government.

As Alvin Toffler (1978) observes in "Anticipatory Democracy" "the political technology of the industrial age is no longer appropriate technology for the new civilization taking form around us. Our politics are obsolete". Therefore, the new direction should be to make public safety a community responsibility, transforming the police officer from an investigator and enforcer into a catalyst in a process of community self-help (OSBORNE, 1993).

9 REFERENCES

De Santo, A.	2009	I conflitti ambientali e la comunicatione. Roma, Italy: Fondazione Willy Brandt.
ECPR	2006	Efficiency versus Democracy? Towards New Syntheses. Workshop at the Joint Sessions in Nicosia, Cyprus. 25 – 30 April 2006.
EEA	2009a	Available at: http://glossary.eea.europa.eu/.
Eurostat	2003	Waste generated and treated in Europe, 46.
Eurostat	2009	Available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/data/wastemanagement/treatment.
IPPC	2006b	Reference Document on Best Available. Techniques for the Waste Treatment Industries. Available at: http://eippcb.jrc.es/.
ISTAT	2007	Statistiche Ambientali. Available at: www.istat.it/dati/catalogo/20070817_00
Juniper Consultancy Services	2005	MTB: a guide for decision makers, processes, policy and markets. Available at: http://www.juniper.co.uk/Publications/mbt_report.html.
OECD	2000	Innovation and the Environment. OECD, Paris.
OECD/Eurostat	2000	Questionnaire on the state of the environment.
OECD	2002a	Towards Sustainable Household consumption. Paris. 158.
Osborne, D. & Gaebler, T.	1993	Reinventing Government. Reading, MA, USA, Penguin.
Pinna, L.	2009	Il selvaggio tecnologico. Analisi del caso Campania. Available at: http://www.energiaspiegata.it/2009/03/il-selvaggio-tecnologico-analisi-del-caso-campania/.
Worldwatch Institute	2004	Good Stuff? A Behind-the-Scenes Guide to the Things We Buy. Available at: http://www.worldwatch.org/taxonomy/term/44.

The Waste Management Board Reuse	2004	Available at: http://www.ciwmb.ca.gov.

Author's address:

Stefania Romano

Regional Environmental Center for Central and Eastern Europe

Ady Endre ut 9-11

2000 Szentendre

Hungary

Telephone: + 36 26 504 013 / +36 20 914 8993

Email: sromano@rec.org

Website: http://www.rec.org

Von der Abfall- zur Rohstoffwirtschaft

Gabi Schock

Deutsche Gesellschaft für Abfallwirtschaft e.V., Berlin

From waste management to raw material economy

Abstract

Based on several preliminary considerations about the raw material supply and consumption approaches of the waste framework directive concerning the paradigm shift from waste management to raw material economy are highlighted.

Future strategies in product design and the potential of a more efficient recycling are developed.

Inhaltsangabe:

Ausgehend von einigen einleitenden Überlegungen zur Rohstoffversorgung und zum Rohstoffverbrauch werden Ansätze der Abfallrahmenrichtlinie zum Paradigmenwechsel „Von der Abfall- zur Rohstoffwirtschaft“ aufgezeigt.

Zukunftsstrategien im Produktdesign und Möglichkeiten eines effizienteren Recyclings werden entwickelt.

Keywords:

Raw material supply, consumption of raw materials, waste framework directive, waste management, raw material economy, product design, recycling.

Stichwörter:

Rohstoffversorgung, Rohstoffverbrauch, Abfallrahmenrichtlinie, Abfallwirtschaft, Rohstoffwirtschaft, Produktdesign, Recycling

Deutsche Gesellschaft für Abfallwirtschaft e.V.

Einleitende Überlegungen

- Einige Rohstoffe gehen weltweit zur Neige
- Insbesondere wertvolle, in geringen Mengen eingesetzte Rohstoffe, müssen wieder recycelt werden → daher müssen Methoden entwickelt werden, um diese zurückzugewinnen oder wiederverwertbar zu machen.
- Welche Rohstoffe gehen zur Neige?
- Diese Rohstoffe sind in welchen Produkten enthalten?

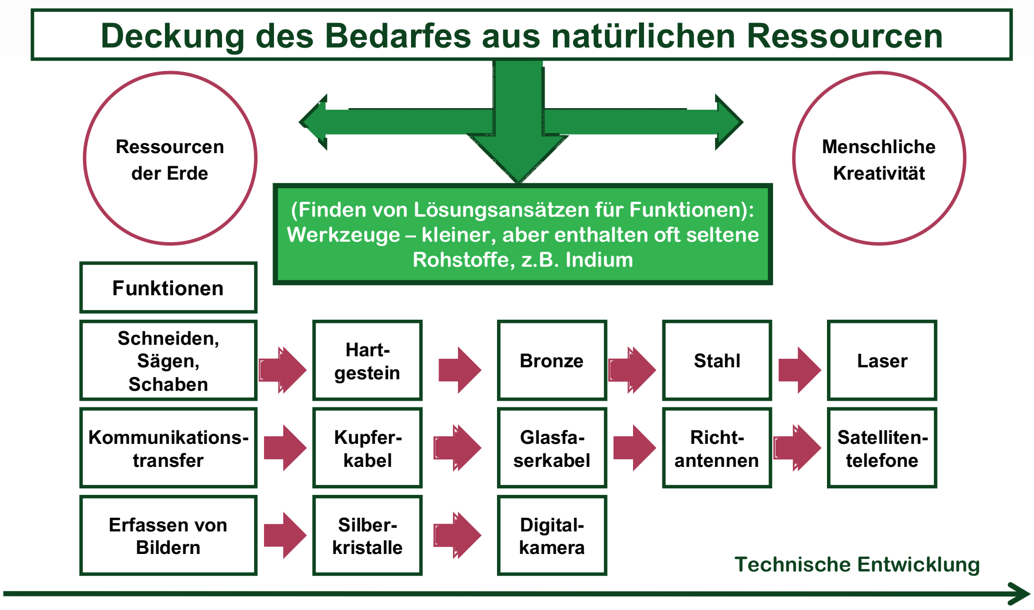
www.DGAW.de

6

Deutsche Gesellschaft für Abfallwirtschaft e.V.

Einleitende Überlegungen

Rohstoffversorgung



www.DGAW.de

7

Deutsche Gesellschaft für Abfallwirtschaft e.V. DGAW

Einleitende Überlegungen

Rohstoffversorgung

Stoffe	Laufzeit
Pottasche/Kalisalz	302
Chromeisen	220
Braunkohle	197
Steinkohle	178
Platinmetalle	175
Bauxit	158
Niob	155
Vanadium	147
Phosphate	130
Eisen	122
Erz oder Element	121
Grafit	108
Manganerz	82
Ilmenit/Titan	81
Erdgas	67
Kobalt	65

Stoffe	Laufzeit
Uran	50
Fluorit	50
Molybdän	46
Erdöl	45
Nickel	45
Tantal	39
Kupfer	32
Wolfram	32
Bariumsulfat	30
Zinn	29
Blei	29
Zink	26
Gold	16
Antimon	14
Silber	12

www.DGAW.de 8

Deutsche Gesellschaft für Abfallwirtschaft e.V. DGAW

Einleitende Überlegungen

Rohstoffverbrauch

Anstieg der weltweiten Rohstoffentnahme:

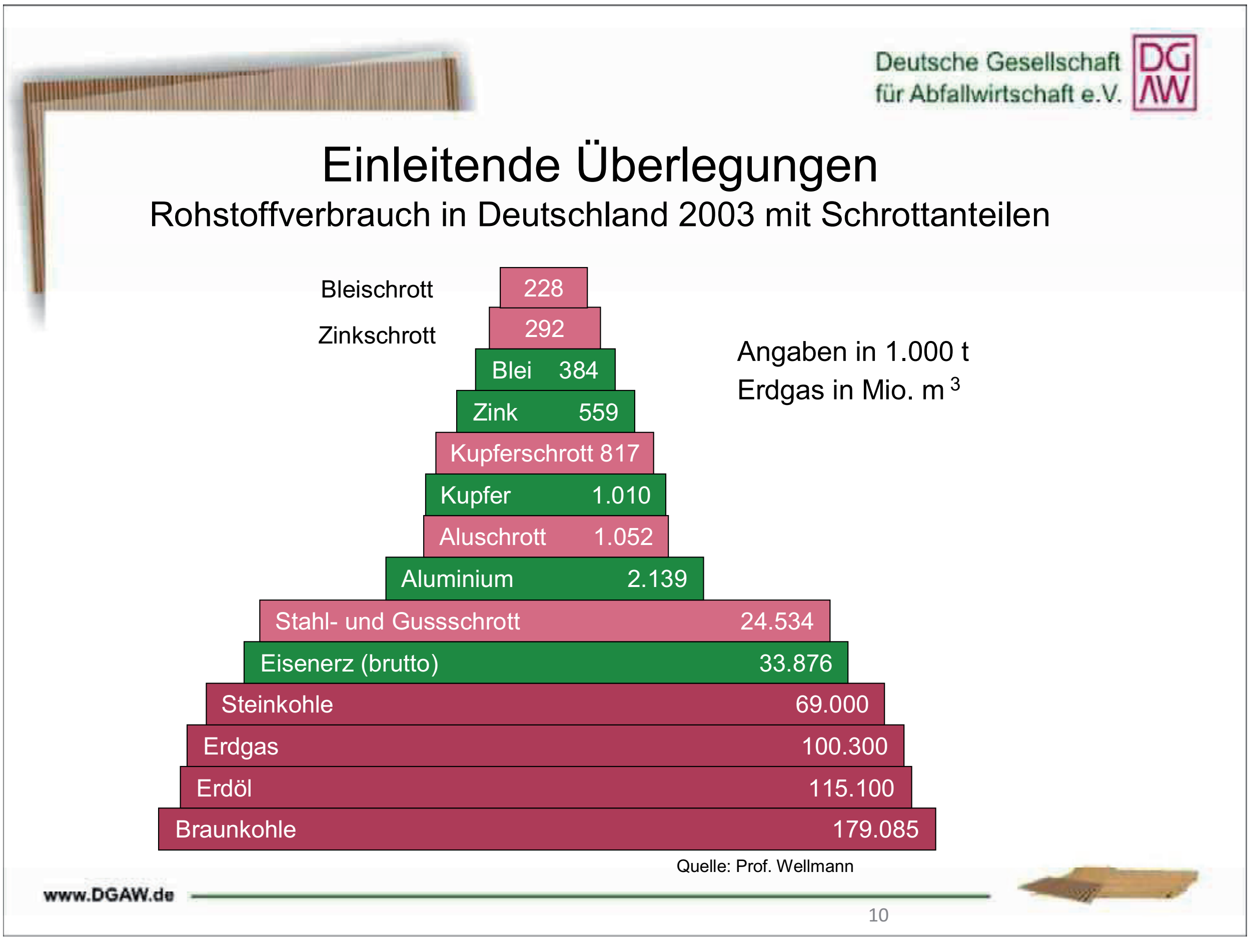
2005: **53 Mrd. Tonnen**
2020: **80 Mrd. Tonnen**

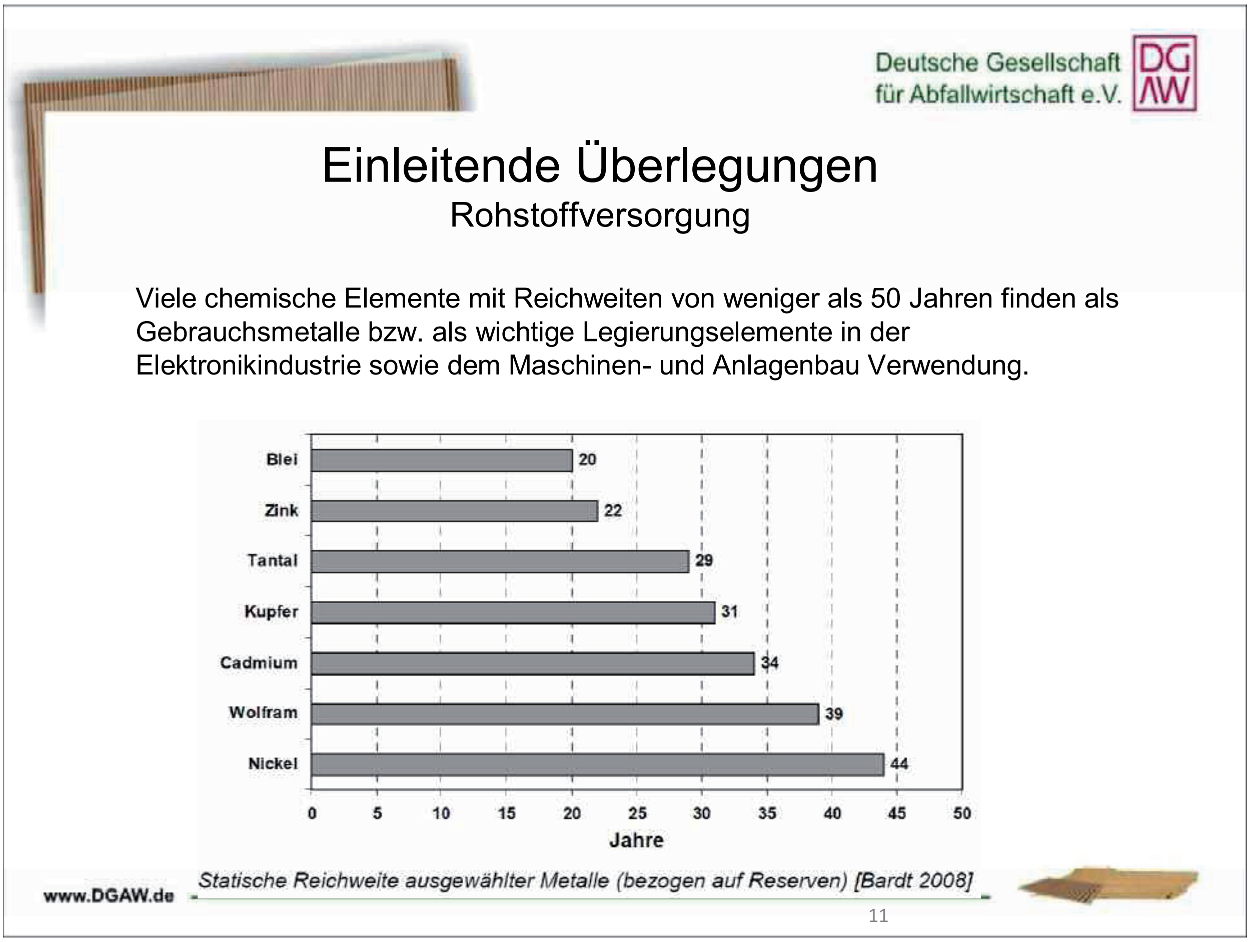
Rohstoffverbrauch pro Kopf/Jahr:

Deutschland: **60 Tonnen**
EU: **50 Tonnen**

Quelle: EUWID, 22.09.2009 – Schätzungen der OECD

www.DGAW.de 9


Deutsche Gesellschaft
für Abfallwirtschaft e.V.
DG
AW
Einleitende Überlegungen
Rohstoffverbrauch in Deutschland 2003 mit Schrottanteilen
Bleischrott 228
Zinkschrott 292
Blei 384
Zink 559
Kupferschrott 817
Kupfer 1.010
Aluschrott 1.052
Aluminium 2.139
Stahl- und Gussschrott 24.534
Eisenerz (brutto) 33.876
Steinkohle 69.000
Erdgas 100.300
Erdöl 115.100
Braunkohle 179.085
Angaben in 1.000 t
Erdgas in Mio. m³
Quelle: Prof. Wellmann
www.DGAW.de
10


Deutsche Gesellschaft
für Abfallwirtschaft e.V.
DG
AW
Einleitende Überlegungen
Rohstoffversorgung
Viele chemische Elemente mit Reichweiten von weniger als 50 Jahren finden als Gebrauchsmetalle bzw. als wichtige Legierungselemente in der Elektronikindustrie sowie dem Maschinen- und Anlagenbau Verwendung.
Blei 20
Zink 22
Tantal 29
Kupfer 31
Cadmium 34
Wolfram 39
Nickel 44
0 5 10 15 20 25 30 35 40 45 50
Jahre
Statische Reichweite ausgewählter Metalle (bezogen auf Reserven) [Bardt 2008]
www.DGAW.de
11

Deutsche Gesellschaft für Abfallwirtschaft e.V.

Einleitende Überlegungen
Rohstoffversorgung

Die Vereinigung der Bayerischen Wirtschaft (**vbw**) sieht die Versorgung mit folgenden Rohstoffen kritisch:

- Metalle: Lithium, Chrom, Platin, Kobalt, Wolfram, Selen
- Seltenerden: Yttrium, Neodym, Scandium

Forderungen der vbw:

- Erhalt und Öffnung der Rohstoffmärkte
- Vertiefung der Kontakte zu ausländischen Partnern→Politik, Rohstoffinitiativen der EU
- Mehr Forschung zum effizienten Rohstoffeinsatz
- Mehr Forschung zu möglichen Rohstoffsubstituten
- Entwicklung tragfähiger Recyclingkonzepte mit der Wirtschaft

Quelle: EUWID, 29.09.2009 – Rohstoff-Risiko-Index, Rohstoffgutachten von vbw

www.DGAW.de

12

Deutsche Gesellschaft für Abfallwirtschaft e.V.

Einleitende Überlegungen
Rohstoffversorgung

Laut **BDI** drohen Deutschland Versorgungsengpässe mit Sekundärrohstoffen:

→bei Metallschrotten bereits deutlich merkbar.

→Die entstehende Rohstofflücke kann nur durch eine ganzheitliche Rohstoffstrategie geschlossen werden.

Vorschläge:

- Anknüpfen an EU-Rohstoffinitiative
  - Abbau von Handels- und Wettbewerbsverzerrungen bei Rohstoffen im Rahmen der Wirtschafts-, Außen-, und Entwicklungspolitik
- Eindämmung der Exporte von Abfällen, Reststoffen und Schrotten

Quelle: EUWID, 01.09.2009

www.DGAW.de

13

Deutsche Gesellschaft für Abfallwirtschaft e.V. DGAW

Einleitende Überlegungen

Rohstoffversorgung

Die Bundesvereinigung Deutscher Stahlrecycling- und Entsorgungsunternehmen (**BDSV**) unterstützt die Forderungen des BDI:

•Nachhaltige Rohstoffpolitik muss zu einem Hauptthema der neuen deutschen Bundesregierung werden
•Stoppen des Abflusses von Vormaterialien wie Altfahrzeuge oder Elektrogeräte
→ Verwertung im eigenen Land
•Kein unberechtigter Bürokratieaufwand beim Recycling
•Definition des Begriffs „Sekundärrohstoff" – Abfallendekriterien der AbfRRL

Abfallgesetz → Rohstoffgesetz

↑ ↑

Gefahrenabwehr Daseinsvorsorge

Quelle: EUWID, 01.09.2009

www.DGAW.de 14

Deutsche Gesellschaft für Abfallwirtschaft e.V. DGAW

2 Abfallrahmenrichtlinie

Richtlinie 2008 / 98 / EG des Europäischen Parlaments und des Rates vom 19. November 2008

www.DGAW.de 15

Deutsche Gesellschaft für Abfallwirtschaft e.V. DGAW

Abfallrahmenrichtlinie

Art. 8: Erweiterte Herstellerverantwortung

- Mitgliedstaaten können Maßnahmen erlassen, um sicherzustellen, dass Hersteller eines Erzeugnisses zur Verbesserung der Wiederverwendung und der Vermeidung, des Recyclings und der sonstigen Verwertung von Abfällen eine erweiterte Herstellerverantwortung tragen (Satz 1).
- **Mitgliedstaaten können Maßnahmen ergreifen, die die Entwicklung, Herstellung und das Inverkehrbringen von Erzeugnissen fördern, die mehrfach verwendbar sind, technisch langlebig und, nachdem sie zu Abfällen geworden sind, zur ordnungsgemäßen und schadlosen Verwertung und umweltverträglichen Beseitigung geeignet sind (Satz 2).**

www.DGAW.de

16

Deutsche Gesellschaft für Abfallwirtschaft e.V. DGAW

Abfallrahmenrichtlinie

Art. 10: Verwertung

- Mitgliedstaaten treffen die erforderlichen Maßnahmen, um sicherzustellen, dass Abfälle Verwertungsverfahren im Einklang mit den Artikeln 4 (Abfallhierarchie) und 13 (Schutz der menschlichen Gesundheit und der Umwelt) durchlaufen (Satz 1).
- Hierzu können Abfallfraktionen getrennt gesammelt werden (Satz 2).

www.DGAW.de

17

Deutsche Gesellschaft für Abfallwirtschaft e.V. DGAW

Abfallrahmenrichtlinie

Art. 11: Wiederverwendung und Recycling

- Recyclingziele der EU bis 2020:
  - Ergreifen von Maßnahmen, um hohe Qualität der Abfallverwertung zu fördern (z.B. ab 2015 getrennte Sammlung von mind. Papier, Metall, Kunststoffe und Glas)
  - Siedlungsabfälle (mind. Papier, Plastik, Metalle, Glas) 50%
  - Bau- und Abbruchabfälle 70%
- Mitgliedstaaten berichten der Kommission alle drei Jahre über den Umfang, in dem sie die Ziele verwirklicht haben.
- Kommission sieht **Review für 2014** vor:
  - Änderungen und Präzisierungen, falls sich negative Auswirkungen abzeichnen sollten
  - **Definition von Recyclingzielen für weitere Abfallströme**

www.DGAW.de

18

Deutsche Gesellschaft für Abfallwirtschaft e.V. DGAW

Abfallrahmenrichtlinie

Forderungen der DGAW

- Zu Gunsten einer nachhaltigen Rohstoffwirtschaft soll anstelle eines Ablagerungsverbots eine **differenzierte Zwischenlagerung** von Stoffen, deren Aufbewahrung bis zur Erreichung der ökonomischen Voraussetzungen für deren Kreislaufführung notwendig wird, zugelassen werden.

  → Entwicklung von gesonderten Anforderungen für diese Zwischenlager in Abgrenzung zu Vorschriften für Deponien notwendig.

- Ergänzung um Regelung zum **Beginn der Abfalleigenschaft**, da beim praktischen Vollzug der Herstellerverantwortung festzustellen ist, dass die abfallrechtliche Begriffsbestimmung zu spät greift. Konsumgüter können somit nach Gebrauch außerhalb des Abfallregimes über nationale Grenzen hinweg verbracht werden (z.B. Elektroaltgeräte, Altfahrzeuge).

www.DGAW.de

19

Deutsche Gesellschaft für Abfallwirtschaft e.V.

3 Zukunftsstrategien

www.DGAW.de

20

Deutsche Gesellschaft für Abfallwirtschaft e.V.

Produktdesign

- mit anderen Wertstoffen werden teilweise gleiche Funktionen erzielt wie mit inzwischen nur noch wenig vorkommenden Rohstoffen

  → in Zukunft muss nicht alles recycelt werden, Forschung auch in die Richtung, welche Wertstoffe knappe Rohstoffe sinnvoll ersetzen können

- Bionik Universität Bayreuth Prof. Dr. Scheibel forscht zu Inspirationen aus der Natur

- recyclinggerechteres Produzieren

www.DGAW.de

21

Deutsche Gesellschaft für Abfallwirtschaft e.V. DGAW

Produktdesign

- Verwertbare Elemente in z.B. Elektrogeräten so platzieren, dass sie gut wieder recycelt werden können

  - Herausforderung an Technik: neue verwertbare Elemente so einbauen, dass einfacher auf sie zugegriffen werden kann, um sie für das Recycling zu gewinnen

  - Produzenten über Kostenanreize dazu bringen, recyceltes oder gut recycelbares Material zu verwenden

www.DGAW.de

22

Deutsche Gesellschaft für Abfallwirtschaft e.V. DGAW

Möglichkeiten des Recyclings

Ressourcen in Europas Abfällen

- Derzeit werden in den 27 EU – Mitgliedstaaten noch große Mengen Sekundärrohstoffe deponiert oder ohne bedeutende Energiegewinnung verbrannt
- Untersuchung von 17 ausgesuchten Stoffströmen von Aschen über Kunststoffe bis hin zu EBS:
  - Von 675 Mio. Tonnen aus diesen Strömen wurden nur 55 % stofflich als Sekundärrohstoff oder energetisch als Brennstoff verwertet.
- Voraussetzungen für weitere Rückführung von Stoffen in den Wertstoffkreislauf:
  - Verschärfte Abfallgesetzgebung (z.B. bezüglich Recyclingraten)
  - Deponieverbote
  - Ökonomische Instrumente und Anreize zur Verwendung v. Sekundärrohstoffen
  - Auf- und Ausbau von Getrenntsammelsystemen
  - Ökonomische Anreize zur Abfallvermeidung
  - Stärkung der Produktverantwortung

Weg von der Abfall- zur Rohstoffgesetzgebung

Quelle: EUWID, 29.09.2009 – „Europäischer Sekundärrohstoffatlas 2006“ von Prognos

www.DGAW.de

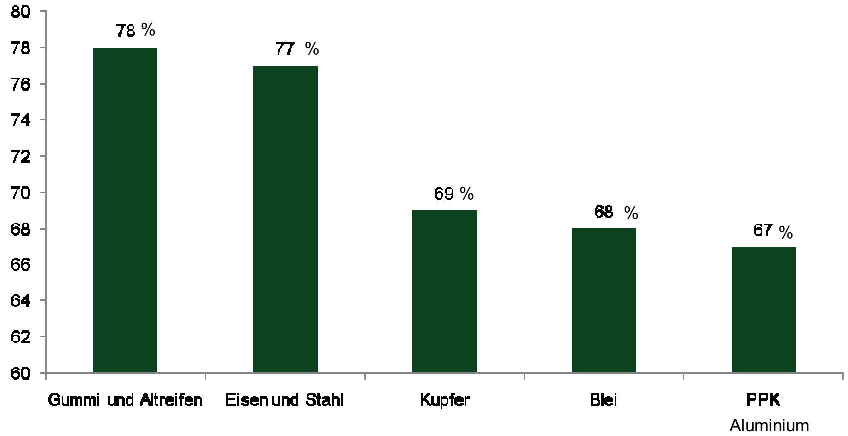
23

Deutsche Gesellschaft für Abfallwirtschaft e.V. DGAW

Möglichkeiten des Recyclings

Verwertungsquoten

Unterschiedliche Verwertungsquoten der Stoffströme in Prozent:



Quelle: EUWID, 29.09.2009 – „Europäischer Sekundärrohstoffatlas 2006" von Prognos

www.DGAW.de

24

Deutsche Gesellschaft für Abfallwirtschaft e.V. DGAW

Möglichkeiten des Recyclings

- Errichtung von Zwischenlagern für verwertbare Elemente
- Schaffung von Rückgewinnungszentren dort, wo Produkt (Stoff) zum Abfall wird
- Händische Demontage → geregelte Stoffströme, Entwicklungshilfe: auch Technik muss zur Verfügung gestellt werden
  - Rückführung von Rohstoffen in Industrieländer – Wiederverwertung
- Ökobilanzen: bisher nicht berücksichtigte Kriterien müssen zum Recycling in Überlegungen mit einbezogen werden

www.DGAW.de

25

Deutsche Gesellschaft für Abfallwirtschaft e.V.

Möglichkeiten des Recyclings

Potential – Verwertbare Elemente eines Computers

Quelle: Bundesanstalt für Geowissenschaften und Rohstoffe

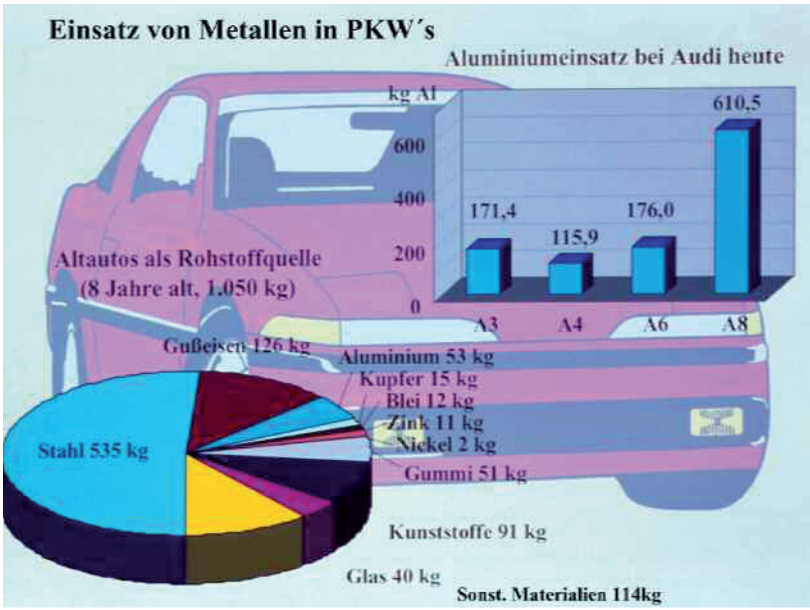
www.DGAW.de

26

Deutsche Gesellschaft für Abfallwirtschaft e.V.

Möglichkeiten des Recyclings

Potential – Verwertbare Elemente in PKW`s



Quelle: Bundesanstalt für Geowissenschaften und Rohstoffe

www.DGAW.de

27

Deutsche Gesellschaft für Abfallwirtschaft e.V.

Rohstoffrecycling in der Zukunft

Vision für 2030 am Beispiel von Elektrogeräten

Voraussetzungen für das Recyceln von Elektro(nik)geräten:

- Speicherchip (technische Daten: Konstruktionsdaten, auch über die Laufzeit, den Hersteller, die Käufer und die Benutzung)
  - rechtzeitige Warnung bei Defekten
  - Klassifizieren der Materialien
- Geräte können mit einem normalen Handy / Mobiltelefon abgefragt werden (Laufzeiten, Käuferdaten, Vorbesitzer, ausgetauschte Komponenten, etc.)
- Schnapp- und Drillverschlüsse (einfachere Reparatur)
- Einheitliche Maße für die Wiederverwertung
  - z. B. Verwenden von Baugruppen verschiedener Hersteller
  - Austausch funktionsgleicher Komponenten

www.DGAW.de

28

Deutsche Gesellschaft für Abfallwirtschaft e.V.

Rohstoffrecycling in der Zukunft

Vision für 2030 am Beispiel von Elektrogeräten

Neue rechtliche Rahmenbedingungen:

- Wertgutscheine für Kunden
- Herstellersubventionen bei Verwenden von Recycling-Bauteilen
- Absatzgarantie für recycelte Produkte oder Komponenten
- Firmengründungen zwecks Rohstoffsammlung, -verarbeitung und zum Rohstoffhandel
- Einführen einer Recycling-Rohstoffbörse
- Internationaler Handel recycelter Materialien
  - Einbezug der südeuropäischen und Entwicklungsländer

www.DGAW.de

29

Deutsche Gesellschaft für Abfallwirtschaft e.V.

Rohstoffrecycling in der Zukunft

Vision für 2030 am Beispiel von Elektrogeräten

Maßnahmen in der Übergangsphase:

- Weniger Einschmelzen und Schreddern von Metallen
- Öffnen alter Deponien als neue Rohstoffquellen
- Ermitteln der Selbstkosten unter Einbeziehung der Entsorgungskosten

Erste Erfolge auf dem Weg nach 2030:

- Entsorger kommen für das Recycling auf, nicht die Haushalte
- Laufende technische Erneuerung der Geräte durch öfteres Recycling ohne Rohstoffverbrauch

www.DGAW.de

30

Deutsche Gesellschaft für Abfallwirtschaft e.V.

Verantwortung für Gesellschaft und Rohstoffwirtschaft

www.dgaw.de

www.DGAW.de

31

Author's address:
Gabi Schock
Deutsche Gesellschaft für Abfallwirtschaft e.V.
Nieritzweg 23
D-14165 Berlin
Telefon +211 821 8176
Email gabi@schock.org
Website: www.dgaw.de

Maximum utilisation of municipal solid waste with the efficient Maximum Yield Technology system

Georg Person*, Matthias Schreiber**

*Zweckverband Abfallbehandlung Kahlenberg, Ringsheim; **Schreiber Umwelt- & Bioverfahrenstechnik, Giessen, Germany

Abstract

Against the background of increasingly scarce raw materials, the use of alternative resources is becoming ever more important. In this context, municipal solid waste is also gaining in importance as a resource. Maximum Yield Technology (MYT®) was developed by Zweckverband Abfallbehandlung Kahlenberg (Kahlenberg Waste Treatment Association), ZAK, with the aim of recovering as much of the waste's raw material and energy content as possible and harnessing the energy potential in the form of usable energy sources. Thus, instead of the exclusive use of landfill or incineration, maximum economic use is made of the waste in the form of raw materials, quality-assured fuels and energy-rich biogas. This paper describes the Kahlenberg MBT plant's genesis, process steps, current operational results and technological developments as an MYT® reference plant which is generating a great deal of interest both nationally and internationally.

Keywords

MYT®, municipal solid waste, Kahlenberg MBT plant, DAMP®, fermentation, RDF

1 Introduction and History

Zweckverband Abfallbehandlung Kahlenberg (Kahlenberg Waste Treatment Association), or ZAK for short, is a public enterprise with a current workforce of over 80 employees. Its registered office and plant are located at the Kahlenberg site in Ringsheim, Germany. The association is made up of two adjacent administrative districts, Emmendingen and Ortenau.

ZAK has been operating the Kahlenberg landfill site since 1973, during which time some 6 million Mg of waste has been disposed of there. The landfill site, which is directly adjacent to residential areas, is publicly accessible and landscaped like a park. The Kahlenberg site covers an area of approximately 100 ha and includes modern technical facilities for landfill operation and the treatment of waste. At the same time, the Kahlenberg area is very interesting from a nature conservation point of view and is a popular recreational area for the region's population.

In the 90s, changes to the framework conditions in terms of waste legislation, along with various other factors, led ZAK to undertake an intensive examination of the possibilities of mechanical-biological treatment of municipal solid waste. Extensive testing of mechanical-biological waste treatment was therefore carried out at the Kahlenberg landfill site from 1996 onwards. The results of preliminary tests on the separate collection of organic waste showed that it is advantageous to integrate the utilisation of organic waste into the MBT concept, thus not requiring the separate collection of such waste. In parallel to the results from these tests, ZAK developed the concept for an environmentally friendly process that maximises the utilisation of jointly collected organic waste and municipal solid waste, with the following objectives:

Materials recycling

- Production of physically usable fractions (secondary raw materials, e.g. metals)
- Separation of mineral fractions for landfill or recycling

Energy recovery

- Energy recovery through the production of quality-assured fuels
- Production of usable biogas from waste

Cost-effectiveness

- Major reduction in mass as a result of water removal and biological degradation as well as minimisation of non-recyclable fractions which have to undergo thermal treatment
- Integration of new facilities into the existing infrastructure (landfill site, CHP station, district heating)
- Energy self-sufficient operation

Ecology

- Enclosure of all process components as well as effective wastewater and exhaust air treatment
- Production of fuels from waste to help conserve fossil energy resources

Between 1996 and 1998, two different fermentation processes were tested on a pilot scale as possible biological treatment solutions for mechanically processed municipal solid waste.

The first two process stages – mechanical processing and biological – of an industrial-scale demonstration plant based on the ZAK process, with a treatment capacity ranging from 15,000 up to a maximum of 20,000 tonnes per annum, were completed at the

Kahlenberg landfill site in 2000. The two remaining process stages – biological drying and mechanical separation – were implemented in 2001 and 2002. This industrial-scale plant served as an interim step towards a planned overall facility with a throughput of around 100,000 tonnes per annum, thereby demonstrating the transferability of the pilot trial results to industrial-scale conditions. The demonstration project was supported with funds from the state of Baden-Württemberg, Germany.

The process steps developed on the basis of the tests have been patented as the ZAK process.

Following this period of testing, which lasted several years, and a difficult planning, contract awarding and construction phase, the first large-scale plant based on the ZAK process – the Kahlenberg MBT plant – was commissioned in May 2006. The short commissioning phase of around three months went according to plan and largely without hitches, as did the subsequent full-capacity operation, which meant that the planned throughput was achieved at all times. Most of the operational targets were achieved and in some cases even exceeded. At the end of 2008, approval was granted to increase the plant throughput to 110,000 Mg/a. Since the Kahlenberg MBT plant went into operation, ZAK has pursued a policy of ongoing optimisation, thus continuously improving the already good operational results. The project as a whole has therefore been very successful.

Meanwhile, the Kahlenberg MBT plant is the only mechanical-biological waste treatment plant for jointly collected municipal solid waste and organic waste in Baden-Württemberg, and the only one of its kind worldwide. The successful implementation of this MBT technology, aimed at recovering as much of the waste's raw material and energy content as possible and harnessing the energy potential in the form of usable energy sources, is reflected in the name **Maximum Yield Technology, MYT®** (OHIM1, 2010). The considerable national and international interest in MYT® led to activities aimed at marketing this MBT technology. To this end, ZAK founded MYT Business Unit GmbH in 2010, which now works in cooperation with strong industrial partners and planning offices to offer MYT® as a pioneering MBT technology primarily in the European market, but also beyond.

2 MYT® in the Kahlenberg MBT plant

2.1 Process Steps

The Kahlenberg MBT plant processes and treats municipal solid waste mechanically and biologically in precisely coordinated process steps:

Step 1: Waste delivery

Step 2: Mechanical processing

Step 3: Biological stage

Step 4: Biological drying

Step 5: Mechanical separation

2.1.1 Delivery

The waste is delivered to a closed and airtight hall with a special ventilation system. Precise control of the intake and waste air and the use of high-speed doors and air vents ensure that no odours escape during the waste delivery process. A wheel loader conveys the waste to a stationary excavator, which loads two conveyor belts at an even rate and also sorts recyclable and undesired material. From this point on, the waste is only handled and treated in enclosed units, which also have the air extracted from them via a ventilation system in order to minimise emissions from the process.

2.1.2 Mechanical processing

The conveyor belts move the waste to the twin-line mechanical processing stage, where it is first separated into coarse, medium and fine fractions using drum screens. After the foreign and recyclable material check, which involves the removal of coarse foreign material, metals and inert material, the coarse fraction (>150 mm) is available for energy recovery. The medium fraction (60-150 mm) is initially separated into a heavy fraction and a light fraction using ballistic separators. After checking for foreign and recyclable material, the heavy fraction is once again merged with the light fraction as well as the fine fraction (< 60 mm) from the previous screening and forwarded to the biological stage.

2.1.3 Biological Stage

Using distribution systems developed specifically for this purpose, the waste that is forwarded to this stage in two lines – now 90% of the originally delivered mass – is distributed to the six mixing units of the **D**efined **A**erobic **M**ixing **P**rocess, DAMP®, (OHIM2, 2010). These are six horizontal stirred reactors with a U-shaped cross section, a length of approximately 25 metres and a clear cross section of approximately 4 metres. The waste is slowly stirred as water is added. As a result, it is homogenised, reduced in size and broken down. During the process, organic components of the waste dissolve in the added water or become suspended in it. After an average residence time of two days, the waste is put through screw presses for dewatering and forwarded to the next stage – biological drying – with a residual moisture of approximately 40%.

The press water, which is rich in organic material, then passes through a mechanical process water treatment stage. Screens and settling tanks are used to separate the solid material contained in this water. Coarse and fibrous material rich in organic substances is returned to the process. Inert solid material passes through a washing process, which removes the vast majority of organic substances adhering to it, before being moved to the inert material landfill. The treated press water is then forwarded to three anaerobic fermenters with a capacity of 1,500 m³ each. Here the organic content of the water is converted into biogas. Most of the organically depleted effluent water from the fermenters is returned to the DAMP® process. The excess water undergoes biological wastewater treatment with downstream activated carbon treatment, thereby purifying it to the level required for discharge into the local sewerage system.

While some of the biogas that is produced in the anaerobic fermenters is reused in the process itself, most of it is converted into electricity (approx. 1 MWe) and heat in a combined heat and power station. The heat is fed into a district heating network which supplies parts of the neighbouring municipality of Ringsheim.

2.1.4 Biological Drying

The dewatered solid material from the DAMP® process – about 60% of the waste mass originally supplied – has a defined moisture and structure thanks to the positive properties of the mixing process and, moreover, it still contains sufficient biodegradable organic material and biological activity for the subsequent process of biological drying. This takes place in large concrete housings – so-called tunnels with aeration floors and tightly sealable doors – into which the dewatered material is filled. Once a tunnel has been filled and tightly sealed, aeration of the still-moist material begins. This quickly heats up, causing the water content to evaporate. As the water vapour is removed with the warm exhaust air, the solid material dries out within 8-10 days, is turned over and transferred to a new tunnel once during this process and ends up with a water content of just 10%. A discharge system removes the dry solid material from the tunnels and supplies it to the final stage, that of mechanical separation.

2.1.5 Mechanical Separation

A vibrating screen separates the dry material – approximately 40% of the waste mass originally supplied – into coarse, medium and fine fractions. The coarse fraction (> 80 mm) can be used directly as a high-calorific material with a low heavy solid content for conversion to energy. The medium fraction (40-80 mm) is separated into a heavy fraction and a light fraction in an air separator. The light fraction is supplied to an energy recovery process.

The fine fraction is conveyed onto a flat screen measuring several square metres and separated using hole sizes of 4, 8, 12 and 22 mm. Downstream separating tables separate the individual screening fractions into light and heavy material through a combination of pneumatic and ballistic methods.

The flat screen's overflow (22-40 mm) falls into an air separator which separates the light components of the screen overflow from the heavy components through air separation.

The light fractions, of which there are five in total, can now be mixed in any combination and then loaded into appropriate transport vehicles. The heavy fractions are brought together and landfilled.

2.1.6 Exhaust Air Cleaning

A range of technical measures were implemented in order to achieve the process objective of minimising emissions to the greatest possible extent. Thus, firstly, all the waste-handling and processing units are enclosed and sealed, and also have the air extracted from them to maintain negative pressure. Some of the encapsulation technologies used in this process have been specially developed and/or refined by ZAK. The halls surrounding the units also have the air extracted from them. This slightly polluted exhaust air from the halls and units is collected and supplied to the biological processes. This multiple use significantly reduces the MBT plant's total exhaust air emissions. The remaining amount of slightly polluted air is first humidified using an air humidifier and then cleaned in a biofilter system before being released into the atmosphere.

The biological processes, in particular biological drying, generate a second exhaust air flow of heavily polluted process exhaust air. It mainly contains ammonia, hydrogen sulphide and, of course, considerable concentrations of organic carbon compounds, collectively referred to as TOC (total organic carbon). In order to comply with German limits for exhaust air emissions from MBT plants, this air stream must first pass through several chemical purification stages, in which ammonia and hydrogen sulphide are removed. Degradation of the organic contents then takes place in a regenerative thermal oxidiser (RTO). The Kahlenberg MBT plant generates some 60,000 standard cubic metres of exhaust air per hour for purification.

2.1.7 Fuel Utilisation

Differentiated screening and separation in the mechanical separation phase yields light fractions in different particle sizes which can be used as refuse derived fuels (RDF). The fractions can be mixed or extracted separately, depending on the fuel customer's particle size requirements. At present, the individual light fractions are mixed to produce the following substitute fuels:

- Medium-calorific RDF with a particle size up to 8 mm or up to 40 mm
- High-calorific RDF with a particle size greater than 40 mm

These fuel fractions are used in cement works, industrial cogeneration plants and RDF power plants. Due to the special MYT® production process (DAMP®, drying, material separation), these RDF fractions possess ecological and combustion-related advantages for energy recovery (homogeneity, low chlorine and mercury content, biomass content) and are much in demand.

Some of the higher-calorific coarse fractions >80 mm are currently also being converted into energy in waste incineration plants.

2.2 Material and Energy Analysis

The Kahlenberg MBT plant treats over 100,000 Mg of municipal solid waste a year (approved throughput: 110,000 Mg). Since it was commissioned in May 2006, it has treated over 485,000 Mg of municipal solid waste (as of 28.02.2011). The operational results have been further improved through the continuous optimisation of various processes. The following figures relate to 2010, and all percentages to the total MBT plant input:

Of the 103,700 Mg of municipal solid waste delivered to the plant, metals (1.3%), mineral substances (0.8%) and undesired material (1%) were sorted out in the delivery bunker and during mechanical processing. After separation of a high-calorific coarse fraction (>150 mm; 7.7%), about 90% was left for further treatment in the biological stage.

During mechanical treatment of the process water in the biological stage, approx. 1% was removed in the form of sands. Fermentation of the process water yielded approx. 5% biogas with a methane content of 70% by volume. After the separation of sludge from the fermentation process that was not processed internally (1%) as well as excess process water (23%) for wastewater purification, a residue of approx. 59% remained for biological drying.

In the biological drying process, the material lost approximately 22% of its mass as a result of water evaporation and partial degradation of the organic content. Just under 38% of dried solid material remained, which was separated mechanically into light material for energy recovery (28%) and heavy mineral material (approx. 9%).

Of the entire MBT plant input, approx. 11% – heavy substances including the previously separated inert material – went to landfill. Without any further treatment, they satisfy the strict disposal criteria of landfill category 2 for MBT materials in accordance with German landfill regulations.

All the streams of fuel together amount to an SF output of approx. 36% of the MBT input, plus about 5% biogas.

The proportion of residual fractions which have to be disposed of thermally and which are neither suitable for landfill nor can be used in any other way has now been reduced to below 3%.

In 2010, approx. 15% of the biogas was needed to operate the RTO. The rest of the biogas was used to generate over 9,000 MWh of electricity and over 16,000 MWh of heat in the nearby cogeneration plant. Approximately 82% of the electricity and 10% of the heat generated was needed to operate the MBT plant. This means that the Kahlenberg MBT plant is energy self-sufficient.

3 MYT® - Positive Aspects and Developments

3.1 Ecological consideration

The German waste recycling and management law is currently being amended as part of the implementation of European requirements (EP, 2008). According to the current draft (BMU - German Environment Ministry, 2010), separate collection and recycling of organic waste is to be introduced nationwide by 01.01.2015. According to legal evaluation, an absolute obligation to introduce separate organic waste collection cannot be inferred from the existing draft (VON BECHTOLSHEIM ET. AL., 2011); the introduction of separate organic waste collection is subject to a so-called “Erforderlichkeitsvorbehalt” [a “necessity proviso” which stipulates that these collections should be introduced, provided they can be shown to be necessary].

As mentioned in the introduction, organic waste in the catchment area for the Kahlenberg MBT plant is collected and treated together with municipal solid waste via the grey bins for residual waste. The question of whether this joint collection and treatment at the Kahlenberg MBT plant – and thus an MYT® plant – has ecological disadvantages compared with the separate, high-quality recycling of organic waste that is being called for is the subject of a comparative life cycle analysis currently being carried out on our behalf (IFEU, 2011). According to the provisional results obtained so far, the joint treatment of organic waste together with municipal solid waste, in accordance with the MYT® concept used at the Kahlenberg MBT plant, is essentially equal in ecological terms to the best possible method of recycling separately collected organic waste (known as organic waste treatment with optimised fermentation). Separate collection, treatment and high-grade recycling of organic waste should not therefore be an absolute necessity from an ecological point of view when using MYT®; in fact, in our estimation it would even be economically disadvantageous (more complex collection logistics, possibly higher investment for two treatment plants, loss of the energy self-sufficiency of MYT®).

3.2 Energy Efficiency

The concept of Maximum Yield Technology (MYT®) includes the objective of using MBT technology to recover as much as possible of the raw material and energy content of municipal solid waste and to transform the energy potential contained in this waste into usable energy sources.

Based on the operational results of the Kahlenberg MBT plant, which operates in accordance with the MYT® concept, the results in terms of converting the energy potential of municipal solid waste into substitute fuels and biogas – more versatile energy sources – for an MYT® project with an annual throughput of 120,000 Mg (MYT® 120 Project) are shown in Figure 1. According to this, the fuel and biogas yield based on the energy potential of municipal solid waste is over 85% with MYT®, which in our opinion represents comparatively excellent energy efficiency (WALLMANN, 2008).

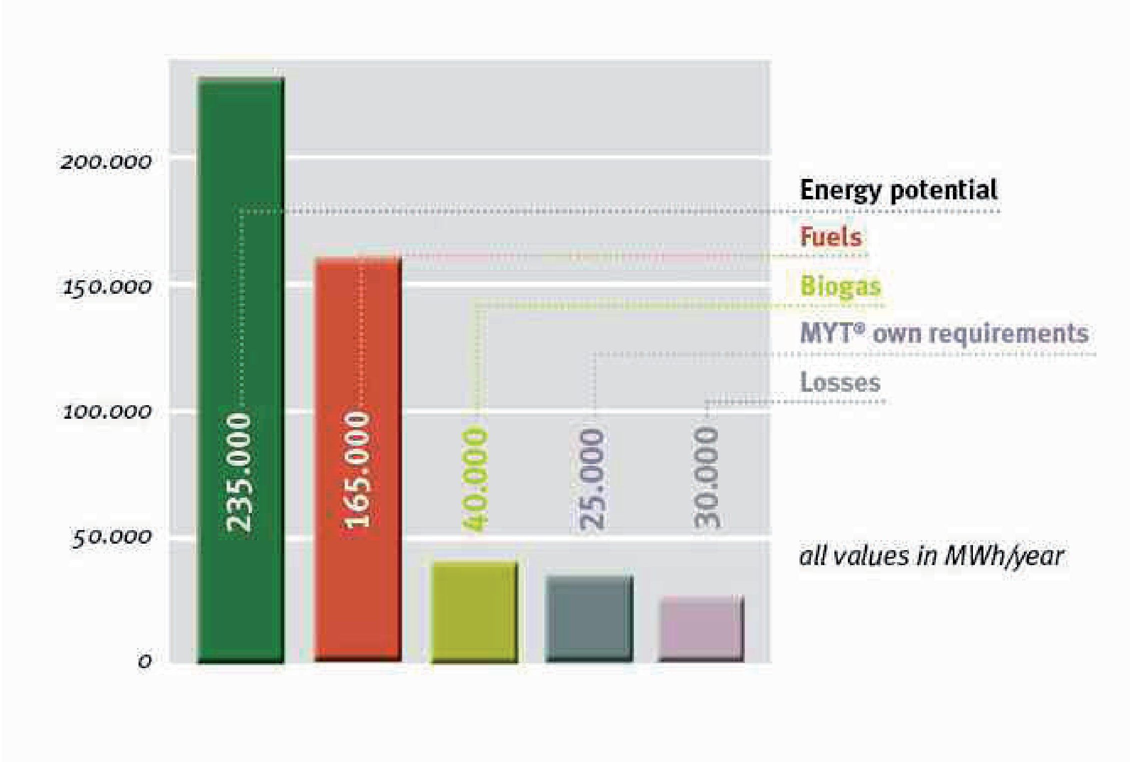


Figure 1 Yield of usable energy sources from municipal solid waste (left bar) for MYT® 120

3.3 Technological Developments

In parallel to the operation of the Kahlenberg MBT plant, the process technologies used there have been tested intensively and optimised in a number of areas. In the biological stage in particular, there have been innovative modifications in water management, water treatment and solid-matter treatment which have led to relevant patent applications being filed. In the MYT® process, the original percolators have been replaced – specifically for the implementation of DAMP® technology – with heavily modified mixing reactors which feature new functions, are more efficient and reliable, and for which patent applications are planned to be filed this year.

3.4 Conclusion and Outlook

International interest in the Kahlenberg MBT plant has been growing ever since it was commissioned. The main focus has been on the high yield of high-quality substitute fuels as well as the plant's good emissions performance, high operational reliability and extraordinary cleanliness. In addition, there has been ongoing work on improving the process and the units that are used at the plant. Patent applications have been filed for various optimisations which are part of the MYT® process. MYT Business Unit GmbH (MYT BU), based in Ringsheim, was founded in 2010 in order to market the innovative technology along with the technical and operational expertise. The company is working on implementing MBT projects in Europe and Asia in cooperation with national and international partners. MYT BU supports its partners as a licensor and knowledge provider during planning, construction and commissioning as well as by providing training for operating personnel.

4 Literature

EP;	2008	Directive 2008/98/EC of the European Parliament and of the Council of 19.11.2008 on waste and repealing certain Directives, Official Journal of the European Union dated 22.11.2008, L312/3ff
Wallmann R., et al.;	2008	Energy efficiency of mechanical-biological treatment of residual waste, Müll und Abfall 2008, 07, pp. 332-339, ISSN 0027-2957
BMU;	2010	Draft bill for reform of the German waste recycling and management law, as at 02.11.2010, which contains in Article 1 a “law to promote the recycling economy and safeguard environmentally compatible waste management (waste recycling law – KrWG)
Ohim1;	2010	Office for harmonization in the internal market, registered 05/04/2010; Certificate of registration No. 008271892
Ohim2;	2010	Office for harmonization in the internal market, registered 05/04/2010; Certificate of registration No. 008271901
von Bechtolsheim, C. et. al.;	2011	RE KrWG – Requirements for reorganizing the disposal of biowaste – Part 1, Müll und Abfall 2011, 03, pp. 114 - 117, ISSN 0027-2957
IFEU;	2011	Kahlenberg MBT plant – Comparative life cycle analysis of organic waste recycling 2011, unpublished

Authors' addresses:

Dr. Georg Person
Zweckverband Abfallbehandlung Kahlenberg
Bergwerkstr. 1
D-77975 Ringsheim
Telephone +49 7822 89 46 10

E-mail: georg.person@zak-ringsheim.de
Website: www.zak-ringsheim.de

Matthias Schreiber
Schreiber Umwelt- & Bioverfahrenstechnik
Meininger Weg 5
D-35396 Giessen
Telephone +49 641 971 902 41
E-mail: kontakt@schreiberonline.de
Website: -

Preparation of biological waste and municipal solid waste using the VMpress

Karl Dirkes

VMpress Technologies GmbH /Nordhorn

Abstract

Municipal solid waste (MSW) or green household waste contains a large amount of energy and exists of three main components:
- recyclable materials;
- organic biodegradable fraction;
- dry fraction with refuge derived fuel (RDF).

Current separation systems create an organic fraction with a lot of non-organics and a non-organic fraction still containing organics. The VM Press, however, is a waste pressurizing machine designed to physically separate waste into two fundamental fractions, an organic wet fraction with hardly any non-organics and a solid dry fraction with almost total absence of organic biodegradable substances. This wet organic fraction can be used in anaerobic digestion plants. Through an additional separation process the dry non-organic fraction is prepared into RDF and recyclables.

Keywords

biodegradable waste, municipal waste, domestic waste, organic fraction, wet fraction, dry fraction, refuse derived fuel, recyclables, energy from waste

1 Introduction

Municipal waste has always been considered a problem, something that no one wants to see, something to be removed and hidden as soon as possible. However, the mixed fraction of municipal solid waste (MSW), the materials that remain after separate collection of the recyclable components of urban waste, still contains large quantities of energy. MSW are mainly composed of:

- inert materials ("dry") such as wood, plastic, paper and cardboard and (if not previously removed) metals and glass;
- damp and fermentable organic substances ("humid").

The machine's function is to treat the solid urban waste, separating "dry" and "humid" parts by way of high-pressure extrusion into two valuable streams of material that are each more valuable with the absence of the other.

2 The process

2.1 Introduction of the process

The traditional separating methods create an organic fraction with a lot of non-organics and a non-organic fraction still containing organics. In this way, the organics are very difficult to digest, whereas the RDF is difficult to extract at an acceptable quality level. There are thermal processes to split these fractions, but these are very energy inefficient.

The VM Press, however, is a waste pressurizing machine designed to physically separate waste into two fundamental fractions, an organic wet fraction with hardly any non-organics and a solid dry fraction with almost total absence of organic substances. The process involves the treatment of the solid municipal waste “as it is collected” and the use of a very simple form of refuse-disposal technology, which is considered compatible with the situation of practically any territorial or local administration department.

2.2 The heart of the process: the machine

The VM Press extruder compactor, which performs hyperbaric separation of waste, is the core of the system. The machine features a horizontal functional and structural arrangement, which was tested and developed over a long period of time. It is the second-generation design after an original vertical model in the 90’s.

The active part, formed by the cylinders, the gear mechanism and all functional parts are fitted in a massive support structure produced in special welded metal. The whole structure is held together with 4 gigantic pull rods that resist the force acted during the compression phase.

A rotating revolver drum is the central component of the machine structure. In this revolver three impact-plate matrices are integrated. The construction of this is made of a special alloy. These matrices are replaceable compression chambers, which are designed with a 120° setting. The drum is driven by hydraulic motors which control the cyclical rotation and is synchronized with the general operation of the machinery.

The pressing and extrusion cycle features the following phases:

- the material is loosely loaded into the feed-system hopper undergoes three compression cycles;

- first stage, the input material pressed by the feed ram, bringing it into the cylindrical ram (volume reduces);
- second stage: a cylindrical ram brings and compresses the material into the revolver / compression chamber;
- third stage: Extrusion: the main cylinder compresses the material extremely high and the liquidized material is pressed out of the chamber;
- Emptying: a cylindrical ram pushes the remaining material out of the compression chamber.

In every cycle, by means of successive rotations through 120°, the matrix/impact-plate support drum brings the matrices to the position in which they are penetrated by a pressure ram. In this way the stages described above are carried out simultaneously in the three matrices.

2.3 Result of the extrusion process

The municipal solid waste is split into a dry and a wet fraction, the physical and biological characteristics of which allow for advantageous disposal systems.

2.3.1 The dry fraction

The dry fraction is formed by materials which are mechanically more stable and strong such as plastic, wood, paper and cardboard, various minerals, metal etc, with the following significant physical properties:

- upstream density 0,7/0,8 t/m^3 approximately
- residual humidity about 18%-20%
- average calorific level > 14/16,000 kj/kg
- organic (except wood) < 4-5 %

The dry fraction can be used as a raw material for refuse-derived fuel (RDF). RDF is a fuel producing thermal or electrical energy. Part of it can be further separated in special sorting plants extracting recyclables. The dry fraction that cannot be put into recyclables or RDF can be advantageously disposed of in landfills or storage areas, because of the considerable reduction in volume (up to 1/3 of the volume), with considerable savings in terms of the duration of the landfill or waste-disposal unit (e.g. a 2-year old landfill or disposal area could be used for a further 5-6 years). Its volume reduction also gives reduction in logistics or transportation costs. Finally, the minimal amount of organic substances and moisture result in minimization of damping and gas forming, resulting in less odours and insects.

2.4.2 The wet fraction

The wet phase is essentially formed by organic substances (foodstuff refuse) with low quantities of various fibers, plastic materials and minerals. The physical appearance is that of a semi-fluid, fine-grain paste (depending on the moisture). In particular, the low quantities of glass and ceramics have a granulometric shape. The characteristics of the wet fraction are:

- the level of humidity is about 60-65% and there is no floatation of material from the paste-like mass;
- the upstream density is approximately 0.8-0.9 t/m^3;
- in case of anaerobic digestion:
  - biogas yield >180m3/h;
  - CH4 approximately 60%;
- extrusion efficiency of digestible organics approximately 95%.

(All numbers depend on the input material.)

2.4.3 Products from MSW

The process described above allows the user to obtain the following products from municipal solid waste (mass % depends on the input):

- wet fraction 30-40 % approx
- dry fraction 60-70 % approx
  Off which:
  - metals 1-3 % approx
  - sand and minerals 10-15% approx
  - remaining plastics, wood, cardboard, textiles and leather and whatever is in the solid waste.
  - the remaining organics 5% approx

All of the above products are almost biologically inert and therefore do not generate the negative effects typical for a landfill for municipal solid waste such as leakages, pollutants, biogas, and noxious odour.

3. Usage of products coming from the extrusion process

3.1 Dry fraction

The dry fraction, characterized by a degree of humidity lower than 20 %, can be used in incinerator plants, gasification, pyrolytic or cement factories systems as RDF. This contributes significantly towards the reduction of the mass of waste transferred to landfill areas and disposal sites in general and the equally significant advantage owing to a recovery of energy. If the mineral and metal fractions are separated from the dry waste the calorific value will increase accordingly, also the amount of slag will reduce significantly since the inert fraction that is taken out is the main part of the slag. The RDF can be formed into bales or briquettes for later use. To facilitate transportation the blocks can be wrapped in (recycled) plastic.

If incineration for the conversion to energy is not an option, nor is any other thermal conversion, then the remaining option is disposal of the material to a landfill. It should be noted that the size of the mass is reduced five or six times with respect to the size of the original waste treated, this because the organic wet fraction is removed from it and the dry fraction is compacted. The immediate advantage, besides the considerable saving due to the reduction in transportation costs is that of a significant increase in the life of the landfill area and simplification of the operation cost of the disposal unit itself because of the fact that the processed waste material is highly biological inert.

3.2 Wet organic fraction

The organic fraction that is produced by the VM press is very suitable as raw material in digestion or composting processes. The mechanical effect, to which the material is submitted in the compression and extrusion phase, causes a breaking-up of the solid material forming the wet phase, which allows for a rapid fermentation process, the initiation of which is also facilitated by a raise in temperature of the extruded mass when it comes out of the extruder compactor. Because the material is pressed through small holes in the extruder, this functions as a screen allowing only small material to reach the wet fraction. During the compression, the solid material in the compression chamber holds itself, allowing only minor movement. In this way less solid material and no mechanically hazardous material will end up in the wet fraction. Stainless steel knives, for instance, could ruin pump linings potentially resulting in downtime of the later fermentation process. The amount of mineral fines is a lot less than with conventional screening because the material is pressed while it is how steady not allowing the sand and glass pieces to move to the screen. The same is applicable for the film fraction, there is some small film in the material but not disturbing for the digestion process. Because of this stable raw material, it is even possible to use dry digestion systems. The high quality of the wet fraction guarantees a durable fermentation process.

After fermentation, the digestate could treated by drying, screening and sifting to make the split of water, minerals and high quality stable RDF possible.

4 Conclusion

By using the extrusion procedure it is possible to separate municipal solid waste into two streams of material, a dry mainly non-organic fraction and a wet organic fraction, that each are more valuable with the absence of the other.

Author's address
Karl Dirkes
VM Press Technologies GmbH
db technologies BV
c/o Kolkmansweg 18
NL-7433 CL Schalkhaar
Telephone: + 31 (0) 55 72 82 37
Email: karl.dirkes@db-technologies.nl
Website: www.vmpresstechnologies.com

Current Status and Prospects of Mechanical-Biological Treatment in Germany

Thomas Grundmann, Michael Balhar

Arbeitsgemeinschaft Stoffspezifische Abfallbehandlung (ASA) e. V.

Stand und Perspektiven der mechanisch-biologischen Abfallbehandlung in Deutschland

Abstract

A total of around 25 % of urban wastes is pretreated by means of MBT technology (MBT = Mechanical-Biological Waste Treatment) in Germany. This technology is based on a material stream specific waste treatment. It means that the material properties of residual wastes - which are varying to a large extent - determine the selection and specification of treatment steps.

A large part of today’s residual wastes remaining after the collection of all substances which can't be recycled by means of material recovery and therefore need to be disposed of are a very inhomogeneous mixture of various materials with very differing properties. Some of these wastes are from mineral origin and thus inert, i.e. are not able to react. Others consist of dry materials like plastics, textiles, paper or composites, all of them showing energy contents higher than average. Some others with higher portions of organic material are able to be biologically degraded and are possibly able to produce usable gas. Here the principle of material stream specific waste treatment starts to become effective.

Material specific waste treatment segregates waste mixtures in different fractions. A first treatment step is the mechanical preparation where the waste mixtures are released from impurities and harmful substances, then classified in different partial streams, comminuted and prepared for the following treatment steps. Used for these purposes are e.g. sorting excavators, shredders, screening and mixing equipment, separators for the heavy and light fraction as well as for ferrous and non ferrous metals.

In most cases the subsequent biological treatment steps are based on aerobic treatment by means of different decomposition processes. The scope ranges here from open decomposition processes on landfill areas to completely encapsulated systems with exhaust air treatment. To some extent anaerobic digestion steps are integrated, producing - under air tight conditions - usable biogas.

In Germany about 50 MBT plants have been realised. These plants are pretreating approx. 6 million tons of municipal solid waste annually.

ASA is the association of German MBT plant operators. The main targets of ASA are:

- The promotion of waste stream specific waste treatment
- Extensive exchange of experience and knowledge in planning, construction and operation of mechanical biological treatment plants by means of meetings of working groups and plant operators with the target to provide all members with the experi-

ences about planning, realisation and operation of plants as well as with findings from research

- Support in the optimisation of plants and their operation
- Utilisation of plant capacities in a network/establishment of a common shortfall concept
- Support of members and public relation work
- Organisation and management of the international ASA Waste Days Conference.
- Research projects and expertises
- Statements on legislative drafts and ordinances for German and EU legislation

ASA is an active member in the European Compost Network (ECN) e. V. and in the Quality Assurance Association for Secondary Fuels and Recycling Wood (BGS) e. V.

Inhaltsangabe

Insgesamt werden in Deutschland ca. 25 % der Siedlungsabfälle mittels MBA- (MBA = Mechanisch-Biologische Abfallbehandlung) Technik vorbehandelt. Diese Technik basiert auf einer stoffstromspezifischen Abfallbehandlung. Das bedeutet, dass bei der Auswahl und Festlegung von Behandlungsschritten für Restabfälle deren - größtenteils sehr unterschiedliche - stoffliche Eigenschaften maßgebend sind.

Ein Großteil der heutigen Restabfälle, die nach der Erfassung der stofflich verwertbaren Abfälle noch übrig bleiben und somit entsorgt werden müssen, stellt ein sehr inhomogenes Gemisch aus den verschiedensten Stoffen mit sehr unterschiedlichen Materialeigenschaften dar. Manche dieser Abfälle sind mineralisch und damit inert, also nicht reaktionsfähig. Andere bestehen aus trockenen Materialien wie Kunststoffen, Textilien, Papieren oder Verbundmaterialien, die allesamt einen überdurchschnittlichen Energiegehalt aufweisen. Wieder andere enthalten höhere Anteile organischer Stoffe, die unter bestimmten Umständen sehr gut biologisch abbaubar sind und auch dabei noch möglicherweise nutzbares Gas produzieren. Hier setzt nun das Prinzip der stoffstromspezifischen Abfallbehandlung an.

Bei der stoffspezifischen Abfallbehandlung werden Abfallgemische in unterschiedliche Fraktionen getrennt. Die erste Behandlungsstufe ist die mechanische Aufbereitung, in der die Abfallgemische von Schad- und Störstoffen befreit, in die verschiedenen Teilströme aufgegliedert, zerkleinert und für die nachfolgenden Behandlungsschritte vorbereitet werden. Zum Einsatz kommen dabei beispielsweise Sortierbagger, Zerkleinerungsmaschinen, Sieb- und Mischanlagen und Abscheider für Schwer- und Leichtstoffe sowie Fe- und NE - Metalle.

In den nachfolgenden biologischen Behandlungsstufen erfolgt in den meisten Fällen eine aerobe Behandlung mittels verschiedener Rotteverfahren. Die Bandbreite reicht hier von offenen Rotteverfahren auf den Deponieflächen bis hin zu vollständig gekapselten Systemen mit Abluftbehandlung. Teilweise sind anaerobe Vergärungsstufen integriert, die unter Luftabschluss verwertbares Biogas erzeugen.

Die ASA ist der Zusammenschluss von deutschen MBA-Betreibern. Ziele sind:

- Förderung der stoffstromspezifischen Abfallbehandlung

- Umfangreicher Erfahrens- und Wissensaustausch aus Planung, Bau und Betrieb Mechanisch-Biologischer Anlagen in Form von Arbeitsgruppen- und Betriebsleitertreffen, mit dem Ziel, allen Mitgliedern die Erfahrungen aus Planung, Realisierung und Betrieb der Anlagen sowie die Erkenntnisse aus der wissenschaftlichen Begleitung zugänglich zu machen
- Unterstützung bei der Anlagen- und Betriebsoptimierung
- Nutzung von Anlagenkapazitäten im Verbund/Aufbau eines Ausfallverbundkonzeptes
- Mitgliederbetreuung und Öffentlichkeitsarbeit
- Organisation und Durchführung der internationalen ASA-Abfalltage
- Forschungsvorhaben und Gutachten
- Stellungnahmen zu Gesetzes- und Verordnungsentwürfen im Bundes- und EU-Recht

Keywords

Mechanisch-Biologische Abfallbehandlung, MBA, Ersatzbrennstoff, Energieeffizienz, Klimaschutz, Ressourcenschutz

Mechanical Biological waste Treatment, MBT, Refuse Derived Fuel, RDF, Energy Efficiency, Climate Protection, Protection of resources

1 ASA e. V. – The Association of German MBT Operators

Behind the abbreviation ASA stands the Registered Association for Material Specific Waste Treatment. The ASA e. V. is a consortium of German plant operators with the opinion that an economical and ecological waste treatment can be guaranteed in future only with material specific processes. All in all this includes of course thermal treatment and energy recovery of waste streams. For example the energy content of wastes is used to generate fuels for industrial power plants or cement kilns. At present 49 members are organised herein. The association's structure is shown in the following organisation chart:

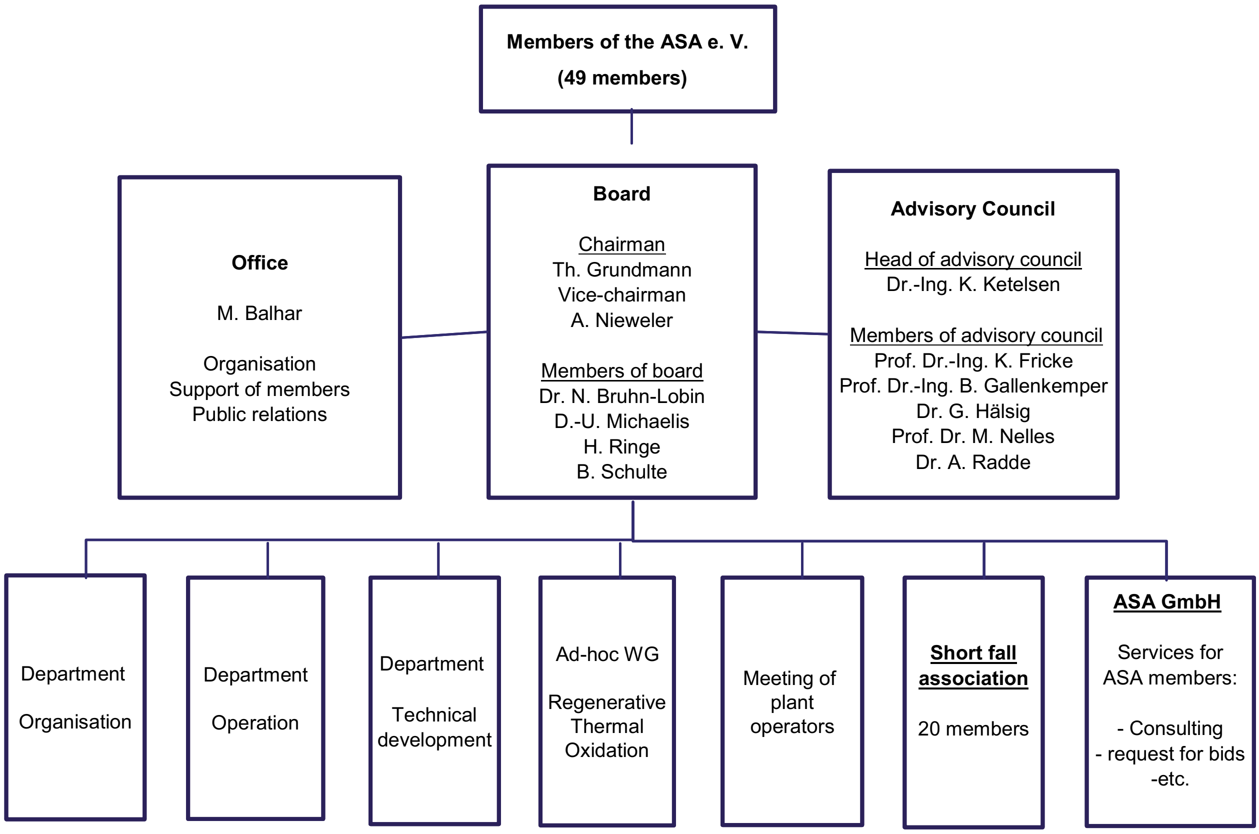


Abbildung 1 Organisation chart of the ASA Registered Association (January 2011)

The aim of ASA is to let their members participate in the experiences of planning projects, realisation and operation of plants together with findings from research. The Advisory Board of ASA stands for a close integration of the most recent state of the art of scientific knowledge.

ASA acts as service provider for its members. The association offers a broad spectrum of activities and benefits on different levels for their member companies. The target is to represent the interests of the members at the best; be it on the political platform or with public relations work and public representation, also on conferences, exhibitions and at training courses for member companies.

The roots of the association are based in the German State of Lower Saxony. This State positively influenced the development of MBT technology by supporting three pilot plants during the mid-nineties!

2 Status of MBT technology in Germany

The MBT technology is a comparatively young and innovative technology contrary to the technology of waste incineration which exists for more than 100 years. Therefore it must be understood that the MBT technology during its introductory phase showed some deficiencies, which in between are of no fundamental relevance anymore. These first problems increased through the short implementation period of the MBT concept. The enactment of the “Technical Instructions for Urban Wastes (TASi)" in 1993 showed the direction of the development but the German legal frame conditions for MBT as an alternative to waste incineration, the Landfill Directive and 30th Ordinance of the Federal Pollution Control Act (30. BImSchV), have been legalised not before March 2001. This left only four years for planning, tendering, approval, construction and start-up until the deadline of TASi organics diversion targets from landfills by the 1st of June 2005.

The approach to material specific waste treatment is shown in the three following processing concepts:

- **M**echanical-**B**iological **T**reatment (MBT-process, aerobe/anaerobe),
- **M**echanical-**B**iological **S**tabilisation (drying, MBS-process),
- **M**echanical-**P**hysical **S**tabilisation (drying, MPS-process).

The following diagram shows the locations of MBT, MBS and MPS plants set-up in Germany. Purely mechanically operating pre-treatment plants are not shown.

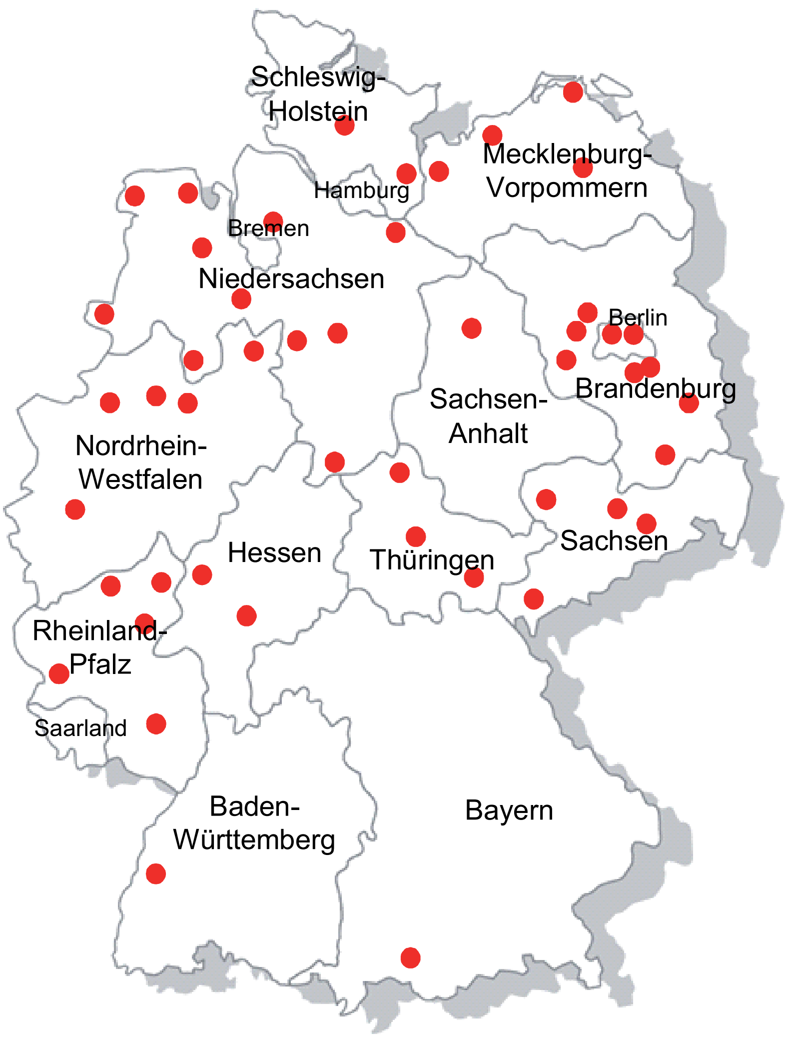


Abbildung 2 MBT, MBS and MPS plants in Germany

The data of single plants are published in the MBT Plant Profiles ("MBA-Steckbriefe") of the ASA. The plant descriptions have been compiled by the operators being also responsible for complete and correct specifications. The latest MBT Plant Profiles Collection can be ordered at the ASA Office.

The most common process for a material specific waste treatment is the **Mechanical-Biological Treatment (MBT)**. The material streams for recycling and for energy recovery are segregated first and then biologically treated. The biological treatment can take place in a decomposition step (tunnel, channel or windrow) or in a digestion step (dry or wet digestion). The final product is a material ready to be landfilled.

Abbildung 3 MBT plant of Ennigerloh, intensive decomposition hall of BIOWEST

A further process alternative is the **Mechanical-Biological Stabilisation (MBS)**. The aim of the MBS process is the biological drying of the total waste input to generate waste rich in calorific value in order to minimise the material stream to be landfilled. The first pre-treatment step is followed by conditioning for a subsequent drying. The total waste stream is furnished to biological drying in order to achieve a lowest possible organic degradation to reduce the humidity in the wastes. The released heat arising through self-heating processes of the organic waste components is purposefully used for the evaporation of waste humidity. The following dry-mechanical pre-treatment separates the dried wastes after segregation of metals, inert materials and impurities into one or several waste fractions with a high calorific value of different qualities.

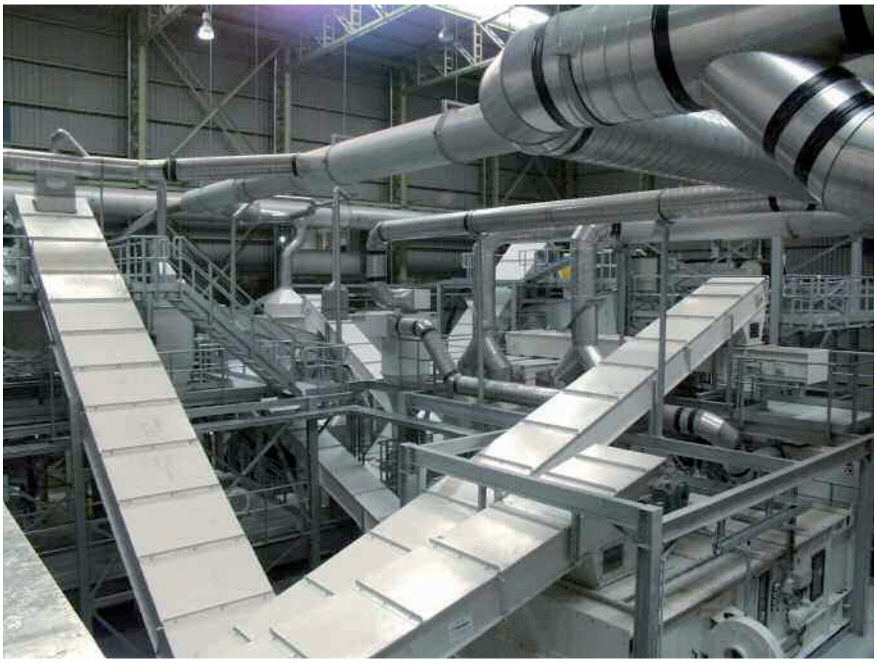


Abbildung 4 MBS AWIGO/Herhof, machine hall, Osnabrück

The third alternative, the **Mechanical-Physical Stabilisation (MPS)** selects waste components with high calorific values from municipal solid wastes just by means of mechanical and physical processes and prepared in the frame of a multi-step treatment process as substitute fuel (Refused Derived Fuel, RDF). This preparation process incorporates e.g. the separation of components low in calorific values and of the Fe and non ferrous metals and a multi-step comminution. If necessary, harmful partial fractions are segregated and the highly calorific fraction dried.

Abbildung 5 MPS BSR, drying unit, Pankow

In total about 25 % of the municipal solid wastes are pretreated in Germany by means of the MBT technology (MBT, MBS and MPS), this amounts to approx. 6 million tons annually! With the pre-treatment of wastes approximately 3 million tons of RDF are produced having a heating value comparable to wood or brown coal. With the energy produced a larger nuclear power station could be replaced. In addition the components of these fuels are of biogenous origin and thus CO_2-neutral. In such a way the MBT operators are contributing to the targets of climate protection.

A great part of the ASA members are realising the treatment of biogenous fractions of the waste by anaerobic methods. That means the waste is digested anaerobically and the produced gas is transformed e.g. in combined heat and power CHP plants into energy and heat, much to our regret predominantly without a feed-in reimbursement by the German Renewable Energy Act (“EEG”).

The residues from mechanical-biological treatment processes are stored in landfills compliant to the German TASi regulation so that we do not leave contaminated land to our future generations and the existing infrastructures can be used further.

Some of the regional MBT concepts did not solve the question of the destiny of the high calorific fraction at an early stage which led to shortcomings in the recovery of this fraction so that temporarily limited interim storage capacities had to be built.

Presently a multitude of power plant projects (so-called “RDF power plants”) are built in Germany on industrial sites like e.g. in the paper and cellulose industry or at soda factories, with the intention to make themselves more independent from the energy suppliers. ASA members are involved in many of these projects.

The MBT technology has established itself in Germany but meanwhile this technology is also of great interest for our European neighbours.

If one doesn't consider the very ambitious German requirements and limit values as standard, relatively small investments are necessary to realise the EU provisions and guidelines all over Europe quite rapidly.

3 Perspectives for MBT technology

The ASA Registered Association and the MBT operators agree upon that the future will be designed with a sustainable management of resources. The advantages of the MBT technology are to be seen in the material stream specific treatment and thus in an efficient recovery of resources.

These advantages have been supported by the present life cycle assessment research work of thermal disposal processes for combustible wastes of the Ifeu institute for the Federal State of North-Rhine Westphalia. This study emphasizes that the development of individual waste treatment processes can be designed individually with regard to the life cycle assessment. The available infrastructures are relevant for the individual advantages for the selected process. Even for the production of substitute/refuse derived fuels with following co-incineration.

The MBT technology enables a specific utilisation of the co-incineration and thus a substitution of fossil fuels at the generation of steam and energy.

Optional actions

For the fulfilling of future tasks and for an enlargement of the market for MBT technologies further developing work has to be done beside the increase of the availability and operating safety:

- Increase of energy efficiency through reduction of the internal consumption, more energy recovery from the high calorific and the wet organic fraction together with a reduction of emissions
- Further development of efficient sorting and confectioning technologies as module for the manufacturing of products for material and energy recovery
- Development of integrated concepts
- Provision of modular MBT technology for the international market

3.1 Increasing Energy Efficiency and Reduction of Emissions

The key to an increase for energy efficiency lies primarily in the increase of energy recovery from waste fractions with high calorific value, followed by the anaerobic utilisation of the wet organics part. The saving potential through a reduction of internal energy consumption is relatively low. Emissions can be reduced mainly by improved energetic effectiveness, partly also by use of up-to-date respectively modified treatment and recovery technologies.

3.1.1 Increase of the energy recovery of waste components with high calorific value

The following paragraph deals with two approaches regarding MBT processes with which plants which are presently adjusted to the generation of products to be landfilled can be retrofitted to generate products for energy and material recovery of refuse derived fuels.

- Approach 1 aims on the segregation of a higher portion of the high calorific fraction. For this purpose merely a modification of the screen profile in pre-treatment respectively confectioning is necessary. Reducing of the screen profile of the first screening step - before biology works - assures that the fractions with a high calorific value but also biodegradable like paper/cardboard/paperboard containers, packaging material and diapers can be transferred into the fuel fraction. Supplementary the screen profile could also be reduced after biological stabilisation.
- Approach 2 provides - in addition to the modification of the pre-treatment and confectioning technology - a changeover of the biological treatment towards drying and if necessary the integration of physical drying.

  Basically all MBT aerobic technologies (tunnel, box, table windrow processes) presently aiming on the manufacturing of products suitable to be landfilled, are also useable for drying and the manufacturing of RDF. A pre-condition is a sufficient content of biodegradable components. Through modification of the aeration equipment not pretreated waste and percolation residues can be dried to a water content of < 15 % without any problems with the existing technology. Solid residuals from digestion are only restrictedly able to be dried on account of the DM degradation in the digestion process of about 40 to 50 %. On the other hand the drying target to a water content of < 15 % can be achieved here, too, if external heat is supplied into the aeration process, available through the combined heat and power station CHP which usually exists on digestion plants.

  The available decomposition volume by means of the reduction of the treatment time can partly be used for a co-treatment (drying) of parts of the highly calorific fraction. A further option exists in a co-treatment of bio wastes - separated from the residual wastes - for the manufacturing of compost, refuse derived fuels or a preliminary product for fuel production. Both of the last-mentioned recovery options have one common treatment target which is drying. Other biomasses besides bio waste can be co-treated, first of all agricultural production residues and energy crops. If water contents are achieved being distinctly lower than 15 % physical dehumidifier must be used, if necessary also in addition to the existing biological drying. Special advantages deliver processes on sites with unused exhaust heat like e.g. in digestion, sewage and power plants, landfills or waste incineration sites without heat consumers.

As far as the market situation for refuse derived fuels and the availability of recycling capacities justifies this MBT plants could be retrofitted on modified “production targets” - thus having a high flexibility.

3.1.2 Developments at anaerobic technology

The anaerobic technology in residual waste treatment hasn’t yet the significance, which on account of their energy efficiency would be justified. The reasons why are complex:

- Digestion plants with a downstream aerobic step show higher investment costs than pure aerobic plants

- Compared with the aerobic technology the anaerobic digestion technology doesn't have the same development status and not all of the cases can grant the required operational safety

However, in Germany the use of digestion technology when treating solid wastes increased considerably. This technology gained a massive support through the appreciation of regenerative energies regarding their sustainable contribution for the protection of climate and resources.

A need for research work exists for the following areas:

- Retrofitting of anaerobic steps
- Confectioning of solid digestion residuals for the manufacturing of products for energy and material recovery
- Type of biogas recycling
- Operational safety and availability

By means of these development and optimisation works the performance of the digestion technology can be increased, the economical basic data improved and the relevance of digestion as a process with a high recovery efficiency enhanced.

Biogas recycling

The most common kind of use of biogas momentarily is to provide electric power as joint district heating in combined heat and power plants with an efficiency of maximal 40 $\%_{electrical}$. The use of the heat is mostly restricted on the heating of the substrate in the fermenter. Future utilisation methods should have distinctly higher efficiency degrees. High expectations are placed on the fuel cell technology, which has a series of advantages compared to combined heat and power plants CHPs:

- According to the manufacturer's specifications a total efficiency of up to 90 % and electrical efficiency of nearly 50 %
- Extensively poor in maintenance and noise
- Good exhaust gas qualities on account of the spatial separation of fuel and oxidation agents which on principle avoids the arising of harmful gases, like nitrous oxides

Some types of fuel cells could prove their usability in the frame of a demonstration project. Due to the early stage of development of the fuel cell technologies they are still very cost intensive. However, distinct cost reductions are expected for the future.

Further options for recycling with a high energetic effectiveness are:

- The upgrading of biogas to natural gas quality and the feeding in the natural gas grid
- The operation of combined heat and power plants CHPs with absorption refrigerating plants
- The use of surplus heat of CHPs for drying of waste material in biological or physical drying plants

Aerobic stabilisation of digestion residues in the liquid phase

The aerobic stabilisation of digestion residues in the liquid phase (“wet oxidation”) is arranged as a second biological treatment step following wet digestion with and without downstream conventional decomposition. The following advantages are expected from wet oxidation:

- Cost advantages compared to the conventional decomposition by comparably short dwelling times
- Smaller exhaust gas emissions, especially when air is enriched with oxygen
- Improved energy effectiveness by lower energy demand at the stabilisation step

The wet oxidation is realised in several MBT plants on a large scale with wet aerobic steps for a post-treatment of the liquid digestion residues. The successful implementation of this technology would have decisive effects on the digestion technology with both the biological and residual waste treatment.

3.2 Sorting Technology

Despite of the considerably improved sorting technology the separate collection of paper, cardboard, glass and bio waste cannot be questioned on account of the quality demands related to hygiene and the potential toxic elements load. Considering the total system no advantages for these materials can be expected when it comes to cost analysis. Another situation is given with the collection of light packaging material, where in the past in Germany several alternatives for the collection and pre-treatment of packaging material have been discussed and tested respectively are still in a testing phase (e.g. “yellow bin plus”, “dry recyclables bin”, "bag in container”).

MBT technologies are offering good preconditions for the integration of the sorting of wastes from packaging and probably non-packaging materials similar to packaging through the existing construction and process engineering infrastructure.

3.3 Development of Integrated Concepts - Using Centralised MBT Sites as a Centre for Renewable Energy Production

In most of the cases MBT plants in Germany are situated on landfill sites or close by. MBT sites, especially those connected to landfills, have a very well developed logistic, disposal and traffic infrastructure thus offering good preconditions for the processing of bulky goods like biomass and products from biomass. Additional synergistic effects can be seen if near the MBT location biowaste composting and digestion plants are operated especially for the biomass recycling and the construction of centres for the production of renewable energies from biomass:

- The on-site infrastructure for gas or leachate recovery/treatment offers ideal conditions for the additional installation of a digestion unit for residual organic materials. If gas recycling plants exist decreasing gas amounts from landfills can be compensated by biogas from the digestion of organic residues from agriculture respectively by means of energy crops.
- From an economical point of view in future rather large scale plants will be preferred for the recycling of organic residues and energy crop (digestion plants and biomass

power stations). In cooperation with agriculture correspondingly large units on the MBT respectively on the landfill site can be built.

- Pellet works, too, could be a component of these energy centres: agriculture, forestry and suitable industrial business are delivering biomass to produce pellets for small and smallest fire places - if applicable with interim storage - for the final consumer (industrial business, domestic heating), centrally or decentrally sold respectively marketed.
- Regarding the future essentially tightened requirements for soil protection and by the energy supporting effects of the Renewable Energy Act "EEG" besides the soil related use of compost also energy recovery approaches can be realised. Considering green wastes this process started already. Biowastes and biowaste-digestion residues are then treated to generate fuels instead of compost. Necessary for that option is a mechanical pre-treatment and drying.
- In order to produce so-called BTL fuels („Biomass to Liquid") plants with processing capacities of several 100.000 tons/a will be necessary. To lower the transport activities and to balance seasonal fluctuations of arising biomass a decentralised collection with interim treatment and drying together with interim storage at a MBT site could be a suitable solution.

All of the above mentioned process modifications can be integrated in the MBT process or additionally operated with synergy effects. A capacity enlargement usually associated herewith a better utilisation of capacities and of the synergy effects are offering best preconditions for an improvement of efficiency and the ecological total assessment of the MBT technology - last not least the economical frame conditions could be sustainably improved.

Author's addresses:

Thomas Grundmann, Michael Balhar

Arbeitsgemeinschaft Stoffspezifische Abfallbehandlung (ASA) e. V.

Westring 10

D-59320 Ennigerloh

Telefon +49 2524 9307-18

Fax +49 2524 9307-12

Email info@asa-ev.de

Website: www.asa-ev.de

THE IMPACT OF INCREASED DIFFERENTIATE COLLECTION ON EXISTING MBT PLANT AND POSSIBLE UPGRADING SCENARIOS: THE EXPERIENCES OF A CENTRAL ITALY PLANT

Francesco Di Maria* and Moreno Marionni+

*Department of Industrial Engineering, Perugia, Italy – +Centro Ambiente, Foligno, Italy

Abstract

The management and the production of MSW has been interested by many changes, during the last twenty years, mainly related to the new policy strategies in recycling and recovering. A large part of the Italian existing MBT facilities operates since the 1990, designed when the waste quality and quantity were quite different from the current one.
In fact, the increase in differentiate collection and the need to pursue higher amount of recovered materials, have changed significantly the amount and the features of the material entering the existing MBT plants, causing some operative problems.
For these reasons, many existing MBT plants need to be upgraded for being able to operate, in a sustainable and sound way, in the current and future waste management's scenarios. The present work analyses the historical and current performances of an existing MBT facility, that operates in a central Italy's region, and some possible upgrade for increase the whole process efficiency.

Keywords

MBT, Energy, Biological treatment, Solid State Anaerobic Digestion, biogas, SRF, WtE

1 Introduction

Over the past 15 years, the waste management system, in Italy as in Europe, has undergone a cultural revolution geared mainly to environmental protection and to waste material reuse and recovery. An important tool for achieving these objectives is the implementation of efficient differentiate collection systems and the adoption of facilities that can allow an adequate treatment of the different waste that flow from the various waste collection. Among these plants, those MBT have represented and still represent an efficient means both for sorting and stabilization (i.e. composting or aerobic stabilization), of the waste organic fraction (OFMSW). In Italy, the MBT facilities have been build since the end of the ’80, when, both the quantity and the separate refuse collection rate, were quite different from the current and from the one that it is expected to be achieved in the next future. The new goals imposed by the recent European directive 2008/98/CE, concerning the increase of the waste material's recovery rate, have increased the amount of waste collected in differentiated way. In Italy, the current rules impose to achieve the 65% of differentiate collection in the 2012 (D. Lgs. 152, 2006).

The waste management system considered in this work is the number 3 of the Umbria (Fig. 1), a central Italy's region, in which, the waste collection and management, is divided in four Main Districts (MD). The Non Differentiate Waste (NDW) collected in the MD n°3, about 75.000 ton in the 2010, are processed in a MBT facility, operating since the ’94, before being disposed in landfill.

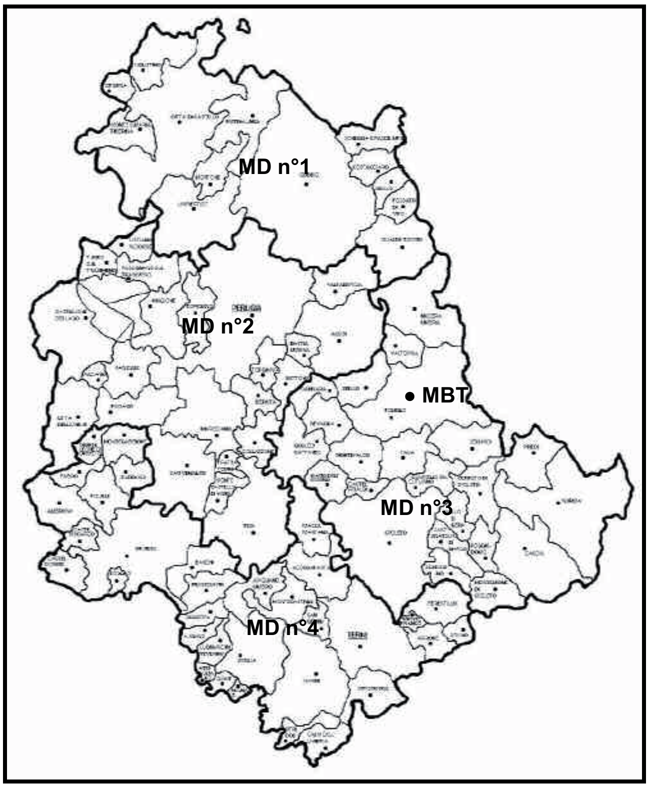


Figure 1 Umbria Region MD and MBT location.

The existing MBT facility was designed for treating a different quantity and quality of waste compared to the one currently collected and from the one that will be collected in the next future. For this reason, in the present work, the possibility of upgrading the existing MBT facility to the new operating conditions, has been analyzed and discussed.

2 THE MBT AND WASTE COLLECTION EFFETCS

2.1 The MBT facility

The Mechanical Biological Treatment facility (Fig. 2), has been designed at the end of the ’80 and starts operating at the end of the ’94. The plant was designed for treating about 38.500 tons per year of NDW, on daily shift of six hours (Tab. 1). The NDW is discharged directly in the storage trench by the collection lorry. By the aid of an orange peel crane bridge, the NDW is inserted inside the bags opener (Fig. 3). Then, by a belt conveyor, is moved to the sorting section, where a trommel with holes of 100mm of diameter, provides to separate the NDW stream in two main flows, an undersize flow and an oversize flow. The metals content of the undersize fraction, rich of organic matter, is separated by magnets and eddy current systems (Marionni and Rossi, 2011). Once the metals have been separated, this fraction is treated in the ACT section of the plant (Fig. 4). This section consist of a concrete basin of 1.700 m3, with an aerate floor, on whom a bridge crane with screws, stirs the organic fraction and moves it from the inlet section to the outlet section. The mean Retention Time (RT) of the undersize in the ACT section, at the design conditions, was of about 21 days. After the aerobic phase, the undersize is further stabilized and then disposed to landfill. The oversize fraction, is deferrized and then further sorted by an aeraulic separator (Fig. 3). The aeraulic separator provides to separate, from the oversize fraction, the lighter components, as paper, plastic and textile, for the production of SRF. The remaining fraction, after the aeraulic separator, is directly disposed in landfill.

Figure 2 Existing MBT plant.

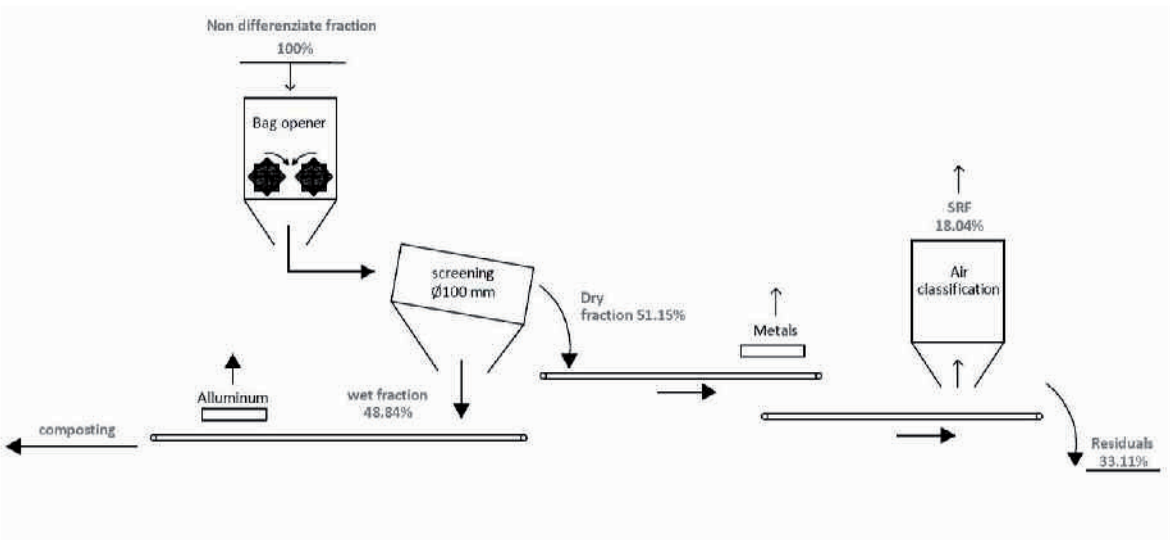


Figure 3 MBT mechanical sorting section.

Figure 4 MBT biological ACT section.

Table 1 MBT design main feature

Parameter	Value	Unit
MSW inlet	38.500	t/year
MSW inlet	110	t/day
Shift hour	6	hour/day
ACT volume	1.700	m^3
ACT RT	21	Day

2.2 Waste collection and effects on MBT process

Since '94 until today, many changes are occurred both on waste quantity, on quality and on management strategy. Since the early '94 (Fig. 5 a) the NDW treated in the MBT facility, was about 38.500 ton per year, but after two years this quantity reached about 60.000 tons per year. During the years, waste rate was continuously increased until the 2007, when the increase in the fraction of Differentiate Collection (DC) and changes in management strategies, starts to give their first results. The increase of the amount of waste treated yearly by the MBT facility, led to an increase of the daily working shift, that passed from the initial 6 hours per day at the 12 hours per day. In this way the amount of waste treatable has been increased from 110 to 220 tons per day. Another important effect of the increased amount of waste treated by the plant, is represent by the significant reduction of the RT of the undersize fraction in the ACT section, with the risk of a consequent reduction of the stabilization degree of the organic fraction (i.e. D.R.I. > 1.000). In fact, this waste, according with Italian rules, can be disposed in land-fill only if its Dynamic Respirometry Index (DRI) is not higher than 1.000 [gO2/kgVS.h]. For this reason, starting from the year 2000, the undersize, after the ACT section, undergoes to a further composting stabilization process with turned heaps (Fig. 5 b). As con-sequence of the increased DC rates and of the needs of achieving both a reduction of the organic fraction disposed to landfill and an increase in waste material recovery, starting from the 2006 the ACT basin's has been split in two different volumes. About 500 m3 were dedicated to the ACT for the production of a high quality organic fertilizer, produced from the waste organic fraction arising from the DC, leaving about 1.200 m3 available for the ACT of the undersize flow.

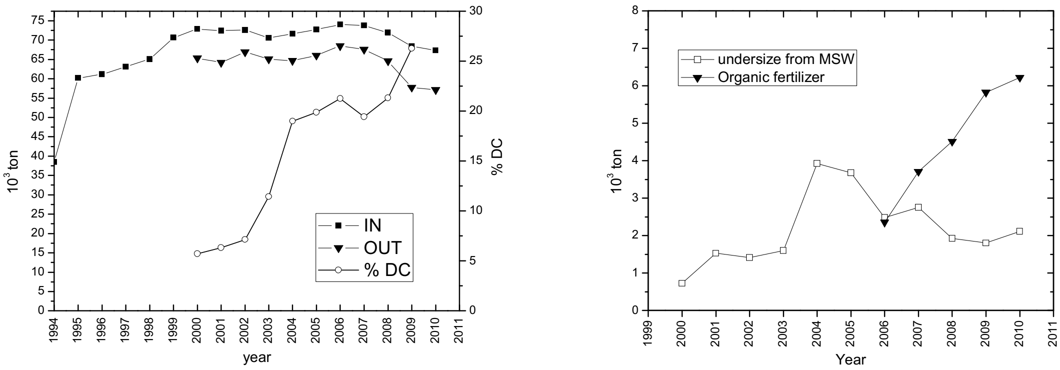


Figure 5 a) MBT plant NDW inlet, waste outlet and DC rate, b) Undersize Compost and organic fertilizer production.

This choice has lead to a further reduction of the RT of the undersize fraction inside the ACT section. As reported in Figure 6, the NDW composition, results to be quite constant during the years, with some reduction in the organic fraction, paper and cardboard, and with an increase in plastic and metals, as consequence of the DC and of the management strategies.

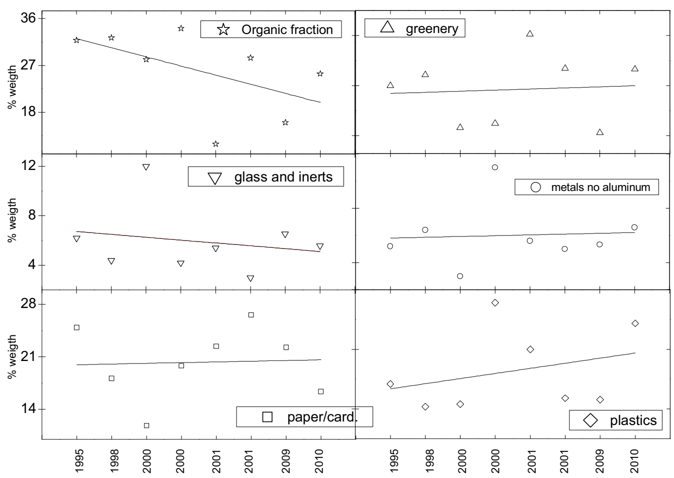


Figure 6 NDW composition.

Currently, the MBT plant recovers also about 700 tons per year of iron, and about 50 tons per year of aluminium, moreover, the absence of a regional incineration plant has prevented the SRF production.

2.3 2012 scenario

Starting from the 2009, some important modification to the regional waste management system have been introduced. Among the different goals, the most relevant are represented by the achievement of 65% of DC at 2012, and the realization of a new regional incineration plant at 2016. On the basis of the forecast adopted by the waste management regional plan (Consiglio Regionale Umbria, 2009), the amount of the different's wastes stream, expected at the MBT plant inlet, is represented in Table 2. Despite the strong reduction of the Organic Fraction (OF) arising from the NDW, a strong increase in the OF from DC is expected at 2012.

Table 2 Waste expected at the MBT inlet (2012).

Parameter	Value	Unit
NDW inlet	36.167	t/year
OF from DC	11.170	t/year
OF from NDW	17.665	t/year

Furthermore, on the basis of different experimental analysis performed on the aeraulic separator of the oversize waste fraction, it is possible to evaluate the incidence and the composition of the lighter fraction exploitable for SRF production (Tab. 3).

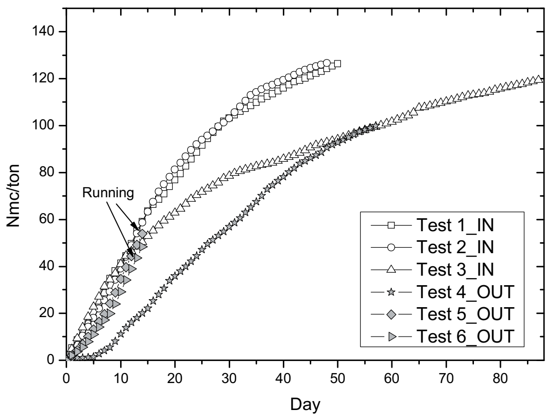
Table 3 SRF production and composition (2012).

Parameter	Value	Unit
SRF	6.526,6	t/year
Plastic	28,4	%
Paper/card.	50,8 %	%
Textil	7,70	%
Organic	4,40	%
Other	8,70	%

The datas reported in Tables 2 and 3 show how the operating conditions of the MBT plant will change significantly in the next future. In particular, the strong increase of the Organic Load [kgV.S./m^3] (OL) treated by the ACT section, will lead to a dramatic reduction in the biological process efficiency and so of the quality of the stabilization process. This means that some facility modification's and upgrading's seem to be urgent for ensuring high efficiency in waste treatment together with high degree of environmental protection.

3 MBT PERFORMANCES ANALYSIS

The first aspect investigated in this study, is represented by an evaluation of the current process efficiency of the MBT plant. Starting from the mechanical sorting section, different experimental evaluations have been performed, both for analyzing the quantity and the quality, of the different streams exiting from this section. The second aspect investigated, concerns the efficiency of the aerobic stabilization process performed in the ACT section. In particular, for the aim of this work, the bio gasification potential, of the NDW undersize fraction, at the inlet and outlet of the ACT, has been performed by the aid of an experimental apparatus (Fig. 7a). Finally, an analysis of the lighter fraction, separated by the aeraulic system, has been performed for evaluating the suitability of this waste fraction for SRF production.



a) b)

Figure 7 a) Experimental apparatus for the evaluation of the Biogasification potential; b) Biogas production of the undersize fraction entering (IN) and exiting (OUT) the ACT section.

Referring to the Figure 3, a mass balance and composition of the different waste streams, entering and exiting from the mechanical sorting section, has been performed (Tab. 4). The NDW enters the drum's sieve, with holes of 100mm of diameter, provides about 50% of undersize and about 50% of oversize. The undersize is composed mainly of biodegradable waste, about 65%, as organic and < 20 mm undersize, while the oversize is mainly composed by dry fraction (>70%) as paper, cardboard, textil, and plastic. The SRF, selected by the aeraulic separator, represents about the 35% of the oversize and is composed mainly by paper, cardboard and plastic (>75%). Also an important quantity of waste with <20's mm dimension, is present in this fraction. For evaluating the biogasification potential of the NDW organic fraction, that enters and exits the ACT section, different samples have been selected and treated in the experimental apparatus shown in Figure 7a. The results show (Fig. 7b) how this particular waste fraction, is able to produce about 120-130 Nm3/t, for the stream at ACT inlet, and about 100 Nm3/t, for the stream at ACT outlet, of biogas with a methane fraction higher than 50% (Di Maria et al., 2010).

Table 4 Different waste streams mean composition, entering and exiting the mechanical sorting section.

Component	NDW	Undersize	Oversize	SRF
Paper/card. (%)	23,0	8,60	36,9	50,8
Plastics (%)	17,2	10,3	23,9	28,4
Org. Fraction & greenery (%)	34,7	58,4	13,2	4,40
Textil (%)	6,96	2,90	10,9	7,70
All. and tin (%)	1,09	1,29	0,93	0,30
Iron (%)	3,29	3,11	3,53	0,30
Glass and inert (%)	5,58	7,15	4,23	0,30
Others (< 20 mm) (%)	7,00	8,20	6,03	7,80
% of NDW (%)	100	48,8	51,2	18,1
Mass rate 2010 (t/year)	67.350,7	32.894,1	34.449,9	12.156,8

The biogas production potential of the stream exiting the ACT section, indicate that the stabilization process is not so efficient in consequence of the overcharge of OL, caused by the strong increase in waste entering the plant. In fact, the current ACT operating conditions are far from the design one. This reduces the RT of the organic fraction inside the aerobic's ACT basin. On the basis of the new waste management regional plan, this scenario will not change as a consequence of the strong increase in the organic fraction arising from the DC, inspite of the reduction of the fraction arising from the NDW. The biogas production potential of the organic fraction, arising from the DC, is not investigated in this study, because already investigated in previous works by the author (Di Maria et al., 2010).

The SRF fraction, drawn by the aeraulic separator (tab. 4) from the oversize stream, is composed mainly by paper, plastic, textile, but there is also an important fraction of organic, inerts and < 20 mm fraction (Fig. 8), that needs to be reduced for increasing the SRF's quality. Another important aspect, that could be improved, concerns the SRF fraction's size. In fact, some incineration plants, like fluidized bed or gassifier, could require dimensions strictly imposed of the SRF.

Figure 8 SRF separated by the aeraulic separator.

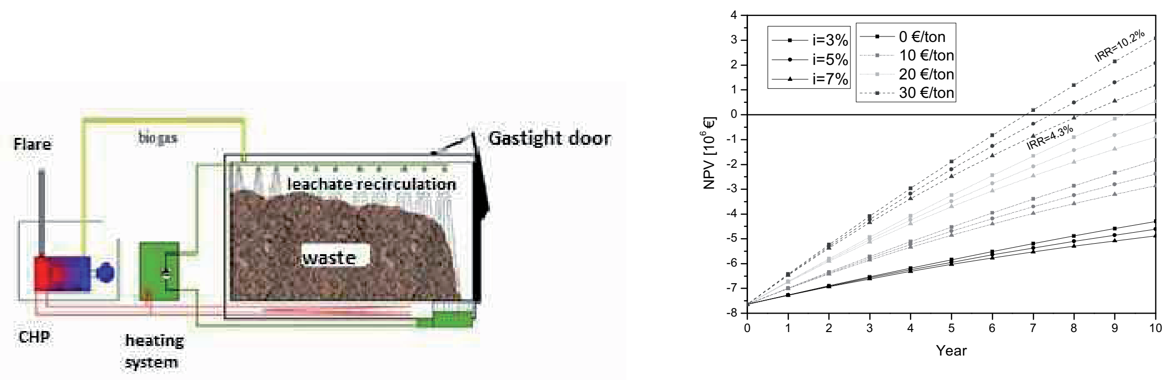
The SRF's quality has been determined on the basis of experimental analysis and data available in literature (Tillmann, 1991). Then, the values obtained have been further modified considering the humidity content evaluated experimentally on different SRF samples (Tab. 5).

Table 5 SRF main features.

Parameter	Value	Unit
NCV	12,593	Mj/kg
Cl	1,36	% db
Hg	< 0,02	mg/MJ
Humidity	33,11	%

4 MBT IMPROVEMENTS

The significant increase of the NDW processed by the MBT plant, compared to the design ones, does not represent a serious threat for the efficiency of mechanical sorting process. In fact, currently the MBT treats about 220 tons per day, working on two shift of 6 hours each one. In this way, the amount of waste treated per hour remain constant (Tab. 1). The significant reduction of NDW expected for the next future will contribute to prevent problems for this section. Otherwise, the biological section's, ACT, shows some relevant drawback and a significant treatment efficiency reduction. These problems can be stressed by the strong increase in the organic fraction arising from the DC, characterized by a higher OL content, expected for the next future. For this reason some upgrades of the plant seems to be necessary. The main goal to pursue for this section is doubtless represented by an in-crease of the capability of reduction the OL of the treated waste. This aim can be achieved in different ways, by the aid of different technologies, but the biological one seems to be the most sustainable. Furthermore, the biological section's upgrading, must allow to the aerobic existing basin, ACT, to continue in operating without significant modifications. For this reason the proposed solution consist in the construction of a new anaerobic section, based on the process of the Solid State Anaerobic Digestion (SSAD) (Di Maria et al., 2010), in which both the organic fraction arising from the DC and from the NDW, can be treated, before a further stabilization process by the existing ACT, biological section. The SSAD is generally performed inside batch, concrete biocells (Fig. 9a), in which all the main parameters of the process are controlled. The pre treatments required for the organic fraction, before being treated inside the biocells, is very similar to the one currently required for the organic fraction treated inside the existing ACT section. Furthermore, this technology shows a narrowed liquid production, that is an important aspect in the management of such process. On the basis of the experimental analysis performed, considering a mean anaerobic process duration of about 28 days, the expected biogas production is of about 80 Nm^3 and 110 Nm^3, respectively for the organic fraction arising from the NDW and from the one arising from the DC (Di Maria et al., 2010).



a) b)

Figure 9 a) SSAD biocell schematic; b) NPV for the SSAD facility.

This means that, considering the data reported in Table 2, the yearly biogas production is of about 2.600.000 Nm^3, from which it could be possible produce about 4.500.000 kWh of electrical energy (Tab. 6). The expected revenues from the sold of the electrical renewable energy, are of about 1.250.000 €/year. The economical simplified analysis of such investment, performed by the aid of the NPV (Fig. 9b), shows that the payback period ranges between 9 to 7 years, depending on the different parameters values. Furthermore, starting from an inlet rate of 20 €/t, the payback period becomes lower than 10 years and the Internal Rate of Return (IRR) is always higher of 4%. The mean RT of the organic fraction in each biocell, is of about 56-60 days, giving a strong contribution to the reduction of the OL, reducing the expected overcharge of the existing ACT section. The SRF separated by the aeraulic sieve, needs some further refining before being exploited as fuel. In particular, the aim is to achieve a fluff fuel with 50x50mm size. The proposed refining line, to be implemented for this aim, is represented mainly by a pre-shredder, with low speed rotation shaft, and post-shredder with hammers (Fig. 10). On the basis of eq. (1), the energy required for the pre-shredder process, is of about 5,5 kWh/t. The energy estimated by the eq. (2) for the post-shredder is of about 7 kWh per ton. Considering also the contribution of the iron separator, of the conveyors and other system auxiliary, the energy consumption for each ton of SRF refined can be assessed in about 15 kWh per ton.

Table 6 SSAD technical and economical parameters.

Parameter	Value	Unit
Biogas	2.641.900	Nm^3/year
Net electrical production	1,70	kWh/Nm^3
Investment	265	€/t_{in}
O. & M.	30	€/t_{in}
Revenue	0,28	€/kWh_{el}
Actualization rate	3-5-7	%

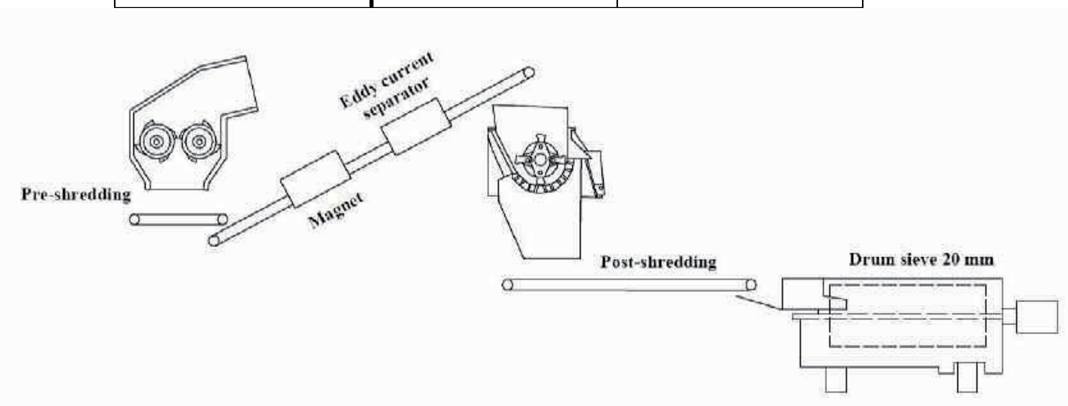


Figure 10 Schematic of the SRF refining line.

$$E = 35{,}55 \cdot (d_{out})^{-0{,}81} \text{ [kWh/t]} \quad (1)$$

$$E = C \cdot \ln\left(\frac{d_{in}}{d_{out}}\right) \text{ [kWh/t]} \quad (2)$$

After the dimensional reduction line, it is proposed the adoption of a drum sieve, with hole of 20mm of diameter, for separating the undersize fraction, generally rich of inert and organic matter. Considering a further humidity reduction of 5%, as a consequence of the mechanical treatments, and considering the reduction of organic and inert content, the obtained SRF seems to be classified as NCV 4; CL 4; Hg 1 (Tab. 7).

Table 7 SRF main features after refining line.

Parameter	Value	Unit
NCV	13,918	Mj/kg
Cl	1,38	% db
Hg	< 0,02	mg/MJ
Humidity	28	%
Treatment costs	6-10	€/ton

5 Literature

Consiglio Regionale Umbria	2009	"Piano regionale di gestione dei rifiuti", Deliberazione n°300, May, 05.
Di Maria, F., Sodi, A., Micale, C.	2010	"MSW "Solid State Anaerobic Digestion to Energy for the organic fraction of MSW: real case experimental analysis", *ORBIT 2010*, June 28 – July 03, Heraklion – ISBN 9789606965251
Tillmann, D., A.,	1991	"The combustion of solid fuels an waste", *Academic press*, San Diego, ISBN 0-12-691255-6.

Author's addresses:

Prof. Francesco Di Maria
Department on Industrial Engineering
via G. Duranti 1/A-4
06125 Perugia, Italy
Telephon +39 5853738
Email fdm@unipg.it

Dr. Moreno Marionni
Centro Ambiente spa
Via delle industrie 9
06037 Foligno, Italy
Telephon +39 0742 391474
Email m.marionni@centroambiente.it

Interaction of systems and feeding of bio methane into the gas pipeline network

Burkart Schulte

Gesellschaft zur Verwertung organischer Abfälle (GVoA) Pohlsche-Heide

Keywords:
MBT, biogas, gas treatment, gas injection

1 Introduction

The Waste Management Center Pohlsche-Heide is responsible for the management of the waste generated from the 330,000 inhabitants and the commercial waste at the district of Minden-Lübbecke. This district is located in the east – north end of the state North Rhine-Westphalia.

At the Pohlsche-Heide are treated about 200,000 tons of waste per year. To save our natural resources, optimal solution for waste is the reutilization at a high efficient level.

Three highlights of our waste treatment centre at Pohlsche Heide are the mechanical-biological treatment plant, the compost plant, two digesters and the landfill.

Waste of up to 100,000 tons can be treated in the MBT per year. The waste is segregated in the mechanical part of the MBT into different components.

The combustible components are delivered to an incineration plant in Minden to produce process steam for the industry. Other valuable components are sorted out and used as raw materials. The organic components are fermented in a digestion reactor of the type DRANCO and produce around 120 m3 per ton input; the produced gas is conveyed into CHP and also used for the thermal treatment of exhaust air coming out of the compost plant. After de-gassing, the solid organic matter is fed to the compost unit of MBT and finally dumped at the landfill.

As a consequence only one third of the combined input is being dumped at the landfill. The majority of input material leads to energy production or to valuables.

The landfill run by The Pohlsche Heide was built 1988 and expanded in 1994. It is up to date and fulfils all technical and legal requirements. The landfill is equipped with a modern refuse dump seepage treatment and gas extraction system with utilization of gases in two CHPs.

The Minden Luebbecke District is going to use this engineered landfill for a long-term period. Around 2 million m³ are filled already and another 2.5 million m³ are ready to be filled up. At the landfill only biological inactive material of the MBT as well as non-utilised mineral waste are implemented into the system.

At the waste treatment centre Pohlsche Heide the GVoA is operating a compost plant for biological household and garden waste. Brought into continuous operation since beginning of 1995, 40,000 tons of bio waste and about 10,000 tons of garden waste are being composted per year. The ready-made products of compost are being directly sold from us. Since December 2009 we have add a digester type BEKON prior to this plant. Herewith we are able to produce around 90 m3 of gas with a Methane content of 55% per ton input or around 400 m3 per hour. This gas is treated to the quality of natural gas (95 % Methane) and feed into the public Gas net. Raw biogas produced from digestion is roughly 60% methane and 29% CO_2 with trace elements of H_2S, and is not high quality enough if the owner was planning on selling this gas or using it as fuel gas for machinery. The corrosive nature of H_2S alone is enough to destroy the internals of an expensive plant. The solution is the use of a biogas upgrading or purification process whereby contaminants in the raw biogas stream are absorbed or scrubbed, leaving 98% methane per unit volume of gas.

For the treatment of the gas we use a pressure swing adsorption (PSA) process by means of carbon molecular sieve and catalytic H_2S-removal from the company Carbotech (see figure 1).

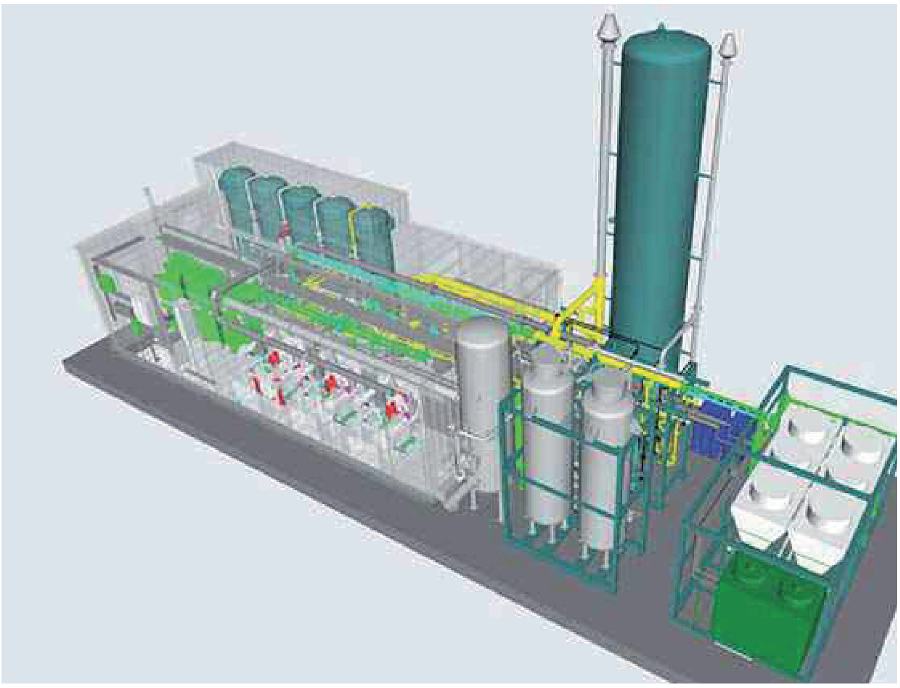


Figure 1: Carbotech's carbon molecular sieve and catalytic H_2S-removal

The biogas is compressed and then first removed from H_2S by a catalytical active activated carbon followed by a moderate cooling to knock out the water. This pretreated biogas is then streaming through one of four adsorbers filled with molecular sieve; here the impurities like CO_2 , H_2O, H_2S siloxane, NH_3 , odors, partial N_2 & O_2 and others are taken up by a sponge and methane is produced. After certain time intervals it will be switched over to the next adsorber and the previous is then regenerated completely by vacuum. PLC-control and online CH_4 - / O_2 analysis ensure an automatic operation.

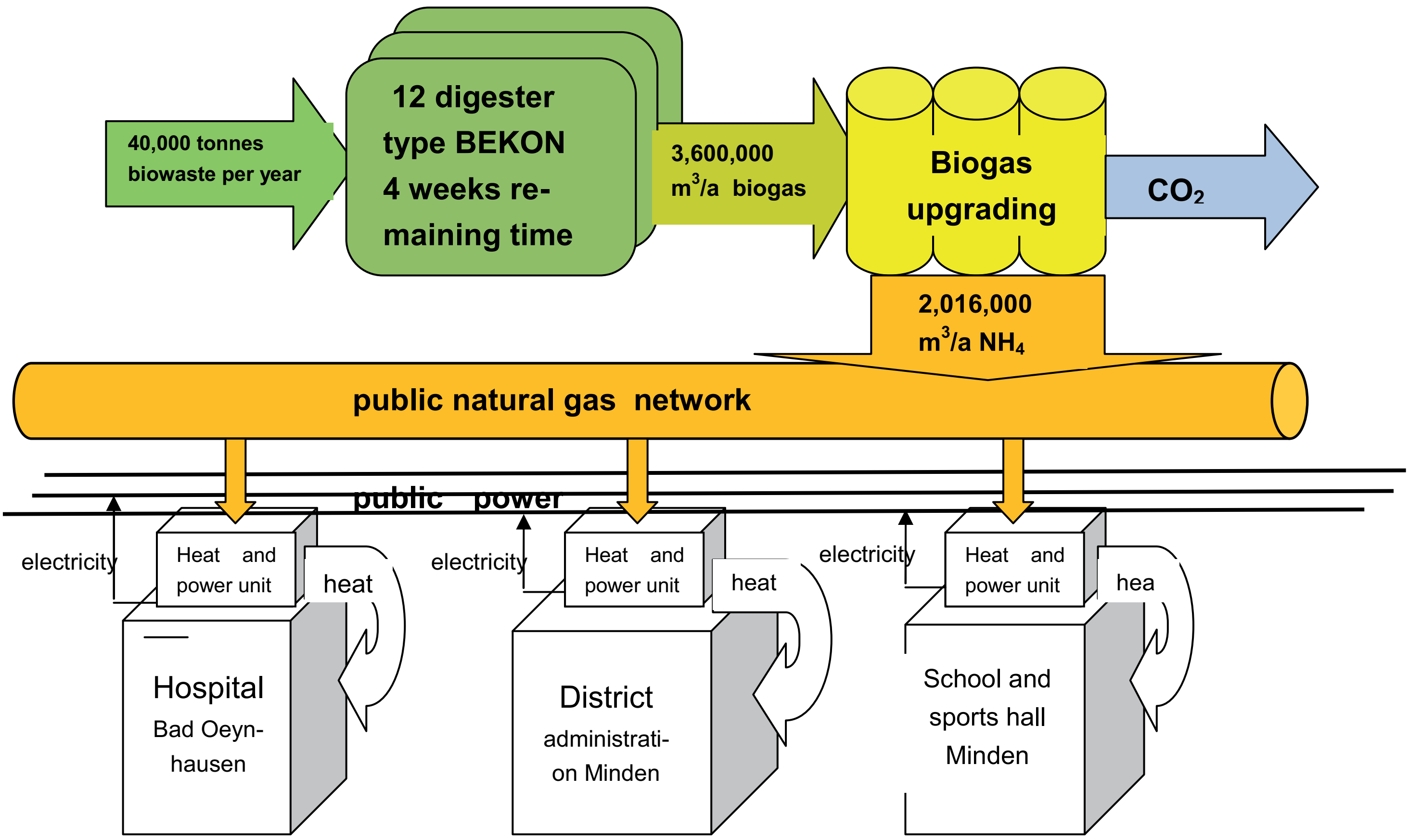


Figure 2: gas network example

The biogas is transported by the public gas pipeline to important belongings of district government and converted there in cogeneration unit into electricity and heat. This is also an innovative solution for the residents of the district government in the form of a limitation of the energy costs as a result of separate bio waste collection. The generated and in the public net fed electricity from biogas is compensated according to the renewable energy law (EEG).

The processed biogas (bio-methane) must have the quality of the natural gas, so that it can be fed into public gas pipeline. The quality demands are formulated by the gas pipeline operator and are based on a comprehensive DVGW set of rules.

Up to now the plant has been operated for 16 months. The first 6 months have to be considered as commissioning and cannot be taken as a normal operation. Since the beginning of the normal operation the plant has run mostly undisturbed. However, it shows that the combination of a batch digestion operation with a continuously operated gas processing leads to specific problems. In case more tunnels has the digestion operation, more constant is the gas composition. We have 12 tunnels available for on average 400 m³ gas per hour. This is the lower limit for an economical combination with a biogas upgrading by pressure swing adsorption for gas treatment according to our experience.

Author's address:

Dipl.-Ing. Burkart Schulte
Gesellschaft zur Verwertung organischer Abfälle im Kreis Minden-Lübbecke GVoA
Pohlsche Heide 1
32479 Hille
Telephone: +49 57 03 98 02-21
Fax: +49 57 03 98 02-99
Mobile: +49 170 56 31 537
Email: schulte@gvoa.de
Website: http://www.pohlsche-heide.de

.

Treatment of Municipal Solid Waste before Anaerobic Digestion - CAPEX and OPEX as model calculation

Michael Langen

HTP GmbH & Co. KG

Abstract

Treatment of **M**unicipal **S**olid **W**aste (MSW) before **A**naerobic **D**igestion (AD) is highly considerable in terms of capital expenditure (CAPEX) and operational expenditure (OPEX). The paper determines different treatment options like “Standard” and “AdvancedBioSolids” and characterizes the treatment options. The “Standard“ option is relatively simple and comprises only few process steps. The “AdvancedBioSolids” option is more complex and refines the biosolid fraction by sorting of inorganic items and other non-digestibles in a multi-stage dry refining process.

Model calculation of mass balance and product quality is based on a typical composition of MSW in western urban settlements, this is e.g. 41 mass-% of digestible biosolids. The quality of digestible biosolids going from pre-treatment to digestion is increased from 71,2 %, achieved by a “Standard” process to 93,9 %, achieved by an “Advanced-BioSolid” process.

The calculation of CAPEX is done for annual capacities of 180.000 t/y and of 320.000 t/y. As a result CAPEX for mechanical & electrical installation for pre-treatment is 15 to 30% of CAPEX for total installation. Total installation means pre- treatment plus digestion, combined-heat and power (CHP) and emission control installation. Calculation of OPEX is done by summarizing all operational costs deriving from the pre-treatment plus digestion, CHP and emission control. As a result higher CAPEX for pre-treatment installation leads to lower OPEX. OPEX can be decreased up to -7,4 % by an “Advanced Biosolids”-process compared to a “Standard”-process.

The paper finalizes with a draft of a catalogue of pre-treatment steps and their relevance for product quality and yield. Decision makers of authorities and companies get a hint of what is relevant in terms of process evaluation and meeting the targeted figures of OPEX.

Keywords

pre-treatment, MBT-AD, CAPEX, capital expenditure, OPEX, operational expenditure, cost saving, MSW, Municipal Solid Waste, HTP, engineering

1 Treatment of Municipal Solid Waste before Anaerobic Digestion

1.1 Flow sheets

Treatment of Municipal Solid Waste (MSW) before Anaerobic Digestion (AD) is commonly done in processes comprising a screen cut and metal separation. The screen cut applies cut- sizes of about 40 to 60 mm, and metal separation applies magnetic and eddy-current separation. The process flowsheet of a so- called “Standard” – process can be summarized as follows:

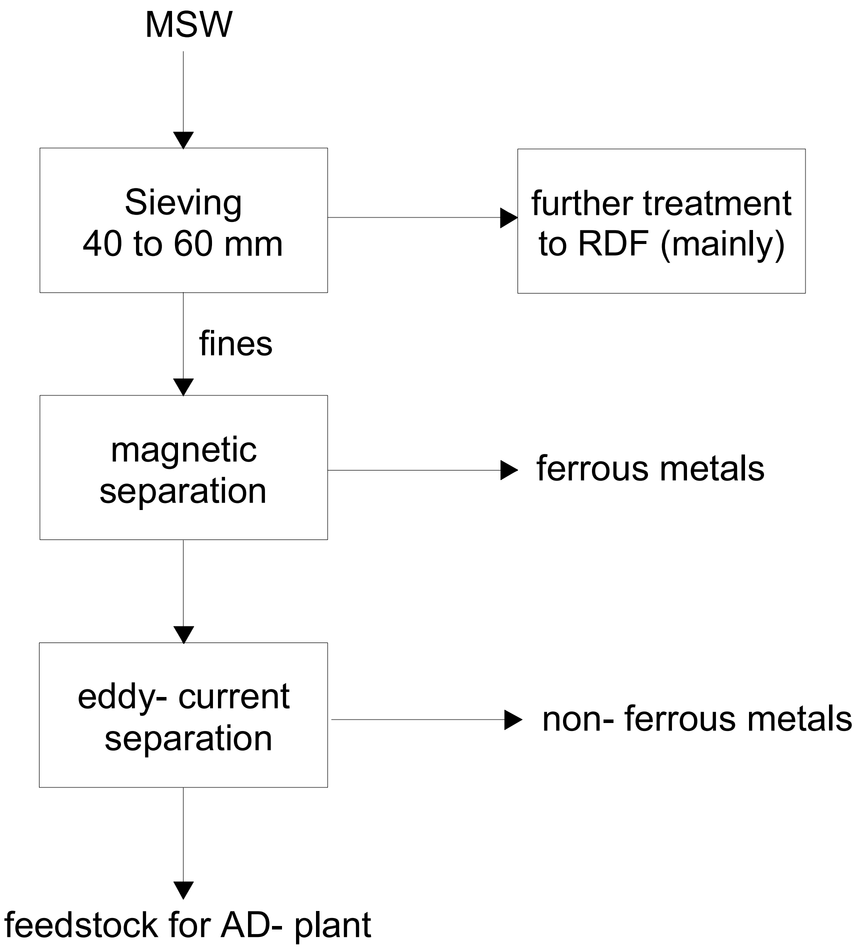


Fig. 1: process flowsheet of a so- called “Standard” – process

Mechanical-Biological-Treatment plants (MBT-AD) with a pre-treatment installation like the “Standard”- process are being commissioned or under construction in two of the Greater Manchester projects delivered by Viridor and in the West Sussex project delivered by Biffa, both in the UK.

The composition of the feed for the AD- plant is roughly 2/3 digestible organic items and 1/3 other items, mainly inert items like glass, stone, ceramic etc. and non- digestible organics like plastic, fibres etc. The quality of the feed for the AD- plant can be enhanced in terms of the grade of digestible biomass by using a more sophisticated dry mechanical pre- treatment. The process flowsheet of a so- called “AdvancedBioSolids” – process can be summarized as follows:

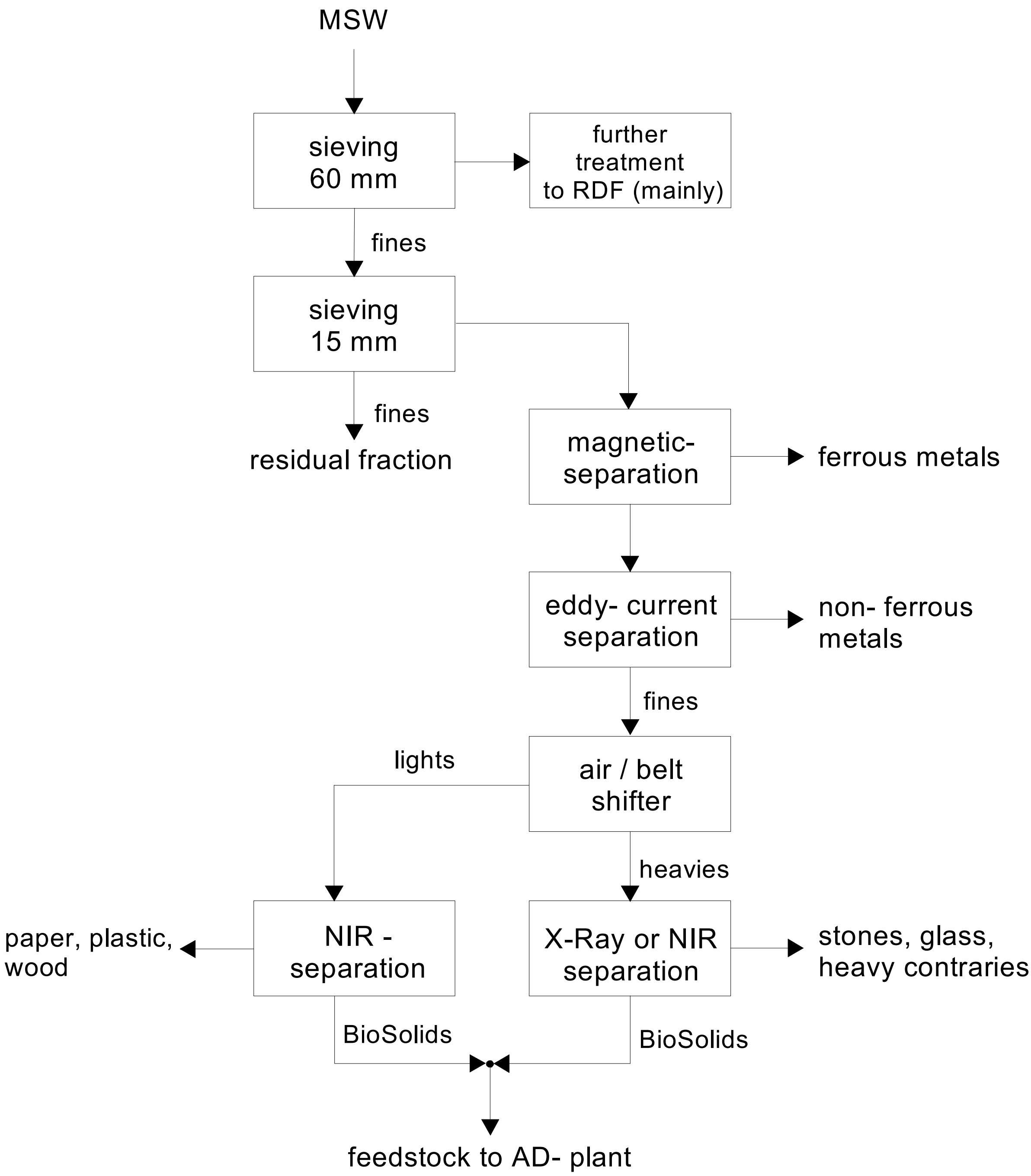


Fig. 2: process flowsheet of a so- called “AdvancedBioSolids” – process

1.2 Mass- balance and Qualities

The composition of the feed for the AD- plant is given in table 1 as a comparison between the “Standard”- process and the “AdvancedBioSolid”- process based on a process model developed by HTP. The process model is based on an average composition for MSW (1) and sorting efficiencies of process equipment documented in the HTP database.

Table 1: Composition of MSW input (curbside) and feed to the AD- plant depending on the type of pre-treatment (dry- mechanical).

	Input MSW-	**feed stock to AD- plant**	
	curbside collection (1)	**Standard process (2)**	**Advanced Bio Sold process (2)**
food and garden waste (Bio Solids)	41%	71,20%	93,90%
paper / cardboard	18%	4,20%	1,10%
metal cans	3%	0,00%	0,00%
plastic	7%	2,00%	0,60%
glass	7%	4,70%	1,10%
wood	5%	0,50%	0,50%
sand, stones, ceramic	5%	6,80%	0,50%
textiles	3%	0,00%	0,00%
whitegoods, nappies, miscellaenous, non combustables	11%	10,60%	2,30%
	100%	100%	100%

(1) Analysis of household waste compositions for England, Dr. J. Parfitt, WRAP 2002

(2) HTP - database

The first column from the left gives an exemplary composition of MSW derived from curbside collection. In this case an average composition of household waste in England was chosen. The second and third column from the left shows the composition of the feed stock to the AD- plant produced by pre- treatment in a “Standard” and an “AdvancedBioSolid” process. Whereas the commonly applied “Standard”- process shows a grade of only 71,2 % digestible biosolids the “AdvanceBioSolid”-process increases the grade up to 93.9 %. The “Standard”- process feeds the wet- mechanical AD- plant with a material containing 11,5 % heavies (glass, stone, sand, ceramic), 4,2 % paper fibres and 2,0 % plastics. Those items cause significant operational problems and costs. The “AdvancedBioSolids”- process decreases those items significantly to 1,6 % heavies, 1,1 % paper fibres and 0,6 % plastics.

The loss of digestible biosolids in the “AdvancedBioSolids”- process is less significant. The “Standard”- process feeds 88,9 % of the total digestible biomass of MSW to the AD- facility whereas the “AdvancedBioSolid”- process feeds 82,1 % of the total digestible biomass to the AD- plant which is a loss of -7,6 %. The mass- output of pre- treatment to AD is reduced from 51,4 % to 35,4 % which leads to higher overall plant- capacities and lower CAPEX and OPEX.

2 CAPEX and OPEX as model calculation

CAPEX and OPEX for a MSW- AD- plant is calculated on the basis of four scenarios.

Scenario 1: 180.000 t per year capacity
Standard- process

Scenario 2: 180.000 t/y capacity
AdvBioSol- process

Scenario 3: 320.000 t/y capacity
Standard- process

Scenario 4: 320.000 t/y capacity
AdvBioSol-process

2.1 Capital Expenditure (CAPEX)

CAPEX is calculated for mechanical and electrical works only. CAPEX of civil works, such as infrastructure, halls and office space is not calculated as it is not affected by the choice of a process option. Figures may vary depending on a specific site or project more or less. In general the figures give an estimate for a project developed from scratch, based on AD- plants built and operated in Europe.

Table 2: CAPEX of scenario 1 and 2, annual capacity 180.000 t MSW.

	process option Standard	**AdvBioSol**
pre-treatment	5.500.000,00 €	7.000.000,00 €
AD-plant (wet)	17.500.000,00 €	16.500.000,00 €
emission-control	2.800.000,00 €	2.800.000,00 €
process control	1.100.000,00 €	1.100.000,00 €
total	26.900.000,00 €	27.400.000,00 €

CAPEX for pre- treatment rises by 1.5 Mio. or 27 % from 5.5 Mio. € to 7.0 Mio. € whereas the overall CAPEX rises by just 0.5 Mio. € from 26.9 Mio. € to 27.4 Mi. €

Table 3: CAPEX of scenario 3 and 4, annual capacity 320.000 t MSW.

	process option Standard	**AdvBioSol**
pre-treatment	8.250.000,00 €	11.250.000,00 €
AD-plant (wet)	26.200.000,00 €	21.500.000,00 €
emission-control	4.200.000,00 €	4.200.000,00 €
process control	1.600.000,00 €	1.600.000,00 €
total	40.250.000,00 €	38.550.000,00 €

CAPEX for pre-treatment rises by 3.0 Mio. € or 36 % from 8.25 Mio. € to 11.25 Mio. € whereas the overall CAPEX drops by 1.8 Mio. € from 40.25 Mio. € to 38.55 Mio. €

Savings of CAPEX for the AD plant is possible because of a significant lower mass throughput, 35,4 % instead of 51,4 %, without significant loss of biosolids and biogas production for mainly the contraries are separated.

Calculation of OPEX is done on the basis of the following assumptions:

- The lifetime of the plant is 15 years. The interest rate of capital is 4.5 %.
- The runtime of the plant is 7 days a week, 24 h daily in a four shift pattern. This applies for the AD-, emission control and CombinedHeatPower (CHP) - plant. The reception hall and pre-treatment is being operated on weekdays only.
- Biogas is being used in a CHP unit. Electricity of CHP is consummated by the plant itself, the surplus of electricity into the grid are calculated with 0,095 €/ kWh.
- Heat from CHP is being used to warm up the digesters. The surplus of heat is not distributed or marketed any further.
- The number of operating personal is 16 people per shift for the 180.000 t/y scenarios respectively 22 people per shift for the 320.000 t/y scenarios. A plant manager and four people are calculated for each scenario additionally.
- Operational costs of civil works, infrastructure and material transport (internally) are not calculated in accordance to CAPEX calculation where those costs are left blank as well.
- Costs or returns for process products such as metals, secondary fuel, digestate are not calculated.

Figures of OPEX ranges from 26,60 €/t, 320.000 t/y AdvBioSol- process, to 34,90 €/t, 180.000 t/y Standard- process. Table 4 gives an overview.

Table 4: OPEX of an MSW- AD- plant dependent on capacity and process option.

	180.000 t/y		**320.000 t/y**	
	Standard	**AdvBioSol**	**Standard**	**AdvBioSol**
OPEX (absolute)	34,90 €	33,40 €	28,70 €	26,70 €
OPEX (relative)	100%	-4,2%	100%	-7,4%

Savings of OPEX are mainly due to the economy of scale, a loss of about 5,00 €/t by increasing the capacity from 180.000 t/y to 320.000 t/y. Beside savings due to choosing a more sophisticating dry- mechanical treatment are -4,2 % respectively -7,4 %.

3 Summary and main findings

Investors, plant- operators and construction firms should look at dry mechanical treatment before Anaerobic Digestion (AD) with more emphasis. More sophisticated dry-mechanical treatment leads to

- higher grades of BioSolids and lower grades of non- digestible items in the feedstock of the wet AD- plant.
- Up to -8% lower operational expenditures- OPEX, sometimes even lower capital expenditures- CAPEX and
- higher process reliability, particularly in the wet AD- part of the plant, by preventing contraries from being fed to the digesters.

Author's address:

Dr.-Ing. Michael Langen
HTP GmbH & Co. KG
Maria-Theresia Allee 35
52064 Aachen
Telephone: +49 241 94900 0
Email langen@htp.eu

Optimierung von MBA unter Energieeffizienz-, Ressourcen- und Klimaschutzaspekten

Ketel Ketelsen, Karsten Kanning, Carsten Cuhls*

Ingenieurbüro für Abfallwirtschaft und Energietechnik (iba) GmbH, Hannover

*gewitra GmbH, Troisdorf

Optimisation of MBT considering energy efficiency and protection of resources and climate

Abstract

In 18 out of 46 MBTs in Germany biological treatment of organic containing fine fractions takes place with the aim of achieving the deposition criteria exclusively through aerobic rotting. Thus energy potentials contained in the fine fractions are not utilised. Within the context of a study for the German Federal Department of the Environment it was examined to what extent the energy and resource efficiency of these plants can be considerably improved by fitting rotting MBTs with an Anaerobic Digestion (AD). As potential quantities approx. 1.0 million tonnes of fine fraction is available annually in the 18 rotting MBTs. Technical implementation of an AD stage, investment costs for retrofitting and effects on treatment costs of MBT are presented. It is shown, that integration of an AD stage using best available techniques goes along with improvement of energy efficiency and climate balance. Based on the calculated data macroeconomic effects are estimated, expressed as costs for CO_2-reduction.

Inhaltsangabe

In 18 von insgesamt 46 in Deutschland betriebenen MBA wird die bei der Behandlung der Siedlungsabfälle verbleibende Restfraktion in Rottestufen biologisch oxidiert ohne Nutzung des Energieinhaltes der biogenen Abfallbestandteile. Im Rahmen einer Studie für das Umweltbundesamt wurde untersucht, in welchem Umfang mit der Nachrüstung von Rotte-MBA mit einer Vergärungsstufe die Energie- und Ressourceneffizienz dieser Anlagen deutlich verbessert werden kann und welche Auswirkungen sich auf die Wirtschaftlichkeit der MBA ergeben. Als Mengenpotenzial an Feinfraktion stehen hierfür in den 18 Rotte-MBA jährlich ca. 1,0 Mio Mg/a zur Verfügung. Die technische Umsetzung, der für die Nachrüstung erforderliche Invest sowie die Auswirkungen auf die Behandlungskosten werden dargestellt. Es wird gezeigt, dass mit der Integration einer Vergärungsstufe Verbesserungen der Energieeffizienz und der Klimabilanz einhergehen. Diese werden berechnet und daraus die gesamtwirtschaftlichen Auswirkungen in Form von CO_2-Minderungskosten abgeschätzt.

Keywords

MBA, Vergärung, Siedlungsabfall, Treibhausgas-Emissionen, CO_2-Minderungskosten

MBT, anaerobic digestion, municipal waste, greenhousegas, CO_2-reduction-costs

1 Einleitung

Die MBA in Deutschland müssen sich verstärkt den sich verändernden Rahmenbedingungen in der Abfallwirtschaft stellen. Zurzeit nehmen die Kapazitäten für die Behandlung und Verwertung von Abfällen immer noch zu, während die Abfallmengen stagnieren. Gleichzeitig steigen die technischen Anforderungen an die Anlagen zur Sicherung eines hohen Umweltschutzstandards. Die Konkurrenz um die Abfälle sowie der Druck zur wirtschaftlich-technischen Optimierung der Anlagen erhöhen sich.

Ein möglicher Entwicklungsansatz bei den MBA in Deutschland besteht darin, den Anteil der Mengen zur energetischen Verwertung durch optimierte Behandlungsstrategien für die anfallende organikhaltige Feinfraktion zu maximieren. In 18 von 46 MBA in Deutschland erfolgt die biologische Behandlung der organikhaltigen Feinfraktion derzeit noch mit dem Ziel der Erreichung der Ablagerungskriterien ausschließlich durch eine aerobe Rotte. Die in der Feinfraktion enthaltenen Energiepotenziale werden dabei nicht genutzt.

Um die energetischen Potenziale der organikhaltigen Feinfraktion vollständig zu erschließen, stehen mit der Vergärung und/oder der biologischen Trocknung geeignete Techniken zur Verfügung. Nachfolgend werden die Ergebnisse einer für das Umweltbundesamt durchgeführten Studie präsentiert, in der untersucht wurde, in welchem Umfang mit der Nachrüstung von Rotte-MBA mit einer Vergärungsstufe die Energie- und Ressourceneffizienz dieser Anlagen deutlich verbessert werden kann [KETELSEN et al., 2010].

2 Mengen- und Energiepotenzial

Von den in den MBA behandelten Abfällen werden im Mittel ca. 50 % als Feinfraktion abgetrennt und den biologischen Stufen (BA) zugeführt. Die Kapazität der biologischen Stufen in den MBA (ohne MBS, MPS, MA) liegt bei ca. 1,6 Mio Mg/a, von denen der überwiegende Anteil (1,0 Mio Mg/a) auf reine Aerobsysteme entfällt (*Tabelle 1*).

Ca. 30 % der erzeugten Feinfraktion werden zurzeit in einer Vergärungsstufe behandelt. Dadurch werden mit ca. 370 GWh/a etwa 18 % des Energieinhaltes nutzbar gemacht. Verfügbar wären nach einer aktuellen Einschätzung dagegen ca. 2.000 GWh/a bei MBA im engeren Sinne sowie ggf. zusätzlich 2.000 GWh/a bei Ausdehnung des Optimierungsansatzes auch auf MBS, MPS und MA in Deutschland.

Tabelle 1: Mengen und (un-)genutzte Energiepotenziale in Stoffströmen aus der MBA

	Einheit	MBA Rotte	MBA Vergärung	MPS	MBS	MA	Ge-samt
Kapazität	TMg/a	2.075	1.320	530	1.834	2.258	8.017
davon Feinfraktion	TMg/a	959	679	265	917	450	**3.272**
davon zur Vergärung	TMg/a	-	566	-	-	-	
Energieinhalt [1)]	GWh/a	**2.050**		2.000			**4.050**
davon genutzt	GWh/a	370		< 2.000			

1) $H_{u,\,roh}$ = 4-5 MJ/kg

3 Grundlagen der Untersuchung

3.1 Anlagenbestand

Folgende aerobe Verfahrenskombinationen sind in Deutschland realisiert:

- Intensivrotte im Tunnel (4-5 Wochen) mit nachfolgender offener bzw. überdachter Nachrotte (8-11 Wochen)
- Kombination aus gekapselter Intensivrotte im Tunnel oder Container (2-6 Wochen) und eingehauster Nachrotte in Zeilen- oder Wandermieten (3-10 Wochen)

In der Studie wurde als MBA-Bestand eine Tunnelrotte mit Umluftführung und einer Kapazität von 4 bis 5 Wochen Verweilzeit für die Nachrotte nach Integration einer Vergärungsstufe zu Grunde gelegt. Als Variantenbetrachtung wurde zwischen Tunnelrotte-Systemen mit Kühlung der Umluft (Variante NRT1) sowie ohne Kühlung der Umluft (Variante NRT2) unterschieden. Die Abluftbehandlung erfolgt über Biofilter (gering belastete Teilströme) sowie RTO (Prozessabluft).

3.2 Technische Umsetzung

Für die Integration einer Vergärungsstufe bei MBA sind im Wesentlichen folgende Komponenten zu berücksichtigen (Bild 1):

- weitergehende mechanische Aufbereitung der Feinfraktion (verfahrensspezifisch, bei Bedarf)
- Speicher/Dosierspeicher vor der Vergärung
- Gärreaktoren inklusive Beschickung und Entleerung
- Entwässerung der Gärreste und Presswasserspeicher (verfahrensspezifisch, bei Bedarf)

- Gasfassung, Gasspeicher und Gasreinigung sowie Notgasfackel
- Gasverwertung (BHKW) oder Gasaufbereitung zur Einspeisung

Schnittstellen zum Bestand ergeben sich insbesondere bei der Übergabe der organikhaltigen Feinfraktion zur Vergärung und der Rücknahme der festen Gärreste in die Nachrotte, weiterhin bei der Übernahme von Abluft und Biogas aus der Vergärung zur vorhandenen Abluftbehandlung sowie ggf. bei der Einkopplung von Wärme in die Nachrotte oder bei der Verknüpfung der Prozesswassersysteme von Vergärung und Rotte.

Als Grundvariante für die Gasverwertung wird eine Verstromung vor Ort im BHKW angenommen (Variante BHKW). Als alternative Verwertungswege können je nach Rahmenbedingungen am Standort Mikrogasnetze oder die Gasaufbereitung zu Bioerdgas mit Einspeisung in das öffentliche Gasnetz oder zur Kraftstoffnutzung geplant werden. Geeignete technische Verfahren sind hierfür am Markt verfügbar. Eine Abschätzung zu den Kosten der Gasaufbereitung und Einspeisung in das öffentliche Gasnetz findet sich bei KETELSEN. K et al., 2010.

In die Studie eingeflossen sind Betriebsdaten bestehender Anlagen sowie Auslegungs- und Angebotsdaten von Anlagenlieferanten der Trockenvergärung (TV). Für die Nachrüstung stehen sowohl mehrere (quasi-)kontinuierliche Verfahren (TVK) als auch mehrere Batch-Verfahren (TVB) zur Verfügung. Von allen beteiligten Verfahrensanbietern wird eine Ausführung als Teilstromvergärung empfohlen.

Nassvergärungsverfahren erfordern gegenüber der Trockenvergärung einen deutlich höheren technischen Umbauaufwand der bestehenden Anlagentechnik. Eine Weiternutzung bestehender Rottemodule ist nur eingeschränkt möglich. Nach den kommunizierten Betriebserfahrungen in den bestehenden MBA mit Nassvergärung erscheint es eher unwahrscheinlich, dass sich Betreiber einer Rotte-MBA bei einer Nachrüstung aktuell für ein Nassvergärungsverfahren entscheiden werden. Nassvergärungsverfahren haben daher keinen Eingang in die Untersuchung gefunden.

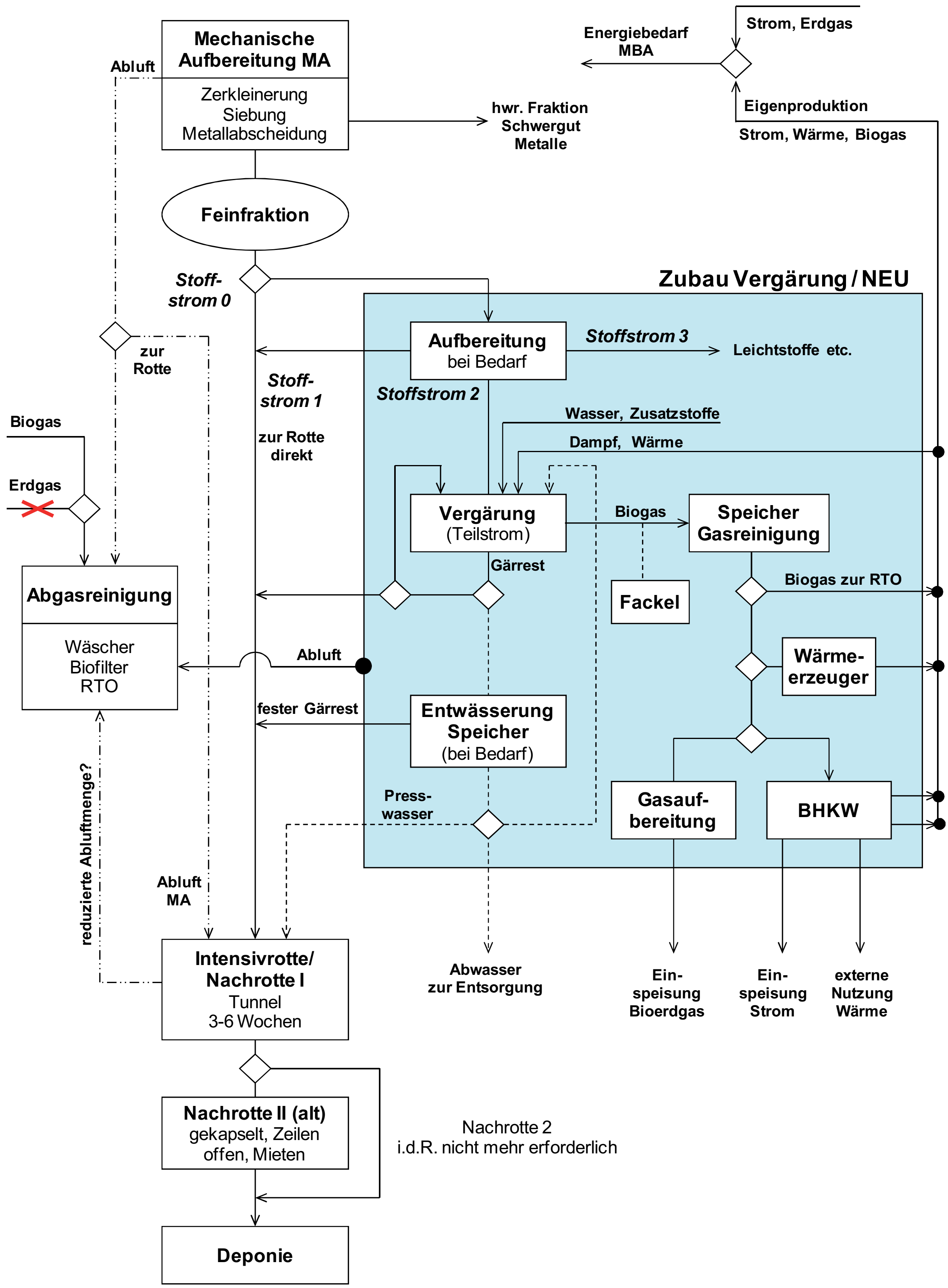


Bild 1: Einbindung einer Vergärung in eine bestehende MBA

3.3 Stoffkennwerte und Stoffstromteilung

Auslegungsbasis für die Integration einer Vergärungsstufe in der vorliegenden Untersuchung ist die organikhaltige Feinfraktion 0-60 mm aus Hausmüll. Die Qualität dieser

Fraktion zeichnet sich durch eine i. d. R. sehr hohe biologische Aktivität aus, ablesbar an den sehr hohen chemisch-biologischen Kennwerten (*Tabelle 2*).

Tabelle 2: Kennwerte der Feinfraktion aus Hausmüll zur biologischen Behandlung in MBA

Parameter	Einheit	Bereich	gewählt[1)]
Trockenmassegehalt (TG)	% FS	50-60	55
Glühverlust = organischer Trockenmassegehalt (GV)	% TG	40-55	50
TOC im Feststoff (TOC_{Fest})	% TG	20-28	25
DOC im Eluat (DOC_{Eluat})	mg/l	>> 2.000	k. V.
Atmungsaktivität (AT_4)	mg O_2/g TG	40-80	k. V.
Gasbildungsrate im Gärtest (GB_{21})	Nl/g TG Nl/g FS	150-300 75-150	230 128

1) Anhaltswerte für die Auslegung der Vergärung für die angefragten Verfahrenslieferanten

Für alle Bilanzierungen wird unterstellt, dass der Anteil der abgetrennten organikhaltigen Feinfraktion 50 % der in die MBA eingetragenen Abfallmenge beträgt.

Gemäß Angaben der Anlagenlieferanten wird bei den kontinuierlichen Verfahren für den Teilstrom zur Vergärung ein Massenanteil von 70 % der Feinfraktion als sinnvoll erachtet. Bei den Batch-Verfahren liegt der empfohlene Anteil bei 80 %. Der Teilstrom, der direkt zur Rotte geht, stellt mit seinen biologisch abbaubaren Bestandteilen sicher, dass sich in der Nachrotte ausreichend Wärme für den erforderlichen Wasseraustrag entwickelt.

3.4 Bilanzrahmen

Ausgehend vom Bilanzkreis MBA zur Ermittlung der Netto-Primär-Zielenergie nach VDI 3460/2 wurde für die Studie ein verkleinerter Bilanzrahmen gewählt, der alle durch die Vergärung beeinflussten Massen- und Energieströme umfasst (*Bild 2*). Dieser umfasst den MBA-Bestand mit mechanischer Aufbereitung (MA), Rotte und Abgasbehandlung (RTO und Biofilter) sowie die für die Vergärung zu integrierenden Komponenten. Alle Zusatzenergien für den Betrieb der MBA sowie Möglichkeiten der MBA-internen Nutzung oder Rückführung der am Standort erzeugten Energieformen werden berücksichtigt.

Hinsichtlich des Energieeintrags aus Abfall wird nur die in der MA abgetrennte Feinfraktion zur biologischen Behandlung betrachtet. Die weiteren Stoffströme aus der MA zur energetischen oder stofflichen Verwertung (EBS, Metalle etc.) werden sowohl beim Energieeintrag als auch bei den Austrägen nicht einbezogen, da sich hierfür durch die Integration einer Vergärungsstufe keine Veränderungen ergeben.

Die ermittelten Energie- und Treibhausgasbilanzen spiegeln demzufolge nicht das Gesamtsystem bzw. den vollständigen Bilanzkreis einer MBA wider. Vielmehr werden nur die sich durch die Integration einer Vergärungsstufe ergebenden Veränderungen erfasst und dargestellt.

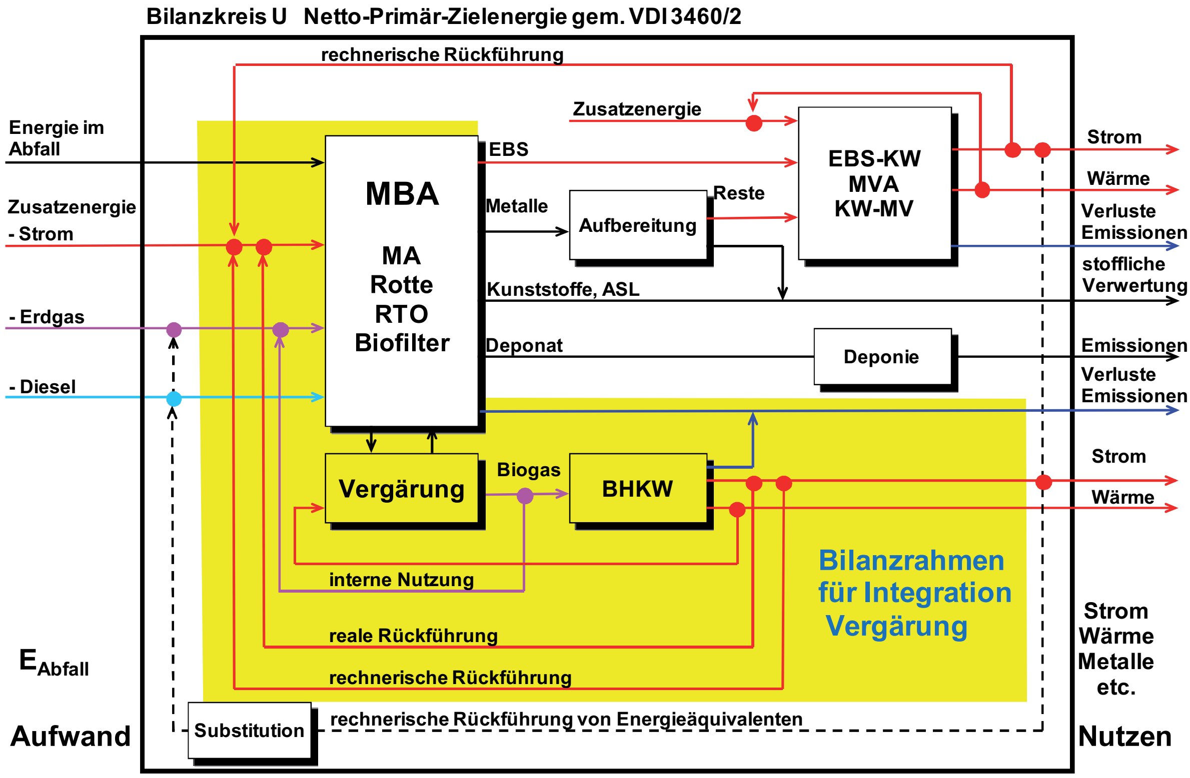


Bild 2: Bilanzrahmen MBA mit/ohne Vergärung zur Ermittlung der Kosten-, Energie- und Klimaauswirkungen

4 Auswirkungen der Integration einer Vergärungsstufe

4.1 Abluftmengen

Die Auswirkungen der Integration einer Vergärungsstufe auf die Abluftmengen einer MBA sind im Wesentlichen abhängig von dem bestehenden Rottesystem. MBA, die mit technisch aufwendigen, auf Abluftminimierung ausgerichteten Rottesystemen (Tunnelrotte mit Umluftführung und Umluftkühlung) ausgestattet sind, weisen ein geringes Potenzial zur Einsparung von Luftmengen auf (*Bild 3*). Bei technisch weniger aufwendigen Systemen, die mit höheren spezifischen Luftmengen in der Rotte arbeiten, lassen sich durch die Integration einer Vergärungsstufe die Abluftmengen aus dem Prozess in relevanter Größenordnung reduzieren. Dies wirkt sich insbesondere durch einen reduzierten Energiebedarf des Abluftsystems positiv auf die Ressourceneffizienz aus.

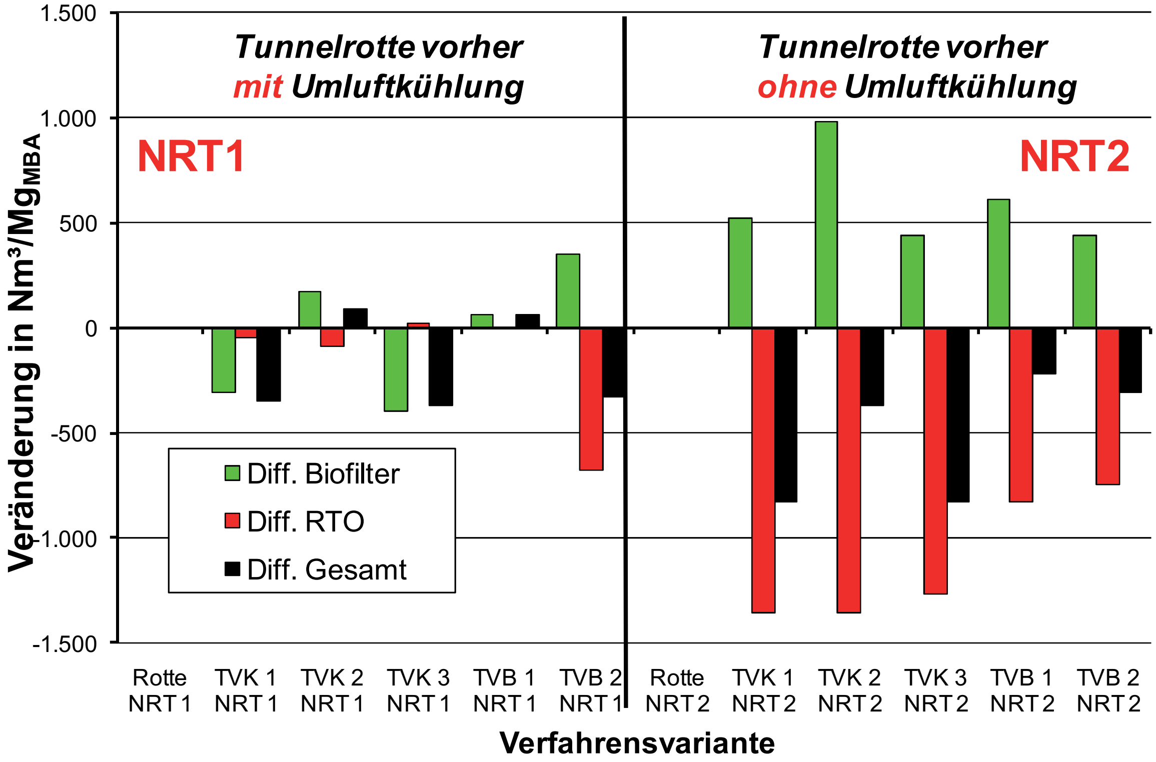


Bild 3: Veränderung der Abluftmengen nach Integration einer Vergärung (Bezug: Tagesmittelwert - TMW)

4.2 Energiebilanz

Die Auswertung zeigt, dass sich im Strombedarf der MBA durch Integration einer Vergärung kaum Veränderungen gegenüber der reinen Rotte ergeben (*Tabelle 3*). Der Gasbedarf (Zusatzenergie für die RTO) sinkt tendenziell nach Integration einer Vergärung. Der Wärmebedarf der Vergärung (Fermenterheizung) stellt einen zusätzlichen Energiebedarf dar. Die Entwicklung des Kraftstoff-Bedarfs hängt vom gewählten Vergärungsverfahren ab (kontinuierliche Verfahren: Geringerer Kraftstoffbedarf bei Entfall einer Radlader-bewirtschafteten Nachrotte; Batch-Verfahren: Tendenziell erhöhter Kraftstoffbedarf wegen Radlader-Bewirtschaftung der Vergärung).

Während sich beim Energiebedarf für den Betrieb der MBA keine gravierenden Unterschiede zwischen den Vergärungsvarianten zeigen, liegen die Energieerträge aus dem Biogas bei den kontinuierlichen Verfahren bezogen auf die Summe Nutzenergie um ca. 30 % höher als bei den Batch-Verfahren.

Beim Strom führt dies zu einem deutlichen Nettoüberschuss im Bereich von 9 bis 23 kWh/$Mg_{EintragMBA}$ bei den kontinuierlichen Verfahren. Bei den Batch-Verfahren wird der Strombedarf nur unter günstigen Rahmenbedingungen durch den Stromertrag ausgeglichen.

Tabelle 3: Auswirkungen der Vergärung auf die Energiebilanz der MBA (TV mit BHKW; Mengenvariante 100; konservativer Ansatz)

Anlagenbereich/ Variante		**MBA mit Rotte**	**MBA mit TVK**	**MBA mit TVB**
Energiebedarf MBA Betrieb				
Strom	$kWh/Mg_{EintragMBA}$	59-63	59-72	55-62
Erdgas / Biogas	$kWh/Mg_{EintragMBA}$	30-50	22-36	26-40
Diesel	$kWh/Mg_{EintragMBA}$	8	5,5	8,5-14,5
Wärme	$kWh/Mg_{EintragMBA}$	0	0-40	9-26
Energieertrag aus Biogas				
Biogas erzeugt	$kWh/Mg_{EintragMBA}$	0	245-254	165-188
davon zur Wärmeerzeugung (Dampf-/Heizkessel)	$kWh/Mg_{EintragMBA}$	0	0-12	9-10
davon zur RTO	$kWh/Mg_{EintragMBA}$	0	22-25	16-30
davon zur Fackel	$kWh/Mg_{EintragMBA}$	0	13-24	11
davon zum BHKW	$kWh/Mg_{EintragMBA}$	0	196-219	114-153
• daraus Strom (ηel = 0,40)	$kWh/Mg_{EintragMBA}$	0	74-90	44-61
• daraus nutzbare Wärme (ηth = 0,45)	$kWh/Mg_{EintragMBA}$	0	86-99	49-64
Nettoenergieerträge				
Stromabgabe	$kWh/Mg_{EintragMBA}$	-	9 bis 23	-17 bis -1
Extern nutzbare Wärme	$kWh/Mg_{EintragMBA}$	-	51 bis 93	29 bis 55
Diesel	$kWh/Mg_{EintragMBA}$	-8	-5,5	-8,5 bis -14,5

Der (Bio-)Gas- und Prozesswärmebedarf der MBA kann nach Integration einer Vergärungsstufe jeweils vollständig aus dem Energieertrag gedeckt werden. Es verbleibt ein Überschuss an extern nutzbarer Wärme in der Größenordnung von 15 bis 35 % des Energieertrages (Rohbiogas gesamt). In den nachfolgenden Betrachtungen zur Klimawirksamkeit und zu den Kosten stellt die Nutzung des Wärmeüberschusses eine wichtige Stellgröße dar, der daher bei der konkreten Anlagenplanung entsprechende Beachtung geschenkt werden sollte.

4.3 CO_2-Minderung

Durch die Integration einer Vergärungsstufe in eine MBA lässt sich, unter den hier zu Grunde gelegten durchschnittlichen Rahmenbedingungen, eine CO_2-Einsparung von ca. 50 bis 100 $kgCO_2/Mg_{EintragMBA}$ gegenüber der MBA mit Rotte erzielen (*Bild 4*). Im Einzelfall können unter günstigen Rahmenbedingungen sogar bis zu 150 $kgCO_2/Mg_{EintragMBA}$ eingespart werden. Auf der hier betrachteten Bilanzebene des

MBA-Betriebs wird eine ausgeglichene CO_2-Bilanz bis hin zu deutlichen Netto-Entlastungen bei der Klimawirksamkeit erreicht.

Kontinuierliche Vergärungsverfahren weisen beim Kriterium CO_2-Minderung wegen des höheren Energieertrages Vorteile gegenüber Batch-Verfahren auf. Deutlichen Einfluss auf die CO_2-Einsparung besitzt bei einer Gasverwertung über BHKW der erzielte Grad der Wärmenutzung. Sofern am Standort der MBA keine relevanten Wärmeabnehmer zur Verfügung stehen, sollten im Hinblick auf den Klima- und Ressourcenschutz andere Verwertungsmöglichkeiten geprüft werden (Gasaufbereitung und Einspeisung oder Mikrogasnetz, ggf. Kraftstoff-Nutzung).

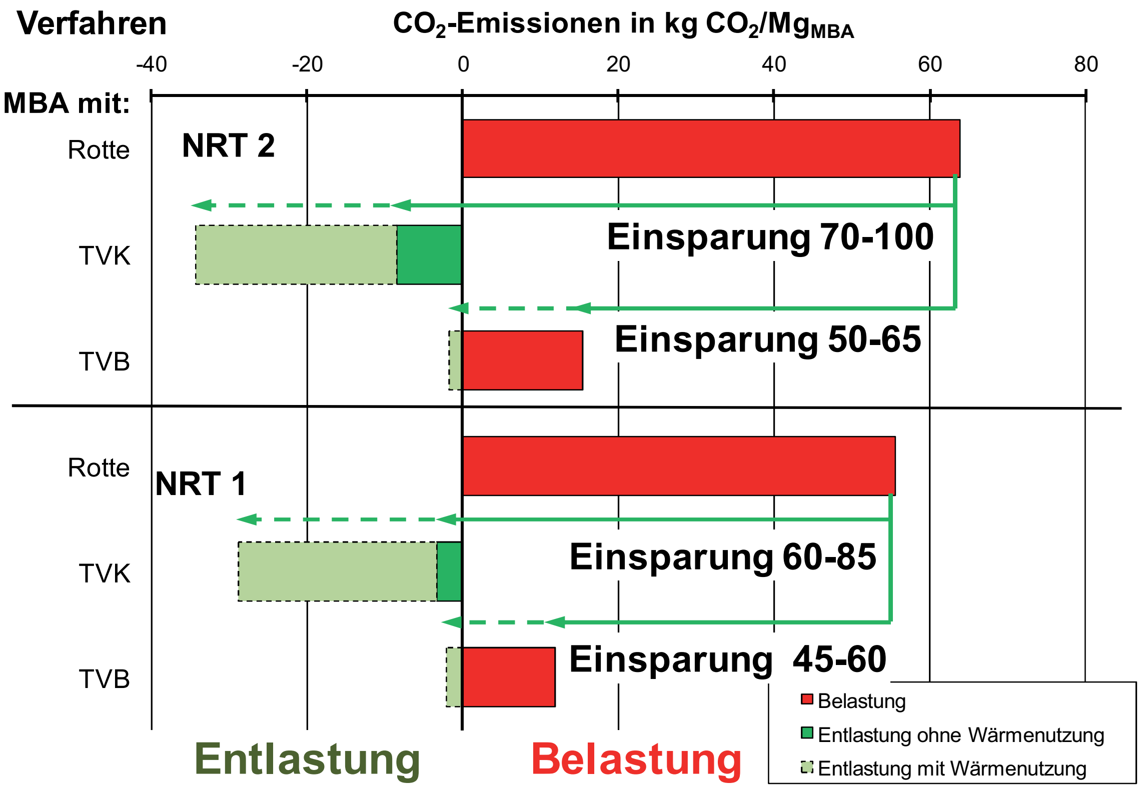


Bild 4: CO_2-Minderung bei MBA durch Integration einer Vergärung (Variante: TVK/TVB 100 mit BHKW)

4.4 Vergleich der Energieeffizienz und Klimabilanz

Erweitert man den Bilanzrahmen um die stoffliche und energetische Verwertung der erzeugten Stoffströme inklusive der heizwertreichen Fraktionen(s. *Bild 2*, gesamter Bilanzrahmen), lässt sich der Vergleich der Energieeffizienz und Klimabilanz auf andere Verwertungswege von Restabfall sowie weitere Behandlungsoptionen der organikhaltigen Feinfraktion in MBA, wie z. B. die biologische Trocknung, ausweiten.

Eine biologische Trocknung der Feinfraktion ist nachfolgend zur Vergärung oder alternativ in den bestehenden Rottetunneln der MBA möglich. Durch biologische Trocknung lässt sich der Wassergehalt der Feinfraktion von 40-50 % innerhalb verkürzter Rottezeiten von 1-2 Wochen auf ca. 15 % reduzieren. Durch nachfolgende Abtrennung von inerten Bestandteilen lässt sich eine Brennstofffraktion mit hohen biogenen Anteilen (> 70 %) und Heizwerten zwischen 8-10 MJ/kg_{OS} herstellen, die z. B. in Braunkohlekraftwerken verbrannt werden kann (WIEGEL, U., 2010; MIELKE, F./TISCHLER, C., 2010).

Im Vergleich der MBA-Verfahren mit Rotte, Vergärung + Nachrotte, Vergärung + biologischer Trocknung zeigt sich die höchste Energieeffizienz bei der Kombination von Vergärung + Trocknung, gefolgt von der alleinigen biologischen Trocknung. Beide Verfahren machen den Energieinhalt der organikhaltigen Feinfraktion weitestgehend nutzbar. Die Vergärung besitzt den Vorteil höherer Wirkungsgrade bei der Umwandlung von Biogas in Nutzenergie im BHKW im Vergleich zur energetischen Verwertung getrockneter Feinfraktion im Kraftwerk im Anschluss an die biologische Trocknung. Bei der Kombination Vergärung + Nachrotte entfällt die energetische Verwertung des Gärrestes, wodurch sich die Energieeffizienz gegenüber den beiden vorgenannten Verfahren etwas reduziert. Die niedrigste Energieeffizienz ergibt sich erwartungsgemäß für reine Rotteverfahren, da hier der Energieinhalt der organikhaltigen Feinfraktion nicht nutzbar gemacht wird.

Die Rangfolge der vier Verfahren in der Klimabilanz folgt der Rangfolge der Energieeffizienz (*Bild 5*, KETELSEN, K., 2010). Als Beitrag der Vergärung zur CO_2-Minderung ergeben sich hier ca. 90 $kgCO_2/Mg_{EintragMBA}$, wobei der Einsatz eines hinsichtlich der Klimabilanz günstigen Vergärungsverfahrens unterstellt wird.

Für die Gesamtverfahren ergeben sich im dargestellten Vergleich Netto-CO_2-Gutschriften im Bereich von ca. 260 $kgCO_2/Mg_{EintragMBA}$ (reine Rotte) bis 430 $kgCO_2/Mg_{EintragMBA}$ (Vergärung + Trocknung). Die Vergärung kann hier mit einem Anteil von 20 – 25 % an der Netto-CO_2-Gutschrift einer MBA einen relevanten Beitrag zur Klimaentlastung leisten.

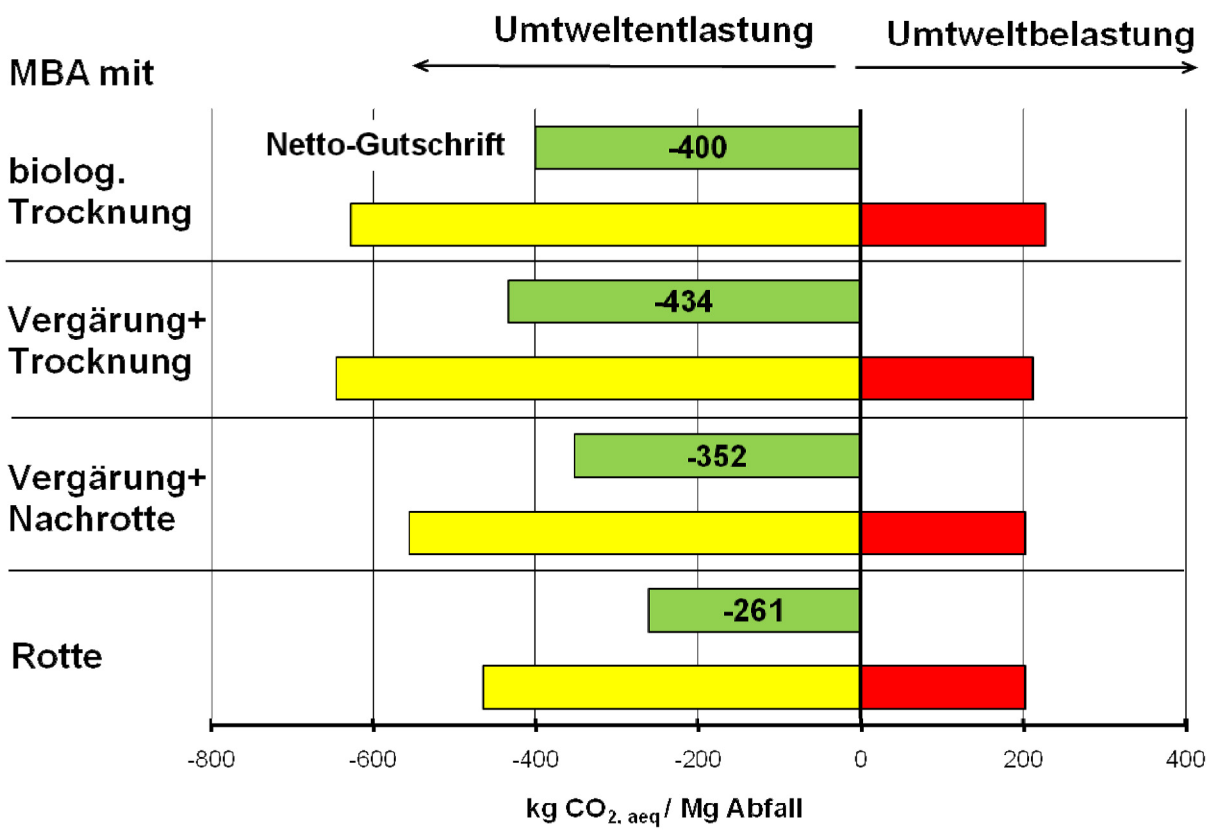


Bild 5: CO_2-Bilanz der MBA bei unterschiedlicher Behandlung der Feinfraktion

4.5 Investkosten

Die Investkosten für die Integration einer Vergärungsstufen bewegen sich im konservativen Ansatz (Szenario A) je nach Anlagengröße und Verfahren zwischen 190 und 390 €/$Mg_{Vergärung}$ (Mittelwerte, *Tabelle 4*). Die Ergebnisse decken sich damit weitgehend mit Literaturangaben für die Vergärung von Bioabfällen (TURK, TH. et al., 2007; UEC, 2010).

Die Investkosten liegen bei den Batch-Verfahren für die betrachteten Durchsatzleistungen der Vergärung um ca. 30 % bis 40 % niedriger, als bei den kontinuierlichen Verfahren. Die Differenz nimmt mit zunehmender Anlagengröße ab. Die günstigsten kontinuierlichen Verfahren erreichen für große Anlagengrößen annähernd das Investitionskostenniveau der Batch-Verfahren.

Um eine Bandbreite unterschiedlicher Standortvoraussetzungen abzubilden, wurde in weiteren Szenarien (B und C/D) der Invest unter Ansatz von Einsparmöglichkeiten reduziert.

Die angesetzten Einsparungen variieren verfahrensabhängig und bewegen sich gegenüber dem konservativen Szenario maximal (Szenario C/D) im Bereich von 15 %, im Einzelfall bis 25 %. Sofern an einem Standort die Möglichkeiten zu einer umfassenderen

Nutzung vorhandener Gebäude und Einrichtungen bei der Integration einer Vergärung gegeben sind, sind ggf. noch höhere Einsparungen im Invest realisierbar.

Tabelle 4: Investkosten der Vergärung
(inkl. Kosten des Lieferanten für Planung und Inbetriebnahme)

Mengenvariante	**Eintragsmenge Vergärung** (Mg/a)	**Kontinuierliche Verfahren (TVK)** (€/Mg$_{Eintrag\ Vergärung}$)			**Batch-Verfahren (TVB)** (€/Mg$_{Eintrag\ Vergärung}$)		
		Szenario			Szenario		
		A	B	C/D	A	B	C/D
30	21.000	330-440	310-430	290-420			
	24.000				220-240	195-215	180-205
50	35.000	240-360	225-350	210-340			
	40.000				210-220	195-200	180-190
100	70.000	200-340	160-325	150-310			
	80.000				180-200	160-190	150-180

4.6 Behandlungskosten

Im konservativen Ansatz (Szenario A) ergeben sich für die untersuchten Mengenvarianten nach Integration einer Vergärungsstufe Mehrkosten für die Abfallbehandlung in der MBA von ca. 2 bis 13 €/Mg$_{MBA}$ (*Bild 6*).

Unter günstigen Bedingungen am Standort (Szenarien B und C) reduzieren sich sowohl die Behandlungskosten der Vergärung als auch der mechanischen Aufbereitung und Rotte. Daraus resultiert z. B. im Szenario C in Summe eine Kostensenkung um ca. 4 bis 8 €/Mg$_{MBA}$ gegenüber Szenario A. Die Mehr-/Minderkosten durch Integration einer Vergärungsstufe betragen bei Szenario C dann noch ca. -6 bis +9 €/Mg$_{MBA}$.

Gemäß Szenario D können die Behandlungskosten noch einmal um bis zu 3 €/Mg$_{MBA}$ sinken, wenn sich erhöhte Erlöse aus der Energienutzung (10 ct/kWh für Strom + 4 ct/kWh für Wärme statt 6 + 2 ct/kWh) und günstige Kreditzinsen (p = 4 % statt p = 6 %) für die Finanzierung der Vergärungsanlage realisieren lassen.

Bei großen Anlagen sowie günstigen Rahmenbedingungen kann die Integration einer Vergärungsstufe demnach kostenneutral oder sogar verbunden mit einer Senkung der Behandlungskosten der MBA vorgenommen werden.

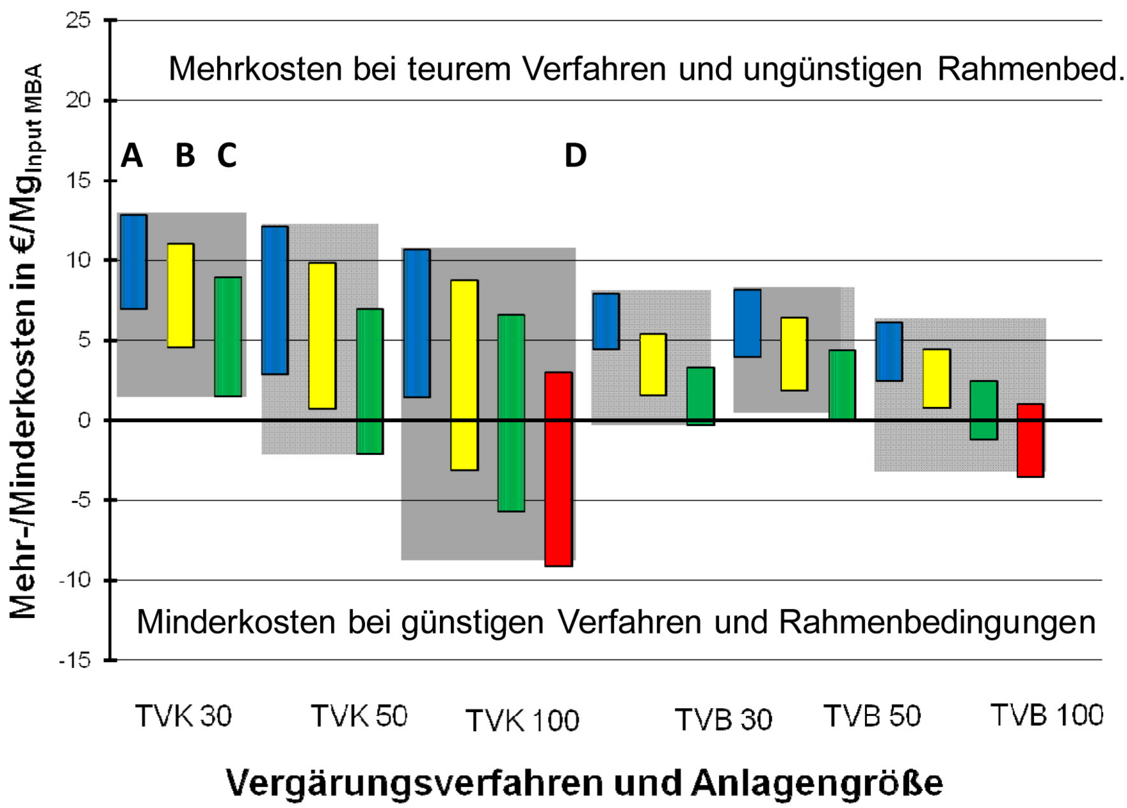


Bild 6: Veränderung der Behandlungskosten MBA in Abhängigkeit von Vergärungsverfahren, Durchsatz und Rahmenbedingungen, Min/Max je Verfahren

4.7 CO_2-Minderungskosten

Zur Abschätzung des volkswirtschaftlichen Aufwandes werden nachfolgend die CO_2-Minderungskosten bei Integration von Vergärungsstufen mit BHKW am MBA-Standort in allen 18 Rotte-MBA in Deutschland berechnet. Die Hochrechnung erfolgt unter der Prämisse, dass sich projektbezogen das jeweils wirtschaftlichste Verfahren durchsetzt und dass die gesamte Bandbreite an standortbezogenen Rahmenbedingungen (Szenarien A, B, C und D) zum Tragen kommt.

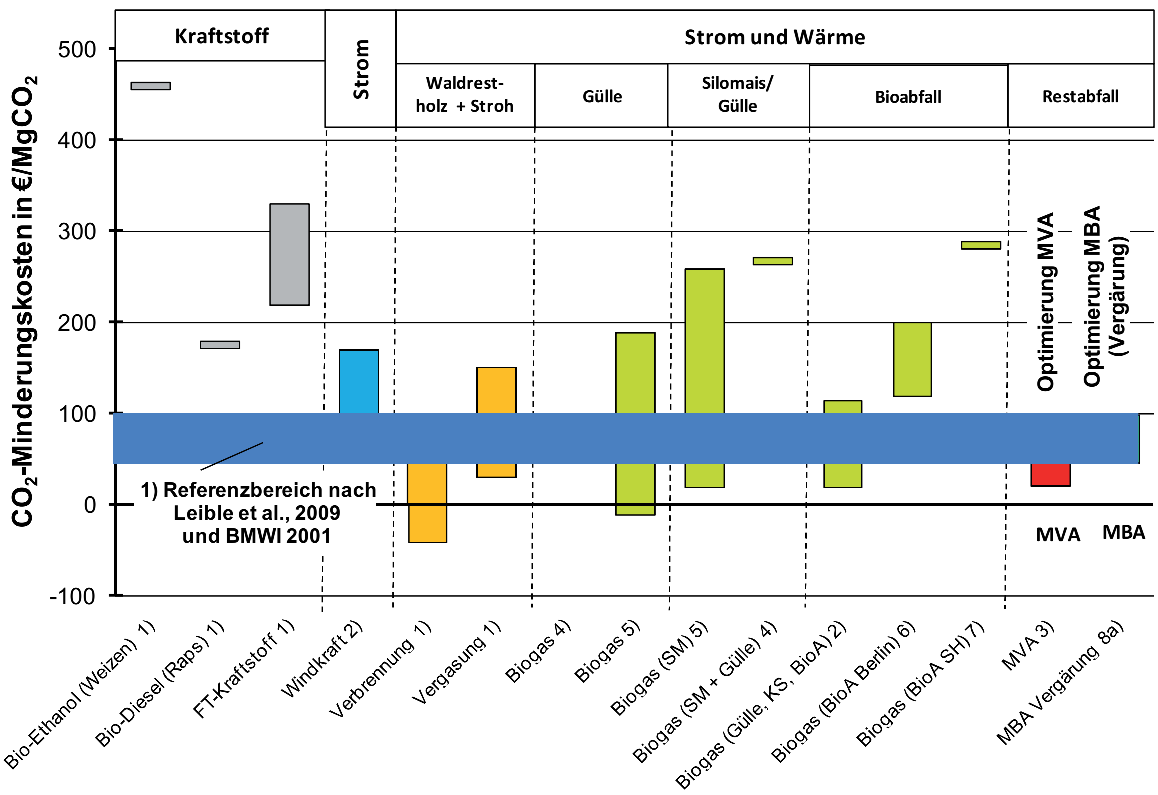
Die Integration von Vergärungsstufen in allen Rotte-MBA in Deutschland wäre danach unter Berücksichtigung von Erlösen (projektbezogener Ansatz) im Bereich der Kostenneutralität zu erreichen (Mittel: -1 €/MgCO_2-Äq.).

Bei Berechnung der CO_2-Minderungskosten gegen eine fossile Referenz (gesamtwirtschaftlicher Ansatz) ergeben sich im Mittel +73 €/MgCO_2-Äq.

Im Vergleich mit anderen CO_2-Minderungsstrategien aus dem Bereich der regenerativen Energieerzeugung liegt die Integration von Vergärungsstufen bei MBA damit am unteren Ende der ermittelten CO_2-Minderungskosten (*Bild 7*).

Laut einer Untersuchung von BILITEWSKI, B. et al., 2010 könnte durch die Ertüchtigung aller deutschen MVA zur Verbesserung der Energieeffizienz eine Steigerung der Gesamtenergieabgabe im Mittel um ca. 7 %-Punkte erreicht werden. Es werden in Abhängigkeit von der Einzelmaßnahme CO_2-Minderungskosten zwischen +22 bis +95 €/MgCO_2-Äq ausgewiesen und in dieser Größenordnung als „kostengünstige“ Minderungsstrategie eingestuft.

Aus der Gegenüberstellung der Minderungsstrategien kann abgeleitet werden, dass das Prädikat „kostengünstig“ für die Integration von Vergärungsstufen bei MBA mindestens ebenso gilt, wie für viele andere Strategien. Die aus der Hochrechnung auf alle Rotte-MBA in Deutschland ermittelten CO_2-Minderungskosten liegen innerhalb des Referenzbereichs nach BMWi, 2001. Eine Weiterverfolgung dieser Strategie ist dementsprechend zu empfehlen. Nach vorliegender Abschätzung lässt sich bei geringem gesamtwirtschaftlichen Aufwand ein THG-Minderungspotenzial bezogen auf alle Rotte-MBA in Deutschland von 120.000 – 160.000 MgCO_2-Äq./a erschließen.



1) LEIBLE et al, 2009; 2) Leible et al, 2006; 3) Bilitewski et al, 2010; 4) WBA, 2008; 5) KTBL, 2007; 6) Kern et al, 2009; 7) UEC, 2010; 8a) und 8b) KETELSEN et al., 2010

Bild 7: CO_2-Minderungskosten der Strom- + Wärmegewinnung aus Restabfall (Hochrechnungen) sowie Vergleichswerte

5 Fazit

Die nachträgliche Integration einer Vergärungsstufe in MBA ist technisch möglich und wirtschaftlich darstellbar. Das wirtschaftliche Ergebnis wird maßgeblich bestimmt vom gewählten Verfahren und erzielten Invest der Anlage. Verfahrens- und durchsatzabhängig liegt der Invest bei konservativer Betrachtung im Bereich von 200 bis 400 €/(Mg/a). Die Behandlungskosten verändern sich je nach Standortrahmenbedingungen im Bereich von +10 bis -10 €/Mg, d. h. bei günstigen Standortbedingungen können sich durchaus wirtschaftliche Vorteile ergeben. Die Integration einer Vergärung führt zu einer deutlichen Verbesserung der Energieeffizienz und Klimabilanz der MBA. Es lassen sich klimawirksame CO_2-Emissionen in der Größenordnung von 50 bis 100 $kgCO_2/Mg_{EintragMBA}$, im Einzelfall bis zu 150 $kgCO_2/Mg_{EintragMBA}$ einsparen. Bezogen auf alle Rotte-MBA in Deutschland beträgt das CO_2-Minderungspotenzial ca. 120.000 – 160.000 $MgCO_2$-Äq./a. Bei Ausdehnung auf alle MBA (auch MBS, MPS) lässt sich das Potenzial noch erheblich steigern. Hierfür ergeben sich bei gesamtwirtschaftlicher Betrachtung CO_2-Minderungskosten von im Mittel +73 €/$MgCO_2$-Äq. Die Integration einer Vergärungsstufe bei MBA stellt damit ein kostengünstiges Instrument zur Reduzierung klimarelevanter Treibhausgasemissionen im Bereich der mechanisch-biologischen ABFALLBEHANDLUNG dar.

6 Literatur

BILITEWSKI, B. / WÜNSCH, C./ JAGER, J./ HOFFMANN, M.	2010	Energieeffizienzsteigerung und CO_2-Vermeidungspotenziale bei der Müllverbrennung – Technische und wirtschaftliche Bewertung. Hrsg.: Entsorgergemeinschaft der deutschen Entsorgungswirtschaft e. V. (EdDE), EdDE-Dokumentation Nr. 13, Köln, April 2010
BMWI (HRSG.)	2001	Energiepolitische und gesamtwirtschaftliche Bewertung eines 40%igen Reduktionsszenarios. Endbericht von Prognos, EWI und BEI, Juli 2011. Gutachten erstellt im Auftrag des BMWi, Dokumentation 492, Berlin
KERN, M./ RAUSSEN, T.	2009	Optimierte stoffliche und energetische Bioabfallverwertung. In: Witzenhausen-Institut, Neues aus Forschung und Praxis, Bio- und Sekundärrohstoffverwertung IV stofflich – energetisch, Hrsg.: K. Wiemer/M. Kern, Witzenhausen 2009, S. 349-369
KETELSEN, K.	2010	Umrüstung von mechanisch-biologischen Abfallbehandlungsanlagen - unter Kosten-, Klima- und Energieeffizienzaspekten -, Berliner Energiekonferenz - Erneuerbare Energien -, 06.-07.09.2010, Hotel Berlin, Berlin
KETELSEN, K./ KANNING, K./ CUHLS, C.	2010	Optimierung der mechanisch-biologischen Restabfallbehandlungsanlagen (MBA) unter Berücksichtigung von Ressourcen- und Klimaschutzaspekten, Hrsg.: UBA, Dessau, FKZ 363 01 254, Endbericht, Juni 2010

KTBL	2007	Kuratorium für Technik und Bauwesen in der Landwirtschaft: Faustzahlen Biogas, Hrsg.: KTBL, Darmstadt 2007
LEIBLE, L./KÄLBER, S./KAPPLER, G./NIEKE, E./FÜRNISS, B.	2009	CO_2-Minderungskosten verschiedener Biomassenutzungskonzepte. In: Witzenhausen-Institut, Neues aus Forschung und Praxis, Bio- und Sekundärrohstoffverwertung IV stofflich – energetisch, Hrsg.: K. Wiemer/M. Kern, Witzenhausen 2009, S. 165-180
LEIBLE, L./KÄLBER, S./KAPPLER, G./LANGE, S./NIEKE, E./FÜRNISS, B.	2006	Energiebereitstellung aus biogenen Reststoffen und Abfällen in Deutschland – eine Perspektive?. In: Müllhandbuch, Hrsg.: ESV Verlag, Berlin, Lfg. 03/06, Kennzahl: 7590
MIELKE, F./TISCHER, C.	2010	Energetische Verwertung von Reststoffen aus der MBA. In: Witzenhausen-Institut, Neues aus Forschung und Praxis, Bio- und Sekundärrohstoffverwertung V stofflich – energetisch, Hrsg.: K. Wiemer/M. Kern, Witzenhausen 2010, S.649ff
TURK, T./KERN, M./SPRICK, W./HAKE, J.	2007	Vergärungsanlagen als Vorschaltanlagen vor der Kompostierung – Technik, Kosten und Wirtschaftlichkeit. In: Witzenhausen-Institut, Neues aus Forschung und Praxis, Weiterentwicklung der biologischen Abfallbehandlung vor dem Hintergrund von TA Luft und EEG, Hrsg.: K. Wiemer/M. Kern, Witzenhausen 2007, S. 153-183
UEC	2010	Bewertung der vorhandenen Bioabfallbehandlungsstandorte in Schleswig-Holstein im Hinblick auf eine Ergänzung um Vergärungsstufen, Hrsg.: MLUR Schleswig-Holstein 02/2010
WBA	2008	Wissenschaftlicher Beirat Agrarpolitik beim Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz: Nutzung von Biomasse zur Energiegewinnung – Empfehlungen an die Politik (verabschiedet: Nov. 2007; Erscheinungsdatum: 24.01.2008). Online:http://www.bmelv.de/cln_045/nn_751706/DE/14-WirUeberUns/Beiraete/Veroeffentlichungen/NutzungBiomasseEnergiegewinnungVorwort.html
WIEGEL, U.	2010	Umrüstung der MBA zur Brennstoffgewinnung. In: Witzenhausen-Institut, Neues aus Forschung und Praxis, Bio- und Sekundärrohstoffverwertung V stofflich – energetisch, Hrsg.: K. Wiemer/M. Kern, Witzenhausen 2010, S. 611ff

Anschrift der Verfasser(innen)

Dr.-Ing. Ketel Ketelsen, Dr. rer. nat. Karsten Kanning
Ingenieurbüro für Abfallwirtschaft und Energietechnik (iba) GmbH
Friesenstr. 14
30161 Hannover
Telefon: +49 511 34 91 90 50
Email: iba@iba-hannover.de
Website: www.iba-hannover.de

Dr.-Ing. Carsten Cuhls
Ingenieurgesellschaft für Wissenstransfer (gewitra) mbH
Mülheimer Str. 26
53840 Troisdorf
Telefon: +49 511 99 90 874
Email: cuhls@gewitra.de
Website: www.gewitra.de

Umrüstung der MBA zur erweiterten Ersatzbrennstoffgewinnung

Ulrich Wiegel

ICU –Partner Ingenieure

Abstract

Compared to other treatment options of mixed municipal solid waste the pure aerobic MBT cannot exploit the energy of the organic fraction, since it is just biologically oxidized for the aim of inertization. Converting the process to a biological drying provides a material, of which an organic high calorific fraction can be separated by established mechanical means. Due to the shorter biological treating time, composting capacity is made available to treat biowaste or fermentation residues. Needed adaptations of the MBT-facility can be financed by the revenues of this additional treatment. This integrated co-treatment activates an energy amount from the organic in the mixed waste being 2-3 fold higher than the energy content of the biowaste itself.

Inhaltsangabe

Durch Umstrukturierung der MBA auf biologische Trocknung des Unterkorns der mechanischen Aufbereitung kann ein trennfähiges (Trocken)Gut erzeugt werden, aus dem mit bekannten Verfahrenstechniken ein regenerativer Brennstoff ausgetrennt werden kann. Rd. 80 % des regenerativen Energiegehaltes im Unterkorn können damit zurückgewonnen werden. Je Tonne MBA-Input kann damit eine zusätzliche Minderung von rd. 250 kg CO2 erreicht werden.

Keywords

Waste, MBT, climate protection, biowaste treatment, waste treatment, organic fraction

1 Vorbemerkung

Im Gegensatz zu anderen Restmüll-Behandlungsverfahren nutzt eine MBA mit rein aerober Behandlung den Energiegehalt der Organik im Unterkorn der Aufbereitung nicht. Bisheriges Arbeitsziel ist allein, das spätere Deponiegut durch energieaufwändige biologische Oxidation zu inertisieren. Die in der Organikfraktion gebundenen regenerativen Energie geht dabei verloren.

Durch Umstrukturierung der MBA auf biologische Trocknung des Unterkorns der mechanischen Aufbereitung kann ein trennfähiges (Trocken)Gut erzeugt werden, aus dem mit bekannten Verfahrenstechniken ein regenerativer Brennstoff ausgetrennt werden kann.

Das Konzept der energetischen Unterkorn-Nutzung im Sinne dieses Projektes erfordert im Wesentlichen zwei Arbeitsschritte:

Biologische Trocknung im Rottesystem der MBA: Jeder aerobe Prozess setzt Wärme frei und verdampft damit Wasser. Diese Eigenschaft kann in vorhandenen MBA zur biologischen Trocknung des Unterkorns auf rd. 20 % Restfeuchte genutzt werden.

Trennung in Brennstoff und Deponiegut: Das biologisch getrocknete Material enthält zu viele Inertstoffe, um direkt als Brennstoff eingesetzt werden zu können. Erforderlich ist eine Trennanlage, die einerseits den Brennstoff von Inertstoffen weitgehend freihält, andererseits so wenig Organik im inerten Deponiegut belässt, dass dieses möglichst direkt abgelagert werden kann.

Beide Arbeitsschritte sind in ihrer Grundfunktion bereits erprobt:

- Die biologische Trocknung mehrfach durch Bewässerungsausfälle in den MBA (mittels derer sonst 300–500 l Wasser je Tonne Rottegut eingegeben werden),
- die Trennung als Routineverfahren für die Auftrennung von biologisch stabilisiertem Gesamtmüll in verschiedenen MBS-Anlagen (insbesondere nach dem HerHof-Verfahren), ebenso zur Trennung physikalisch/thermisch getrockneten Abfalls in MPS-Anlagen.

Gegenstand des darauf ausgerichteten Förderprojektes ist es, die Möglichkeiten und technischen Modalitäten einer Nachrüstung anhand großtechnischer Versuche zu untersuchen. Das Projekt wird unter Förderung der Deutschen Bundesstiftung Umwelt in Zusammenarbeit mit dem Institut für Abfallwirtschaft und Altlasten der Technischen Universität Dresden durchgeführt.

2 Versuchsdurchführung

Das Konzept wurde bislang in folgenden, ersten Versuchsansätzen erprobt, deren Ergebnisse hier kurz skizziert werden.

a. Auf der MBS-Anlage des ZAB[1] Niederlehme wurden rd. 260 Mg Restmüll-Unterkorn als Monocharge biologisch getrocknet und das Trockengut nachfolgend mit der dort installierten Trenntechnik separiert. Die Anlage ist spezifisch auf die biologische Trocknung und Trennung von Restmüll ausgerüstet, so dass praktisch nur das verarbeitete Material, nicht aber die Betriebstechnik geändert wurde.

b. Auf der „klassischen" MBA-Anlage der abh[2] in Schwanebeck wurden drei Tunnelchargen mit jeweils rd. 150 Mg Abfall-Unterkorn aus Berlin angesetzt und im Routinebetrieb, jedoch ohne Wasserzufuhr verrottet.

c. Auf der abh-Anlage wurde - analog zur konventionellen MBS-Technik – Gesamtmüll biologisch getrocknet, aus dem Trockengut das Unterkorn < 80 mm ausgesiebt und dieses in zwei Technikumsversuchen in Brennstoff- und Inertmasse trockenmechanisch getrennt.

3 Ergebnisse

Die Ergebnisse des Trennversuches beim ZAB und der biologischen Trocknung in den Rottetunneln der MBA Schwanebeck zzgl. der Hochrechnung der Trennung sind in der nachstehenden Abbildung standardisiert für 10.000 Mg/a an Unterkorn gegenüber dem abgeschätzten IST-Zustand dargestellt.

---

1 ZWECKVERBAND ABFALLBEHANDLUNG NUTHE-SPREE

2 ABFALLBEHANDLUNGSGESELLSCHAFT HAVELLAND MBH

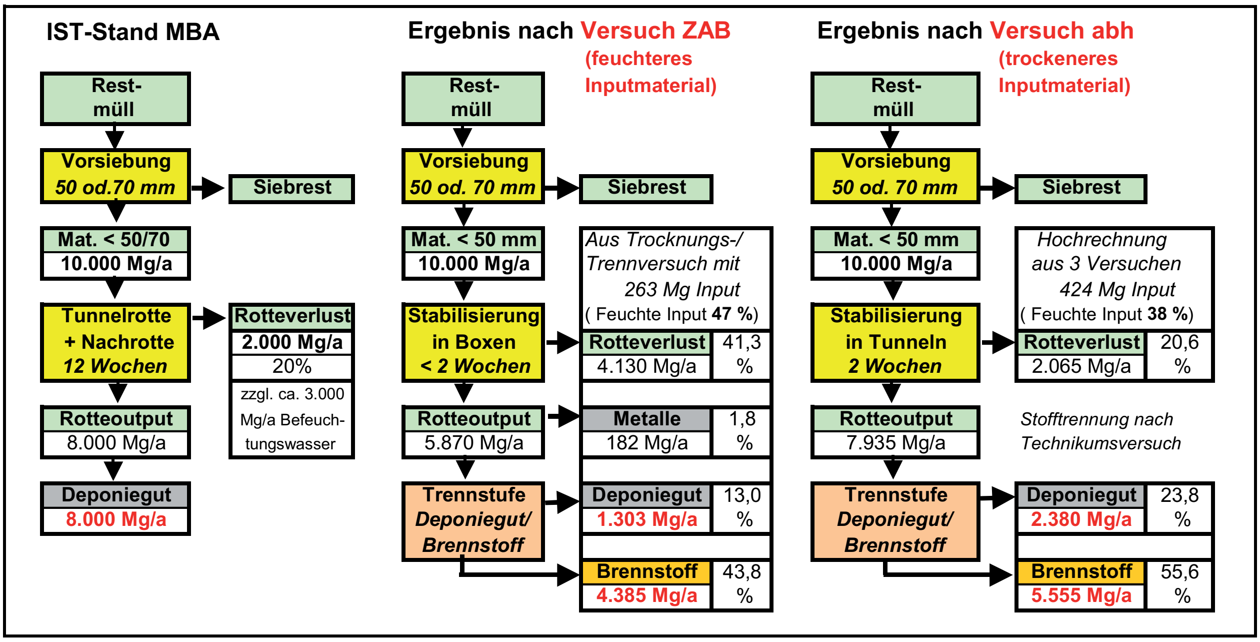


Abbildung 1: Mengenbilanz der Trocknungs- und Trennversuche für Unterkorn

3.1 Versuche beim ZAB

Das Hausmüll-Unterkorn ließ sich beim ZAB technisch problemlos trocknen. Der Wassergehalt sank innerhalb von rd. 9 Tagen Rottezeit von 47 auf 15 %.

Das getrocknete Material – knapp 60 % des Inputs – ließ sich technisch problemlos trennen, bezogen auf den Feuchtmasse-Input wurden 44 % an Brennstoff und 13 % an Inertstoffen ausgebracht. Die nachstehenden Abbildungen vermitteln einen Eindruck über die Konsistenz der beiden erzeugten Hauptfraktionen Brennstoff und Inertgut.

Abbildung 2: Brennstoff (links) und Inertmasse aus Restmüll-Unterkorn

Die Inertfraktion erfüllt auch die (hauptsächlich kritisch interessierenden) biologischen Parameter für die Deponieklasse 2 ohne Weiteres.

Der erzeugte Brennstoff konnte im Kraftwerk Jänschwalde ohne verfahrenstechnische Schwierigkeiten verarbeitet werden, der regenerative Kohlenstoffanteil liegt bei rd. 75 % (vom Gesamtkohlenstoff).

3.2 Versuche bei der abh

Eine Restfeuchte von 20 % im Hausmüll-Unterkorn ist innerhalb von 14 Tagen Rottezeit ohne wesentliche Änderung der Betriebsführung erreichbar. Ein länger gefahrener Einzelversuch lieferte im Hauptteil des Tunnels Restfeuchten um 10 %.

Die Unterschiede in den ausgebrachten Brennstoffmengen sind nicht durch die Anlagentechnik beeinflusst, sondern fast ausschließlich aus der Feuchte des Inputmaterials. Ein ähnlich trockenes Inputmaterial hätte im ZAB-Versuch zu gleich hohen Brennstoffmengen geführt wie für den abh-Versuch berechnet. Maßgeblich durch die unterschiedliche Feuchte der jeweilig verarbeiteten Unterkorn-Mengen ergeben sich zwischen 44 % und 56 % an ausgebrachtem Brennstoff. Die direkt abzulagernde Unterkorn-Menge sinkt von 70-80 % (IST-Stand MBA) auf max. 25 % (zzgl. der abzulagernden Asche aus dem energetisch verwerteten Brennstoff).

3.3 Versuche zur trockenmechanischen Auftrennung des getrockneten Unterkorns

In der Technikums-Einrichtung der Fa. Trennso-Technik GmbH wurden rd. drei Mg des getrockneten Hausmüll-Unterkorns über Sichter und Trenntische trockenmechanisch aufbereitet, dies in zwei Versuchen mit drei und sechs Kornfraktionen, die jeweils in Leicht- und Schwergut getrennt wurden. Die Verteilungsergebnisse nach Feuchtmasse und OTS zeigt Tabelle 1.

Zwischen 64 und 68 % des getrockneten Unterkorns konnten danach als Leichtgut incl. Staub und damit als Brennstoff ausgetrennt werden, rd. ein Drittel verblieb als abzulagerndes Schwergut.

Über 90 % der heizwertliefernden OTS wurden in den Brennstoff überführt. Rd. 10 % der Input-OTS werden während der Trocknung zur Wasserverdampfung verbraucht, somit liegt die **Netto-Ausbeute an OTS als Brennstoff bei gut 80 %**. Dieser Anteil liegt höher als der energetisch nutzbare OTS-Anteil in einem Vergärungskonzept, in dem ca. 50 – 60 % der OTS als Biogas verfügbar gemacht werden können.

Tabelle 1: Verteilung von Feuchtmasse und OTS auf Brenn- und Inertstoffe bei Auftrennung des biologisch getrockneten Materials

Mengen-Verteilung Schwer-Leicht	**Versuch 1: 6 Fraktionen**		**Versuch 2: 12 Fraktionen**	
	Summe Schwer	**Summe Leicht/Staub**	**Summe Schwer**	**Summe Leicht/Staub**
Anteil von < 10 mm Input	22,4%	77,6%	25,0%	75,0%
Anteil von 10/25 mm Input	50,4%	49,6%	37,9%	62,1%
Anteil von 25/80 mm Input	43,6%	56,4%	38,5%	61,5%
Anteil von < 80 mm Input	**36,5%**	**63,5%**	**31,8%**	**68,2%**

OTS-Verteilung Schwer /Leicht	**Versuch 1: 6 Fraktionen**		**Versuch 2: 12 Fraktionen**	
	Summe Schwer	**Summe Leicht/Staub**	**Summe Schwer**	**Summe Leicht/Staub**
Anteil von < 10 mm Input	5,2%	94,8%	4,9%	95,1%
Anteil von 10/25 mm Input	9,7%	90,3%	1,7%	98,3%
Anteil von 25/80 mm Input	12,3%	87,7%	12,9%	87,1%
Anteil von < 80 mm Input	**8,9%**	**91,1%**	**7,7%**	**92,3%**

Qualität des Brennstoffs

Die stofflichen Eigenschaften der erzeugten Brennstoffe sind in Tabelle 2 aufgelistet. Aufgenommen sind rechts die Ergebnisse des Trennversuches beim ZAB.

Signifikant ist eine relativ enge Spannbreite der gefundenen TS-, der OTS-Gehalte und der **Heizwerte** – letztere im Bereich von 9,2 bis 10,1 MJ/kg. Ein höherer Heizwert ist technisch kaum herauszuarbeiten, da der OTS-Gehalt mit rd. 60 % recht niedrig ausfällt. Dies liegt an der hohen im Brennstoff mit ausgetragenen Inertstoffmenge der gesichteten Feinfraktion < 10 mm.

Chlor liegt im Bereich von 0,7 – 1,0 % d. TS, der Schwefelanteil bewegt sich beim Doppelversuch zwischen 0,2 und 0,3 % der TS, beim ZAB –Versuch um 0,6 %.

Bei den **Gesamt-Kohlenstoffgehalten** (TC – incl. Karbonat-Kohlenstoff) fallen die Unterschiede gering aus, untypisch niedrig ist der organische Kohlenstoffanteil (TOC) im Material aus Versuch 2 (erwartet werden kann für native organisches Material ein TOC in Höhe von 50 % des Glühverlustes – hier sollten also rd. 300 g/kg TS an TOC auftreten). Knapp 75 % des Gesamt-Kohlenstoffes sind biogener Herkunft, der nicht biogene Kohlenstoff entstammt überwiegend dem Karbonatanteil.

Bei den Schwermetallen treten erwartungsgemäß deutlich größere Abweichungen auf, die größten sind beim Kupfer und Antimon zu verzeichnen.

Tabelle 2: Qualitätsdaten der gewonnenen Brennstoffe

		Aliquotmisch. "Leicht"		**Brennstoff**
Parameter	**Einheit**	**Versuch 1**	**Versuch 2**	**ZAB-Vers.**
TS-Gehalt	Gew.-% FM	86,4	85,9	82,9
oTS	Gew.-% TS	64,8	62,1	57,3
Hu OS	kJ/kg	10.040	8.899	9.973
Hu TS	kJ/kg	11.998	10.764	12.525
Hu OTS	kJ/kg	18.524	17.339	21.859
Dichte	kg/m³	260	281	150
Chlor	Gew.-% TS	1,0	0,9	0,7
Schwefel	Gew.-% TS	0,22	0,28	0,61
TC	g/kg TS	315	294	357
TOC	g/kg TS	287	237	-
As	mg/g TS	3,1	2,9	3,4
Cd	mg/kg TS	1,6	5,3	2,4
Co	mg/kg TS	3,7	4,5	6,8
Cr	mg/kg TS	61	74	205
Cu	mg/kg TS	143	2.040	236
Hg	mg/kg TS	1,2	1,4	1,07
Mn	mg/kg TS	242	298	329
Ni	mg/kg TS	42,3	37,6	82,3
Pb	mg/kg TS	232	167	225
Sb	mg/kg TS	24	3	1
Sn	mg/kg TS	14	18,3	10,5
Tl	mg/kg TS	<0,001	<0,001	0,15
V	mg/kg TS	9,3	12,5	13,9

Qualität der Schwerstoffe

Der Vollständigkeit halber seien noch die Ergebnisse der Schwerstoff-Analysen hinsichtlich der hauptsächlich kritischen Parameter Eluat-TOC und Atmungsaktivität erwähnt:

Beim AT4 wurden in der Untersuchung der Schwerstoff-Mischungen Atmungsaktivitäten um 3 mg O_2/ g TS und damit Unterschreitungen des Grenzwertes (5 mg O_2/ g TS) gefunden.

Der Grenzwert von 300 mg/l TOC ist nach Abbildung 2 ohne eine zusätzliche Nachrotte nach den vorliegenden Ergebnissen nur einzuhalten, wenn eine korndifferenziertere Trennung erfolgt. Gerade im Feinkornbereich < 25 mm wird damit die Verunreinigung der Schwerstoffe durch Restorganik stärker gesenkt.

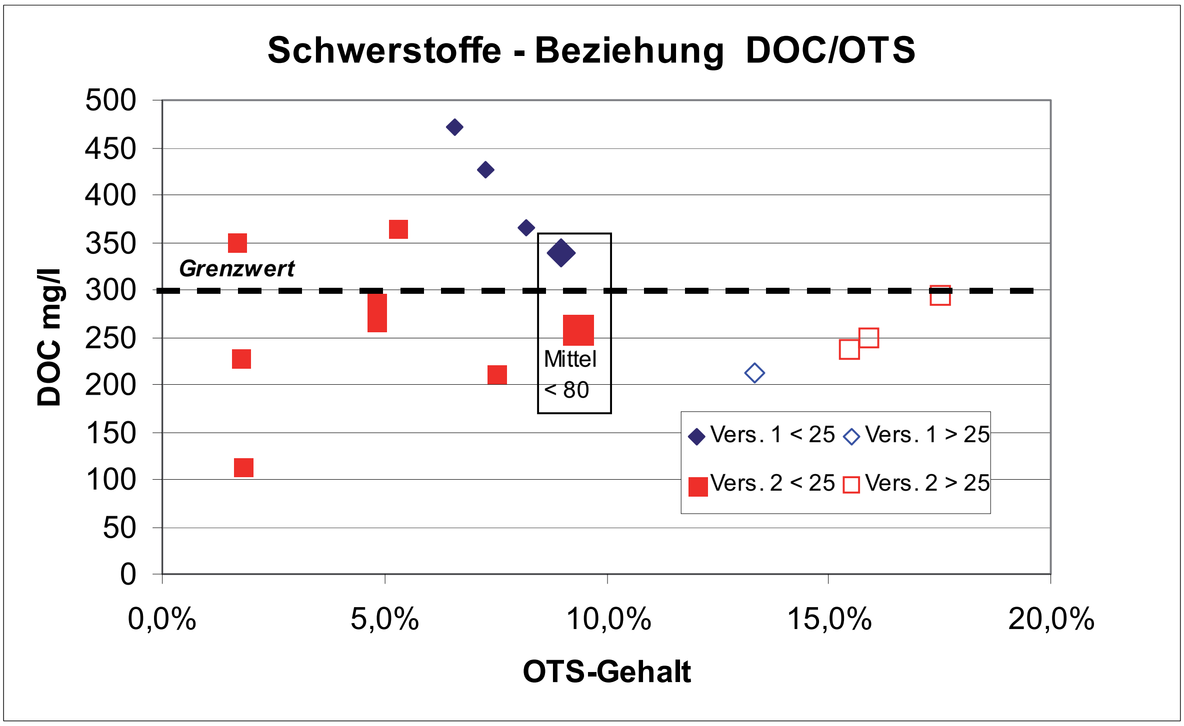


Abbildung 3: DOC-Eluat-Ergebnisse der Schwerstoffe

4 Erstabschätzung zur Klimarelevanz

Unter der Anwendung des bei dem ZAB-Versuch ermittelten Anteils an regenerativem Kohlenstoff von 73,5 % vom Gesamt-Kohlenstoff im Brennstoff (incl. Karbonatanteil) lassen sich für die erzeugten Brennstoffströme die freigesetzten Kohlenstofffrachten regenerativen Ursprungs für die Verbrennung errechnen.

Die Einsparungen an CO2-Äquivalenten gegenüber Braunkohle liegen demzufolge etwa bei

- 320 g CO_2 je kWh eingesetztem Brennstoff,
- 840 kg CO_2 je Tonne erzeugtem Brennstoff (mit rd. 9,5 GJ bzw. 2,64 MWh/Mg),
- 390 kg CO_2 je Tonne behandelten Unterkorns (bei 50 % Brennstoffanteil des Unterkorns),

- 250 kg CO_2 je Tonne Hausmüll (bei 30 % rückgewinnbarem Unterkorn-Brennstoff-Anteil im Hausmüll)

Gegenüber Steinkohle sind die o.g. Werte um rd. 15 % zu mindern. Bei dieser Betrachtung einer energieproportionalen Brennstoffsubstitution spielt der Wirkungsgrad des Kraftwerkes keine Rolle.

5 Fazit

Biologische Trocknung: Das Hausmüll-Unterkorn ließ sich auf einer darauf lüftungstechnisch speziell ausgerichteten Anlage (MBS-Anlage des ZAB) innerhalb von 9 Tagen auf rd. 15 % Restfeuchte trocknen. Bei einer konventionellen MBA ist eine Restfeuchte von 20 % im Hausmüll-Unterkorn innerhalb von rd. 14 Tagen Rottezeit ohne wesentliche Änderung der Betriebsführung erreichbar.

Auftrennung in Brennstoff und Inertmaterialien: Das getrocknete Hausmüll-Unterkorn ließ sich in der großtechnischen Anlage des ZAB wie auch in zwei Technikumsversuchen technisch problemlos trennen, wobei orientierend, je nach Materialkonsistenz

- rd. 2/3 des getrockneten Materials als Brennstoff zurückgewonnen werden,
- rd. 80 % der brennbaren Inhaltsstoffe (dominierend nativ organische Substanz) in den Brennstoff überführt wurden (10 % im ausgetrennten Schwergut, 10 % Abbau bei der Trocknung)

Ausgetrennte Inertstoffe: Die Mengenanteile der abzulagernden Schwerstoffe liegen in beiden Versuchen etwa bei

- rd. 35 % des biologisch getrockneten Siebgutes,
- rd. 17 % des Roh-Abfalls (dies entspricht etwa dem abgelagerten Anteil konventioneller MBS/MPS-Anlage) ,
- bei 20 – 30 % des im bisherigen MBA-Routinebetrieb abgelagerten Materials.

Die Deponiequalität hängt von der Aufbereitungstiefe des Trockenmaterials ab.

Ausgetrennter Brennstoff: Der Brennstoff hat einen relativ geringen Glühverlust im Bereich von 60 %, verursacht durch einen hohen Inertanteil im Feinkorn < 10 mm. Der untere Heizwert liegt zwischen 9 und 10 MJ/kg.

Rd. 75 % des Gesamtkohlenstoffs (einschließlich Carbonat-Kohlenstoffs) im Brennstoff sind regenerativer Herkunft. Der erzeugte Brennstoff konnte von Vattenfall im Kraftwerk Jänschwalde ohne verfahrenstechnische Schwierigkeiten verarbeitet werden.

Klimarelevanz: Je Tonne behandelten Unterkorns können bei Substitution von Braunkohle je nach Verwertungs- und Berechnungsverfahren rd. 250 - 390 kg CO_2 netto eingespart werden bei 50 % Unterkorn-Anteil im Abfall sind dies 125 – 195 kg CO_2 je Tonne MBA-Input.

6 Literatur

ASA	2010	MBA-Steckbriefe der Arbeitsgemeinschaft Stoffspezifische Abfallbehandlung, 2010
Kern et al	2008	Kern, M.; Raussen, Th.; Lootsma, A.; Funda, K.: Vergleichende Bewertung der stofflichen und energetischen Verwertung von Bio- und Grünabfall. 2008,
UBA	2005	Johnke, B.; Butz, W.: Klimarelevanz der Abfallwirtschaft. Umweltbundesamt Berlin, 2005
UBA	2010	Dehoust, G.; Schüler, D.; Vogt, R.; Giegrich, J.: Klimaschutzpotenziale der Abfallwirtschaft – Am Beispiel von Siedlungsabfällen und Altholz. Studie von Öko-Institut e.V. Darmstadt sowie ifeu-Institut Heidelberg im Auftrag des Umweltbundesamtes, Förderkennzeichen 370831302, Berlin, Januar 2010
Wallmann	2008	Wallmann, R.: Energieeffizienz bei der mechanisch-biologischen Restabfallbehandlung. In Thomé-Kozmiensky, K.J.; Beckmann, M. (Hrsg.): Energie aus Abfall. Band 5, TK Verlag Karl Thomé-Kozmiensky, Neuruppin, 2008, S.163-179

Anschrift des Verfassers

Dr.-Ing. Ulrich Wiegel,
ICU – Partner Ingenieure
Wexstraße 21
10715 Berlin
Telefon +49 857 33 490
Email: u.wiegel@icu-berlin.de
Website: www.ICU-Berlin.de

Experimental Optimisation of Static Composting Reactors

Kay Weichelt

Technische Universität Dresden
Fakultät Maschinenwesen

Experimentelle Prozessoptimierung statischer Rottereaktoren

Abstract

This study focuses on investigations for process optimisation of static dynamic reactors of the mechanical-biological waste treatment. This contains the process as self and the increase of the transparency of the whole control system. To achieve this, measurement equipment for temperature, gas composition and pressure was developed. It has been proved very resistant and practically in the special environmental conditions. For the first time ever it was possible to observe the procedures in a real waste composting tunnel with a very high accuracy by means of a measuring grid. By raising the measuring height of the installed three temperature lances, a resounding success for a much smoother and more homogeneous control was achieved. In the tunnel the appearance of wall effects due to undesired separation effects by the filling with a band-conveyor was detected. By the closure of vent holes in these areas, the effect was prevented and thus success for the process visible. A flow tube was designed and applied to determine the pressure drop and the settlement of the composting material. The results were faced to the density and the water content. The special relevance of water content for cooling the bed was noted, the water absorptive capacity was investigated and compression tests were performed.

Keywords

Mechanisch-biologische Abfallbehandlung, Statischer Reaktor, Optimierung, Mess-raster, Strömungsrohr, Druckverlust, Setzung

Mechanical biological waste treatment, static reactor, optimisation, measuring grid, flow tube, pressure drop, settlement

1 Introduction

The mechanical-biological waste treatment has become an integral part of the residual waste management in Germany. The majority of the installed MBT-systems are working on the principle of static aerobic fixed-bed processes and are based on partial streams due of the initial mechanical treatment before the biological step. Often the real operation behavior of such large simple static reactors is significantly different from the behavior aspired. This is reflected in low degragation rates with high variablity and significant gradients within the material. The aim of the research carried out by the TU Dresden is the process and procedure optimisation of static reactors at working plants.

The examinations are held in cooperation with the Märkische Entsorgungsanlagen-Betriebsgesellschaft mbH (MEAB) that uses a typical plant of the described typ on one location. The biological treatment in the intensive composting phase is realised in rotting tunnel with a length of 30 m and a cross section area of 5 m wide and 4.20 m height. The height of the rotting pile is nearly 2.40 m. The filling and emptying of the tunnel is done semiautomatically by means of a feeding and discharge machine. The filling takes place with a band-conveyor driven from the end to the front of the tunnel. Nozzels on the tunnel blanket are used for the irrigation; the ventilation is realised as pressure aeration through openings in the floor. Because of the installed air circulation the condition of the air followed from the position of three dampers (circulating air, fresh air, outlet air). For process control and mangement three temperature lances are placed in the material after filling. They are inserting into the tunnel from holes in the blanket.

In the further explanations, a material to treat in the first intensive rotting phase is named an entry material, while a portage as the discharged material will treat in a second phase.

2 Materials and Methods

2.1 General procedures

Because of the complex interaction of different influences in the three-phase system of the static fixed-bed process, not a purely analytical solution of the mentioned problems is possible. The processing had to be based on special experimental examinations, because it´s feasible to describe the activities with selected physical indicator values. Therefore the investigation focuses on the following aspects:

To show the relevance of improvements and thus for the examinations, the recent operating data of the process control system were evaluated firstly. This is followed by experimental tests. By the use of measurement intrumentation in the composting tunnel the real performance of the composting material and the system during the operating time was identified. Therefore a measuring grid was used. This allowed the acquisition of fundamental relationships for a better reaction on changings and thus the derivation of improvements for the process operation. Furthermore, it is possible to registrade the effects of a tunnel modification, maybe by a change of the aeration conditions or a change in the heigth of the rotting pile. To identify key characteristics of the treated material, studies on the behavior of the airflow through the composting material were necessary. With a flow tube the pressure drop and the settlement performance for a lot of batches were recorded and correlations to the water content and the material density were determined. Tests for water transport and the water absorption capacity complemented the findings.

2.2 Measuring methods

The technique developed and used for the work in the intensive composting tunnel is characterized by a very economical construction and the suitability for reuse under the specific environmental conditions of waste. It allows a determination of the temperature, gas composition and pressure situation in several places in the rotting material. For this, from outside a combination of flexible gas suction tube and temperature sensor is inserting through the hole of the blanket into the tunnel. Inside you can install the probes into the composting material at any heigth you want. On the blanket, you passed into the ports for gas sampling and seperate the cable of the thermocouples from this combined tube. The temperature is recorded continuously by means of an external stationary data logger; in the first instance the gas composition (CO_2, O_2, CH_4) is affected manually with a portable analyzer. At the ports for gas sampling it is possible to determine the pressure at the measuring points. The measurement equipment is removed before the discharge of the composting material, so it´s available for further tests in several times.

The settlement of the composting material and the typical pressure drop of a bed at a certain flow are examined with an individual developed flow tube (useable volume 0.5 m³). It enables studies with a real bed height (2.90 m) and ensures with their large cross-sectional area and the specific properties of the material that there isn´t expected a significantly influence of the results due wall effects. Because of the low wall friction the settlement is not disturbed. The material lies on a grid, under which the injected air is distribute and enter the bed. This forms a measurable pressure drop. The tube can also used for other kinds of material.

3 Results and discussion

3.1 Current situation with control system data

First the qualitative analysis of the time course and the level of temperature of the thermocouple lances was done. We´ve seen that only 27 % of the considered batches shows an aimed temperature profile with a few up and downs on the composting time and a temperature of nearly 55 °C. In 38 % there were significant variations in the course, but the temperatures were close to each other. The remainder batches show partial very large differences both at the temperatures and in the course.

Important is that the good state occurs at the entry material only to 9 %, but at the rearranged composting material (portage) to 47 %. All three temperatures of the lances show a different value in case of 28 % of the tested entry material batches, but only in 4 % of the portage. The duration of treatment in the intensive composting rot of the entry material was in one third one week and in two-thirds two weeks. Three-quarters of the portage takes two weeks and equally one or three weeks in the composting tunnel.

Another point is also relevant. In 77 % of the cases, the temperature of the process outlet air is completely or partly higher than the temperature of the lances. The average divergence is 5 till 10 K. And sometimes the temperature of the exhaust air was lower than the one of the lances. A possible reason could be a short-circuit flow through the bed, just as a result of the phenomenon of wall effect which is described later.

The results show that an optimum process management is possible, but in particular, that a consistent approach and further development is required.

3.2 Process management of the intensive rotting tunnel

To determine the current behavior of the composting material, a measuring grid of temperature, gas composition and pressure situation was installed in the entry and the portage material in the rotting tunnel. The tunnel was equipped area-wide at twelve places with the described measuring probes. The height of the measuring was at 1 m above the floor. As an example of the achieved results, the figure 1 compared the temperature at the twelve measuring points with the temperature of the three lances (bulk broken lines) at the same time.

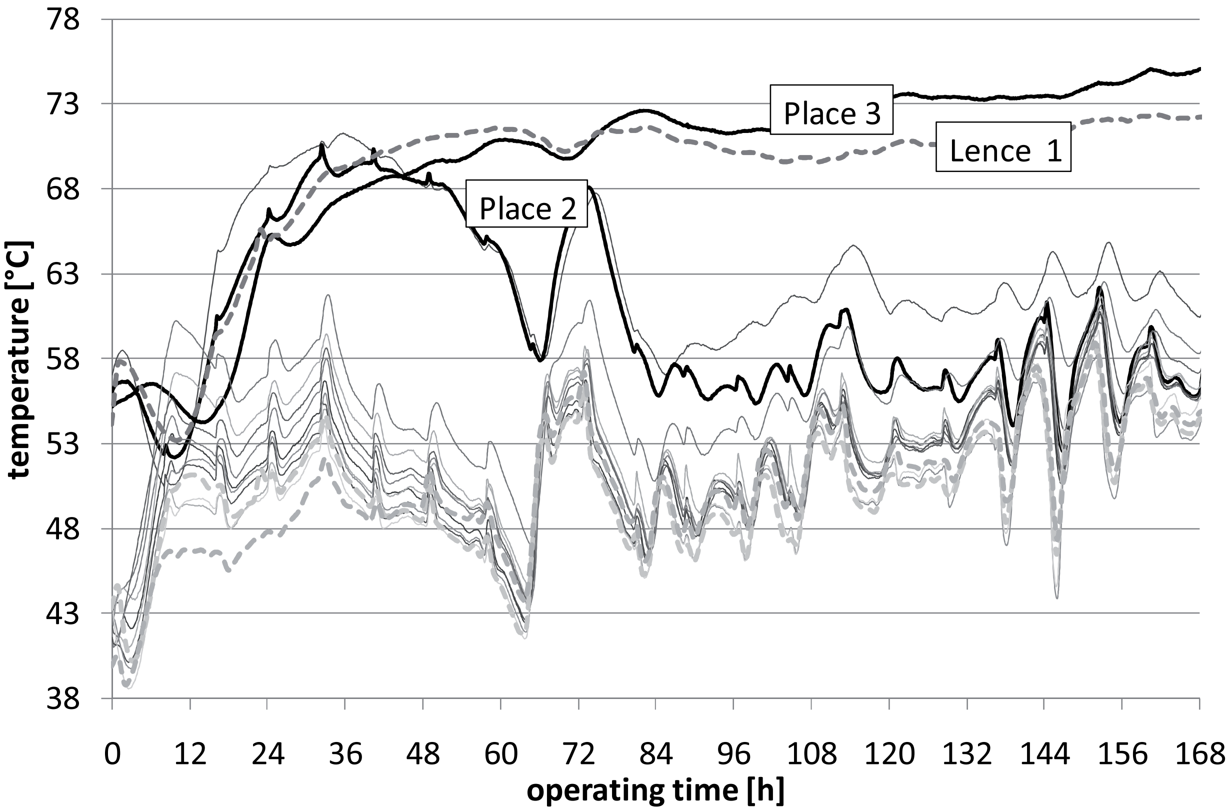


Figure 1 Temperature of the three temperature lences and the own twelve measuring probes

Therefore, in some cases the recorded values of the measuring probes are significantly above the temperature of the lances. In addition, you see the big differences between the lances as self and also between the twelve individual measuring points. The massive discrepancies already in a small space represent the non-uniform flow through the material accumulation in a special matter. For example the distance between the places 2 and 3 is less than 80 cm, but the temperature difference is sometimes more than 15 K.

The maintenance of good conditions from the start of the process is problematic in the further progress. Because of physical laws inhomogeneities (gradients) will be arise quickly. It´s clear that the preferred flow of the air is through areas with a less flow resistance. But this will lead to a drying of these regions; thereby the permeability will be even more improved. For that reason a deficit of air is created in the other zones of the bed with negative phenomenon like an increasing temperature and a bad biodegradation. This problem could be solved mainly by using a segmented air basement. In this case it is possible to react on differences in the pile lying above the segment. Otherwise, creating the best possible initial state is even more important.

With the conventional process control the intensity of the heterogeneity is determined only unsatisfactory. Currently, interventions take place especially after a certain period of time and by the experience of plant operators than of fixed resilient criteria. Due to principal specifications the process control can only react on each state by the adjustment of the irrigation and of the ventilation. The process control must follow the specified values, which are given in each rotting phase.

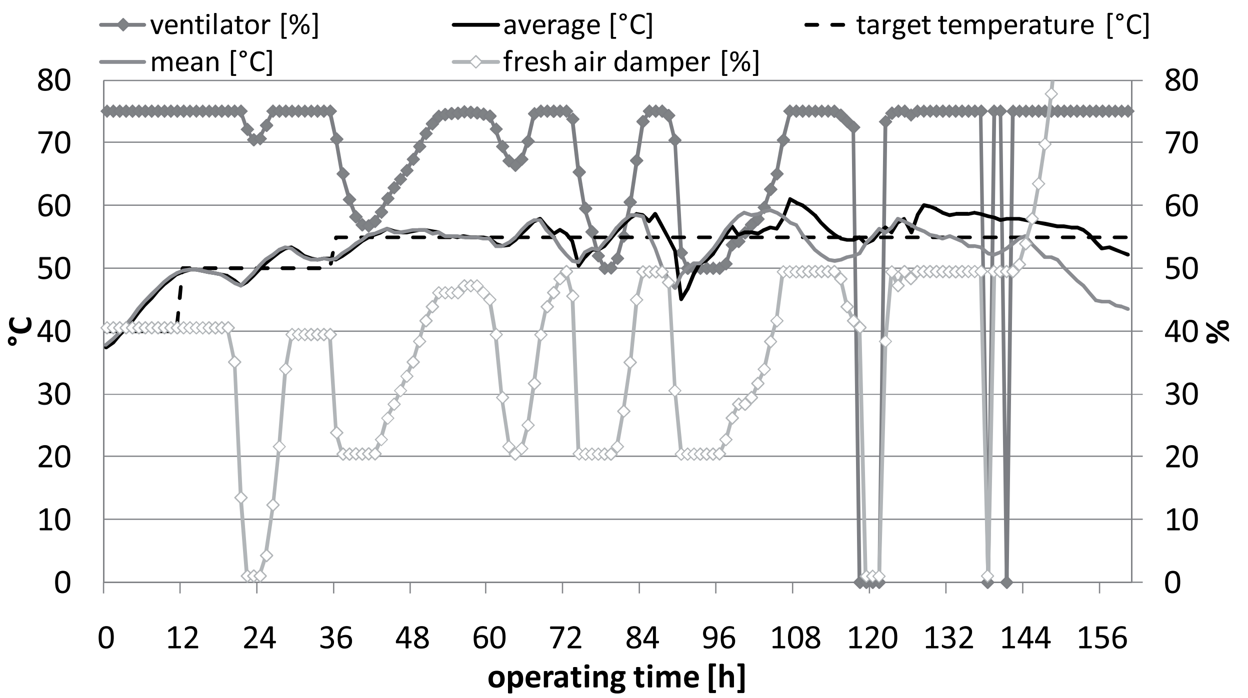


Figure 2 Operating performance without a correction of the lences measuring height

Figure 2 shows the control process exemplary. Herein, the average represents the real or current control value. This value is the relevant one to manage the process to achieve the desired target temperature of such as 55 °C in the main rotting phase. The mean is the self calculated arithmetic average of the three temperature lances. While it initially matches a correlation, the mean and the average form a difference in course of the process. The explanation for this aspect lies in the increasing formation of gradients. The discrepancy is a symbol of too large temperature differences between the lances each other. Because in this case, as a special characteristic of the control system, not all lances are incorporate in the internal calculation of the average.

General, the entire process flow looks quite discontinuous. It’s also visible at the ventilation power and at the position of the fresh air damper. A resounding success for greater stability was achieved by a correction of the lances measure height, which was increased from 0.25 to 1 m above the aeration floor. Experience knowledge shows that it comes to a very intensive formation of gradients in the lower areas, while homogeneity is maintaining longer in higher altitudes. The method leads to temperature profiles which are more harmonious and consistent. The deviations of the lances each other and the previously observed variations are mainly fundamentally lower. The same applies to the damper position and the ventilator revolution speed. This is a sign for a much smoother process control. In face of the existing principle disadvantages of the simple designed large static composting reactors, this method was an improvement and will be affecting a long term.

However, based on the improved representation of the reality due the increased measuring height, the detected temperature is about 70 °C. And this is far greater than the desired value and requires a consideration in the process management. But this new situation wasn´t based in the implementation and conception of the whole control system. The following description shows that it’s not trivial to react with the existing regulation. In the described case, the ventilator is operating already at the implied maximum, and the fresh air damper has reached the maximum possible degree of opening in this rotting phase. But for all that, the temperature in the bed is not reduced.Together with the consequently high temperature level of the outlet air, the limited fresh air damper position leads to the situation, that the entry air temperature is already higher than the target temperature in the bed.

In this context, it must be suggest to the fundamental phenomena of cooling a waste accumulation. A dissipation of heat is only possible by evaporation heat. However, with the basic idea of minimising the amount of air, the composting tunnels were equipped with an air circulation. But the induction of a part of the extracted air from the tunnel as inlet air is nearly ineffective, because no condenser was installed in the recirculation loop. Thus, nearly moisture-saturated air is moved in the circuit, because it isn´t considered to recover the cooling capacity of air due the separation of water.

Another complicated situation arises from the tunnel filling with the band-conveyor of the filling machine. There is an unavoidable separation effect, when the material is dropping from the band. Because special parts roll down of the developing material cone and will be deposit on the wall. Hence, in these areas occurs a bed with a greater porosity and thus a lower flow resistance. Consequently, the flow from the aeration floor in these regions is increased, which leads to the phenomenon of a wall effect. This also occurs at the two cones at the front and the end of the pile. Because of the different height of the bed, different flow resistance will arise. On initiative of the TU Dresden, the vent holes in these areas were sealed, because reduction of wall effects and short-circuit flow is essential for a homogeneous moisture and temperature distribution in the bed.

The detection of the wall effect can only be effected by experiments and here only by indirect measurements. In experiments gas measuring points and temperature data logger were placed in the composting material at different heights along the tunnel wall and in the middle of the pile. The measurements demonstrated that the concentration of CO_2 in the middle of the bed has clearly higher values than in the boundary area. This is a sign that the flow through the regions near the wall is proven better than in the rest of the bed. The temperatures also support this result.

In further studies the wall effect was excluded by sealing the vent holes in a width of 1 m in the edges. Without cover, the temperature at the edge was lower than in the middle of the bed, but with the sealing it is more evenly distributed across the tunnel width. This aspect also applies to the pressure. With the sealing it is not as far a less pressure at the outer probes as in the middle. In general, the determined pressure is greater at all points now. Possible consequences of the increased pressure on the floor to a possible reduction of the ventilator revolution speed must be part of further explorations. It is obvious, that the degradation parameter also must be considered.

3.3 Characterisation of the composting material

The flow through the composting material has a significant importance for the success of the process and the energy consumption of the plant. The investigations at the flow tube were carried out with superficial velocities of 6 till 42 $m^3/(h\ m^2)$.

In the examined flow range, there was an almost linear relationship between superficial velocity and pressure drop. The proportionality is set by the flow resistance coefficient R_{tot}, which is independent from the flow volume and thus practicable to use in the discussion. The figure 3 shows the flow resistance over a test period of seven days for different batches. A same numbering and the same marker type indicate the corresponding material of the two rotting phases. The broken lines represent a portage and all the rest an entry material.

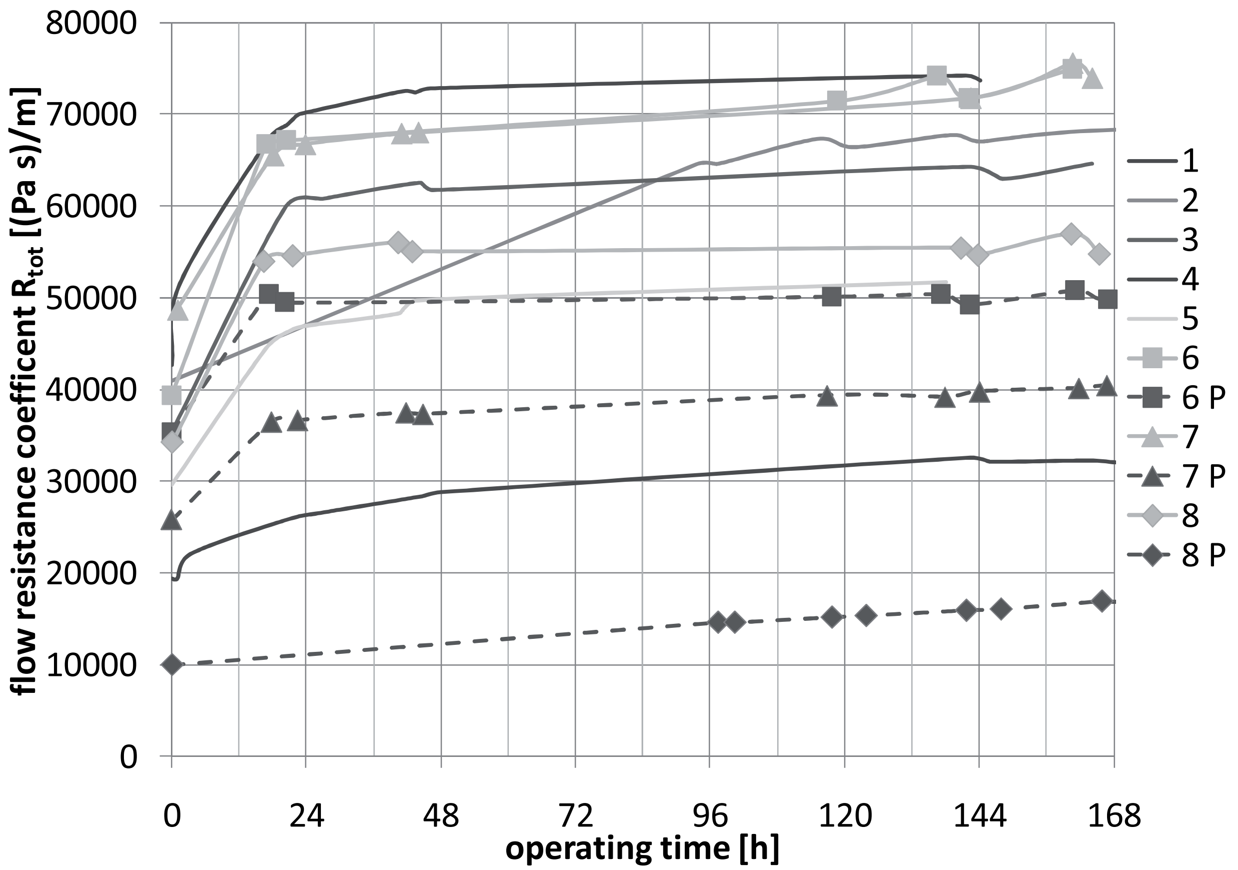


Figure 3 *Flow resistance of the composting material in relation to the operating time*

At the beginning the flow resistance is between 10000 and 49000 (Pa s)/m. With increasing time the coefficient gets mostly raised within 48 h to the maximum value which is 40 to 80 % above the initial data. Thus may require an adjustment of the aeration. The level of initial pressure loss is not relevant to the relative increase, but indicative for the absolute value at the end of the procedure. Due to the composting process the flow resistance of the portage material was always significantly lower than the value of the entry material. So it’s essential to consider this aspect in the process management as well.

Accordingly it was necessary to find reasons for the huge differences in the initial pressure drop. It was obvious to use the initial material density, which was determined by means of mass and settlement, and also to use the moisture determined by gravimetric analysis. The comparison of the initial density with initial water content (figure 4) shows an unusually good relationship. A rational explanation is that material with a huge mass includes more organic matter, which can principally hold and store much water. The expectation that a lower density leads to a lower pressure drop could confirmed only by tend (figure 5). Therefore, no direct correlation between water content and flow resistance can be derived. Other variables, which are not influenceable, maybe cover the effects.

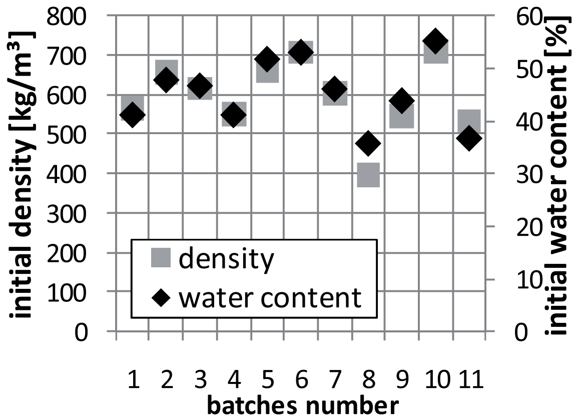


Figure 4 Initial density and water content for some batches

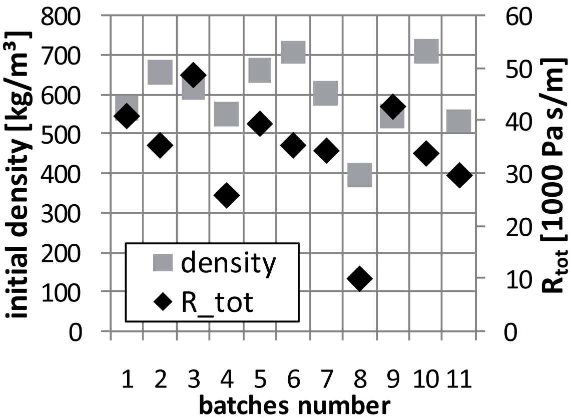


Figure 5 Initial density and flow resistance coefficient for some batches

In preliminary investigations, the water content of composting material has been changed manually and a flow through this matter was realised. According to this, the flow resistance decreased at the beginning with increasing water content. But from a certain point the value rise again. A detailed analysis must bring further illustration and an explanation.

A major determinant of the increase in pressure drop over time must be found in the settlement of the material. The level of settlement with 25 to 42 cm was very different. At an initial height in the column of 2.90 m, this means between 8 and 15 %. In general, the settling of the entry material is stronger than that of the portages. Suspected correlations between settlement and R_{tot} are confirmed, because it mentioned above, that the flow resistance of the portage is lower as well. In general, proportionality between flow resistance and settlement was observed for the most cases. However, the reason for the different pressure drop could not be found definitely. In further experiments, in which the material properties were excluded by utilisation of the same matter, an exponential increase of the settlement with increasing bed height was noted. On the other hand the flow resistance increased approximately linear. To insert this information in the previous results is a way for the explanation of the effects.

3.4 Hydrology of the composting material

As already described, the water content of the composting material represents a very important technological parameter for the biodegradation and for the cooling of the bed. In an experimental arrangement, the current irrigation profile was reproduced on a smaller amount of material. Surprisingly the humidification was relatively uniform and the presumed formation of water streets could not be detected at moderate water volume. But as expected, the water conductivity of the composting material was insufficient to transport the required water to the relevant deeper areas in the bed. Compared to the heigth of the pile, only a small region at the top was wet.

So the irrigation of a bed with a height up to 3 m only by means of nozzles of the tunnel blanket is not possible. Thus the only improvement lies in creating initial water content large as possible. But the aspects of the pressure drop and the compression phenomena must be considered. With a series of experiments, the water absorption capacity of several batches of waste was examined. A maximum water level of 70 % led to the total mass was always occured. The optical properties of a material with average initial values of 45 % often hide the remaining reserves. Moreover, this value must be reflected as a limiting factor in the recent statements, what didn´t happens till now and thus it is a task for further research.

With compression tests in a smaller examination column the limit of maximum process water content was identified. It must to prevent that it comes to partially pressing of water by the settlement of the material, because this one will exit the bed and flow into the aeration basement. And also the danger exists that water streets due to a total wetting form a prefered flow arrangement for the air. Analogous to landfill simulators, the material was stressed with a static pressure from above. The compression was detected and the water amount to the column was collected. Accordingly, at a constant load the discharged water volume increases exponentially with the water content of the material. And it was also indicated that no water discharged with unmodified entry material and that therefore reserves for increased water content still exists. Further series of experiments must to substantiate these results.

4 Final remarks

The achievements described were the result of experimental procedures and cannot be replaced by purely theoretical considerations because of the specific conditions of the real waste treatment plant and of the special waste proporties. The big effort was justified because the analysis clarifies the necessity for an optimisation of such systems. The application of the measuring system in almost any arrangement of this type is given and strongly desired from the Technical University of Dresden. Because of similar conception and construction, the described phenomena and problems are to detect in several plants. Further investigations should generate new experiences under a lot of different conditions and to support the operator on the way to an optimisation of the own system. This should make it possible to define compilations of response in the process to react on anomalies in the bed specifically.

Using the current developed computer-controlled measurement system, a continuous gas analysis is possible in the future. This allows a far better and more sensitive process monitoring, and will generate clear advantages in relation with the temperature and the control system.

To increase the transparency of the process and the control guidance, flow measurements would be required. Due to structural conditions, the implementation is not possible. Helpful is here an integration of local pressure measuring points in the arrangement of the process control management. This made it possible to detect the current effects of the coupled process air system. This includes unexplained false air entry flows and the interactions of the tunnel with one another due to the air circulation. The phenomenon is reflected in a cross flow between the fresh air and outlet air manifold.

An optimised bed height should be determined by taken the previous results and the inclusion of additional evaluation points and the degradation parameter. Possible advantages are the less amount of material to decrease the number of potentially different batches and to reduce the flow resistance and therefore to reduce the ventilation effort. On the other hand it´s not clear if a feasible minimizing of the composting time by the improved biological degradation could compensate the decreased capacity. However, a minimised height could increase the possibility that discontinuity areas ranged from the bottom to the top of the pile. Hence, the effect of short-circuit flow could be greater than before.

The researches would not have been possible without the project partner MEAB. We thank a lot for their active and constructive support.

Author´s adress:

Dipl.-Ing. Kay Weichelt
Technische Universität Dresden
Institut für Verfahrenstechnik und Umwelttechnik
Lehrstuhl für Thermische Verfahrenstechnik und Umwelttechnik
01062 Dresden
Telephone +49 351-463 33282
Email: kay.weichelt@tu-dresden.de
Website: www.tvt-uvt.tu-dresden.de

An innovative approach for grape marc treatment: biodrying before combustion

Simona Ciuta*, Elena Cristina Rada, Adrian Badea*, Marco Ragazzi**, Felix Ast***, Cosmin Marculescu*, Tiberiu Apostol***

* Department of Energy Production and Use, Politeh. University of Bucharest, Romania

** Department of Civil and Environmental Engineering, University of Trento, Trento, Italy

***Metal Inox di Barison G.&C. sas, Gardolo, Italy

Abstract

The aim of this paper is to present the results of a study on one of the possible uses of exhausted grape pomace/marc aimed to energy recovery. The chosen process was the bio-drying one, followed by combustion, for producing steam used to cogenerate thermal and electrical energy. Details regarding proximate and ultimate analysis of dry and wet grape marc, seed, skin and stalks are presented, and also some details regarding the mass and energy balances for the proposed approach are reported. Additionally some details regarding the anaerobic digestion as a suitable process for grape marc treatment are presented in this paper.

Keywords

Grape marc, pomace, biodrying, energy.

1 Introduction

Viticulture has an important role for the economy of a country. Romania, like Italy, has a great potential for the exploitation of vines. In Romania there are a total of 37 vineyards, which include 123 centers with added 40 independent wine centers, located outside the vineyards (National Ownership of Vine and Wine, 2007).

The term grape marc identifies the material that appears as a result of the crushing of the grapes in the wine companies. The pomace is consisted of skin, rich in perfumes but poor in sugar content or alcohol, of residues of the must or wine, from seeds of the grape, called pips, and the support of the berries (stalks). The grape marc attributed to the distillery has a consistence of 56% seeds, 46% skins and approximately 2% stalks (Ministry of agriculture, forests and rural development, 2007). Some wineries reuses this material as fertilizer while others are exploring options of selling the used pomace to biogas companies to be used in the creation of renewable energy.

2 Physical, chemical and thermal characteristics of grape marc

The products used in this study are derived from a wine institute in Romania, from red and white grapes. Grapes after being separated from their stalks in a special machine, are pressed in automatic presses for high quality wine production.

The fresh grape marc obtained after juice extraction was treated in a drying oven for 24 hours at 105°C. The moisture content of the material as arrived, after pressing, was estimated at about 60%. For the determination of volatile solids (VS), the dried sample has undergone a medium temperature pyrolysis process at a temperature of 800°C and the crucible with material previously graded, stayed in the oven for 40 minutes. The samples obtained were subjected to a combustion process in order to determinate the total content of the combustible materials and respectively the one of inert (non-combustible). This process took place at a temperature of 1000°C, for about an hour (Apostol et al., 2006). The VS content of total solids (TS) resulted 96%, while the inert material represented 4%. An elemental analyzer (EA 3000 Series) was used to establish the composition of the product. The carrier pressure has been established at 80 kPa, the front furnace temperature at 980 °C and also the weight of the samples varied from 0.8 to 2.5 mg. The results of the analysis are presented in Table 1. The high heating value (HHV=20,397 kJ/kg) in order to establish the energetic potential of the material was measured using a calorimetric bomb.

Table 1 Elemental composition of grape marc [%TS]

C	H	O	N	S	Ash
41.21	5.94	45.50	0.65	3.24	3.46

3 Bio-drying followed by energy recovery

Because of its high content of moisture (60%), the bio-drying process was chosen in order to treat this material (Rada et al., 2009). The aim of this aerobic process is the exploitation of the exothermic reactions for the evaporation of the highest part of the water present in the treated material with the lowest conversion of organic carbon. This process was chosen for giving an alternative to the typical grape marc drying approach (thermal drying usually performed in the same site of combustion, in order to exploit the heat of off-gas).

The solution taken into account in this paper is proposed in Figure1: three decentralised bio-drying followed by combustion and cogeneration system for energy production.

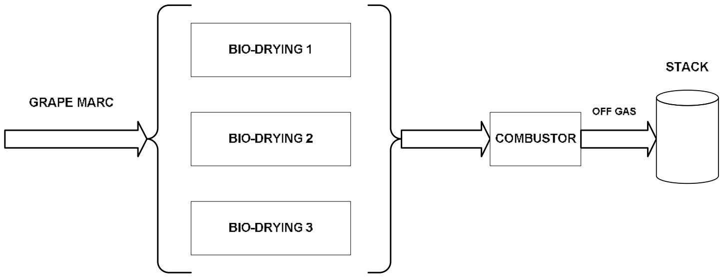


Figure 1 Grape marc thermal treatment with decentralized bio-drying

4 Results and discussion

The lasting of the bio-drying process was considered 3 weeks for obtaining a better value of LHV. For this specific period of time, the theoretical energy consumed for treating one kilogram of grape marc resulted 35 kWh; the percentage of weight loss was 28% (0.028 kg_{VS} and 0.252 kg_{H2O}) and moisture decreased from 60% to 48%.

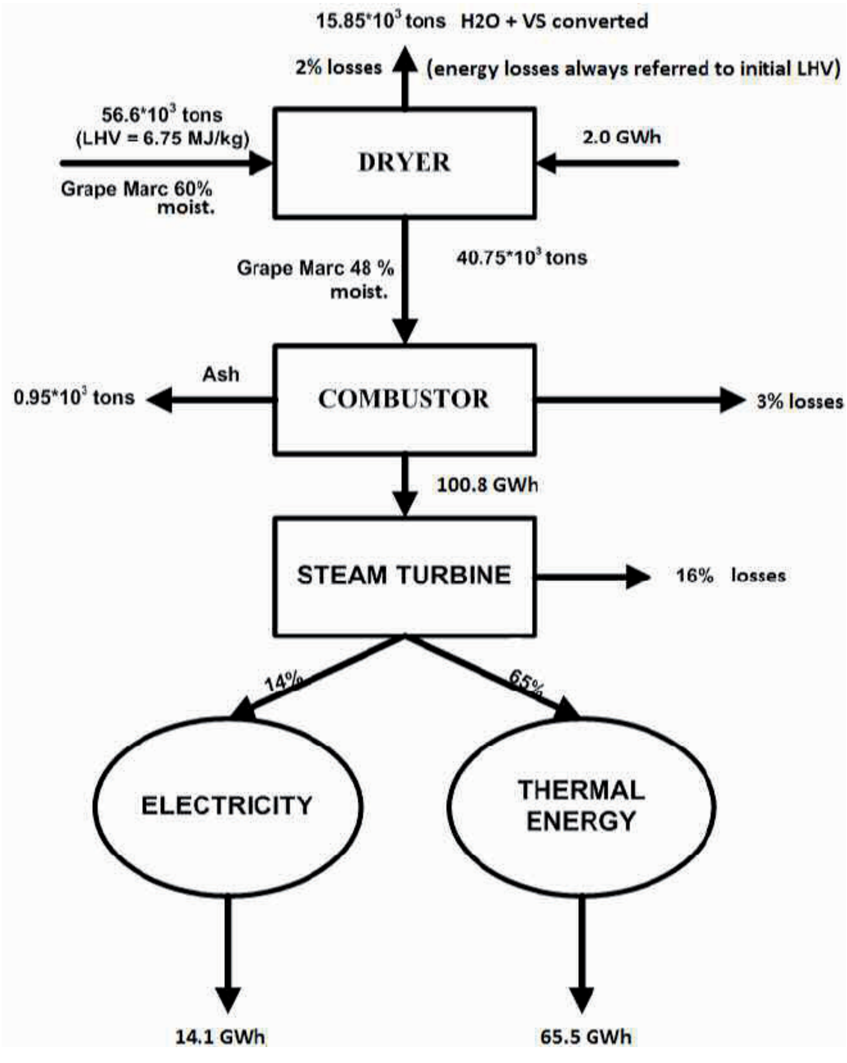


Figure 2 Bio-drying scenario (mass and energy balance)

Assuming one of the three decentralized bio-driers needed for the national amount of grape marc, some balances are shown in Figure 2. A turbine connected to an alternator would be able to generate 14.1 GWh/year of electricity (14% of the input) (Grau et al., 1995), but the internal consumption for aeration must be taken into account. Grape marc bio-drying seems to guarantee the minimal value needed for a good combustion alone in a burner without integrated pre-heating or integrated pre-drying.

An alternative to this scenario is the anaerobic digestion process as a wet process without the need to dry the input material and hence mainly suited for an input material with high water content like grape marc. Mass and energy balance of this scenario is presented in Figure 3. As process lasting is limited by technical needs, only a part of the biodegradable matter can be converted to biogas. In this paper a preliminary balance is proposed assuming about 50% of Carbon conversion into biogas. Results show a higher generation of electricity and a lower availability of heat, compared to bio-drying (that is not affected by digestate management requirements).

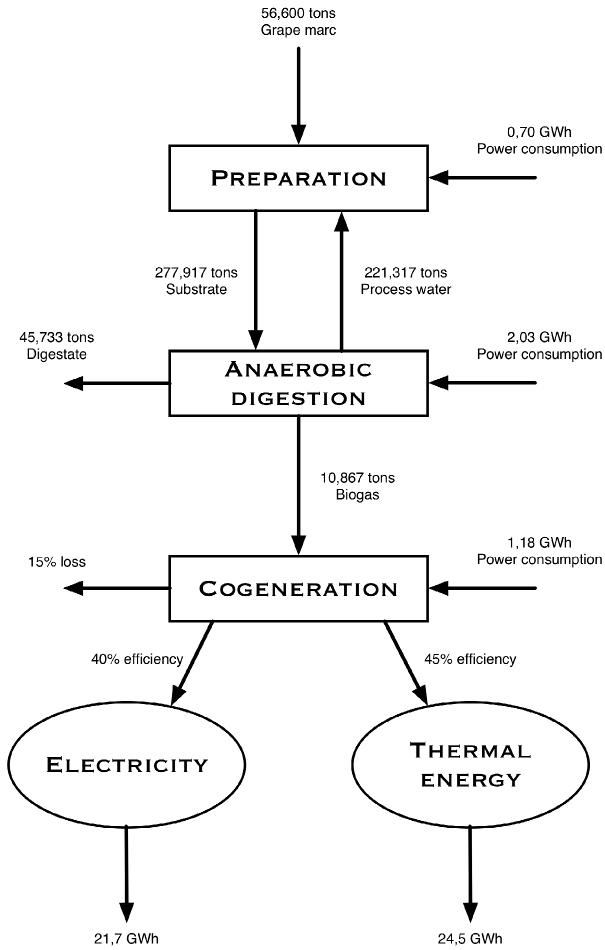


Figure 3 *Anaerobic digestion scenario (mass and energy balance)*

5 Literature

National Ownership of Vine and Wine	2007	***http://pnvv.ro/
Ministry of agriculture, forests and rural development	2007	*** http://mapdr.ro/
T. Apostol, C. Marculescu,	2006	Management of solid wastes, Editor AGIR, 2006, pp 29-31, ISBN 973-720-060-8
E.C. Rada, M. Ragazzi, L. Fiori, D. Antolini,	2009	Bio-drying of grape marc and other biomass: a comparison, in WATER SCIENCE AND TECHNOLOGY, v.60, n. 4, p. 1065-1070
S. Grau, T.B. Reed	1995	An Atlas of Thermal Data for Biomass and Other Fuels, NREL

Author's addresses *:*

Ing. Simona Ciuta
Department of Energy Production and Use, Politehnica University of Bucharest, Bucharest, Romania
Spl. Independentei 313
RO-060042, Bucharest 6, Romania
Telefon +40 21 402 96 75
Email: ciuta_simona@yahoo.com

Dr.-Ing. Elena Cristina Rada
Department of Civil and Environmental Engineering, University of Trento
via Mesiano 77
IT-38122 Trento
Telefon +39 0461 28 26 13
Email : Elena.Rada@ing.unitn.it
Website: http://www4.unitn.it/People/it/Web/Persona/PER0038284

Dr.-Ing. Adrian Badea
Department of Energy Production and Use, Politehnica University of Bucharest
Spl. Independentei 313
RO-060042, Bucharest 6, Romania

Telefon +40 21 402 96 75
Email adrian.badea@energ.pub.ro

Dr.-Ing. Marco Ragazzi
Department of Civil and Environmental Engineering, University of Trento
via Mesiano 77
IT-38122 Trento
Telefon +39 0461 28 26 09
Email : Marco.Ragazzi@ing.unitn.it
Website: http://www4.unitn.it/People/it/Web/Persona/PER0003630

Dipl.-Ing. Felix Ast
Metal Inox di Barison G. & C. sas
Via Vienna 14,16,50
IT-38121, Gardolo, Italy
Telefon +39 0461 992569 int. 9
Email mail@lefixast.de
Website: www.metalinox.tv

Dr.-Ing. Cosmin Marculescu
Department of Energy Production and Use, Politehnica University of Bucharest
Spl. Independentei 313
RO-060042, Bucharest 6, Romania
Telefon +40 21 402 96 75
Email: cosminmarcul@yahoo.co.uk

Dr.-Ing. Tiberiu Apostol
Department of Energy Production and Use, Politehnica University of Bucharest
Spl. Independentei 313
RO-060042, Bucharest 6, Romania
Telefon +40 21 402 96 75
Email: tiberiuapostol80@gmail.com

Mechanical Dewatering of Digestate

- Necessity and Potential

Peter Schalk

InnoWaste, Germany

Abstract

Anaerobic digestion has become an established component of mechanical and biological treatment of municipal solid waste. However, anaerobic digestion does little to reduce the mass of solid waste in the form of biogas. The water content of digestate is increased after anaerobic digestion. Even dry fermentation systems produce a surplus of process water, which can inhibit the decomposition process. Mechanical dewatering of digestate can increase the yield of biogas and improve the conditions of decomposition.

Inhaltsangabe

Bei der mechanischen und biologischen Behandlung von Siedlungsabfällen erfährt die Vergärung der biologischen Fraktion eine zunehmende Bedeutung. Die Vergärung von Biomassen und Abfällen führt nur zu einem geringen Massenverlust in Form von Kohlenstoffen im Biogas. Dementsprechend nimmt der Wassergehalt im Gärrest insbesondere aber der Anteil von freiem Wasser aus dem anaeroben Abbau zu. Auch die sogenannten Trockenvergärungssysteme erzeugen einen Prozesswasserüberschuss, der in der nachfolgenden Kompostierung die Startphase erheblich erschweren oder gar blockieren kann. Die Betriebserfahrungen mit der mechanischen Entwässerung von Gärresten haben gezeigt, dass einerseits in der Vergärungsstufe die Biogasausbeute erhöht werden und andererseits die nachfolgende Intensiv-/Nachrotte bzgl. Wasserüberschuss und Rotteführung entlastet werden.

Keywords

anaerobic digestion, biodegradation, biogas, dewatering, leaching, mechanical-biological treatment, treatment of digestate, dewatering by screw press

Vergärung, Entwässerung, mechanisch-biologische Abfallbehandlung, Gärrestbehandlung, Entwässerung mittels Schneckenpresse

1 Process Water in Anaerobic Digestion

1.1 Introduction

The wet organic fraction keeps water at the centre of the treatment of municipal solid waste. Water is the main component of solid waste and it plays a key role in biological processes such as hydrolysis and aerobic treatment (see Fig. 1).

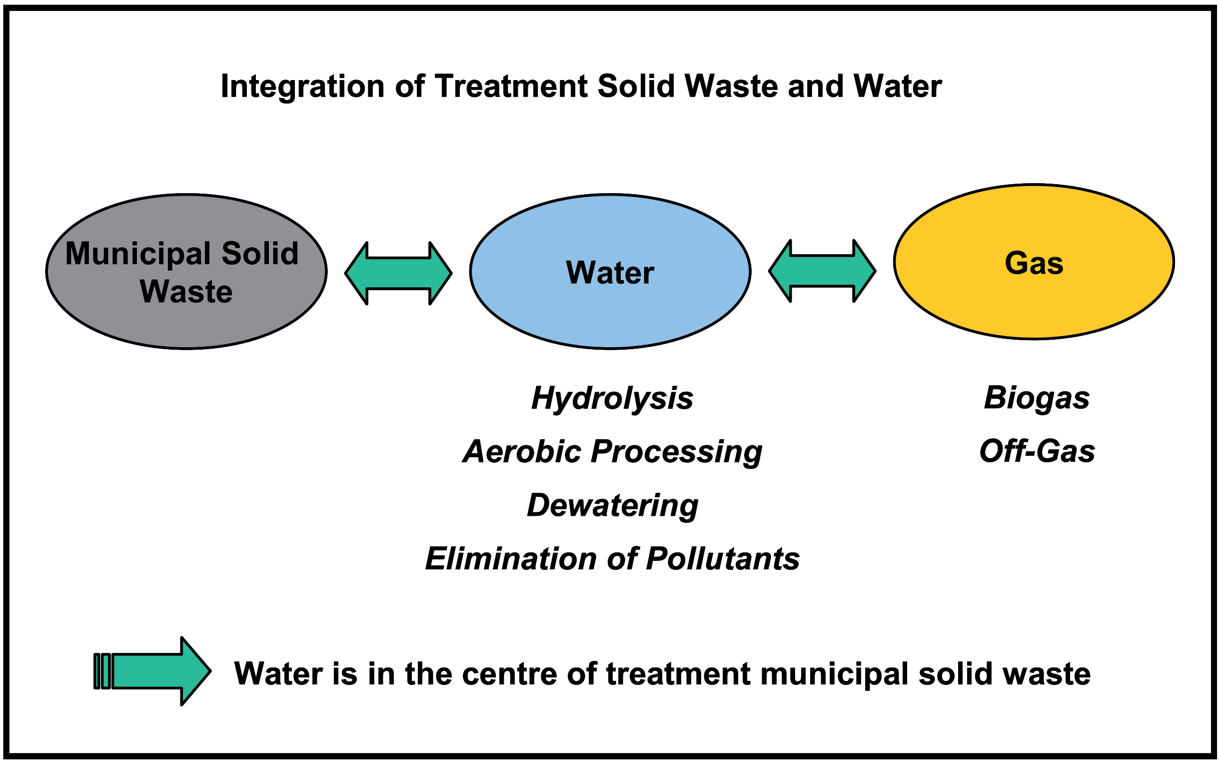


Fig. 1 Water at the centre of mechanical biological treatment

Basically, treatment of digestate must be part of anaerobic digestion of municipal solid waste. This challenge has to be accepted on the path to an integrated concept for treatment of municipal solid waste:

- High moisture content
- Enrichment and concentration of pollutants (ammonia, chlorine, POP)
- Inhibition of decomposition process

The recirculation of process water to fermentation accumulates pollutants (ammonia, chlorine, persistent organic substances), which are not biodegradable by anaerobic digestion. These concentrated substances can compromise the process stability of fermentation and additionally downgrade the quality of digestate.

Regarding mass balance of a plant for mechanical biological treatment (exemplary MBT), the main reduction in mass is achieved by dewatering (see Fig. 2). Biogas makes up only 7% of the total mass of solid waste.

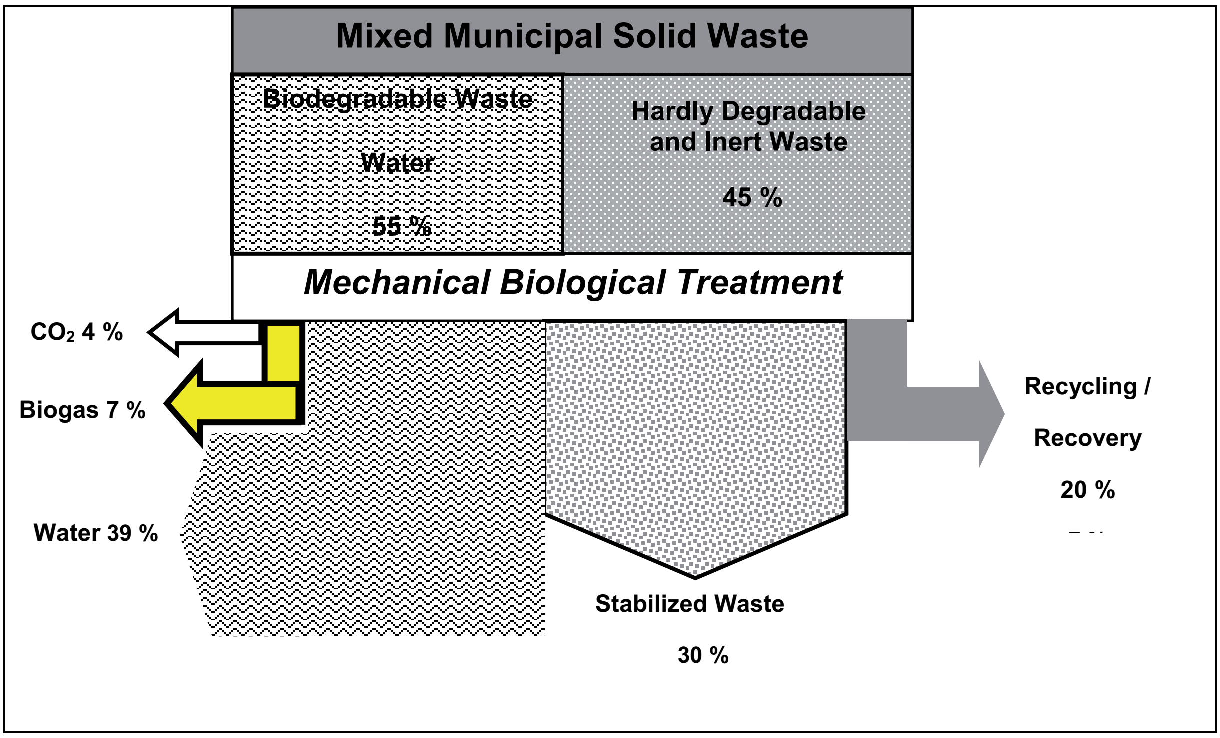


Fig. 2 Mass balance of mechanical biological treatment

1.2 Mechanical Dewatering

Mechanical dewatering is generally installed either before anaerobic digestion or afterwards for treatment of digestate. Dewatering of solid waste is designed to produce process water by percolation or extrusion, and it is then converted to biogas. Dewatering of digestate is intended to reduce water content and to improve conditions for decomposition (see Fig. 3).

(1) Press Screw Separator

The press screw separator has a wide range of applications in the separation of liquid manure and digestate in agricultural fermentation. The press screw separator is basically designed for the separation of solids and liquids. Liquid is recirculated to dilute the solid component of fermentation.

(2) Screw Press

The screw press is generally used to dewater digestate. In an optimal process there is enough bulking solid to run the process without requiring additional chemicals for flocculation.

(3) Centrifuge and Decanter

The centrifuge and decanter are generally used for dewatering excess sludge from sewerage treatment plants. The dewatering process normally needs flocculation chemicals. Digestate should be free of inert materials (sand) to prevent wear.

(4) High-pressure Screw and Screw Extruder

The high-pressure screw and screw extruder are used for dewatering solid waste to reduce the total mass and increase calorific value. Treatment of organic waste or organic solids by the screw extruder increases the yield of biogas.

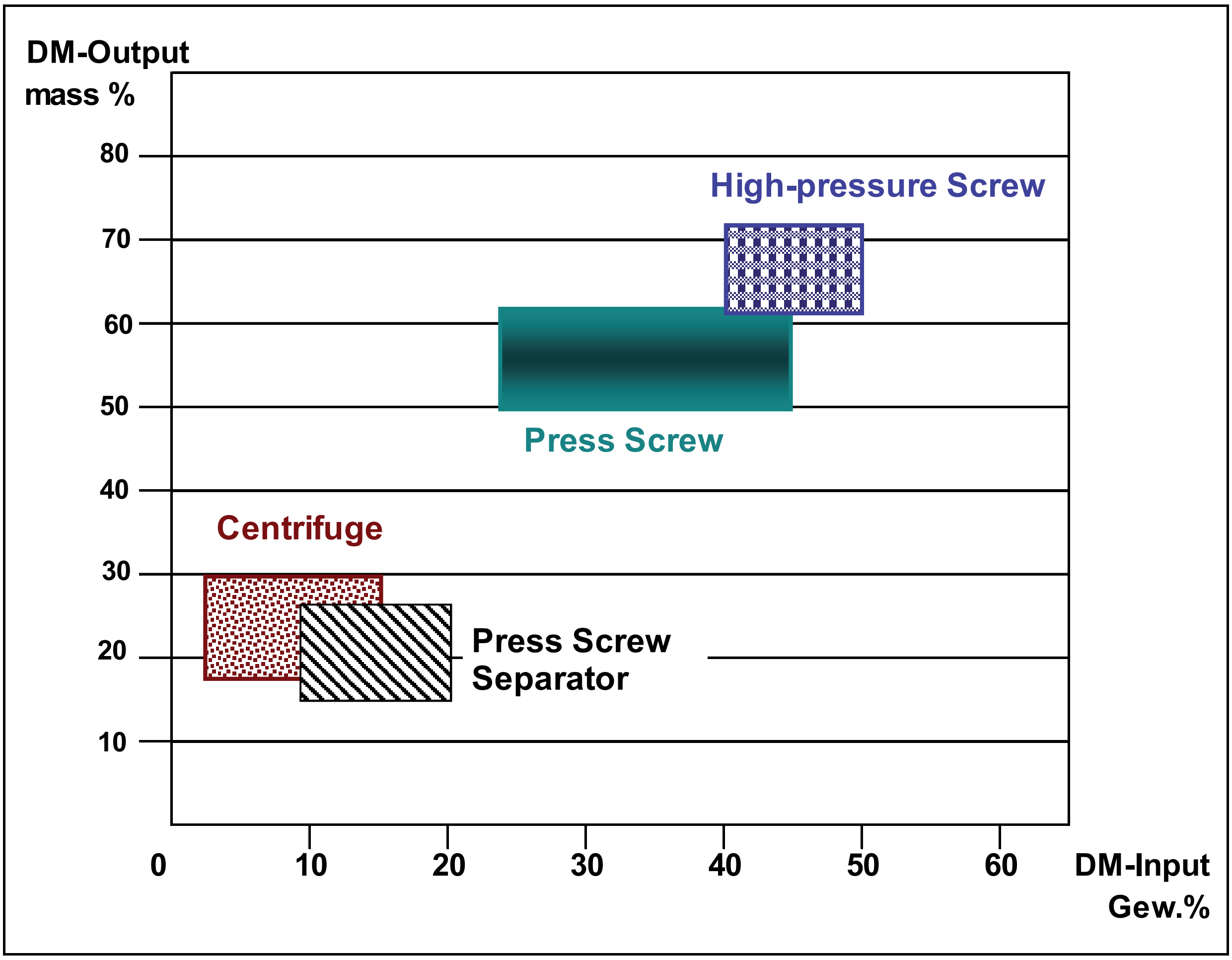


Fig. 3 Technologies for mechanical dewatering

2 Mechanical Dewatering of Digestate

2.1 *BIOLEACHATE® Process*

The *BIOLEACHATE® process* is derived from the percolation process and is important in leaching and dewatering. Most biodegradable organics are dissolved in the process water treatment, which is converted anaerobically into biogas. Mechanical pre-treatment consists of sieving and removal of metals, plastic foils and cardboard (see Fig. 4).

The screen underflow, which contains the bio-organic component, goes to the leaching process. Easily soluble and odoriferous substances are washed out or are dewatered to form solid waste by the mechanical press. After separation of sand and inert fractions process water is degraded aerobically in the hydrolysis reactor. The process water is converted anaerobically into biogas. The resulting biogas is used for energy production in a combined heat and power generator.

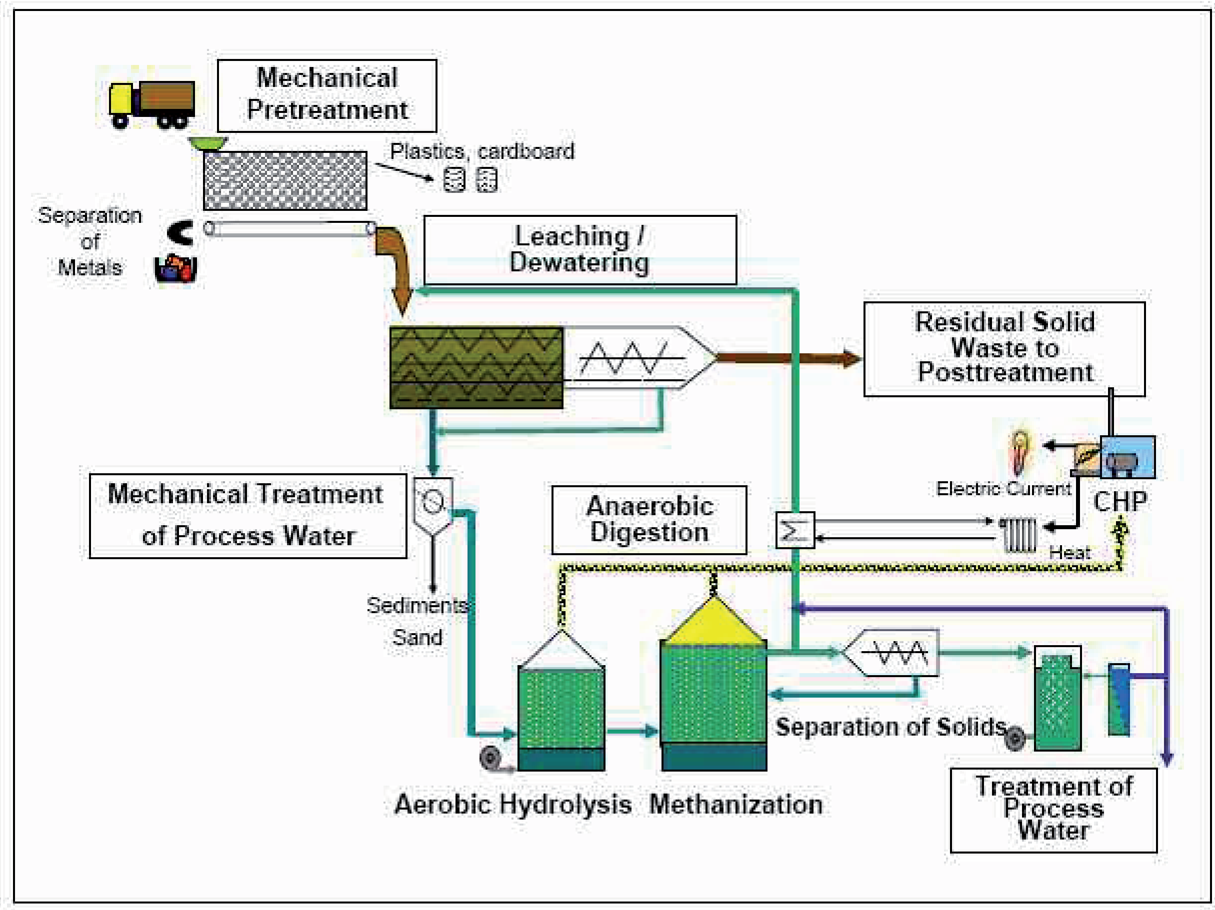


Fig. 4 BIOLEACHATE® process

The effluent of the anaerobic digester is reused as process water for leaching. Part of the circuit water and the excess waste water are treated in an aerobic process water plant. The organic fractions and nitrogen compounds are removed by denitrification and nitrification in a membrane bioreactor system.

The solid output of BIOLEACHATE® is treated by subsequent decomposition to break down biological activity before disposal in landfill. Another option is to reduce moisture by aerobic drying to produce solid recovered fuel (waste-to-energy).

The leaching process is ideal for preparing residual waste for final decomposition or biological drying. Soluble organics are converted to biogas and ammonia is washed out by leaching, thereby supporting aerobic processes. There is also no biological break between anaerobic digestion and decomposition as is known in other systems. After the leaching process there are still enough organics which are easily degradable to supply biological energy for aerobic processes.

2.2 Mechanical Dewatering by Screw Press

InnoWaste has more than 14 years of experience with the dewatering of municipal solid waste on a technical scale. The development of the percolation process (BIOPERCO-LAT®) used the screw press for dewatering solid waste for the first time, and it has been modified and continuously improved over the years. The advantages of the screw press are:

- Solely mechanical dewatering without additional flocculation chemicals.
- Comparatively low consumption of electrical power
- Mechanical disintegration improves biogas yield

The screw press operates in a range of 20 – 45% dry matter mass (input) and has an output of 55% to 65% dry matter. The dewatering yield can be modified by varying the rotational speed and pressure of cone.

In 2010 InnoWaste received a contract for optimisation of a dry fermentation plant in Bavaria. The facility has a throughput of 22,000 t/y source-separated biowaste. In-nowaste developed a concept for repowering the plant:

- Increase in the yield of biogas
- Improved conditions for decomposition of digestate

The *BIOLEACHATE*® process was modified to treat digestate from dry fermentation and was tested on a technical scale in pilot operation.

The mechanical dewatering of digestate yielded process water with a high concentration of soluble organics (see Tab. 1)

Tab. 1 Composition of process water from mechanical dewatering of digestate

Parameter	Unit	Mean Value	Peak Value
COD_{total}	mg/l	70,000	160,000
$COD_{filt.}$	mg/l	25,000	60,000
NH_4-N	mg/l	1,900	2,300
Acetic Acid	mg/l	2,300	3,800

The process water was converted to biogas in a lab test. The *BIOLEACHATE®* process generated an additional yield of biogas of 32 Nm³/t of digestate with a methane content of 64% by volume. This is an increase of 40% in biogas production based on the operating dry fermentation.

The existing plant also requires optimisation of digestate decomposition. Problems include the water content of the digestate, the high organic load (COD) and ammonia. Dewatered digestate was composted in a windrow beside the untreated digestate.

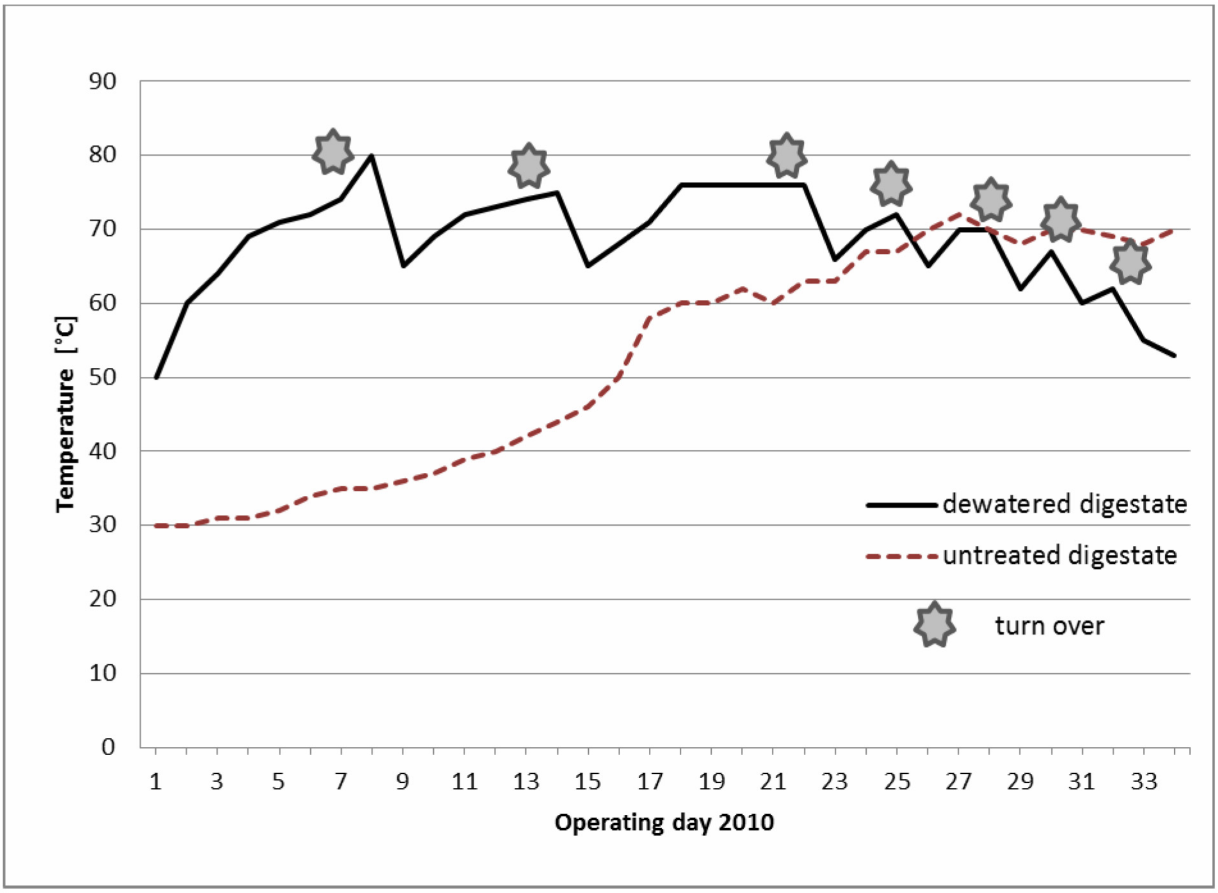


Fig. 5 Decomposition temperatures of dewatered and untreated digestate

Within 2 days after dewatering the temperature of the dewatered digestate increased rapidly up to 65°C. This self-heating is required to sanitize digestate for compost quality. The decomposition temperature was maintained for more than 3 weeks up to 70°C, and after 5 turnovers all digestate was sanitized. The composting process was virtually odour-free. In contrast, untreated digestate required more than 3 weeks to reach the temperature range required for sanitation. The windrow produced unpleasant odours (organic acids, ammonia) for more than 4 weeks.

In summary, the *BIOLEACHATE*® process considerably improves the yield of biogas and the decomposition of digestate.

Costs for mechanical dewatering of digestate (sample):

- Throughput 20,000 t/y
- Working hours 4,000 h/y
- Specific throughput 5 t/h
- DM input approx. 25 – 35% by mass
- DM output approx. 38 – 45% by mass

Tab. 2 Costs: Mechanical dewatering of digestate

Item	Budget Price EUR (net)
Investment costs	
dewatering screw press	200,000
conveyors, mechanical process water treatment	80,000
Operating costs	
electric current	0.42 EUR/t
consumable parts	0.42 EUR/t
staff	from existing plant
Operating costs excluding capital costs	0.84 EUR/t
Operating costs including capital costs	2.85 EUR/t

Costs are justified by the benefits of mechanical dewatering:

- Higher yield of biogas
- Increased throughput at dry fermentation
- Improved decomposition of digestate
- Higher quality of compost

3 Conclusions

Biological processing remains at the centre of the mechanical-biological treatment of municipal solid waste. Water keeps the main component of solid waste. Mechanical dewatering of digestate generates a higher yield of biogas and better conditions of decomposition even in dry fermentation processes. With reference to investment costs mechanical dewatering makes up less than 10% of the total investment cost of an aerobic digestion plant.

4 Literature

RUK	2007	Layman Report from ZAK-process EU-LIFE-Project 2003 - 2006, Ingenierugruppe RUK, Stuttgart
Schalk, P.	2005	Extensive Environmental Technologies for Treatment of Municipal Solid Waste and Waste Water International Symposium MBT 2005 Cuvillier Verlag p. 352-364
Schalk, P.	2009	Simplified Treatment of Municipal Solid Waste by Adjustment of Percolation BIOLEACHATE® Process and Waste Water International Symposium Waste-to-Resources 2009 Cuvillier Verlag p. 243-251

Author's address:

Dr. Peter Schalk
InnoWaste
Bergstr. 3
DE 79331 Teningen
Phone +49 7641 95 86 36
Fax +49 7641 95 86 37
Email: info@innowaste.de
Website: www.innowaste.de

MBT solution with windrow technology – investigations of the process performance

Runge, Karsten

BACKHUS GmbH, Edewecht, Germany

Abstract

The worldwide demand for simple MBT solutions is still increasing. During the study and investigation for new projects as well as for improvement of already existing facilities there is a demand for layout and technological design of the biological treatment process. The necessary time to reach the treatment target, the area needed for this treatment and the necessary treatment methods are the key figures for those studies. By small scale testing under practical conditions the biological treatment process can be simulated and adjusted to find the optimum conditions. With the help of the test results the process engineer is able to estimate the necessary processing time and processing area as well as the operation costs for the full scale project.

Keywords

MBT, biological treatment, process design, processing time, operation costs

1 Introduction

Aerobic biological treatment of municipal solid waste (MSW) to reduce the organic masses and to produce a stabilized fraction for safe landfilling or to produce “compost-like output” for application in landscaping and agriculture are well know MSW processing technologies. Because of simple technology and low operation costs agitated windrow processing technology is common practice in many countries worldwide.

For new facilities and reconstruction of existing MSW treatment plants the design and layout of the biological treatment process very often is an underestimated task. Even in Germany in some cases the original process design of the biological treatment in a MBT facility was not fulfilling the demand of the plant operator.

To be able to give a safe estimation of necessary processing time and processing area for newly upcoming MBT projects in fall of 2009 some processing trials where made with a self-propelled BACKHUS windrow turner (see figure 1) at the roofed maturation area in the MBT plant of Rosenow, Germany (see figure 2).

Figure 1 Self-propelled windrow turner BACKHUS 17.60

Figure 2 Maturation area of MBT Rosenow

2 Description of the test trials

2.1 Used input materials

For the test trials a mixed output material coming from the mechanical separation of the MBT plant was used (see figures 3 & 4). This material contains two different fractions:

- Fine fraction 0 – 60 mm coming from trommel screen
- Heavy fraction 0 – 90 mm from density separation

Figure 2 Maturation area of MBT Rosenow

Figure 4: Detailed view to mixed output fraction from mechanical sorting

2.2 Trial variantes

To investigate the difference between the commonly used two step technology of intensive rotting in static tunnel system followed by windrow maturation and one step windrow processing two trials was started on the same day using the same batch of material coming from the mechanical treatment. The batch was divided in two equal batches of about 200 m³ each. Following this the treatment of the portions was separated in two parts:

Intensive treatment from day 1 to day 21:

Batch 1: Static tunnel system
24h/day computer controlled forced aeration and irrigation
Turning after 7 and 14 days (tunnel change after each week).
Transfer to windrow maturation on day 21

Batch 2: Windrow processing under roof (see figure 5 & 6)
Windrow size 6 x 2,5 meters
Turning five times per week.
Irrigation upon demand

Figure 5: Test trial windrow – Batch 2 – after two weeks processing

Figure 6: Detailed view – Batch 2 – after two weeks processing

Maturation from week 4 to week 12

Batch 1: Windrow processing under roof
Windrow size 6 x 2,5 meters
Turning two times per week
Irrigation upon demand.

Batch 2: Same treatment as batch one

2.3 Sampling & testing

Samples were taken from both batches once per week to evaluate the processing status. Both batches where sampled always on the same day. All samples were tested for AT_4 and DOC_{Eluat} as well. Beginning from week 4 windrow temperatures where monitored from time to time to estimated the remaining biological activity and samples were taken to some screening analysis to detect differences in the particle size distribution because of more frequent turning. Evaluation of the test results

Batch 2 reach the limit for AT_4 according to the German standard for landfilling after 10 weeks of processing, two weeks later than Batch 1 (see figure 7).

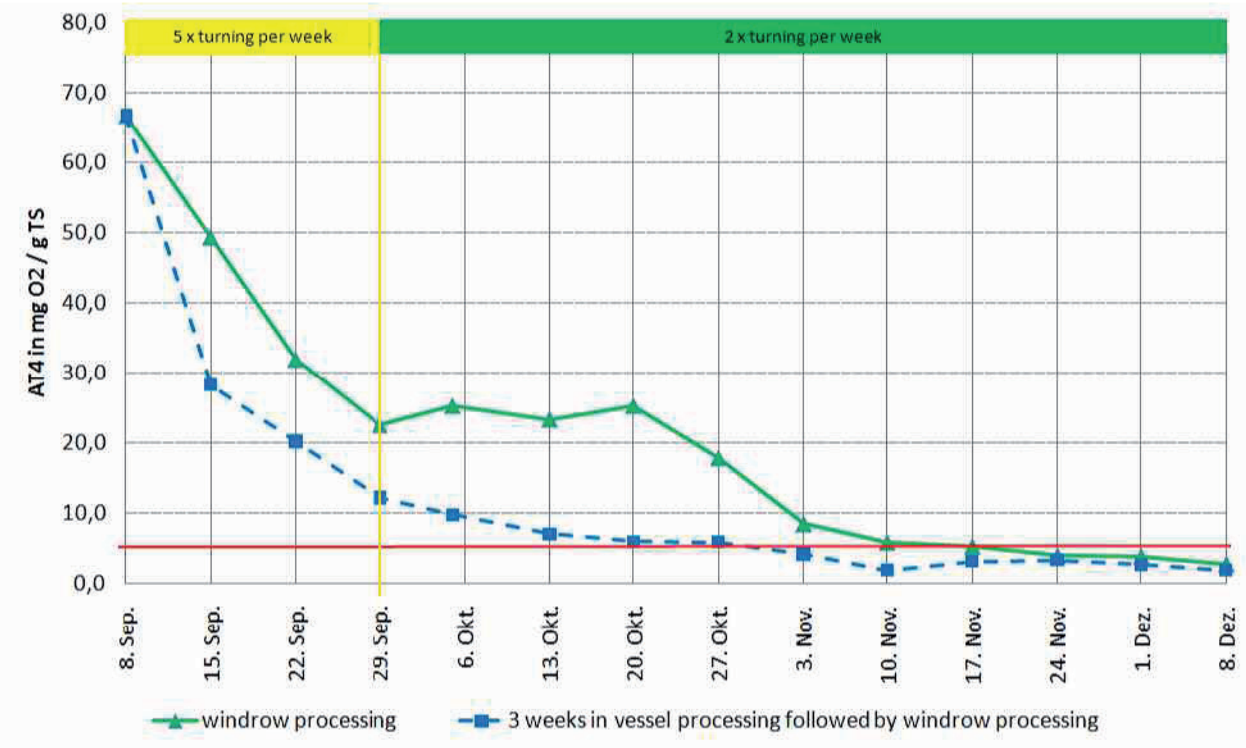


Figure 7: Respiration activity over processing time

The limiting value for DOC_{Eluat} according to German standard was not reached within the test trial period for Batch 2 but was reached for Batch 1 after 9 weeks (see figure 8)

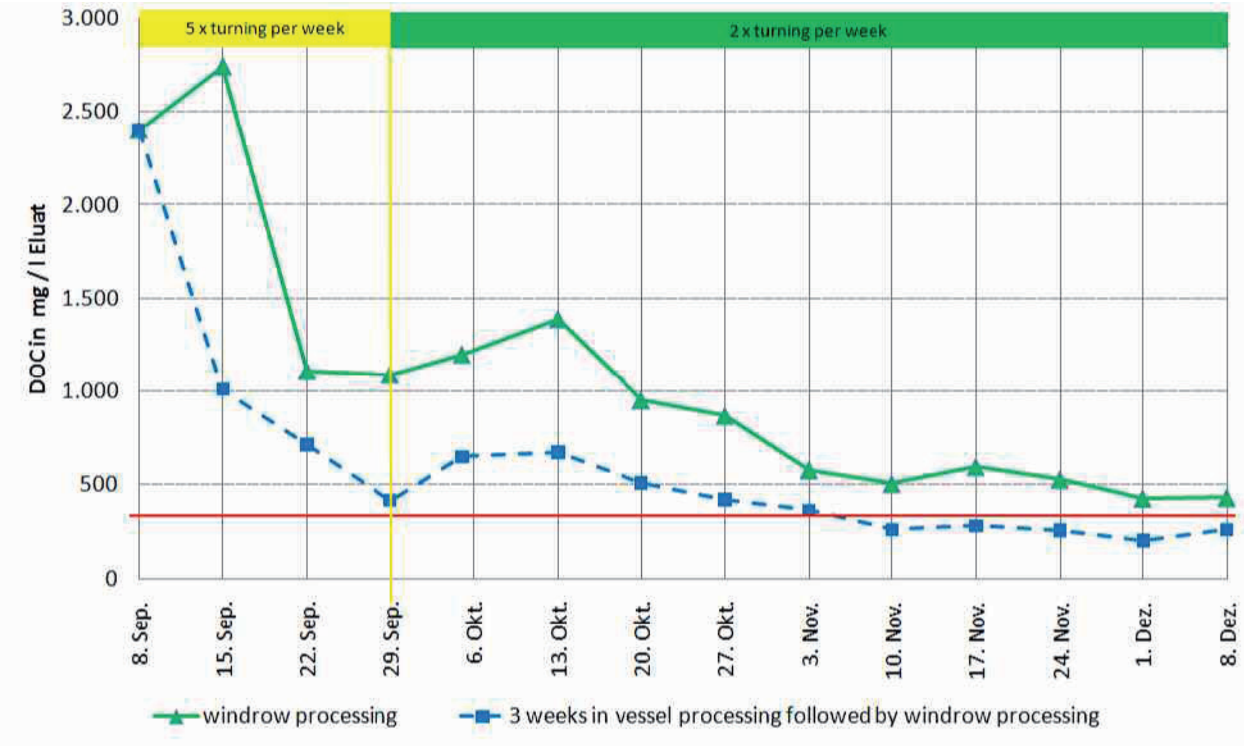


Figure 8: Organic content in eluat over processing time

Temperature monitoring could proof, that the average core temperature of the windrows was always between 65 and 70 °C in the whole time period of the test, with a slight increase from 65 °C in week no. 3 to more than 70 °C in week no. 10 (see figure 9)

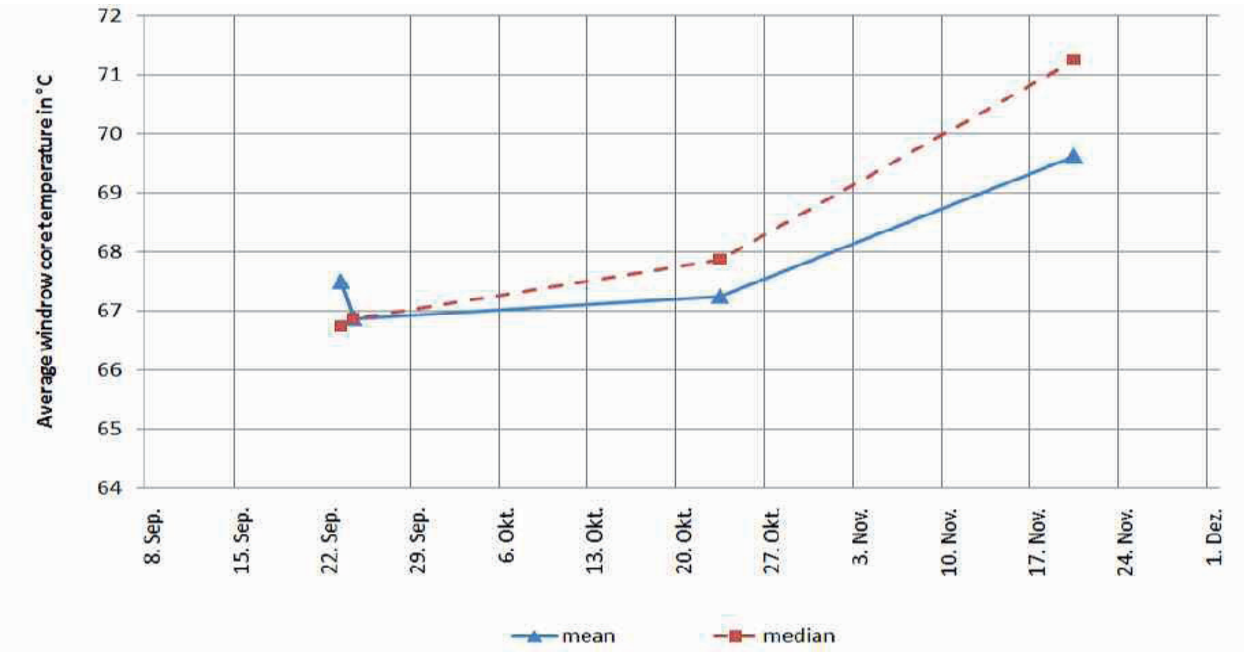


Figure 9: MBT windrows – core temperatures over time

Particle size analysis shows that there was no remarkable difference in particle size distribution between Batch 1 and Batch 2 after three weeks of processing although the turning frequency was very different for both batches. Particle size distribution was found changing to more fine particles after six weeks of processing (see figure 10-18).

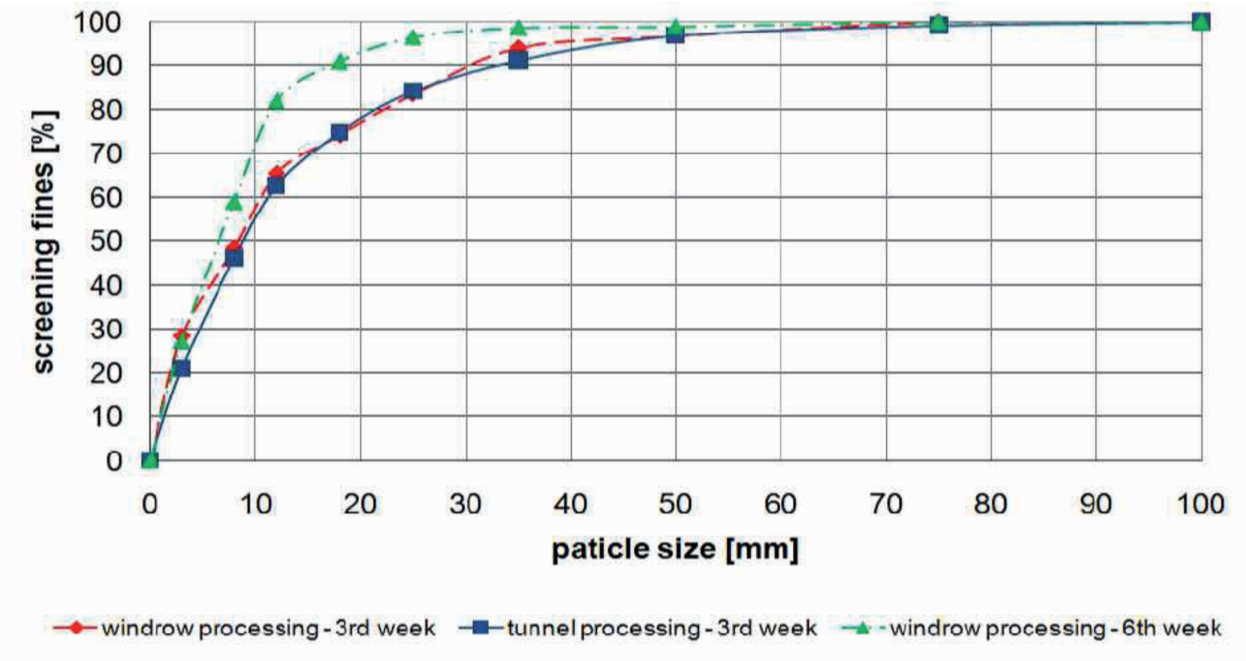


Figure 10: MBT output – particle size distribution

Figure 11: Output material – fraction > 50 mm

Figure 12: Output material – fraction 35 - 50 mm

Figure 13: Output material – fraction 25 - 35 mm

Figure 14: Output material – fraction 18 - 25 mm

Figure 15: Output material – fraction 12 - 18 mm

Figure 16: Output material – fraction 8 - 12 mm

Figure 17: Output material – fraction 3 - 8 mm

Figure 18: Output material – fraction < 3 mm

3 Conclusions

From the evaluations of the processing test trial the collowing conclusions can be done:

1. From processing point of view biological treatment of organic fraction from MSW is possible with windrow processing only without prior intensive treatment in in vessel processing systems. Thus the windrowing process is suitable for processing of MSW assuming that it is allowed by local law.

2. Needed processing time for windrow processing to produce a stabilized output product is about 10 weeks. This figure can be used for process layout and determination of necessary processing area.

3. After ten weeks of processing the biological activity of the processed material is still high enough to finish the processing with a biological drying step. Thus the total output masses can be reduced further and transport costs can be saved.

4. Because of the intensive processing by frequent turning the fine fraction of the output will be increased at the end of the processing. This will cause a higher density of the output product and a better ability for compaction at the landfill. Assuming that the fine fraction below 10 mm is nearly free of visible contamination (glass and plastic) this fraction can be used for landscaping, road construction and recultivation of landfill sites. If this is possible there will be a fraction of 70 mass-percent that can be used for this purposes and the coarse fraction that has to be landfilled after screening will be decreased compared to a similar processing after static processing system.

4 Conclusions and acknowledgement

Windrow processing is suitable to produce a stabilized output product from organic fraction of MSW. By intensive treatment using BACKHUS windrow turning machine the necessary processing time to meet German AT_4 standard for landfilling is about 10 weeks. The constantly high windrow core temperature during the whole processing period can be used for final drying of the output material. Increased fine fraction allows a higher output of compost-like product and reduces costs for landfilling the rest fraction.

We would like to thank so for the practical support during the test trials and contribution to the necessary laboratory analyzes to the following persons:

- Employees of ABG mbH Rosenow, especially Eiko Potreck and Rene Muchow
- Christoph Hofmann
- Christoph Mendel and Thomas Diekmann (Doppstadt Calbe GmbH)

Author's address

Dipl.-Ing. Karsten Runge
BACKHUS GmbH
Wischenstrasse 26
D-26188 Edewecht
Telefon +49 4486 92840
Email: karsten.runge@backhus.de
Website: www.backhus.de

Large-Scale Composting of Biowaste and Bio-Organics from MSW by using the TAIM WESER Composting System

Dietmar Polster and Michael Herken

TAIM WESER GmbH, Bad Oeynhausen

Abstract

Since almost two decades TAIM WESER GmbH (former WESER-ENGINEERING GmbH) is designing, building and commissioning composting-plants for treating curb-side collected biowaste as well as the organic fraction of municipal solid waste in order to produce high quality compost for agricultural use or compost like output, a compost suitable to be used for e.g. road-greens, parks, re-greening of brown-fields or to fight against desertification in arid areas.

TAIM WESER GmbH, is a member of the german/spanish TAIM WESER Group, which is a worldwide supplier for bulk-material handling (mining-industry, port-installations) and heavy-duty-crane-installations, is represented worldwide as GC, supplying process-equipment for combined mechanical- and biological treatment of biowaste and MSW.

TAIM WESER GmbH has designed, fabricated and commissioned the complete process-equipment for biological treatment of 150.000 t/a organic fraction from MSW. Actual the plant is in the phase of final commissioning.

Keywords :

MBT, Biowaste MSW, Flat windrow composting, aerobic treatment of degradable Bio-organics of municipal waste (BMW-Diversion)

1 The TAIM WESER Group

1.1 Company History

In 2006 the TAIM TFG/Zaragoza and WESER-Engineering GmbH have joined to TAIM WESER Group, now consisting of TAIM WESER S:A:, sited in Zaragoza/Spain and TAIM WESER GmbH, sited in Bad Oeynhausen/Germany.

The former TAIM TFG is looking back to a history, starting in 1899. TAIM has supplied custom-designed heavy duty equipment to open pit- and deep-shaft mining, steel-factories, cement-industry and harbor-equipment (loader/unloader).

TAIM WESER Group has developed to be a worldwide supplier of highly reliable steel-constructions.

A parallel developing was made at WESER-ENGINEERING in Germany, which is mainly based on the competence of former PHB WESERHÜTTE.

Former PHB WESERHÜTTE was a well known supplier of heavy-duty equipment for the German heavy industry such as Mining, steel-factories.

Since 2006 the new TAIM WESER Group is unifying the summarized competence on

- GERMAN ENGINEERING
- SPANISH PRODUCTION Capabilities
- WORLDWIDE subsidiaries (Australia, Brazil, Ukraine…)

According to the worldwide network with sales representatives and joint ventures, TAIM WESER Group is well placed to design and execute contracts on steel-construction-works on all continents.

1.2 The TAIM WESER Business Units

The TAIM WESER Group has internally organized the different technologies available into the following Business Units (BU):

- A) Bulk solids handling
- B) Cranes
- C) Urban/Municipal solid waste Treatment
- D) Renewable Energy

For further details please refer to the homepage www.taimweser.com where you can find all data about the TAIM WESER Group, the four business units, the scope of supply and documentation about references built.

1.3 The Scope and competence of Business Unit Waste Treatment

The BU Waste Treatment is located in Bad Oeynhausen.

The competence of the BU Waste Treatment is mainly based on the main product, the flat or trapezoidal windrow-composting system, which was developed, designed and realized in many international plants since almost 20 years.
We are proud being able to say, that all composting-plants ever built by TAIM are **all still existing and in operation to this day** and can be visited as reference-plants.

Following types of plants have been built (extract):

- Mechanical pretreatment of 400.000 t/a MSW (MBT Zaragoza)
- Refining of biologically treated MSW 100.000 t/a (MBT Zaragoza)
- Biological treatment (windrow-composting) 150.000 t/a (MBT Barcelona)

According to actual request of clients and the international markets, TAIM WESER has expanded the scope of composting-technology.

TAIM WESER now offers following biological treatment technologies:

- Lane-Composting,
- Tunnel-Composting (manual, semi- and fully-automated), and the
- flat/trapezoidal windrow Composting-system (“Rotopala”-System)

The selection, what technology should be applied, will be made according to the requested capacity on the specific composting-project.

Wherever requested, TAIM WESER is prepared to include mechanical pretreatment or compost-refining into the specific project-volume.

TAIM WESER Group offers to take full responsibility as the all over EPC-supplier of the complete process-equipment (mechanical and biological) for Biowaste- or MSW-Composting as well as Biodrying-processes.
While the contractual engineering-phase TAIM WESER is determining the basic engineering for the local civil supply, and delivers all process-related material (inbuilt- or accessory-parts) necessary for the erection of civil part.

Also the all-over PLC-System (starting from the main power supply at the entrance on main switch-boards) and the process-visualization-system will be supplied by TAIM WESER. As the latest state of the art MSW-composting-plant built by TAIM WESER, in the following we are presenting the MBT Barcelona plant.

2 The MBT Barcelona Composting-Plant

The MBT Barcelona is designed to receive 250.000 t/a municipal solid waste from the northern Barcelona-Suburb-Area called “VALLES OCCIDENTAL”. Therefore the site is called CTRV (“Centro de Tratamiento de Residuos del Valles Occidental”).

The “UTE Valles Occidental” itself is a joint venture of the Spanish investors and operators URBASER, FCC and HERA

TAIM WESER has received from UTE the order to design and to build a MSW-composting unit with a designed Input of 150.000 t/a, requiring a retention-time to achieve a degrading of biological matter for to achieve a valuable product (=compost-like output) or to have a significantly reduced biological activity on the material when it will be finally landfilled.

2.1 Mechanical Pre-Treatment

The mechanical pretreatment plant contains a complex combination of screens, shredders, metal-separators, ballistic-separators, NIR-sorting and manual sorting in order to produce as much as possible recyclable material such as Fe-metals, PET-bottles, other plastics.

Almost 50 % of the original input-mass-flow (design data: 150.000 t/a) is separated by screening (0 – 70 mm) followed by Fe-metal-separation. In this residual fraction there is concentrated the bio-organic fraction of the household waste, which is designated to be treated in the TAIM WESER MSW-composting plant.

2.2 MSW-Composting Plant

2.2.1 Basic design Parameters

According to client’s requirements on the expected output, the plant was design according to following parameters:

- Capacity : 150.000 t/a mechanical pretreated MSW
- Introduction : 6 days per week, 1,5 shifts per day
- 2 parallel lines installed; total building size 72 x 150 m
- Particle-size Input-Material : 0 – 70 mm; having passed a Fe-separator

- Retention time : 6 weeks
- stack height : 3 m
- air-exchange inside hall : 1,5 – 2 times per hour (= 130.000 m³/h) .
- free space necessary for composting-process-equipment: 8 m
- PLC-controlled process-aeration (top to bottom)

As the main product requirements there have been confirmed:

- Respirometric Activity (AT4) : < 10 mg O_2 / g DM
- Rottegrad (BGK): 4
- Hygienic safe product: no salmonella
- Water content after composting process : < 35 weight-%

2.3 The MBT Barcelona composting process

The mechanical pre-treated fraction 0 – 70 mm from municipal waste pretreatment enters via conveyors into the composting hall. A reversible conveyor defines whether the material gets introduced to Line A or Line B of the two parallel composting bays.

2.3.1 Filling of Infeed-area

For filling the infeed-area there exists an infeed-bridge, which is connected via a diagonal conveyor-bridge with the material-interface-point.
The infeed-conveyor system automatically spreads the material layer by layer on the first field of composting bay, in order to immediately start the process-aeration of the field No. 1.

Typically the filling begins at field No. 1 from Line A and starts on Monday morning, when the first waste-collecting trucks arrive on site and the mechanical pre-treatment-plant starts operation. The filling of both infeed-areas of both lines is completed latest on Saturday evening, when the last trucks have arrived unloaded and the material has passed the pre-treatment-plant.
While filling the first field of composting bay the incoming raw-material gets sprayed either with recirculated process-water or with rainwater (collected from the roofs) in order

to adjust the humidity of material, achieving optimum starting conditions for bacteria growing.

2.3.2 Material output or discharge

While the filling of the field No. 1 is still ongoing, the TAIM WESER windrow turner is starting activity with eliminating the material from the last field of the composting bay (material discharge).

According to the designed retention-time, in both lines there is installed an appropriate number of fields. Each field is representing 1 week retention time.

At MBT-Barcelona there are 5 composting fields plus one discharge field, so the total average retention-time of material in the composting-plant is approx. 6 weeks.

Having a capacity of almost 200 m³/h, the windrow-turner is capable to eliminate the discharge-field in only 3 – 4 hours, but due to local operational obligations (capacity of refining-plant) the discharge time is adjusted up to one shift (8 hours) by reducing the speed of the windrow-turner driving.

2.3.3 Windrow turning

After having finished the discharge the windrow-turner is starting its second task “turning”. Instead of transferring the material onto the discharge-conveyor, the material from field No. 5 now get´s transferred to the empty discharge-field.
Further on, material from field No. 4 get´s automatically transferred to field No. 5 This procedure is repeated according to the number of fields until the infeed-area (field 1) has been transferred to field No. 2.

In order to be prepared for the next raw-material input, the infeed-area of line A has to be empty latest until Monday morning, while the windrow-turning of line B has to be finished with turning latest on Wednesday morning.

The turning of windrow is a fully automated process also runs during the night-shift without local supervising from operational staff.

In case of any malfunction, the PLC-System automatically is sending an SMS to the mobile phone of the operator in charge, in order to have a look onto PLC-system via mobile computer and to identify the cause of malfunction and to initialize activities to restart the process.

2.3.4 Process-aeration, PLC-System and process-control

The floor of the composting-bay is equipped with aeration-ducts. The aeration-ducts from each field are connected to an aeration-collector, which is connected to a main underpressure-piping. The air of each collector can be switched on and off by a butter-fly-valve and gets temperature- and underpressure-controlled. The temperature-control mainly is used for to adjust the composting-temperature of the windrow, in order to achieve hygienization of the composted material according to local requirements. Typically temperatures of above 60 °C are requested for to achieve a pathogens free material in the output. Especially in case of treating biowaste/greenwaste to produce a bio-waste-compost suitable for agricultural nutrient-farming or private gardening this aspect has to be highly respected.

All sensors, electrical engines and adjustments are connected with a Process Leading and Control-(PLC)-System, in order to document the composting-temperatures for all material while staying in the composting-bays (Quality-Documentation for Process-Parameters).

The Process-Visualization-system (PC and Monitor) is the interface between operators and the PLC-System. It shows on several pictures the actual status of the process or condition of engines (on-off) and allows adjusting the settings of several control-circuits. Typically there is on monitor installed in the electrical room, and another monitor will be installed in the central control-room.

2.3.5 Refining of the product from MSW-Composting

According to the input-material of composting (0 – 70 mm) the material in the output of composting still contains not degraded or not hackled solids and bio-organics (e.g. wood pieces) as well as any kind of plastics and other biological solids or inert material.

In order to produce material suitable for covering landfills or to be used as re-greening material for road-greens etc. (= compost like output = CLO) the composted material is passing a refining plant, which consists of the following main equipment:

- Screen-drum 20 mm
- Densimetric separation and
- Dust/foil-separation (wind sifting)

The final products of MSW-Composting at MBT Barcelona plant after having passed the refining plants are

- Stones/glass (hard-particles, to be used for civil works))
- Oversized materials (20 – 70 mm, either used as RDF or transferred to landfill)
- Ferrous metal (scrap-metal recycling)
- Dust/foils

and the final product :

- Compost like material (CLO) 0 – 20 mm

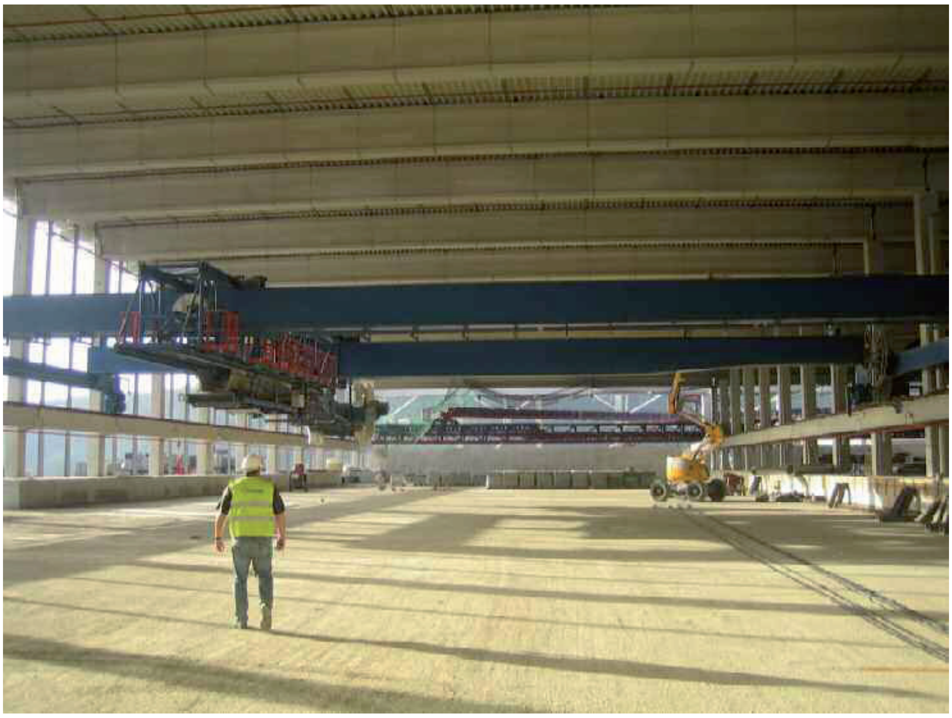
which will be used from client for covering and re-greening the old landfill-site or other purposes (road-greens, remediation, replanting etc.).

Actually the plant is under commissioning. First results and data on product quality achieved will be available until End of May 2011 and will be presented while the Symposium “Waste to Resources”.

3 Pictures from MBT-Plant Valles Occidental

Picture 1: Overview MBT-Plant Valles Occidental/Barcelona

Picture 2: Mechanical Pre-Treatment



Picture 3: Composting-Bay A (under construction)

Picture 4: Aeration-floor (under construction)

Picture 5: TAIM WESER “ROTOPALA”-Windrow-Turner (Cold-Start-Up)

Picture 6: TAIM WESER “ROTOPALA”-Windrow-Turner (Ready for Hot-Start-Up)

4 Summary

The TAIM WESER large-scale-composting system “ROTOPALA” has documented to be **the** well-engineered and proven system for large-scale composting of Biowaste and Municipal Solid Waste.

Any new plant or project contains the accumulated engineering-experience made at TAIM WESER since building our first plant (16 years old Biowaste composting plant “Pohlsche Heide”, still in operation according to client’s satisfaction!)

Highest process-and machinery-availability of the TAIM WESER system fulfills the client´s request on reliable technology to accomplish the client’s tasks of economical public waste-treatment, recycling and disposal.

The main advantages of the TAIM WESER composting-system are:

- In-house detail-engineering (German engineering)
- continuous quality control while fabrication, assembling and commissioning
- highly qualified and solid steel-construction (“mining-proof”)
- highest availability of process and equipment
- controlled and documented product-hygienization
- fulfilling highest demands on biological degradation
  MBT Hannover : < 5 mg O_2 / g DM,
  MBT Barcelona : < 10 mg O_2 / g DM
- invessel-composting (exit air-treatment by bio-filter or RTO)
- less man-power required for operating
- less wear-part-costs per year
- continuously confirmed product quality according to design
- satisfied clients asking for further cooperation on new projects
- worldwide sales representatives or JV-partners working according to our slogan:

Nuestro mundo es el mundo

Author's addresses :

Dipl.-Berg.-Ing. Dietmar Polster
and
Dipl.-Ing. Michael Herken,

TAIM WESER GmbH
Koenigstrasse 45
D-32547 Bad Oeynhausen
Telefon +49 5731 1508-0
Website: www.taimweser.com

Entwicklung und Erprobung von robusten MBA-Systemen zur Ersatzbrennstoffproduktion in Schwellenländern – Ergebnisse einer in Thailand betriebenen Pilotanlage

Sebastian Platz[1]*, Martin Schaub[2], Jochen Amrehn[3], Uwe Menzel[1]

[1] Institut für Siedlungswasserbau, Wassergüte- und Abfallwirtschaft, Universität Stuttgart

[2] WEHRLE Umwelt GmbH, Emmendingen

[3] King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand

Adaption of a German MBT Process to the Boundary Conditions of Newly Industrialized Countries - Results of a pilot plant operated in Thailand

Abstract

A mechanical biological treatment (MBT) process for municipal solid waste (MSW), suitable for the boundary conditions of newly industrialized countries (NIC), was developed and tested in Thailand. The main purpose was to make the process simple, robust and economic. The process focuses on the production of refuse-derived fuel (RDF) and a high biogas yield. The so-called BIOBUNK pilot plant consists of a shredder as mechanical stage and an aerobic mixed reactor as biological stage. The plant was operated with a daily MSW capacity of 2-2.5 Mg. An average retention time in the BIOBUNK reactor of less then 1.4 days was achieved. Biological self-drying tests of the solid output material operated with a high performance. Within seven days, a dry mass content of up to 86 % could be reached. The process produced around 400 kg RDF per Mg of input. The lower calorific value of this RDF ranges from 14-16 MJ/kg with a chlorine concentration clearly below 0.5 %. Thus, it presents an optimal alternative fuel, e.g. for the cement industry. The produced waste water has a chemical oxygen demand (COD) of 30,000 mg/L with a sufficient content of the nutrients nitrogen and phosphate. The biogas potential is estimated up to 40-50 Nm³ per Mg of input.

Inhaltsangabe

Ziel des Projektes war die Entwicklung und Erprobung eines Konzeptes zur mechanisch-biologischen Abfallbehandlung (MBA) von Hausmüll in Entwicklungs- und Schwellenländern. Neben der Produktion von hochkalorischem Ersatzbrennstoff (ESB) und einem Abwasser mit hohem Biogaspotential, sollte der Prozess einfach, robust und kostengünstig sein. Ein Schredder stellt die mechanische Stufe, ein gerührter und bewässerter Reaktor die biologische Stufe dar. Die sog. BIOBUNK-Pilotanlage wurde in Thailand errichtet und mit einem täglichen Durchsatz von 2-2,5 Mg Hausmüll betrieben. Im Durchschnitt konnte im BIOBUNK-Reaktor eine mittlere Aufenthaltszeit von weniger als 1,4 Tagen erreicht werden. Versuche zur biologischen Selbsttrocknung des Austragmaterials erzielten innerhalb einer Woche eine Restfeuchte von 15 %. Es konnte eine spezifische ESB-Produktion von 400 kg pro Mg Input nachgewiesen werden. Der untere Heizwert des Materials bewegt sich im Bereich 14-17 MJ/kg bei einem Chlorgehalt von unter 0,5 %. Das entstehende Abwasser wies einen chemischen Sauerstoffbedarf (CSB) von 30.000 mg/L auf. Stickstoff- und Phosphorverbindung konnten in ausreichendem Maße als Nährstoffquellen für einen anaeroben Abbau nachgewiesen werden. Das theoretische Biogaspotential beträgt 40-50 Nm³ pro Mg Hausmüllzugabe.

Keywords

Mechanical biological treatment (MBT), Municipal solid waste (MSW), Refuse-derived fuel (RDF), Aerobic hydrolysis, Pilot plant

Mechanisch-biologische Abfallbehandlung (MBA), Gemischter Hausmüll, Ersatzbrennstoff (EBS), Aerobe Hydrolyse, Pilotierung

1 Introduction

1.1 Motivation

The worldwide amount of municipal solid waste (MSW), especially in newly industrialized countries, is continuously increasing. Furthermore, the waste composition changes according to the economic growth, the effects of which can be notably observed in East and Southeast Asia. With the exception of developed countries, the current state of the art method used for disposing of MSW is simple landfilling, mostly on unsecured dump sites. On a local scale, leachate pollutes the soil and groundwater as well as causing odour nuisance to the surrounding residents. On a global scale, the emission of the greenhouse gases (GHG) NO_2, CO_2 and especially CH_4, produced from the waste management sector, boosts climate change. In the year 2000 the total anthropogenic GHG emissions released to the atmosphere have been estimated 41,755 $TgCO_2$eq. The worldwide waste sector produced about 1,500 $TgCO_2$eq. (3.6 %) (IPCC, 2007) and around 14 % of the global anthropogenic methane emissions (MONNI, 2006). Other sources estimate the annual GHG emissions exclusively produced by landfill sites up to 1,900 $TgCO_2$eq. (4.5 %) (GIEGRICH, 2008).

Due to severity of these major environmental issues, the Executive Secretary of the Economic and Social Commission for Asia and the Pacific stated these issues during his opening speech at the Ministerial Conference on Environment and Development in Asia and the Pacific 2005 with "…is the high economic growth in Asia and the Pacific region environmentally sustainable? It appears that the answer is no if the current pattern of economic growth, which is "Grow first, clean up later", continues. The time has come to shift towards a new paradigm of economic development which considers the environment as the envelope containing, providing and sustaining the entire economy..." (KIM, 2005).

In order to follow the way of the "Green Growth", newly industrialized countries need affordable and robust environmental technologies. Especially the waste sector has one of the highest demands for that. In most of the cases western technologies are very costly, regarding the investment and operation costs. Also, the processes used for such technologies are complicated and often not fully understood by local operators. In the past, the operation of many new plants built by western companies failed because of the mentioned problems.

For the reason of the demand for suitable environmental technologies in the waste treatment sector, the project team sets the aim to develop and test a new waste treatment process suitable for newly industrialized countries. To make the testing most representative a pilot plant was built and operated in Phetchaburi province, Thailand. The project team was formed of German researchers of the University of Stuttgart, and environmental engineers of the German company WEHRLE Umwelt GmbH as well as waste experts and engineers from Thailand.

1.2 Waste Management in Thailand

Like in most developing countries, the waste management also led to serious problems in Thailand, especially in the municipalities. In 2004, Thailand had an annual waste generation of 14.6 million Mg (TEI, 2004). In this year the metropolitan area Bangkok produced almost 8,300 Mg per day (PCD THAILAND, 2010). Even today the majority of the daily waste amounts is disposed to unsecured landfills. At the moment, about 330 unsecured dumpsites - the estimated number of unknown cases is to be assumed much higher - and 95 simple secured landfills are in operation in Thailand (CHIEMCHAISRI ET AL., 2008). The capacities of these landfill areas will be depleted in near future. New sites hardly can be found as the resistance of the population is increasing continuously.

The Thai authorities have recognised this set of problems and search for future disposal methods. As the Thai waste consists of high amounts of plastic fractions the production of refuse-derived fuel (RDF) via mechanical-biological treatment (MBT) is to be preferred. Waste incineration is not to be preferred because of the relatively high moisture content of the MSW. At the moment, there are only three operational waste incineration plants in Thailand. One is close to the city Phuket (250 Mg/d), another one is located on the island Ko Samui (70 Mg/d) and the third in Lamphun province (10 Mg/d). The construction of a fourth one, located close to the city of Pattaya, is subject of latest discussions (400 Mg/d).

2 Materials and Methods

2.1 Development of the BIOBUNK pilot plant

The underlying idea of the so-called BIOBUNK process is based on a MBT process as it is used at the MBT plant Kahlenberg, Germany. To be applicable also in other regions in the world, the new process has to be adapted to the boundary conditions of the targeted area. The differences between the local waste compared to German/western waste are mainly a higher organic and moisture content. Thus, the machineries of the mechanical stage must be able to handle this wet and doughy waste. In addition, the whole process needs to be simple and robust. Besides, the main target was to develop a reliable and cost-effective MBT technology.

Except of manual sorting the pilot plant does not have any other pre-sorting stages. Freshly delivered MSW is going to be fed directly to the shredder via wheel loader. The two-shaft device cuts the waste down to small pieces. In case of blocking the shredder automatically switches in reversion mode. If this fails after several attempts, the blocking material has to be removed by hand. A closed belt conveyer transports the cut waste into the BIOBUNK reactor. In this biological reactor the waste gets mixed and irrigated with biological active process water. After an intended average retention time of 1.5-2 days, the treated material is discharged via a screw conveyer. A screw press pre-dewaters the output material to achieve a better handling and a higher biological self-drying potential. In order to test the biological self-drying performance, a wheel loader then heaps up an output charge to a rotting heap once a week. After seven days, the wheel loader discharges the ready RDF to the adjacent landfill.

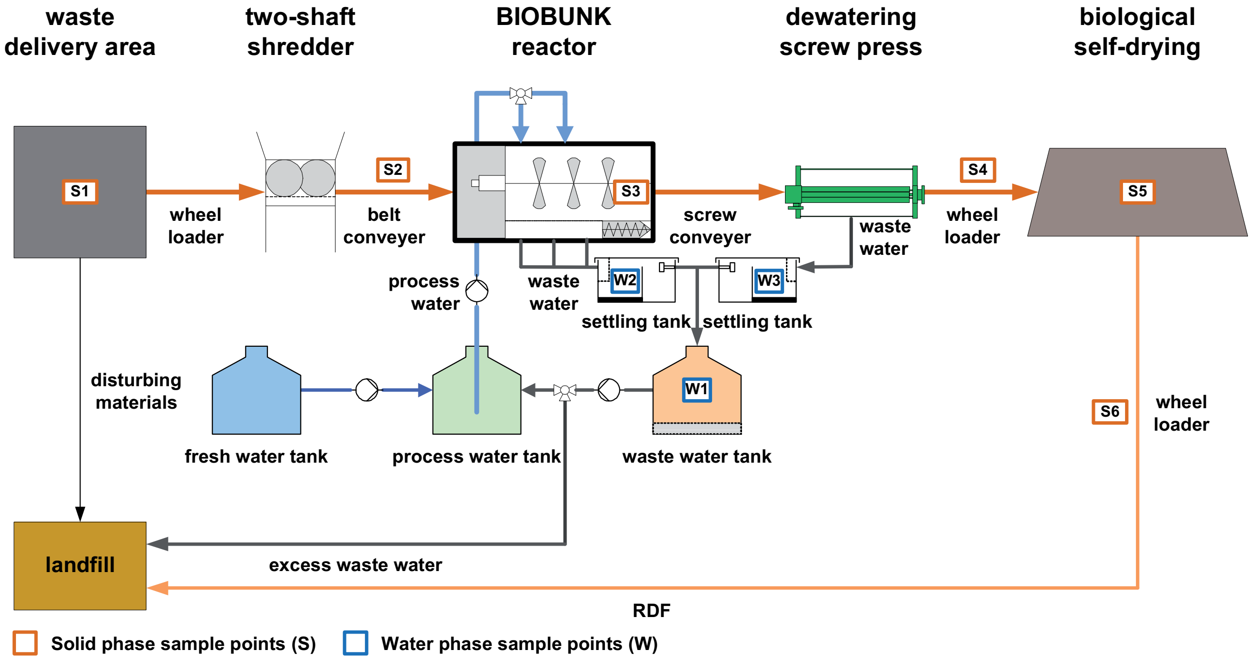


Figure 1 Process flow diagram of BIOBUNK pilot plant

At the bottom of the BIOBUNK reactor and at the dewatering screw press highly polluted water occurs. Two small sedimentation tanks, one for each line, remove sediments and coarse particles. This needs to be done in order to protect following transfer pumps. Also an excessive sediment layer in the waste water tank has to be prevented as all tanks are installed underground and thus are difficult to clean. As no waste water treatment stage is included to the pilot plant, the needed irrigation water for the BIOBUNK reactor has to be emulated by diluting the waste waster with fresh water. The chemical oxygen demand (COD) is used as control parameter. As target concentration, the effluent values and respectively the degradation performance of typical anaerobic digesters are used. The excess waste water is discharged to the landfill. From the process water tank the process water is pumped in intervals to the BIOBUNK reactor where it is used in order to irrigate the waste. Two baffle plates spray the process water over the waste.

2.2 Operation and Testing of the Pilot Plant

2.2.1 Construction of the BIOBUNK pilot plant

The pilot plant was erected in Phetchaburi province about 150 km away from Bangkok in south-eastern direction. The plant was connected with a 22 kV power line. Fresh water had to be continuously carried by a truck. A laboratory and an office container have been provided.

2.2.2 Operation schedule

The pilot plant has been operated from Monday to Friday and on every other Saturday. The fresh waste input has been fed in several small charges (400-500 kg) during the first half of the day. The discharge operation took placed during the second half of the day. On every Tuesday, the heaps for the biological self-drying tests have been set up. The drying heaps have been turned every 24 hours with exception of the weekends. On the next Tuesday, after one week, the heaps have been removed. As the last daily task the process water charge for the next 24 hours for the irrigation system has been prepared.

2.2.3 On-site field measurements and laboratory analyses

The waste input (S1) and output (S4) quantities as well as the drying heap material (S6) have been weighed daily by using a weighting box and a large scale. The waste composition including the moisture content has been determined by manual sorting and weighting before and after drying every three to four weeks. The samples have been taken in small portions after the shredder directly from the belt conveyor (S2). As the waste already was cut down and homogenised by the shredder, samples of 20-30 kg were sufficient in order to achieve reproducible results. The dry matter contents of the material in the BIOBUNK reactor (S3), after the dewatering screw press (S4) and of the drying heap material (S5) have been determined daily by drying samples of about 2 kg at 105 °C. The RDF quality of four samples before and after the biological drying (S4 and S6) has been analyzed by a laboratory at Germany.

The produced waste water amounts have been recorded every day (W1). Also the physical measurement parameters; temperature, pH-value, redox potential and conductivity have been determined daily by using portable measuring instruments. The dry matter content and the average flow of the two sedimentation tanks (W2 and W3) have been checked once a week or in less frequent. The chemical measurement parameters COD, ammonia (NH_3-N), nitrate (NO_3-N), total nitrogen (N_{tot}) and phosphate (PO_4^{3-}) of the waste water (W1) have been measured every other day by using photometric cuvette tests. By titration with hydrochloric acid and sulphuric acid the concentration of volatile organic acids in the waste water was determined three times a week.

3 Results and Discussion

3.1 Waste Collection System and Waste Composition in Thailand

3.1.1 Thai Waste Collecting System

Besides a number of small projects, Thailand does not have any official waste separation systems. Waste bins as we know them from western countries do not exist in Thailand. Mostly, the mixed waste is collected in plastic bags. Smaller bags will be packed together with other small bags in bigger bags or put in wood baskets. Waste trucks will collect these bags directly from the streets. Because of the high temperatures in conjunction with the high moisture and organic content of the waste, a daily collection has been established, especially in the bigger cities.

Like in many developing and newly industrialized countries, valuable materials will be sorted out of the waste in order to sell them to private run waste recycling centres. In Thailand, valuable materials will be collected out of the waste in three stages:

- In the households and offices directly by the inhabitants or the staff,
- By the waste collectors before throwing the plastic bags in the waste trucks or after opening them inside the trucks,
- By waste pickers / scavengers at waste transfer stations or dump sites.

3.1.2 Thai Waste Composition

The average results of the waste sorting analysis are shown in Figure 2. On the left side the fresh waste is shown, the right diagram shows the results after drying at 105 °C.

Almost half of the fresh waste dominates with compostable organic materials. Compared with many other sorting analysis made in Thailand, this is a typical percentage (see Table 1). Together with the plastic fraction of the composite materials (ca. 1/5) plastics have a mass percentage of 25 %. This can be considered as high values for Thai waste. All other fractions are present with typical percentages. The dry mass content of the delivered waste ranges from 55 % to 60 % which is also a typical value for Thai waste (CHIEMCHAISRI, 2007).

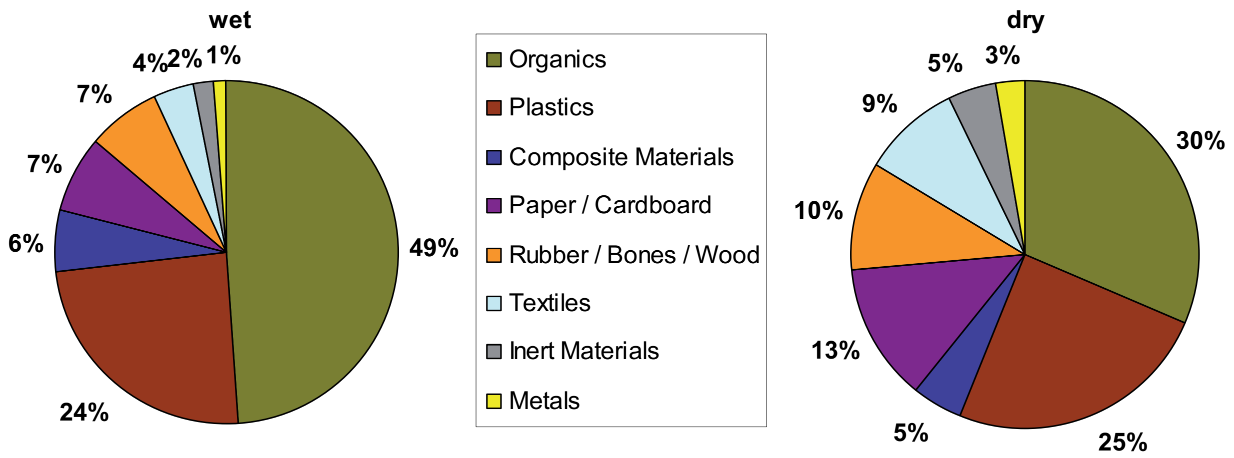


Figure 2 Average composition of the delivered waste for the pilot plant operation (wet and dry)

The fraction of the inert materials, metals as well as rubber, bones and wood the moisture have a relatively low moisture contents. Plastics, paper and textiles show moisture content in the range between 40-60 %. As expected the moisture content of the compostable organic materials has the highest value within almost 75 %.

Table 1 gives an overview of the results of different waste composition analysis made in Thailand. Compared to the result of the composition analysis of Phetchaburi MSW (CHIEMCHAISRI, 2007), the results obtained by own determinations are more or less in the same range. Compared to other studies about Thai MSW, the waste from Phetachburi province, as it was delivered to the pilot plant, also showed a similar composition. Plastics are present with slightly higher amounts and metals with relatively low quantities.

Table 1 Comparison of different results of waste composition analysis

Type / Source	food waste	plastic	paper	metal	glass	others
Phetchaburi province, pilot plant	**49**	**25**	**12**	**1**	**1-2***	**10-11**
Phetchaburi (CHIEMCHAISRI, 2007)	55	19.3	11.3	3.9	0.6	9.9
Bangkok (CHIEMCHAISRI, 2007)	43	10.9	12.1	3.5	6.6	23.9
Thailand (MRFEH, 2007)	48	14	15	4	5	14
Thailand (SWFL, 2011)	42	14	16	3	5	20
Thailand (DPC, 2000)	47	19	9	1	3	21

* Glass was sorted out together with other inert materials (sand, stones, ceramics)

3.2 Results of the Pilot Plant Operation

The pilot plant was operated from January until end of August 2010. In the beginning, various improvements and testings had to be done in order to put the plant into operation condition. Within the following months, suitable operation parameter had to be found. From the 21st of June 2010 the pilot plant worked with stable conditions, only two power blackouts occurred. Thus, all results presented in the following have been taken from that period.

3.2.1 Daily batch Feeding and average retention Time

The daily input and output (after the dewatering press) quantities of the BIOBUNK pilot plant from the 21st of June until the 20th of August 2010 are shown in Figure 3.

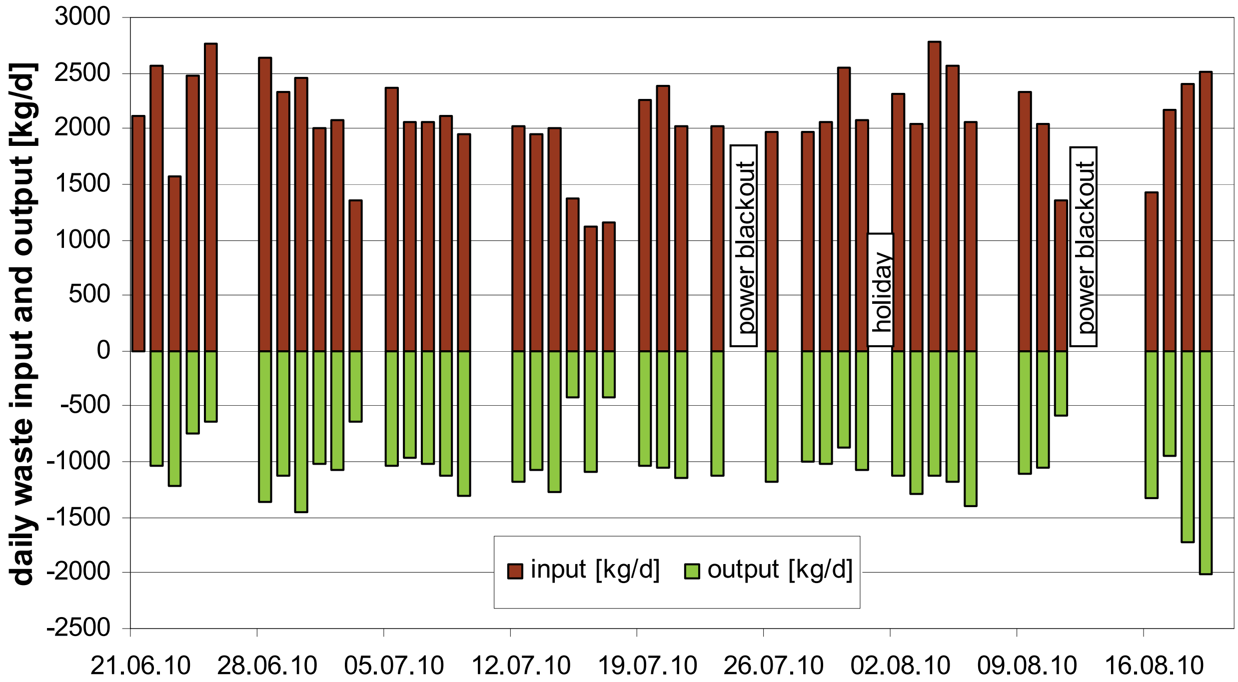


Figure 3 Daily pilot plant input and output quantities

The minimum target value of more then 2000 kg fresh waste input per day could be achieved most of the times. In average 2100 kg/d could be loaded to the BIOBUNK reactor. The daily dewatered output ranged from 400 kg up to almost 1,500 kg. In average 1,100 kg/d could be discharged from the system. Thus, a difference of 1,000 kg/d left the system via the water phase (including sediments) as well as degradation and evaporation losses. An average daily waste water production of around 500 L/d could be determined. Consequently, about 500 kg/d can be assumed as being sediments (sand, fine glass, etc) as well as losses by degradation and evaporation.

With a determined average waste capacity of 2.5-3.0 Mg inside the BIOBUNK reactor, a mean retention time of 1.2-1.4 days could be determined. And also tracer tests confirmed this.

3.2.2 Solid Matter

The daily dry matter contents of the waste material inside the BIOBUNK reactor and after the dewatering screw press are given in Figure 4.

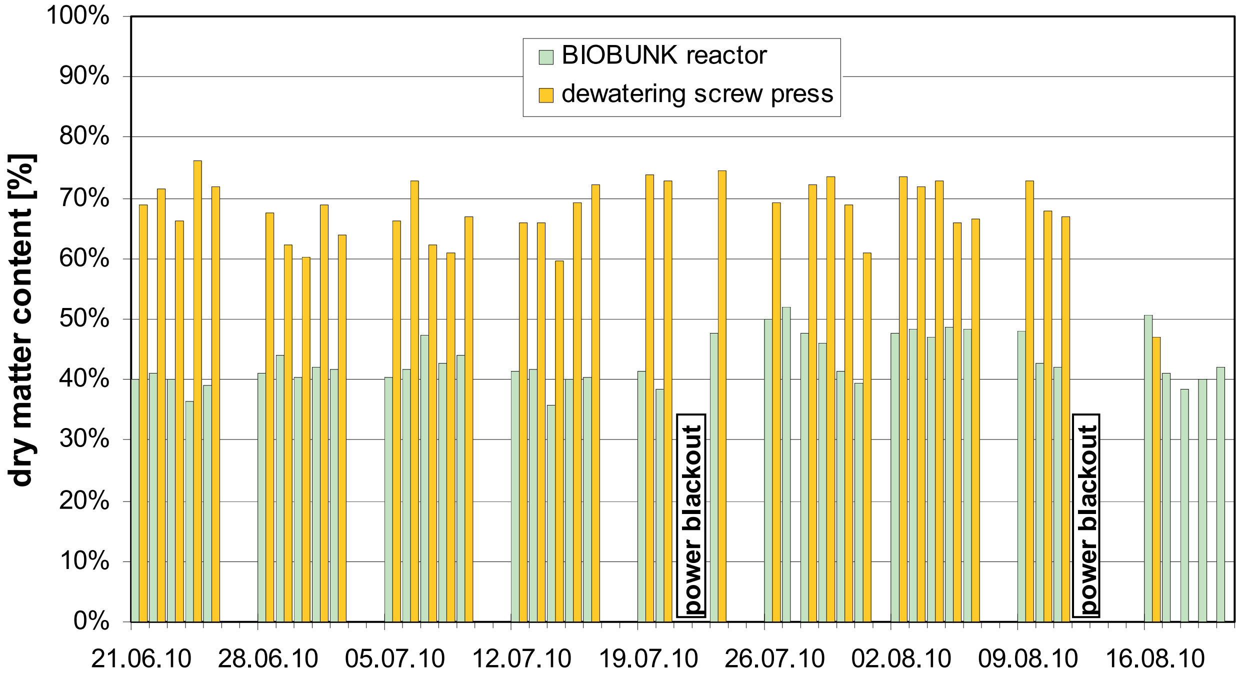


Figure 4 Dry matter values of BIOBUNK material and dewatering press output

Inside the BIOBUNK reactor the dry matter content of the waste material is stable around 40-50 %. In average a dry matter content of 43 % could be determined. The screw press dewatered the output to a dry matter content of up to 75 %. In average 68 % could be achieved. Compared to other MBT plants this can be considered as a high value. It is likely that the high amount of plastics is the reason for such a high dewatering performance.

3.2.2.1 Biological Self Drying

Once a week (always on Tuesdays) about 500 kg of the screw press output were taken and heaped to a trapezoidal drying heap with a height of less then 1 m. The dry matter contents and the temperature gradation of the heaps are shown in Figure 5.

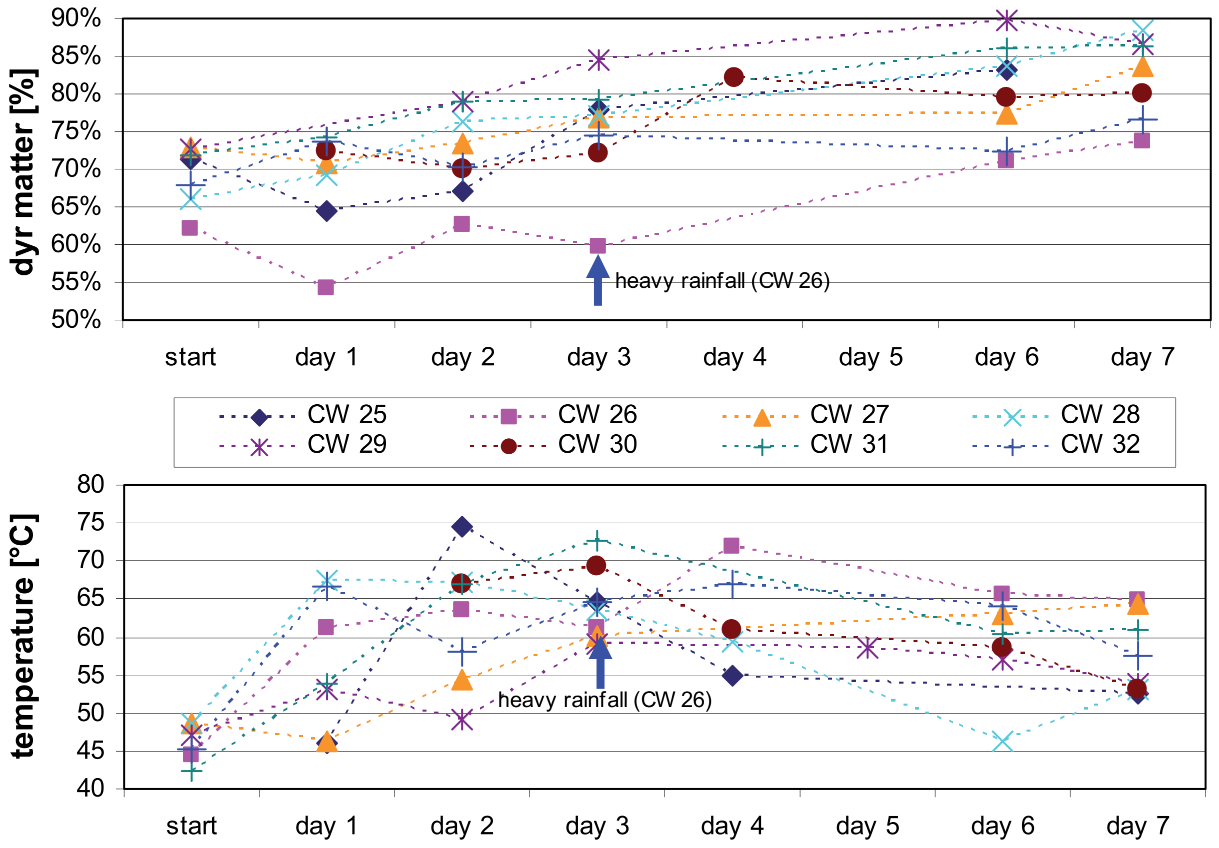


Figure 5 Dry matter content and temperature progression during biological self-drying

The dry matter content of the drying heap material constantly increases within the drying time of a week. After three days the maximum of 80-85 % is almost reached.

The start temperature of about 45-50 °C increases rapidly up to 70 °C within the first two days. Subsequently, the temperature decreases to around 60 °C. As the end temperature inside the drying heaps is considerable higher as the ambient temperature, it can be assumed that the biological self-drying processes have not been finished after seven days. Thus, a further drying performance can be expected with longer drying times. But the achievable gain can be estimated to be marginal (only a few percent less moisture). Consequently, this would not be profitable regarding the longer time and required space.

3.2.2.2 RDF Production

After seven days of biological self-drying, the treated waste can be regarded as ready RDF product. Figure 6 shows the specific RDF production of the calendar weeks 26-32 (without 31). Also the two other main output fractions waste water outflow and evaporation (and degradation losses) are presented in comparison to the fresh waste input.

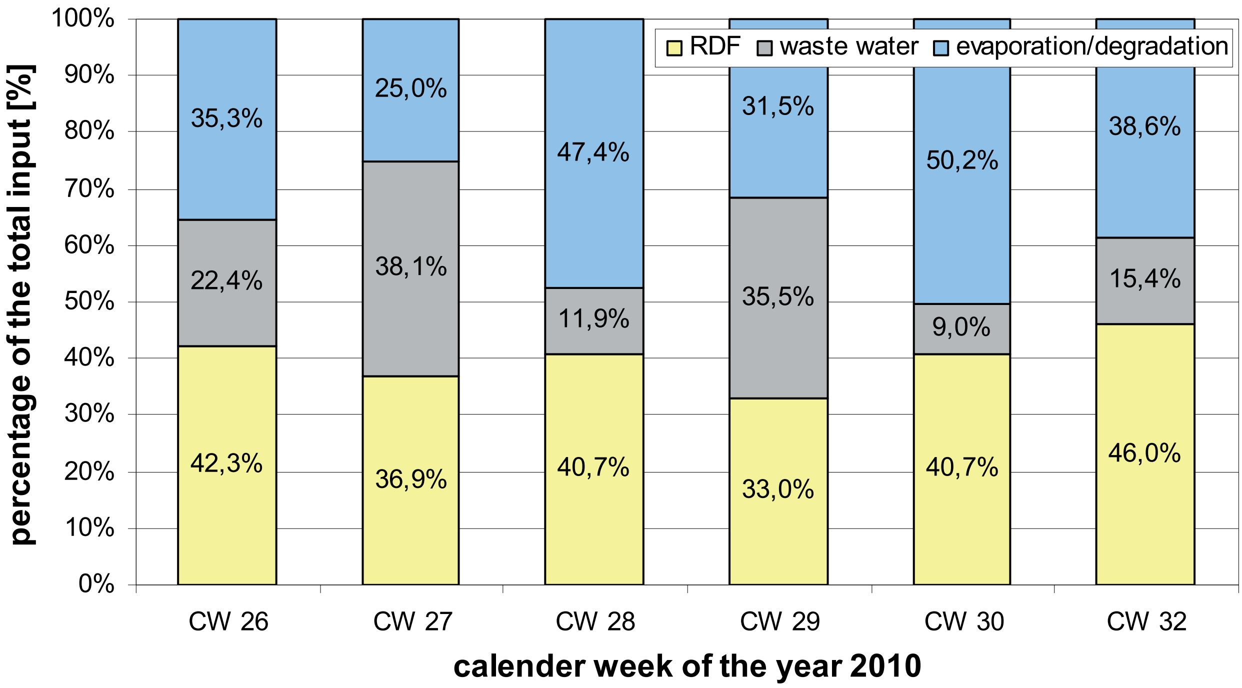


Figure 6 Distribution of the three main output fractions of the BIOBUNK pilot plant

The percentages of the produced waste water (daily collected waste water minus irrigated process water) as well as the degradation and evaporation amounts show variations from week to week. It can be assumed that the changing boundary conditions (temperature, precipitation, sun radiation, etc.), the inhomogenic input waste and measuring inaccuracies are the reason for that. Nevertheless, the RDF production is relatively stable with values between 33 % and 46 %. Over the whole stable operation period (CW 25-33, 2010) the average specific RDF production had a value about 400 kg RDF per 1000 kg of fresh input waste. The average residual moisture content of the produced RDF was 17.6 %. Thus, the specific RDF production regarding a completely dry martial can be estimated with 330 kg RDF per 1000 kg of fresh input waste.

The fresh input waste consists of about 25 % plastics (Figure 2). It can be assumed that almost all the plastic materials can be found in the RDF. Only very small amounts leave the system in the waste water stream. Hence, the RDF output consists of 62.5 % (25 % plastic : 40 % total) in maximum. As the measured moisture content showed values of 17.6 % in average, the RDF consist of almost 20 % other materials such as non- or hardly degradable organic materials, metals, glass and sand.

Table 2 shows analytical results of selected RDF samples made by a lab at Germany. The lower calorific value (LCV) of the dried RDF samples is 4-6.5 MJ/kg lower as the dried dewatered output. At the same time the ash content increases about 10-20 %. Thus, it is to be assumed that the remaining biological active organic content gets degraded during the self-drying process. Regarding the water content of the sample, the LCV of the dewatered BIOBUNK output has a corresponding value of about 13 MJ/kg.

The RDF, with a moisture content of 17.6 %, also reaches 11-13 MJ/kg. Chlorine values are clearly below 0.5 % which means a good suitability of the RDF as alternative fuel, e.g. for the cement industry. The measured heavy metal concentration can be considered as uncritical.

Table 2 Laboratory analysis of selected RDF samples

			dried dewatered output		dried RDF	
parameter	**unit**	**method**	**sample 1**	**sample 2**	**sample 1**	**sample 2**
LCV	kJ/kg	BG SBS 03/2008	20,533	20,407	13,917	16,478
ash content	%	DIN 51719	24.5	21.0	42.2	31.6
chlorine	%	DIN 51727	0.42	0.44	0.31	0.25
aluminium	mg/kg	DIN EN ISO 11885	6,310	6,440	10,200	7,200
chromate	mg/kg	DIN EN ISO 11885	31	33	58	280
copper	mg/kg	DIN EN ISO 11885	130	97	470	150
mercury	mg/kg	DIN EN 1483	0.78	0.43	1.65	0.39

LCV: Lower calorific value

3.2.3 Process and Waste Water

The average values of the routine physical and chemical analysis of the pilot plant's waste water are given in Table 3.

Table 3 Average measurement values of the pilot plant's waste water (week 25-33, 2010)

physical analysis			chemical analysis		
parameter	**unit**	**value**	**parameter**	**unit**	**value**
temperature	°C	32.2	**COD_{WW}**	mg/L	28,939
pH value	-	5.1	**COD_{PW}**	mg/L	7,235
redox potential	mV	+81,7	**NH_3-N**	mg/L	183.4
conductivity	mS/cm	15.0	**NO_3-N**	mg/L	11.0
dry $matter_{filter}$	g/L	11.9	**N_{tot}**	mg/L	631.8
dry $matter_{crucible}$	g/L	23.7	**PO_4-P**	mg/L	455

WW: waste water; PW: process water

The temperature of the waste water is slightly higher then the ambient temperature. The reason for that is the relatively high temperature inside the BIOBUNK reactor due to high biological activity and the sun radiation during the day time. Due to the production of volatile organic acids (VOA) during the aerobic hydrolysis the pH-value drops down a value of 5.1. The redox potential measurements of +81.7 mV indicate an oxidizing milieu in the waste water. This proofs that the system works under aerobic conditions. The conductivity shows values around 15 mS/cm. Without the influence of any other substances this value would correspond to a salt concentration of 7 gNaCl/L. Thailand is considered to be the largest fish sauce producer (SAISITHI, 1994) and to be one of the biggest fish sauce consumers. Fish sauces have a very high salt concentration. Very often fish sauce containing food rests will be disposed to the waste. This fact could be one of the main reasons for the high conductivity of the pilot plant's waste water. The dry matter determined by filtering reaches almost 12 g/L. By evaporation in crucible almost 24 g/L can be found. Thus, 50 % of the dry matter content can be considered to be in solution and exist as very fine particles respectively. The COD has a high value of approx. 29,000 mg/L. By diluting the waste water with three parts fresh water the calculative COD concentration has a value of 8,333 mg/L. Ammonia is present with 183 mg/L, nitrate with 11 mg/L and total nitrogen with 632 mg/L. Phosphate has an average concentration of almost 1,400 mg/L. Regarding a future anaerobic waste water treatment process for the BIOBUNK process, the waste water shows a COD to nutrient ratio (COD:N:P) of 230:5:3.6. For an optimal degradation a ratio of 300:5:1 to 500:5:1 is needed (BISCHOFSBERGER ET AL., 2005). Hence, even with higher COD concentrations the nutrients N and P will be available with sufficient concentrations.

As no anaerobic waste water treatment stage was implemented to the pilot plant, the theoretical biogas potential had to be estimated by calculation. The complete anaerobic degradation of 1 gCOD leads to a methane production of 1/64 mol (BISCHOFSBERGER ET AL., 2005). This corresponds to a gas volume of $0.35 \cdot 10^{-3}$ Nm³. In average, the pilot plant showed a waste water production of 3.12 m³/d. Hence, the daily dissolved COD freight amounts to 93.6 kg COD and 44.8 kg COD per 1000 kg of input respectively. With an estimated average methane concentration of 66 %, a biogas yield of 23.8 Nm³/ Mg input can be assumed. The particulate COD adds 3.6 Nm³ of biogas to a total value of 27.4 Nm³.

Table 4 Biogas potential of the BIOBUNK pilot plant in comparison

	BIOBUNK pilot plant		**MBT Kahlenberg**
specific biogas yield [Nm³/ Mg input]	calculated	estimated	50-60
	27.4	40-50	

Compared with the MBT plant Kahlenberg the pilot plant's waste water seems to have a distinctive lower theoretical biogas yield. However it can be assumed that the practical value will be considerably higher. It is very likely that a part of the COD freight could not be measured and thus misses in the calculation. The sampling, especially of the particulate COD, was technically difficult and partially inaccurate. A closed mass balance of the COD and dry matter freight was not possible because of the following reasons:

- No complete mixing of the waste water tank (unknown sediment quantities),
- Partly unknown sediment amounts in the sedimentation tanks,
  (due to variations of the inflow and to unwanted overflows)
- Only random sampling of the dry matter freight into the sedimentation tanks,
  (due to a very high effort)
- The total organic carbon (TOC) was not determined, only the loss of ignition.
  (Thus, the COD of the sediments and sludge was roughly estimated)

4 Conclusions

The main goal of the project was the development of a simple, robust and effective MBT process which is suitable for the boundary conditions of newly industrialized countries. The so-called BIOBUNK process was tested with a pilot plant in Thailand. The process focuses on the production of refuse-derived fuel (RDF) and a high biogas yield. The pilot plant consists of a shredder as mechanical stage and an aerobic mixed reactor as biological stage. It was designed for a daily capacity of 2 Mg of MSW.

The generated RDF (14-16 MJ/kg) presents an optimal alternative fuel, e.g. for the cement industry. The occurring waste water has a moderate biogas potential (40-50 Nm³/Mg waste). Compared to simple landfilling high amounts of GHG emissions can be saved. Thus, the implementation of clean development mechanism (CDM) can increase the economic efficiency of the developed BIOBUNK process. The determined waste composition and moisture content of the MSW collected in Phetchaburi province and brought to the pilot plant can be considered typical for Thailand. Plastics are present with slightly higher amounts. Consequently, it can be assumed, that the pilot plant will work with a similar performance and results in other regions of Thailand and probably also in other (Southeast) Asian countries. The assumption of achieving a shorter mean retention time compared to the MBT process in Germany could be approved. The reason for that are higher temperatures in Thailand as well as the higher moisture and organic content of the Thai MSW. Because of these boundary conditions the hydrolysis of the waste already starts in the waste bags and trucks. And also this saves time inside the BIOBUNK reactor. In summary it can be said, that the aim to develop a RDF and biogas producing MBT process suitable for newly industrialized countries can be regarded as fulfilled.

Regarding the analytical monitoring of the pilot plant operation following suggestions for improvements can be made:

- Cryo milling in order to determine the loss of ignition of solid samples.
- Membrane filtration (0.45 µm) instead fluted filter for dry matter determination.
- TOC measurements of the waste water sludge.
- Usage of only one sedimentation tank or alternatively of one completely mixed waste water tank in order to simplify the sampling.
- More RDF analysis as the material is inhomogenic.
- Installation of a compact anaerobic waste water treatment in order to determine the biogas potential by measurements.

For a continuation of the pilot plant operation or for a big size plant upscaling following improvements of the process should be considered:

- Using a more effective and powerful shredder (e.g. with four shafts) to avoid blockings caused by textiles. Preliminary tests with such a device showed better results.
- Installation of an anaerobic waste water treatment stage in order to produce a representative process water instead of diluting waste water.
- Installation of technical drying boxes instead using open heaps in order to save time and space as well as to achieve a lower residual moisture content of the RDF.
- Operation of the BIOBUNK as partly flooded reactor in order to increase the elutriation performance of organic waste contents and save irrigation water respectively.

5 References

Bischofsberger, W.. Rosenwinkel, K.-H., Dichtl, N., Seyfried, C. F., Böhnke, B	2005	Anaerobtechnik, 2. Ausgabe; Springer Verlag; Berlin und Heidelberg
Chiemchaisri, C., Juanga, J.P., Visvanathan, C.	2007	Municipal Solid Waste Management in Thailand and Disposal Emission Inventory; Springer Netherlands, ISSN: 0167-6369
Chiemchaisri, C., Visvanathan, C.	2008	Greenhouse Gas Emission Potential of the Municipal Solid Waste Disposal Sites in Thailand; Journal of Air and Waste Management Association, Issue. 58, ISSN: 1047-3289
DPC	2000	Department of Public Cleaning, Bangkok Metropolitan Administration (BMA)
Giegrich, J., Vogt, R.	2008	Strategy Proposals for Optimising German Development Cooperation – Contribution to GHG Mitigation in the Waste Management Sector; IFEU/GTZ, Germany
IPCC	2007	Climate Change 2007, 4th Assessment Report, Working Group III: Mitigation, Waste Management; URL: http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter10.pdf, 29.03.2011

Kim, Hak-Su	2005	Speech on the occasion of the Fifth Ministerial Conference on Environment and Development (28-29 March 2005), Printed in the Report of the Ministerial Conference on Environment and Development in Asia and the Pacific Seoul, http://www.unescap.org/esd/water/publications/sd/MCED-final2.pdf, 29.03.2011
Ministerial Regional Forum on Environment and Health	2007	"Waste management in Thailand", Ministerial Regional Forumon Environment and Health, 8-9 August 2007 in Bangkok, Thailand
Monni, S. Pipatti R., Lehtilä A., Savolainen I., Syri S.	2006	Global Climate Change Mitigation Scenarios for Solid Waste Management, VTT Technical Research Centre of Finland, Finland; ISBN: 951-38-6850-8
PCD Pollution Control Department Thailand	2010	Solid waste generation in Thailand between 2003-2004, http://www.pcd.go.th/info_serv/en_waste_wastethai.htm, 29.03.2011
Saisithi, P.	1994	Traditional fermented fish: Fish sauce production. In Martin A.M. (Ed). Fisheries processing: Biotechnology application, Chapman and Hall. London, pp: 111-131
SWLF	2000	Sustainable Solid Waste Landfill Management, http://www.swlf.ait.ac.th/data/Case%20studies/National%20report-Thailand.pdf, 29.03.2011
TEI	2004	Thailand Environment Institute. In: Municipal Waste Management Report – Status-quo and Issues in Southeast and East Asian Countries, 2007, ISBN: 978-974-8257-73-0, http://www.environment-health.asia/userfiles/file/Municipal%20Waste%20Report.pdf, 29.03.2011

Author's addresses:

M.Sc. Dipl.-Ing. Sebastian Platz
Universität Stuttgart
Institut für Siedlungswasserbau,
Wassergüte- und Abfallwirtschaft
Bandtäle 2
D-70569 Stuttgart
Telefon +49 711 685-65470
Email: sebastian.platz@iswa.uni-stuttgart.de
Website: www.iswa.uni-stuttgart.de/iwt

Prof. Dr.-Ing. Uwe Menzel
Universität Stuttgart
Institut für Siedlungswasserbau,
Wassergüte- und Abfallwirtschaft
Bandtäle 2
D-70569 Stuttgart
Telefon +49 711 685-65417
Email: uwe.menzel@iswa.uni-stuttgart.de
Website: www.iswa.uni-stuttgart.de/iwt

Dipl.-Ing. (FH) Martin Schaub
WEHRLE Umwelt GmbH
Bismarckstrasse 1-11
D-79312 Emmendingen
Telefon +49 7641 585 270
Email: schaub@wehrle-umwelt.com
Website: www.wehrle-umwelt.com

Dr. Jochen Amrehn
International College - King Mongkut's Institute of Technology Ladkrabang (KMITL)
Chalongkrung Road, Ladkrabang District
TH-10520 Bangkok
Telefon +66 2 73 72 580
Email: jo_amrehn@yahoo.de
Website: www.kmitl.ac.th/ic

Effective treatments of household waste using the BHS-Rotorshredder

Christian Hein

BHS Sonthofen GmbH

Abstract

The selective comminution of household waste covers a wide range with huge potential. Also a combination of impact crushing and cutting techniques is considered a positive aspect. This will enhance the product quality and increase the recovery rates of an MBT facility.

The a.m. fields of application show how manifold and variable such a machine can be incorporated into an overall concept. In financial terms, such an optimization makes sense. Lower specific costs per ton, higher availability and less maintenance are important factors that characterize this type of machine.

Keywords

Impact crushing, disintegration, homogenisation, increase of the surface, procedural improvement, effective size reduction, cleaning process, upgrading

1 Design example of a mechanical biological waste treatment (MBT) plant

The first stage of a MBT system usually combines mechanical disintegration with magnetic separation and sorting. The fine particles are typically very moist and will undergo further biological treatment. The coarse particles and the residual products of the shredding process are subsequently sorted and treated to obtain the following end products:

- materials for recycling
- fractions for the energy recovery or thermal treatment
- inert fraction for land fill

In terms of technical equipment and combination of the main process steps indicated, there are many variations of MBT systems. For the operator, the main difficulty lies in producing a homogenous product from a non-homogeneous material.

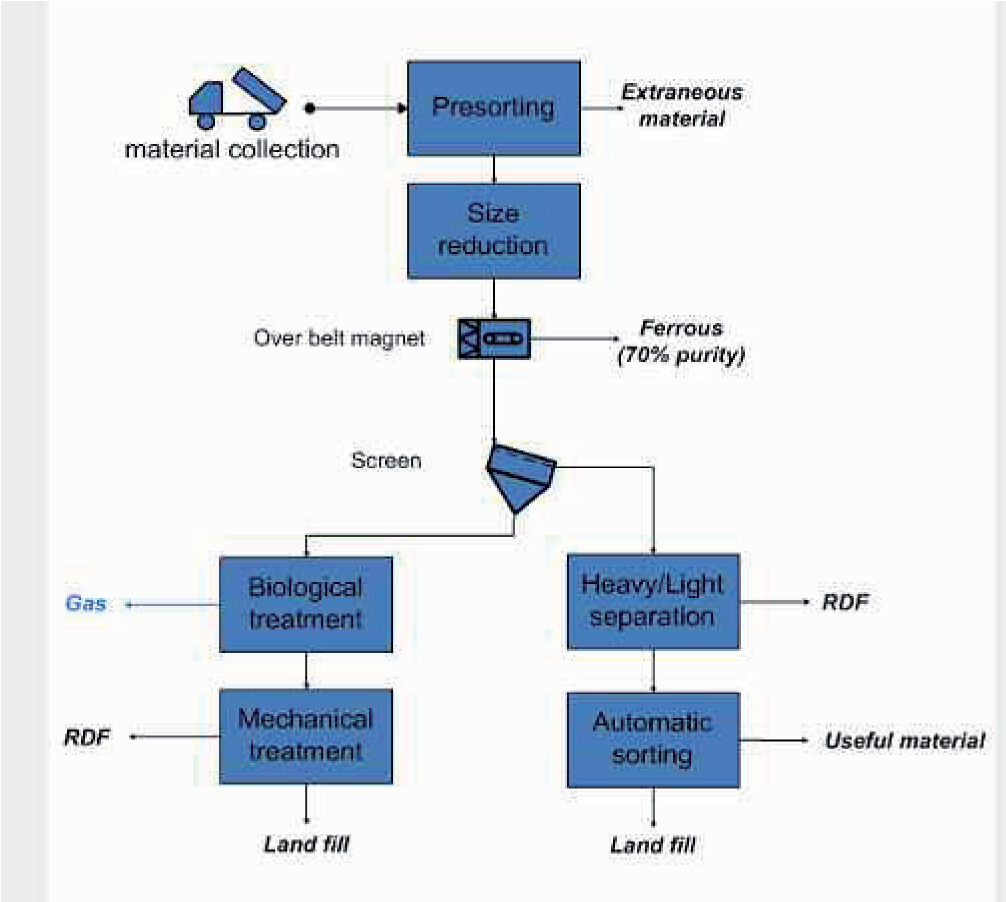


Fig.1: Design example of an MBT system

2 Rotorshredder

The patented BHS Rotorshredder consists of a cylindrical working chamber with double wall housing. In the middle of the machine there is a vertical shaft, which is equipped with overhung mounted pairs of crushing tools. The inner cylinder wall is made up of a solid bar grate. This ensures that the crushed material can leave the machine as fast as possible. The input material is charged into the machine from the top. As the material enters the working chamber, it hits the hammer shaped crushing tools, where it is exposed to quite intense impact, punch and shear forces and leaves the working chamber through the bar grate only a few seconds later. As the material falls down, it passes a variable number of crushing levels, thus achieving an optimal disintegration effect. This continuous operation enables a high throughput rate and it saves energy and wearing costs.

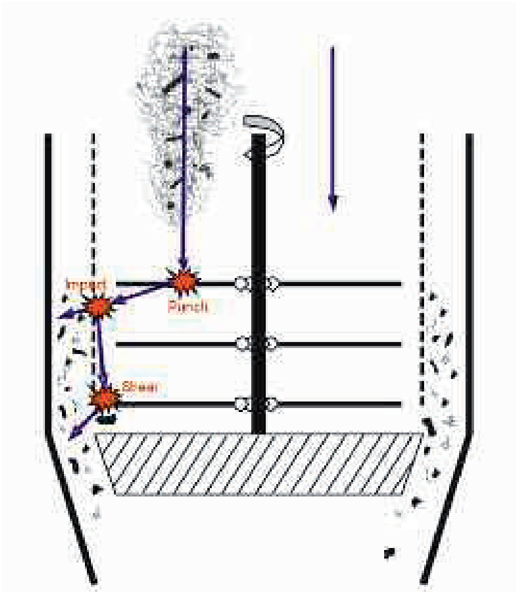


Fig. 2: Principle of the Rotorshredder

Fig. 3: Rotorshredder / RS2018

3 Advantages of a selective crushing

An important topic in the treatment of household waste is not only the compliance with legal requirements, but also the economical efficiency for the operators of such plants. The processing of household waste is relatively independent from raw material market prices. Rather more important is the cost saving potential and the improvement of the complete process. The crushing systems employed at this stage are particularly significant to factoring cost in this process ,the selection of the correct crushing technologies offers the opportunity to save considerable sums of money. Selective crushing brings new possibilities and effects for the treatment of household waste.

3.1 Compared to other systems

Heavy pieces are a problem and have to be sorted out before the crushing stage. Otherwise, blockage or damage to the shredder can occur. The Rotorshredder has the advantage of using flexible hammers, should a heavy or hard piece of material enter the crushing chamber the hammers due to the fixing method employed are able to drop allowing the heavy piece to fall and be ejected. This minimises the risk of damage to either the hammers or the cutting chamber virtually eliminating downtime as a result of damage or breakage.

For mass products like household waste, the very basic construction and simplicity of the machines offers high cost saving potential for maintenance and wear parts as compared to alternative technologies. Running costs of less than 1,50 €/t are a very cost effective alternative to process your material. The easy access and the simple mounting of the hammers make a wear part change feasible within 1-2 hours.

The Rotorshredder with its horizontal design also has a positive effect on energy costs. Motor powers of 132 to 250 kW (depending on the throughput rate) make this machine very economical.

3.2 Procedural wise

Good separation is essential in the treatment of household waste. A high degree of decomposition is achieved by the selective impact, shear and punch forces applied. This improves the efficiency of the downstream machinery and significantly enhances the product quality. The purity of the iron fraction is thus considerably increased and a directly marketable product is produced.

When separating heavy and light fractions it is important to produce a homogenous product of consistent quality. Particularly in the case of wet material the classifying stages are typically adjusted very tightly to separate the organic material.

Due to the impact in the Rotorshredder the material gets frayed, thus providing a larger surface area for sorting. This enables separation at reduced air velocity. The impact and centrifugal forces employed by Rotorshredder drive moisture from the material and when used with dedusting system large surface area materials will show further moisture loss resulting in fractions with a significantly reduced moisture content. As a result, disintegration in the Rotorshredder provides greater selectivity between heavy and light fractions, which has a positive effect on the product quality. First results show that the moisture mainly sticks to the fine fraction (< 12 mm). The coarse particles could be separated and reused already after the mechanical treatment.

The subsequent biological treatment steps include in most cases aerobic treatment employing various composting processes. Under the influence of atmospheric oxygen and bacteria or fungi, the easily recyclable organic material (carbon-hydrogen compounds) is converted to a large extent into carbon dioxide (CO_2), water (H_20) and energy. A good ratio of oxygen supply and water content is the decisive condition for the composting process. How well and how quickly the compost can be recycled by the microorganisms depends on how easily these nutritive substances are available to the microorganisms. One can say the bigger the surface of the material, the better for the chemical process. The well frayed material produced by the Rotorshredder has the advantage of having a significantly larger surface as compared to materials treated by conventional means. The lower bulk density also has a much better air permeability, which is essential for the composting process.

4 Applications

An evaluation of the operating data of various MBT plants carried out by the Registered Association for Material-Specific Waste Treatment (ASA) showed that upon completion of the run-in period, it is mandatory to optimize the parameters of the plant to ensure reliable performance in terms of:

- Quality assurance and improvement of the output produced by mechanical treatment

- Strict compliance with the requirements made on the deposits
- Strict compliance with pollution control and occupational health and safety regulations
- High plant safety
- Minimum operation and maintenance costs

Based on this result, BHS-Sonthofen can imagine three fields of application for the Rotorshredder. This machine enables us to pursue new roads in MBT technology and thus optimizes the overall concept.

4.1 Primary size reduction

For traditional household waste the Rotorshredder is a good machine in the first crushing stage. If also bulky waste is to be processed, it is conceivable to use a primary shredder to adjust the lump sizes. With a feed opening of 1600 x 1200 mm, however, it will usually be sufficient to pre-crush the material very coarsely.

We see the primary technical advantage in the break up and homogenization of the material. Being stressed by impact, punch and shear forces the material is torn on the one hand and cleaned on the other hand, the double-walled grate acting like a washboard. The wet material is rubbed along a grate and gets cleaned more and more. The fine particles (mainly adhesions) can then immediately leave the work area to the outside and will not be mixed with the other material. Only the coarse pieces fall down to the next row of impellers before being finally discharged. The excellent uniformity of the material makes it easier to adjust the subsequent process steps to the material to be separated. In metal separation significantly higher levels of purity can be achieved, the screening has a better selectivity and the heavy-light separation can be adjusted perfectly.

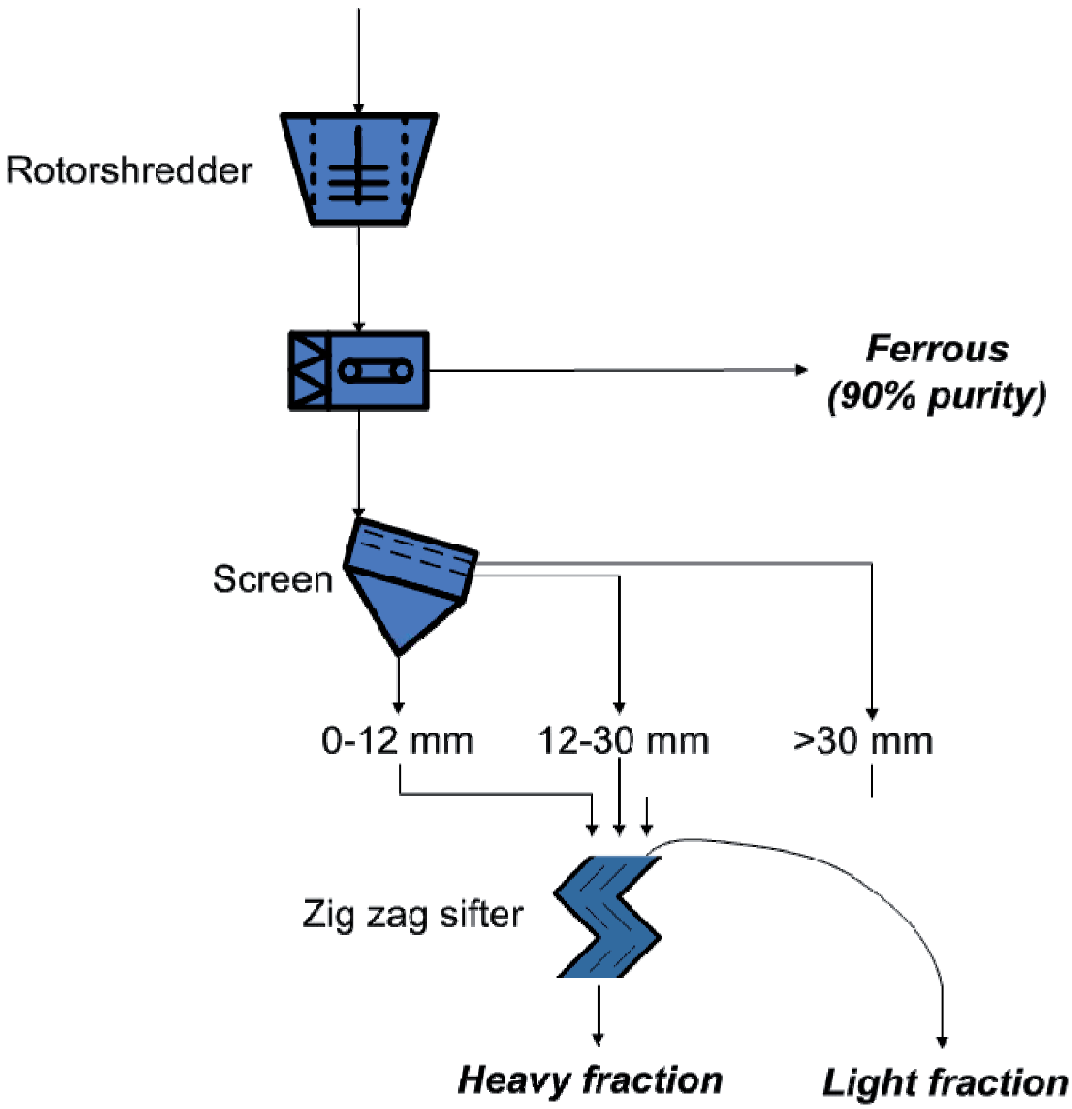


Fig. 4: Example of a pre-shredding line for household waste

We could demonstrate that the moisture has accumulated especially in the fine fraction. The fractions greater than12 mm also showed very good separation characteristics. These light fractions have a low moisture content and can be placed directly on the market. Even the 0-12 mm fraction could be handled in an acceptable manner using the zig-zag classifying principle. The result was a product that is optimally suited for the subsequent biological process. Because its high volume and modified structure the material is very permeable to air.

Light fraction (>30 mm)

Heavy Fraction (>30 mm)

Light fraction (12-30 mm)

Heavy Fraction (12-30 mm)

Light fraction (0-12 mm)

Heavy Fraction (0-12 mm)

Fig: 5: Comparison

4.2 Upgrading of ferrous scrap

The problem that the ferrous fraction (~60-70% ferrous content) from the mechanical biological waste treatment plants is of poor quality is largely known. The low sales prices for this material result in small profits. In order to keep any potential added value to your own company, BHS-Sonthofen offers a solution for cleaning this scrap in the Rotorshredder. The purified iron can be marketed directly at much better returns. The resulting fine fraction shows a high organic content and can go together with the other screen fractions to the biological part of the plant. Another product is the light fraction resulting from the zig-zag classifier. This fraction is ideal for use as refuse derived fuel (RDF) and can be sold at standard market prices.

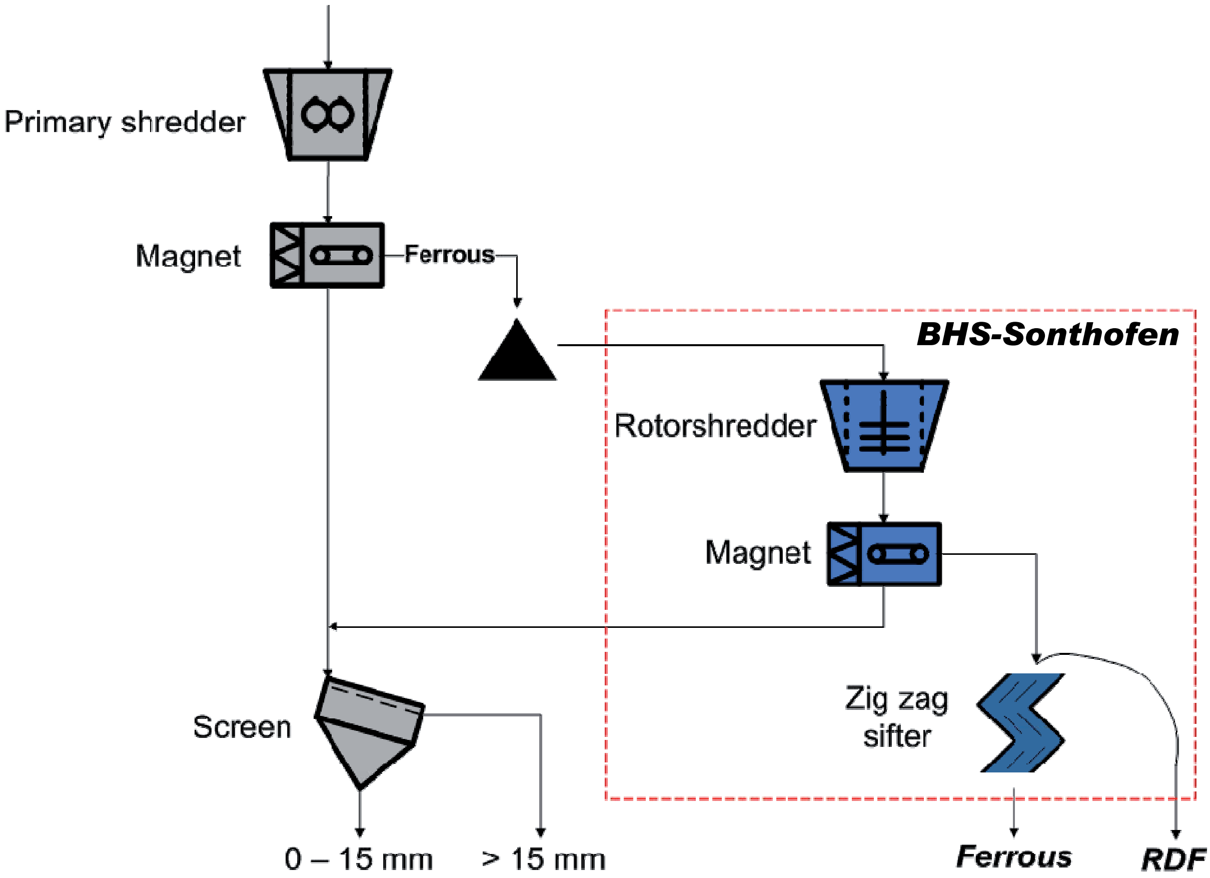


Fig. 6: Example for a ferrous upgrading unit

In the processing of this fraction, it is particularly important to use a crushing machine that brings little energy (heat) into the material. Particularly if hot iron makes contact with the RDF, there is an increased risk of fire. Experience has shown, however, that this problem will not occur in the Rotorshredder. With the continuous operation a certain amount of air flows through the shredder has a cooling effect. Moreover, the material remains only for a few seconds in the crushing zone, which minimizes the generation of heat. Thus, the major portion of the crushed material is only lukewarm and will not pose an increased fire risk.

Ferrous before

Ferrous after

Fine fraction

Light fraction

Fig. 7: Comparison

4.3 Break up of the material after the biological treatment

During composting the material is agglomerated and therefore an efficient separation in the subsequent mechanical processing step is difficult to achieve. Due to the generation of heat, the presence of water and the dead weight the material bed gets compressed more and more. The resulting composite materials and material bridges are disturbing for further sorting. In tunnel and volume composting it is a common problem that after discharge there are still many lumps affecting an accurate mechanical treatment.

For the dry mechanical treatment it is always useful to dissolve or destroy the existing composites. The Rotorshredder, featuring high throughput rates, low specific wear costs and simplicity, is ideal for this application. Especially for mass products such as household waste, these are important criteria for decision making. From a financial point of view, combustion is more interesting than land filling. Therefore the aim of the treatment is to separate inert material from thermally recyclable material as effectively as possible. The excellent decomposition allows for the extraction of more recyclable materials and reduces the amount of waste material being land filled.

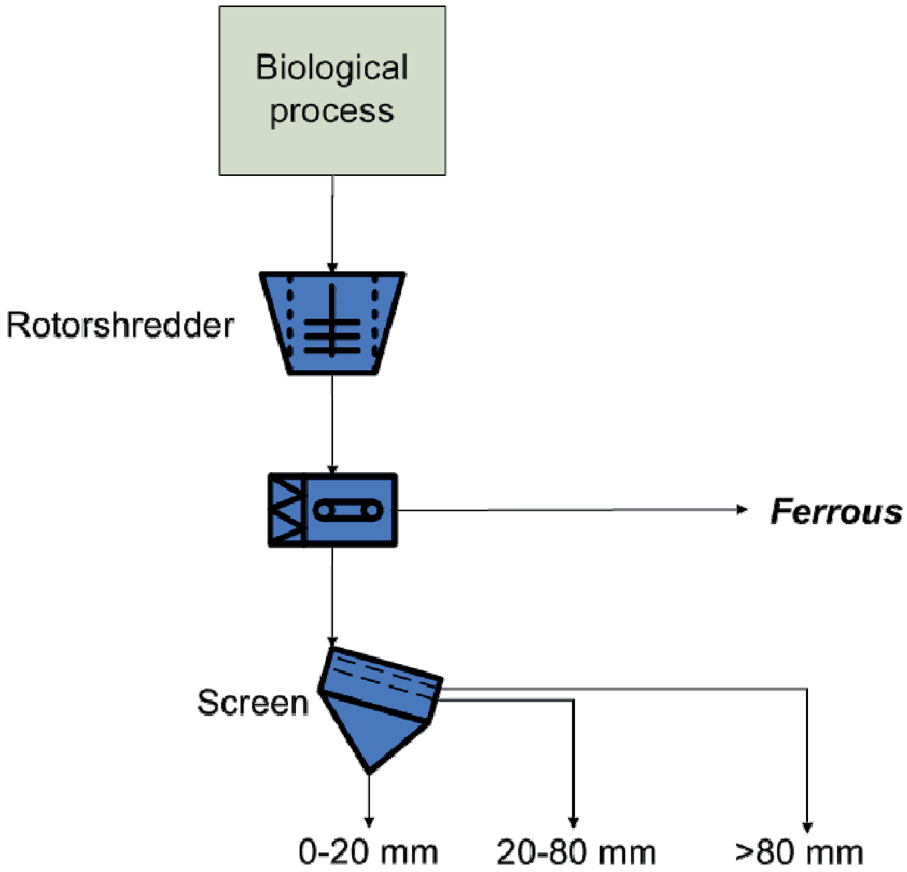


Fig. 8: Example for a treatment line

Very good results can be achieved when using an additional crushing stage before the existing mechanical treatment (sorting, heavy-light separation, magnets, eddy current separator). The metal recovery rate is increased, the fuel separation is maximized and the TOC value of the landfill fraction is reduced.

After composting

Treated with Rotorshredder

0-20 mm

20-80 mm

>80 mm

Ferrous fraction

Fig. 9: Comparison

Author's address

Dipl.-Wirtsch.-Ing. Christian Hein

BHS-Sonthofen GmbH

An der Eisenschmelze 47

87527 Sonthofen

Phone +49 8321 6099 118

E-mail christian.hein@bhs-sonthofen.de

Website: www.bhs-sonthofen.de

MBT Larnaka, Cyprus – Waste Treatment Technology from Komptech

Wellacher Martin

Komptech GmbH, Frohnleiten, Austria

Abstract

The MBT Larnaka has been set in operation in April 2010. The plants capacity is 200.000 t per year. The main purpose of the MBT is the reduction of landfill emissions from untreated municipal solid waste. Additionally there is a substantial rate of recyclables that can be gained out of the input. The plant consists of 3 main treatment processes: 1. mechanic treatment, 2. automatic and manual sorting, 3. biological treatment. Komptech supplied the core technology for the mechanic treatment and substantial technology for the biological treatment, in total 12 machines. Komptech is a leading international technology supplier of machinery and systems for the mechanical and biological treatment of solid waste and for the treatment of biomass as a renewable energy source. The protection of the environment and the quality of life for the citizens of Cyprus have progressed both a lot via the MBT Larnaka.

Keywords

Ballistic separation, composting, Cyprus, Komptech, Larnaka, MBT, optical sorting, screening, shredding

Figure 1: View on the MBT plant Larnaka, Cyprus

1 Introduction

The MBT Larnaka in Cyprus has been set in operation in April 2010 by the Helector S.A. Helector also designed, built and co-financed the plant. After 10 months of operation about 100.000 t of municipal solid waste have been processed. The waste has come from the region around Larnaka and Fammagusta with about 150.000 inhabitants. The plants capacity is 200.000 t per year.

Besides the mixed municipal solid waste about 10% of the input were separate collected yard waste and pre-sorted packaging waste.

Komptech is a leading international technology supplier of machinery and systems for the mechanical and biological treatment of solid waste and for the treatment of biomass as a renewable energy source.

2 Technology

In Larnaka the main purpose of the MBT plant is the reduction of landfill emissions from untreated municipal solid waste. Additionally there is a substantial rate of recyclables that can be gained out of the input. By the way the demand of landfill volume can be reduced significantly.

Figure 2 shows a model of the plant.

The plant consists of 3 main treatment processes.

1. mechanic treatment
2. automatic and manual sorting
3. biological treatment

Komptech supplied the core technology for the mechanic treatment and substantial technology for the biological treatment. In total 12 machines from Komptech are operated at Larnaka.

- 2x Pre-shredder “Terminator 2200 U”
- 4x 3-fraction drum screens “22/78” and “22/90” (see fig. 3)
- 1x coarse shredder “Terminator 3400 XF direct”
- 2x ballistic separators “Ballistor 61-3”
- 1x compost turner “Topturn X60”
- 2x star screens “Multistar 2-SE”

Figure 2: Model of the MBT plant Larnaka

After the initial manual sorting of glass out of the incoming waste the material is pre-shredded to open all bins and bags. Then it is screened into five fractions, of which two are further separated ballistically and via automatic sorting machines for PET, HDPE, plastic film and paper and cardboard and of course magnetic and non-magnetic metal. The oversize screen fraction is shredded and recycled to the screens. The last two undersize fractions are mainly dedicated for composting. In total 12 automatic sorting machines of the German TITECH GmbH separate potential recyclables. Most of the recyclables are gained out of the flat and the rolling fraction of the ballistic separator. Once a recyclable, such as PET, is concentrated a final manual negative sorting upgrades the material to the demanded purity. At the end the recycling products are baled.

Separate collected packaging waste is processed apart from the MSW on certain days after adjusting the plant to the different composition of this material.

Due to the design and use of high technological equipment the plant is flexible to changes of the input material. E.g. by means of an initial belt weigher a change of the moisture content can be reported quickly. So the operator is able to change the plant parameters within short time – e.g. those for the automatic sorting. So the unsteady moisture of the waste will not affect the quality of the process and its output materials.

Figure 3: Drum screens to separate the MSW into five fractions after initial manual sorting and pre-shredding

The fraction 0-70 mm which is dedicated for the composting undergoes a first step in composting boxes from the German supplier Herhof GmbH for 15 days. The waste air is collected and cleaned among others by a RTO step (regenerative thermal oxidation). Then the material is composted in a second step in triangular windrows on a roofed composting area with a compost turner. After about 45 d of composting in total the material is screened at 15 mm.

3 Quality

As usual the output materials ratio depends on the input quality. MSW in Cyprus shows a considerable fluctuation during the seasons due to the tourist oriented economy. Also the input quantity almost doubles in the high season. Figure 4 shows a possible ratio of output materials when MSW is processed. How the fluctuation of the input material moisture influences the output can be seen from a raw estimation of the operator: Once the moisture rise due to rainfall the paper and cardboard ratio on the input declines from the usual 10% to 2%.

Of course the most important products are the recyclables. The following materials are gained:

- PET
- HDPE (see fig. 5)
- Plastic film

- Paper and cardboard
- Magnetic metals
- Non-magnetic metals

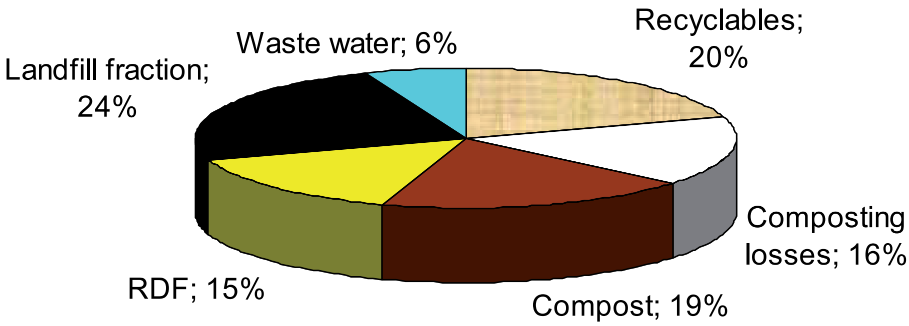


Figure 4: Possible ratio of the output materials and composting losses related to the input quantity (depending on the input quality)

There is a plan to recover the energy of the produced RDF, however at the moment this fraction is disposed to the landfill.

The compost is used as a landfill cover material.

Of course out of separate collected packaging waste a higher rate of recyclables can be gained.

Figure 5: HDPE bale for recycling, gained from MSW treatment at the MBT Larnaka

4 Cyprus

Cyprus covers a landscape of 9.251 km² with 1,1 millions of inhabitants. The household waste production of 778 kg per inhabitant in 2009 was one of the highest in Europe. 2010 there have been 117 landfills in use on Cyprus.

In 2005 the first modern landfill of Cyprus was opened at Paphos, in 2010 the landfill and MBT at Larnaka were set into operation. As usual the waste fee per household in the Larnaka region has risen from about 20 € per year up to about 90. The protection of the environment and the quality of life for the citizens have progressed both a lot. Mainly this has been achieved by the closure of uncontrolled landfills. Furthermore the biological stabilisation of the MSW and the gain of the recycling material in the MBT Larnaka have led to start this new era of sound environmental culture on the island of Cyprus.

Author's address

Dr. Martin Wellacher
Komptech GmbH
Kühau 37
A-8130 Frohnleiten
Telephone +43 3126 505 0
Email: m.wellacher@komptech.com
Website: www.komptech.com

Modernization of MBT plant “KBA Hard” - Erection and commissioning

Reinhard Schu

SCHU AG Schaffhauser Umwelttechnik, Schaffhausen, Switzerland

Abstract

In this paper we will describe the development of the SCHUBIO®-process for mechanical biological waste treatment as well as implementation of the first industrial scale SCHUBIO®-plant.

The SCHUBIO®-process represents a new type of plant, called TSS (Transfer-Stabilization-Storage), different from the common MBT-process. Instead of pre-treating the waste for landfill, the goal of the process is recycling and energy recovery of all output. The plant is a transfer station for all types of waste (Transfer), plastics and dry organic matter are separated from inert matter and easily biodegradable organics are stabilized by biogas production (Stabilization) and stored for energy recovery (Storage). In summer waste-to-energy plants operate at maximum capacity mainly without use of waste heat. With the TSS concept the waste is available for operation in winter when the waste heat is usable for heating purposes.

Keywords

SCHUBIO®-Process, TSS, transfer, stabilization, storage, MBT, mechanical-biological treatment

1 Introduction

KBA Hard in Schaffhausen is the last existing Swiss MBT-plant for municipal solid waste (MSW). This plant has been in operation for 37 years; 22 years ago it was converted from a waste incineration plant to a MBT-plant with composting of mechanically pre-treated MSW together with sewage sludge and separately collected bio-waste. Since the middle of 2009 the plant has been modernized, implementing the innovative SCHUBIO®-process on industrial scale. The new plant will process MSW as well as bio-waste and sewage sludge. Modernization and erection of the new equipment has been done during running operation. The new process has been chosen for economic reasons, energy efficiency, low environmental impact and flexibility of design, so that the equipment fits into the existing operation building. The area of the former composting hall is completely available for storage of stabilized waste. The modernized plant is currently under commissioning and will be in full operation by the end of 2011.

2 The SCHUBIO®-Process

The SCHUBIO®-Process has been developed with a background of long-time experience from mechanical-biological waste management. The process is based on the Finnish/German DBA-WABIO®-Process of 1993 and related wet fermentation technologies and can be applied for treatment of municipal solid waste as well as bio-waste or any other organic matter.

First the material is pre-treated by shredding and sieving at 100 mm as is common practice for MBT-technologies. The dry coarse fraction is baled, wrapped and stored for energy recovery in winter.

The fine fraction is separated into inert matter, organics and a liquid fraction, containing dissolved matter, fine inert particles < 100 µm and organics < 1 mm. The entire process yields surplus water even with municipal solid waste (MSW), water production instead of water usage. The solid fractions are easily dewatered because of prior separation, inert matter down to < 5 % water content, organic matter to < 40 % water content by mechanical dewatering and less than 10% water content by drying. Separation of inert matter and separation of organic matter into fractions of different particle sizes are preconditions for the thermo-mechanical cell-lysis. The cell-lysis is causing the organic fibres to fray and separate, thus breaking down the cell walls so that cell water is released. The liquid phase contains only biodegradables and is fermented for biogas production. After fermentation, ammonia is recovered from MSW, Bio-waste and sewage sludge as ammonium sulphate during waste water treatment. Phosphate from sewage sludge is recovered after thermal treatment of the sludge. A CHP-unit converts biogas into electric power and heat, the waste heat is used for drying of sewage sludge and organics.

The rinsed inert fractions can be recycled as building material; currently inert matter is deposited on a landfill. The dry, solid organic fractions (BioFluff®) are either used as fuel for a biomass power plant or stored for biogas production during the winter when the waste contains less organic matter. Thus, the level of biogas production remains constant all through the year.

The baled coarse fraction, mostly plastics, together with plastics recovered during the process, is treated in a waste-to-energy plant and partly used in cement kilns. Extensive tests have shown that plastics are the main pollution source in municipal solid waste. Due to the complete separation of plastics, all of the plant’s other products are only minimally polluted and therefore easily recyclable or suited for energy use in biomass power plants, co-firing in coal fired power plants or cement kilns.

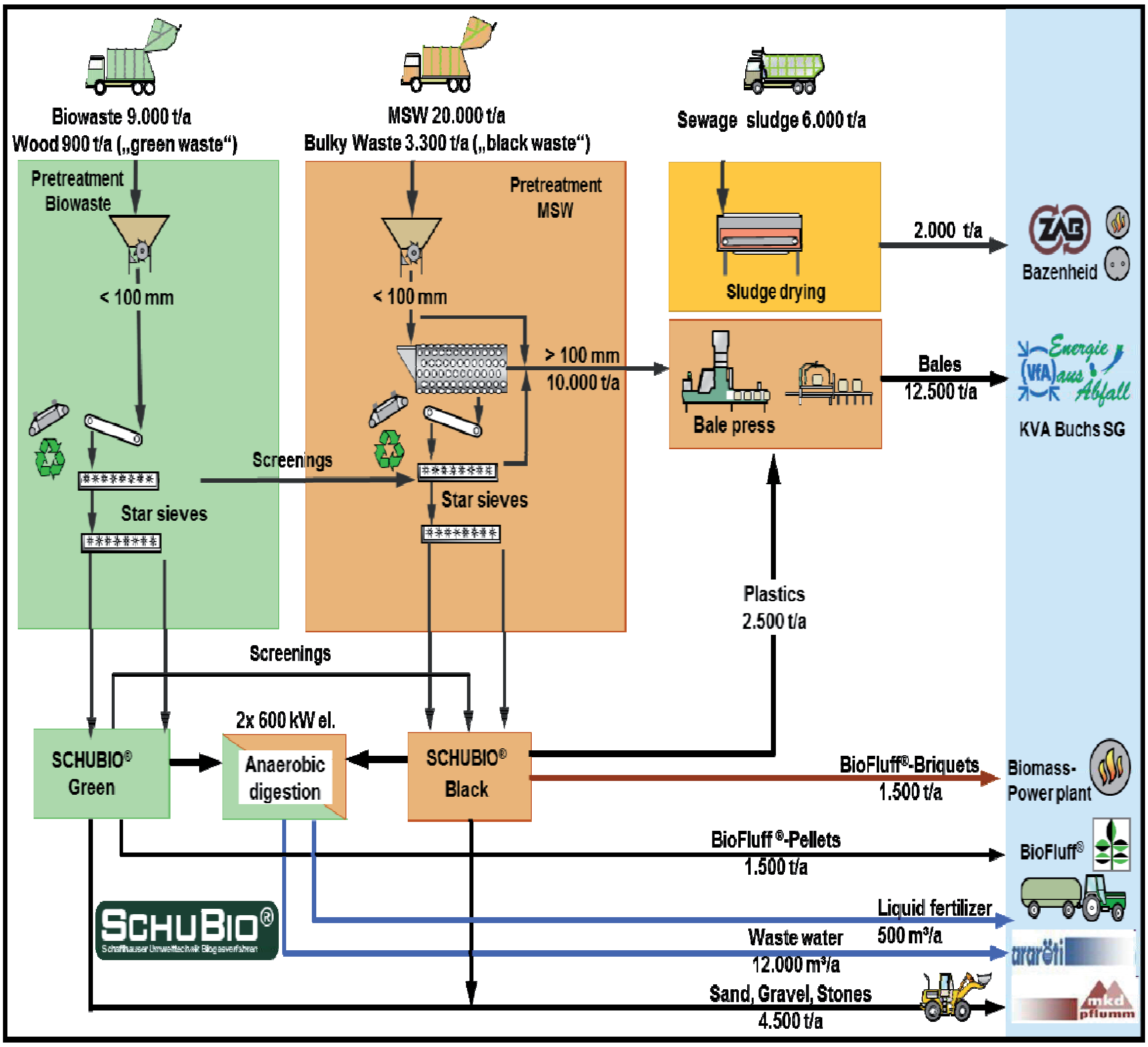


Figure 1 Process flow sheet SCHUBIO®KBA Hard, Schaffhausen

3 Modernization of KBA Hard

The MBT-plant KBA Hard in Beringen, Switzerland, has been built 37 years ago. The plant has been converted from a waste incineration plant and has been in operation as a MBT-plant for 22 years now. At the time the implemented composting technology was considered most innovative and has been known by the term "Schaffhauser Modell".

About 18.000 t/a MSW, 6.000 t/a Bio-waste and about 6.000 t/ sewage sludge as well as 3.000 t/a bulky waste are treated in the plant.

In the old MBT-plant, solids (MSW and industrial waste) were shredded and sieved, producing a dry, coarse fraction with high heating value and a wet fine fraction with lower heating value. The coarse fraction was baled and the bales were burned in the waste-to-energy plant KVA Buchs, either immediately or after intermediate storage at the KBA Hard site. The fine fraction was mixed with sewage sludge and composted in the rotting hall. After composting, the dried, stabilized and mass reduced material was likewise incinerated in the KVA Buchs. Bio-waste was mechanically treated and composted separately. The aerial view in Figure 2 shows the plant before modernization.

Figure 2 Aerial view KBA Hard, Schaffhausen, before modernization

The equipment had reached the end of its technical lifetime and had to be replaced. Moreover, the new waste treatment technology should meet the requirements of better energy efficiency and preservation of resources.

The operating municipality *“Kläranlageverband Schaffhausen, Neuhausen am Rheinfall, Feuerthalen und Flurlingen”* had therefore decided to modernize the KBA Hard by implementing the SCHUBIO®-Process. Figure 3 shows the overall view of the modernized KBA Hard in April 2011.

The new plant equipment fits into the existing operation building. Only the fermentation tanks are located outside, as well as the two 450 kW CHP-units. The former rotting hall has been dismantled and the area will be used for bale storage. The logistics for private delivery have been improved and the shredder for bulky waste is now installed in an enclosed hall. Total investment is at about 30 Million Swiss francs. The layout of the modernized plant is shown in Figure 4.

Figure 3 Overall view of modernized KBA Hard, Schaffhausen, April 2011

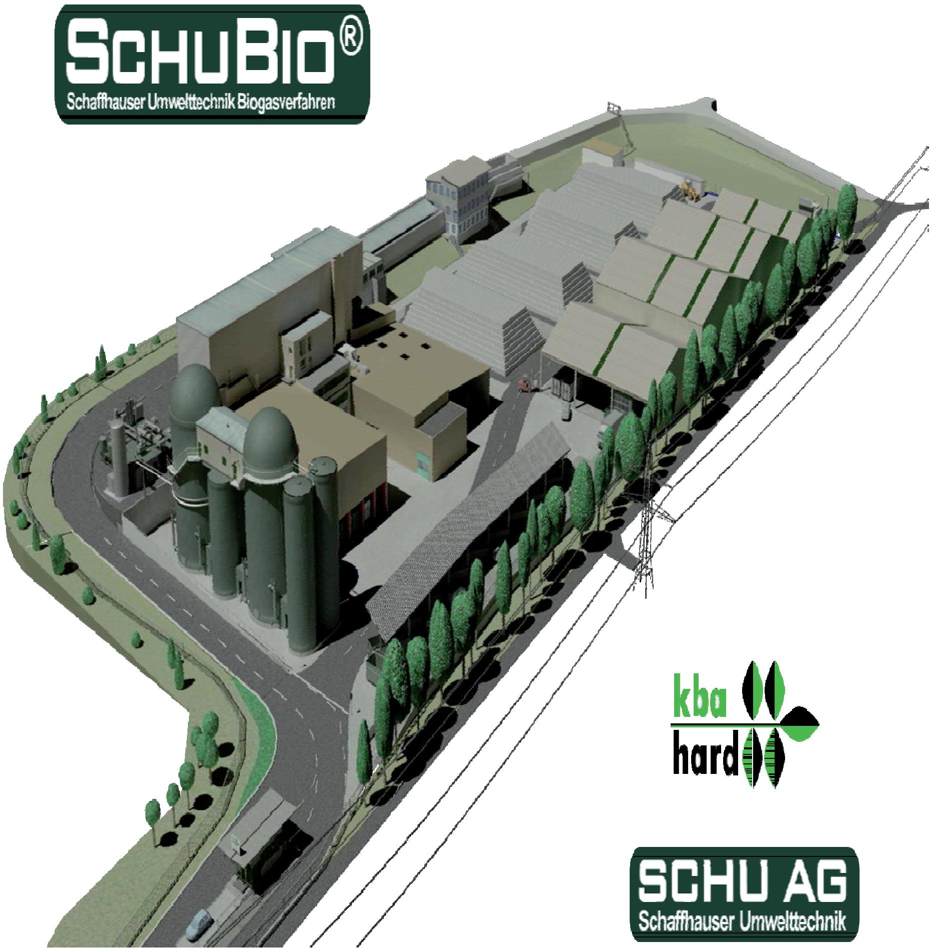


Figure 4 Layout KBA Hard after modernization

4 Project Realisation

Based on a preliminary study and calculation of the proposed budget, the referendum for modernization of the KBA Hard was adopted in 2007 by the voters in Schaffhausen. SCHU AG Schaffhauser Umwelttechnik was commissioned in 2008 to adopt the SCHUBIO®-Process for modernization of the KBA Hard plant.

Extensive tests with the mobile SCHUBIO®- pilot plant on site at KBA Hard were carried out with original waste material from KBA Hard and produced very satisfactory results. Consequently, a design study to implement the SCHUBIO®-Process and modernize the KBA Hard was conducted by SCHU AG and was finished by the end of 2008.

Already in March 2009, the permit application was submitted to the authorities and the building permit was granted in August 2009. Construction work started immediately afterwards. The old equipment stayed in operation during the construction until it was shut down in January 2010. During the following transition phase, the waste was delivered directly to a waste-to-energy plant. Renovation of the operation building was finished in October 2010. By the end of winter 2010/2011, the final process units have been erected. The dry treatment line was commissioned in April 2011. Commissioning of the wet treatment is planned for July 2011 and the plant will be in full operation by the end of 2011.

Table 1 Project Schedule “Modernization of KBA Hard”

Date	Project phase
03/2007:	Referendum for modernization of KBA Hard
06/2008	SCHU AG commissioned to do tests and design study
12/2008:	Design study finished by SCHU AG
03/2009	Application for building permit finished and submitted
08/2009:	Building permit
09/2009:	Start of construction
01/2010:	Shutdown of old equipment; transition phase
10/2010:	Operation building renovated
04/2011:	Commissioning of dry treatment line
07/2011	Commissioning of wet treatment line
12/2011	Plant in operation

5 Summary

With modernization of the KBA Hard the SCHUBIO®-Process has been implemented on industrial scale for the first time. Compared to similarly complex projects with implementing a new waste processing technology, the project has been realized in a very short time.

The ecological footprint of the plant is small since the equipment has been installed mostly within the existing buildings which have been insulated and renovated instead of demolished. The area of the former rotting hall is now usable for additional storage capacity.

Also the project costs stayed well within the budget approved by the voter's referendum in 2007. Furthermore, the municipality "Kläranlageverband Schaffhausen" will save on operation costs and will be getting compensation for feeding electrical energy into the grid (Feed-in-Tariff) from biogas production.

Kläranlageverband Schaffhausen has chosen the SCHUBIO®-Process for economic reasons, energy efficiency, low environmental impact and flexibility of design, so that the equipment fits into the existing operation building. These demands have been met by the SCHUBIO®-Process in every way.

Author's address*:*

Dipl.-Ing. Reinhard Schu
SCHU AG Schaffhauser Umwelttechnik
Winkelriedstrasse 82
CH-8203 Schaffhausen
Phone +41 52 5 11 10 10
Email R.Schu@schu-ag.ch
Website: www.schu-ag.ch

Release of VOCs and leachate during bio-drying process of MSW with high water content

YANG Na, QIANG Ning, LU Fan, SHAO Liming, HE Pinjing*

Institute of Waste Treatment and Reclamation, State Key Laboratory of Pollution Control and Resources Reuse, College of Environmental Science and Engineering, Tongji University, Shanghai 200092, P.R. China

Abstract

Two treatments were conducted to investigate the release patterns of volatile organic compounds (VOCs) and leachate during the bio-drying of municipal solid waste (MSW) by intermittent and continuous passive ventilation. The results showed that butyraldehyde was the major contributor to the VOCs emission, and it's maximum concentration was 254 ppm (v/v). During the bio-drying process, aldehydes and ketones were mainly released in the first 3 days followed by ethanol, their releases kept no more than 5 days. The emissions of methyl mercaptane, thioethers and aromatics lasted for more than 10 days. About 6 L of water was released as leachate, and 3L of water was condensed from the air flow. Continuous ventilation induced 45% higher of VOCs emissions and 45% higher of ammonia releases than intermittent ventilation.

Keywords

Municipal Solid Waste (MSW), Bio-drying, Passive Ventilation, Volatile Organic Compounds (VOCs), Preconcentration, Gas Chromatograph (GC)

1 Introduction

Bio-drying can be used as a pretreatment process for municipal solid waste (MSW) to enhance the mechanical sorting and energy recovery efficiency, and to accelerate the stabilization of MSW prior to landfill (ADANI ET AL., 2002; ZHANG ET AL., 2009). For bio-drying plants with forced ventilation, one of the most concerned problems is the release of odour, among which gaseous volatile organic carbons (VOCs) are of major contributors (HE ET AL., 2010). Moreover, the characteristics of the MSW in most developing countries, with higher water content and higher organic content, may introduce large amounts of leachate generation during the bio-drying process and the generated leachate has to be treated before drainage (SHAO ET AL., 2010). In this study, the generation and characteristics of gases VOCs and leachate were investigated in a simulated bio-drying process with different aeration modes.

2 Material and Methods

2.1 Characteristics of the MSW

The MSW was sampled from a residential area (Shanghai, China) in autumn. The initial was 74% (w/w, in wet weight).The MSW comprised 74% of food wastes, 17% of papers, 5.6% of plastics as well as 3.1% of others. Little metals, glass and textiles (included in the 3.1% “others”) was found in the waste, different from the waste received in treatment and disposal facilities, due to the residential source and the recycling of some valuable wastes by scanvengers before collection.

2.2 Experimental equipment

The laboratory columns, made of PVC plastic, were 1200 mm high and 400 mm inner diameter. The outer wall of the columns was wrapped with 100 mm-thick hollow cotton for thermal insulation. For leachate drainage and air distribution, a 100 mm-thick layer of round stones (with diameters about 5 mm) was placed at the bottom of the column. Above the stones, there was a perforation plate (2 mm mesh) placed to support MSW and facilitate aeration. The layer, including straw and cotton cushions, was placed on the top of MSW to avoid heat loss and vapor condensation. A whirlpool pump (XGB-8, Penghu Co., China) was used for aeration and the aeration rate was controlled by a gas-flow meter (LZB-10, Shanghai Instrument Co., China). To facilitate the gas sampling operation, the aeration pipe was enlarged to 60 mm diameter and 1 m length, and a sampling hole was opened 500 mm far from the column. To collect the water vapor condensed from the air flow and to protect the pump, a condensing equipment was installed before the gas-flow meter.

2.3 Experimental setup and operation

The experiment was conducted in the laboratory columns in duplicate. Each column was filled with 32 kg of the well-mixed raw MSW. The aerobic bio-drying process was performed in two aeration modes, i.e. continuous passive ventilation (CP), and intermittent passive ventilation (IP), with the ventilation rate of 0.014 m^3 per kg wet waste per hour. Intermittent ventilation was conducted with the aeration mode of 7 min run/23 min stop. The bio-drying process lasted for 16 days, and the waste was manually turned at day 8.

2.4 Sampling and analytical methods

For the CP mode, five liters of gas sample was extracted from the air flow through sampling hole of the ventilation pipe every day. While for the IP mode, two kinds of gas samples should be collected to represent the emission of VOCs from ventilation and static stage. During the ventilation, the sampling operation was the same with that of CP mode (labelled as IPa). Immediately after the ventilation, the column was sealed with a cap to avoid gas exchange between in and out of the column. Just before the next aeration circle, two liters of gas sample were extracted (labeled as IPs) from the headspace of the column after nearly 20 mins of sealing. The gas samples were pre-concentrated using a pre-concentration system (7100A, Entech Instruments Inc. USA) and the VOCs concentrations were subsequently monitored by a gas chromatograph (GC-450, Varian, Inc., USA), which was equipped with a flame ionization detector (FID) and a CP-Wax52CB (30m×0.32mm I.D., 2.56µm film thickness) column. Helium was employed as the carrier gas. The aromagrams were recorded with the oven temperature set at 50^{o}C for 2 min, then increased to 180^{o}C with a gradient of 10^{o}C/min, followed by an increase to 220^{o}C with a gradient rate of 30 min, where it was hold for 2 min. The detector and injector temperatures were set at 250^{o}C and 150^{o}C, respectively. The injector was operated with a splitless mode and programmed to return to the split mode after 20s from the beginning of the run.

The leachate was drained from the drainage pipe at the bottom of the columns and the condensed liquid was collected from the condensation equipment every day. The volume and characteristics (e.g. pH, ammonia, TOC) of the leachate were tested.

3 Results and Discussion

3.1 Emission of VOCs

Nineteen kinds of VOCs (Table 1) were detected from the collected gas samples, which included methyl mercaptane, thioethers, ketones, aldehydes, terpenes, alcohols as well as aromatics. Compared with the odour threshold of all the compounds (Table 1), six of them were on the concentration always under the threshold during the entire experimental period. The highest emission concentration was found to be butyraldehyde, 380,000 times higher than the odour threshold, followed by ethanol.

Table 1 Maximum concentration and odour thresholds of the detected VOCs (ppm, v/v)

Compounds	Methyl mer-captane	Dimethyl sulfide	Dimethyl di-sulfide	Dimethyl trisulfide	Acetone
Max	29.8	17.6	23.0	0.535	12.0
Threshold	0.00007	0.003	0.0022	0.00001*	42
Compounds	Butanone	Pentanone	Acetaldehyde	Acrolein	Butyraldehyde
Max	88.5	0.980	29.2	0.551	254
Odour threshold	50*	70*	0.0015	0.0036	0.00067
Compounds	Methanol	Ethanol	α-Pinene	Benzene	Toluene
Max	0.947	198	0.88	0.179	0.183
Odour threshold	33	0.52	0.018	2.7	0.33
Compounds	ethylbenze-ne	p-Xylene	m-Xylene	o-Xylene	
Max	0.090	0.377	2.78	33.3	
Odour threshold	0.17	0.058	0.041	0.38	

*The data were got from the website "http://www.cschi.cz/odour/files/world/Thresholds%20table.pdf"
Other data were collected from the website "http://www.env.go.jp/en/air/odor/measure/02_3_2.pdf"

The emission period was distinct between different compound series. As soon as waste being put into the columns, aldehydes started to emit and the concentration came to the peak value at day 2, and then dropped down rapidly. Actually, after day 5, nearly no acetaldehyde and butyraldehyde was detected (Figure 1). The emission pattern of butanone was similar with aldehydes (Figure 2), while acetone and pentanone experienced a longer emission period, which lasted for 7 days. Interestingly, at the first three days, no acrolein was found in the air, and then the emission peak value arrived quickly at day 4 with the concentration of 0.55 ppm (153 times of the odour threshold). Like the forementioned aldehydes, the emission of acrolein lasted for five days and no more was detected later. Followed with aldehydes, ethanol became dominant and the peak value appeared at day 3 and 4. The emission of methyl mercaptane and thioethers was long live (Figure 3), which kept from day 1 to day 8, and got the highest mission at around day 5. After the turning process at day 8, malodorous sulfur compounds were observed to be released again and the peak of release concentrations appeared on day 10. This second-release phenomenon was not found at the release of ketones, alcohols and aldehydes. The concentrations of aromatics kept at high level until day 13 (Figure 4).

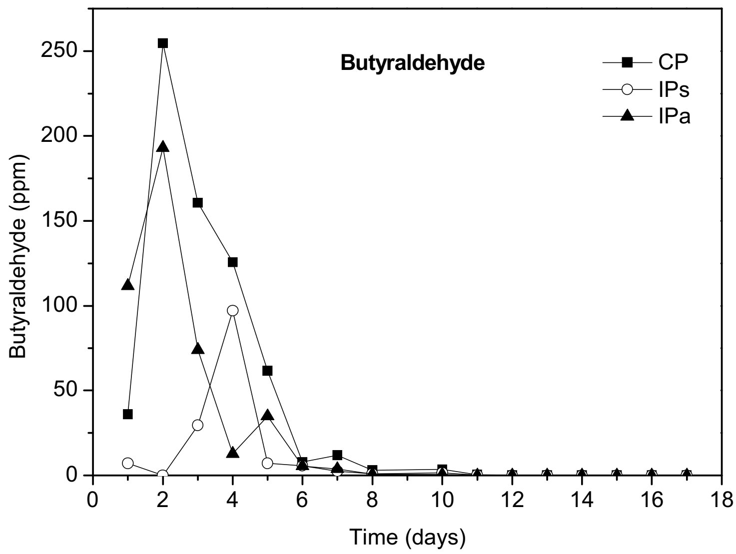


Figure 1 The concentrations of butyraldehyde in the air

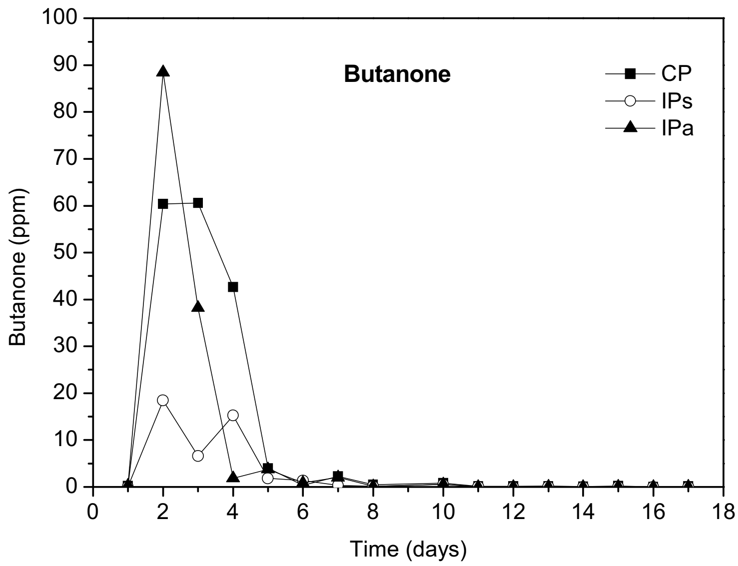


Figure 2 The concentrations of butanone in the air

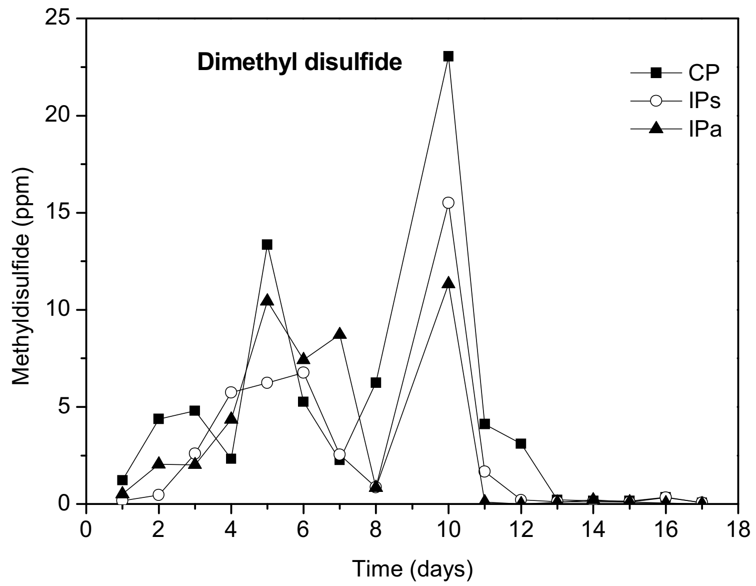


Figure 3 The concentrations of dimethyl disulfide in the air

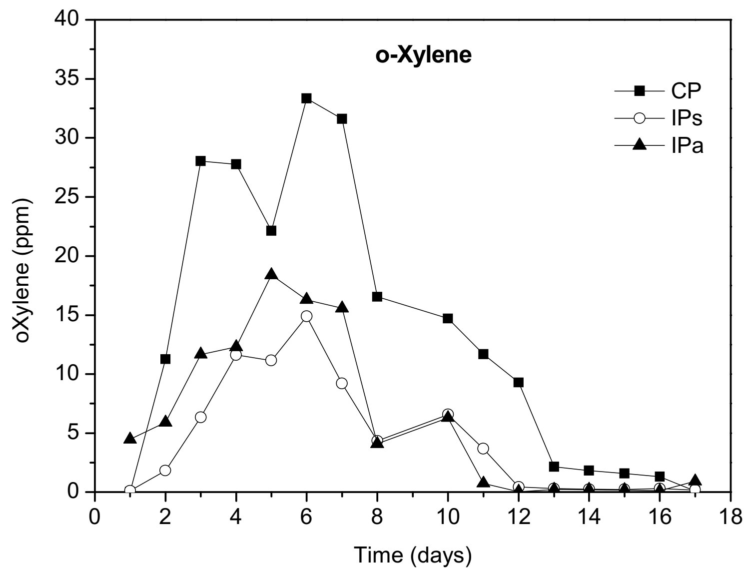


Figure 4 The concentrations of o-xylene in the air

The emission patterns of the VOCs from the three gas sampling points in the two columns were similar. The emission intensities were in the order of CP, IPa and IPs. The total emissions from the two collumns were the summation of all the daily emissions, which was calculated through the equations as follows:

For the emissions during ventilation (IPa and CP), there is $E_i = C_i \cdot Q$ (1)

For the static emissions without ventilation (IPs), there is $E_i = C_i \cdot V \cdot n$ (2)

where, E_i represents the daily emission of the compound i; C_i was the concentration in the tested gas samples; Q was the amount of ventilation per day; V was the volume of the headspace in the IP column; *n* represents the times of the static situation in one day, which should be 2 times/hr×24hr=48 times.

Take butyraldehyde as example (Figure 5), continuous passive ventilation (CP) induced 45% higher emission than intermittent passive ventilation (IP). With the IP ventilation, most of the VOCs was emitted with the drafted air flow during the ventilation, which composed 89% of the total emission, while the emission ratio by static diffusion was only 11%.

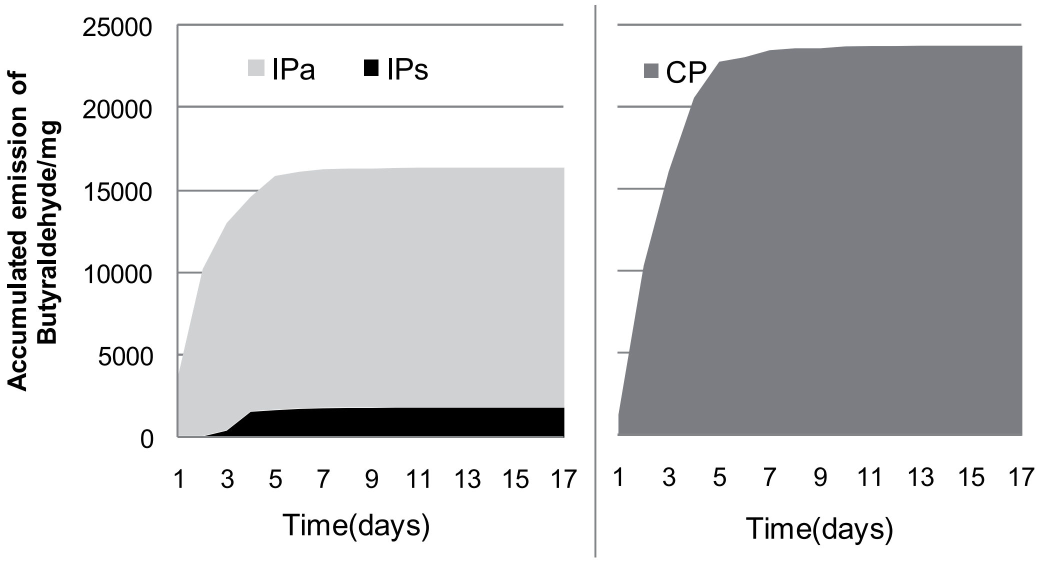


Figure 5 Accumulated emissions of butyraldehyde from MSW bio-drying

3.2 Release of leachate

At the end of the experiments, the total releases of leachate were up to 6.0 and 5.4 L for the IP and CP treatments, and the liquid amount condensed from the drafted air flow were 2.9 and 3.3 L, respectively. Compared with intermitted ventilation, more water can be drafted with the air flow when continuous ventilation was used to aeration. With regards to the active ventilation, only 3.5 L of water was released as leachate (ZHANG ET AL., 2008).

The pH values of the leachates increased from 5.0 at the first two days to around 8.5 after day 4. The ammonia concentration of the leachate was in the same trend as pH, which increased from day 3 and reached around 1500 mg NH_4^+-N·L^{-1}.The TOC concentrations in the two kinds of leachate decreased continuously from around 25000 mg-C·L^{-1} to less than 2000 mg-C·L^{-1}. As to the condensate liquids, the ammonia concentrations were always larger than that in the correlated leachates, but the TOC concentrations were less than that in the leachates. Considering the difference between two ventilation modes, the total emission of ammonia from IP and CP was 12.8 and 18.6 g-N respectively, implying that CP induced 45% higher emission of ammonia. The high concentrations of ammonia in the condensate liquids implied that large amount of ammonia gas was released from the waste during the bio-drying process.

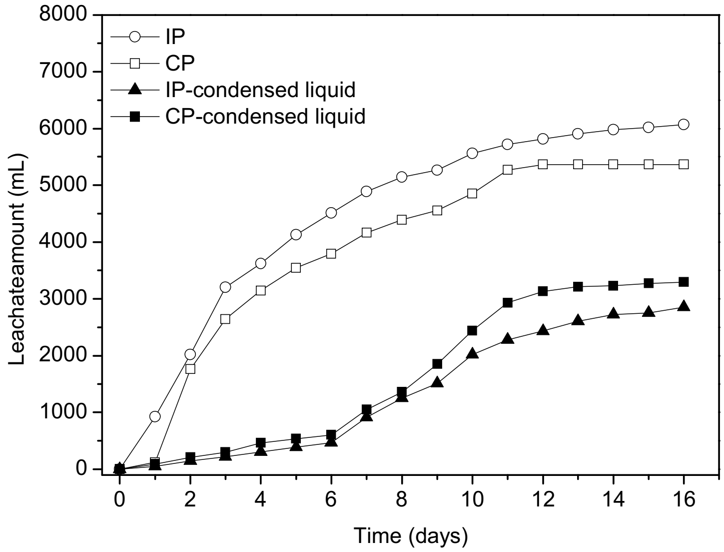


Figure 6 The leachate amounts from MSW bio-drying with two kinds of ventilation

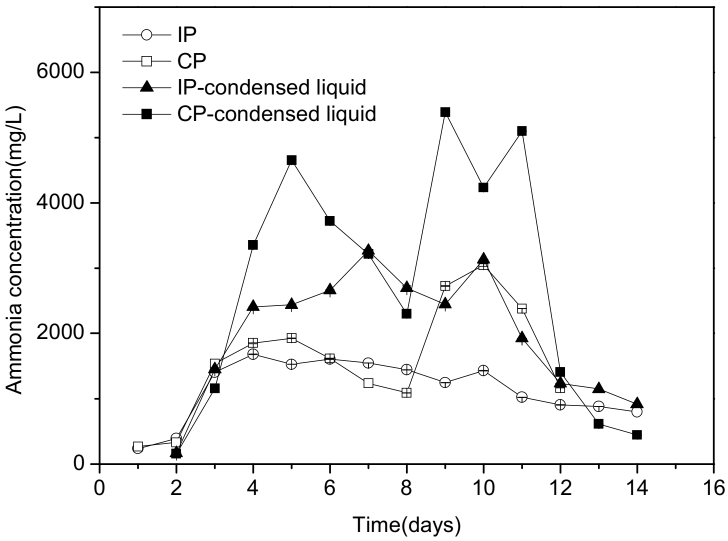


Figure 7 The concentrations of ammonia in the leachate and condensed liquid

4 Conclusion

During MSW bio-drying process, methyl mercaptane, thioethers, aldehydes and aromatics were the dominant VOCs released from the waste, in which butyraldehyde was the highest contributor. Compared with the intermittent passive ventilation, continuous passive ventilation induced large amount of VOCs and leachate ammonia emission.

5 Acknowledgement

This work was financially supported by National Key Technology R&D Program of China (No. 2006BAC06B04) and the Key Special Program on the S&T for the Pollution Control and Treatment of Water Bodies (No. 2008ZX07101-006).

6 Literature

Adani, F., Baido, D., Calcaterra, E., Genevini, P.L.	2002	The influence of biomass temperature on biostabilization-biodrying of municipal solid waste. Bioresource Technology 83: 173-179.
He, P.J., Tang, J.F., Zhang, D.Q., Zeng, Y., Shao, L.M.	2010	Release of volatile organic compounds during biodrying of municipal solid waste. Journal of Environmental Sciences-China 22: 752-759.
Shao, L.M., Ma, Z.H., Zhang, H., Zhang, D.Q., He, P.J.	2010	Bio-drying and size sorting of municipal solid waste with high water content for improving energy recovery. Waste Management 30: 1165-1170.
Zhang, D.Q., He, P.J., Shao, L.M.	2009	Sorting efficiency and combustion properties of municipal solid waste during bio-drying. Waste Management 29: 2816-2823.
Zhang, D.Q., He, P.J., Shao, L.M., Jin, T.F., Han, J.Y.	2008	Bio-drying of municipal solid waste with high water content by combined hydrolytic-aerobic technology. Journal of Environmental Sciences-China 20: 1534-1540.

Author's address:

*Corresponding to : Dr. & Prof. Pinjing HE.
Institute of Waste Treatment and Reclamation
College of Environmental Science and Engineering, Tongji University
1239 Siping Road, Shanghai 200092, P.R. China
Tel/Fax: +86-21-65 981 383

Email: solidwaste@tongji.edu.cn

Municipal Solid Waste bio-drying: odor problem of three configurations

Elena Cristina Rada and Marco Ragazzi

University of Trento, Civil and Environmental Department, Trento, Italy

Abstract

In the sector of mechanical–biological plants, odor is not related to the presence of only one compound. Thus the management of the related problems is not easy. In Italy the odor impact from this kind of plants is often under-estimated, also because, during the design step, the consequences of a few design decisions are not fully understood. The present paper gives a contribution to the knowledge of the different results, in term of odor impact, related to three solutions: biofilter at ground level, biofilter on the roof of the plant, thermal regenerative oxidation with release from a stack. Bio-drying has been selected as reference process. Results obtained from a case-study demonstrate that the design choice can have significant consequences on the acceptability of the plant in an area.

Keywords

bio-drying, biofilter, MSW, odor, RTO.

1 Introduction

The problem of odorous emissions from municipal solid waste (MSW) mechanical – biological treatment (MBT) is one of the most important problems on the carpet in Italy. The interest in this problem has become more and more relevant in the recent years because of the construction of these plants near urbanized areas but also because of the greater attention paid to environmental protection and human health. However the odor perception is a complex phenomenon with a strong subjective component.

Odor is a parameter that cannot be physically or chemically measured, because it is a characteristics of a molecule. The odor concentration instead is measured in odor unit on cubic meter (OU_E/m^3).

In the sector of MBT, the bio-drying process (one-stream option) followed by an adequate use of Solid Recovered Fuel (SRF) as indicated in the UNI CEN/TS 15357 and UNI CEN/TR 15508 norms, is more and more used. Even if this process is already known, a specific European regulation regarding limits for odor concentration does not exist but there are indications regarding these emissions in national/regional standards or guidelines for biological processes (generally 200 – 500 OU_E/m^3). Moreover, the limit values that can be authorized depend also on the induced concentration in ambient air and take into account the distance (d) of the first receptor or potential receptor from the border of the establishment and the nature of the affected area. An example of the values adopted in Italy, in the Lombardy region, is presented in the Table 1 (DGR, 2003).

Table 1 Example of odor concentration limits in ambient air

	d > 500 m	**200 < d < 500 m**	**d < 200 m**
Residential area	1 OU_E/m^3	2 OU_E/m^3	3 OU_E/m^3
Commercial area	2 OU_E/m^3	3 OU_E/m^3	4 OU_E/m^3
Agricultural or industrial area	3 OU_E/m^3	4 OU_E/m^3	5 OU_E/m^3

In the literature the odor problem from the bio-drying process was studied more in details only in the last years, generally highlighting the release of VOCs, volatile organic compounds (He at al., 2010; Ragazzi et al., 2011).

2 Material and methods

2.1 Bio-drying plant

In this paper the one-stream bio-drying plant was proposed for the presented research, as in Italy some initiatives aimed to convert existing two-stream plants into a one-stream plant, where bio-drying is the core of the system, are under discussion. The plant of the case study works 350 d/y and 24 h/d.

For the process air treatment (10 m^3/kg_{MSW}) three configurations are proposed:

- biofilter located at ground level (this is the option most used in Italy for MBTs);
- biofilter located on the roof of the plant building;
- regenerative thermal oxidation (RTO) system (this is an option used generally in Germany) with emission point located at 25 m (stack).

As a case study a flat zone was chosen, having about 760,000 inhabitants producing 408,571 t_{MSW}/y, and a MSW selective collection well implemented (about 65% of efficiency); thus only about one third of the produced MSW is assumed to be treated in the bio-drying plant, having about 23% of organic fraction (according to the case study).

Bio-drying has no effect on inert present in MSW, but affects the MSW moisture and volatile solid content; thus VOCs can be generated as secondary effect of the biological process. In the case-study, the total input of residual municipal solid waste in the plant is 143,000 t/year.

2.2 Mathematical models

The aim of this paper is to assess the odor dispersion from a MSW bio-drying plant. For this reason the Gaussian model AERMOD was used. Before performing the simulation, it is necessary to know the orography of the area, the meteorological values characterizing the atmospheric boundary layer and the quantity of MSW that will be treated in order to estimate the odor flow.

In some countries as the Netherlands, Germany and the United States, in order to simulate the impact of a specific activity on a defined area, the AERMOD mathematical model is often used. The AERMOD Modeling System is a software implementing the calculation of concentration and deposition of pollutants (emitted from either surface or elevated sources) at ground level, over both simple and slightly complex terrain. Dispersion processes are reproduced by means of suitable parameterization of atmospheric structure and planetary boundary layer turbulence (EPA, 2004a).

This model requires a preprocessor that organizes and processes meteorological data and estimates the necessary boundary layer parameters for dispersion calculations in AERMOD. The meteorological preprocessor that serves to this purpose, and that was used for the presented calculations, is AERMET(EPA, 2004b).

AERMET uses available meteorological measurements, representative of the modeling domain, to compute atmospheric boundary layer parameters used by AERMOD to estimate profiles of wind, turbulence and temperature.

For the chosen scenarios a Cartesian grid square having the source located in the center was used. For the biofilter emissions, the considered area has a size 3 km × 3 km, with virtual receptors spaced 20 m, while in the case of point source, a survey area of 4 km × 4 km and 40 m mesh was used.

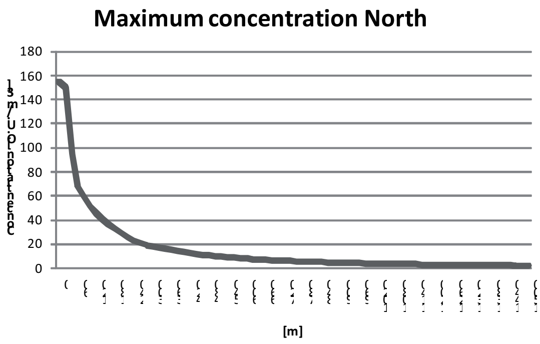
In the model, the emission concentration has been assumed 250 UO_E/m^3 for comply with the Lombardy request (under 300 UO_E/m^3).

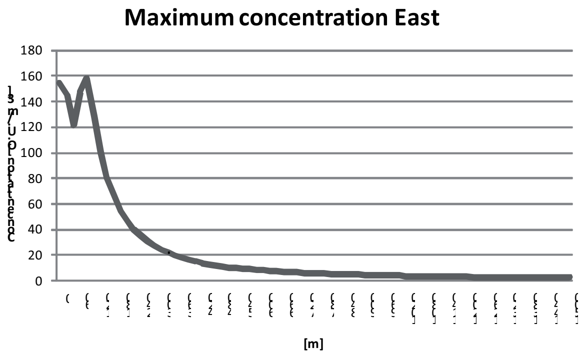
3 Results and discussions

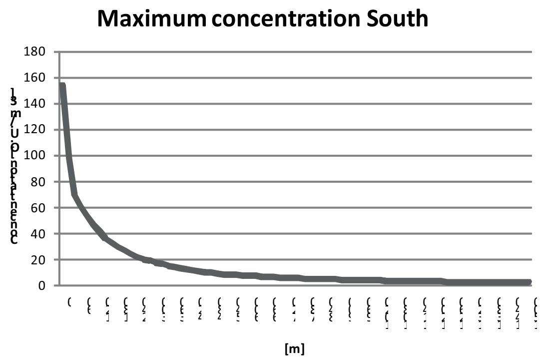
In this paper the results of the three configurations (varying depending on the solution adopted for the air treatment) are presented in terms of odor concentration in all directions and isoconcentration maps.

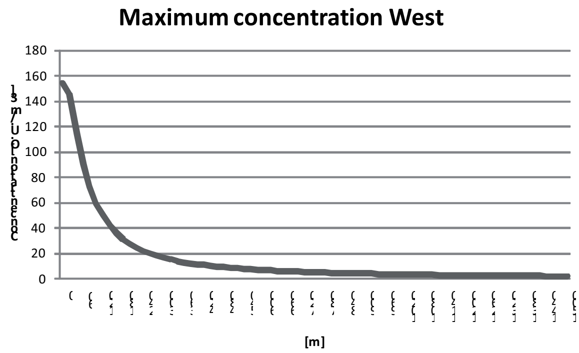
3.1 Bio-drying plant with biofilter located at ground level

From Figure 1 it can be seen that the odor dynamics, for this scenario, is similar in all directions and the concentrations drop rapidly in the first 200 m and then decrease slowly to values close to the unit (within the limits for ambient air). This result should be taken into account when an authorization is given. Anyway, if we look at the odor unit values, the area close to the plant is in critical conditions and odor can be perceived also at a significant distance. Then, ground level biofilter seems not to be a good solution to prevent odor problem in the surroundings. Data in Figure 1 refer to maximum hourly concentrations. The impact on the population is often assessed in terms of hours per year of odor perception, but an additional aspect to be taken into account should be also the moment of the day (day or night) when the odor peak event happens. Results showed that often the unfavorable events happen in early morning when people go out.


Maximum concentration North
180
160
140
120
100
80
60
40
20
0
[m]


Maximum concentration East
180
160
140
120
100
80
60
40
20
0
[m]


Maximum concentration South
180
160
140
120
100
80
60
40
20
0
[m]


Maximum concentration West
180
160
140
120
100
80
60
40
20
0
[m]

follows

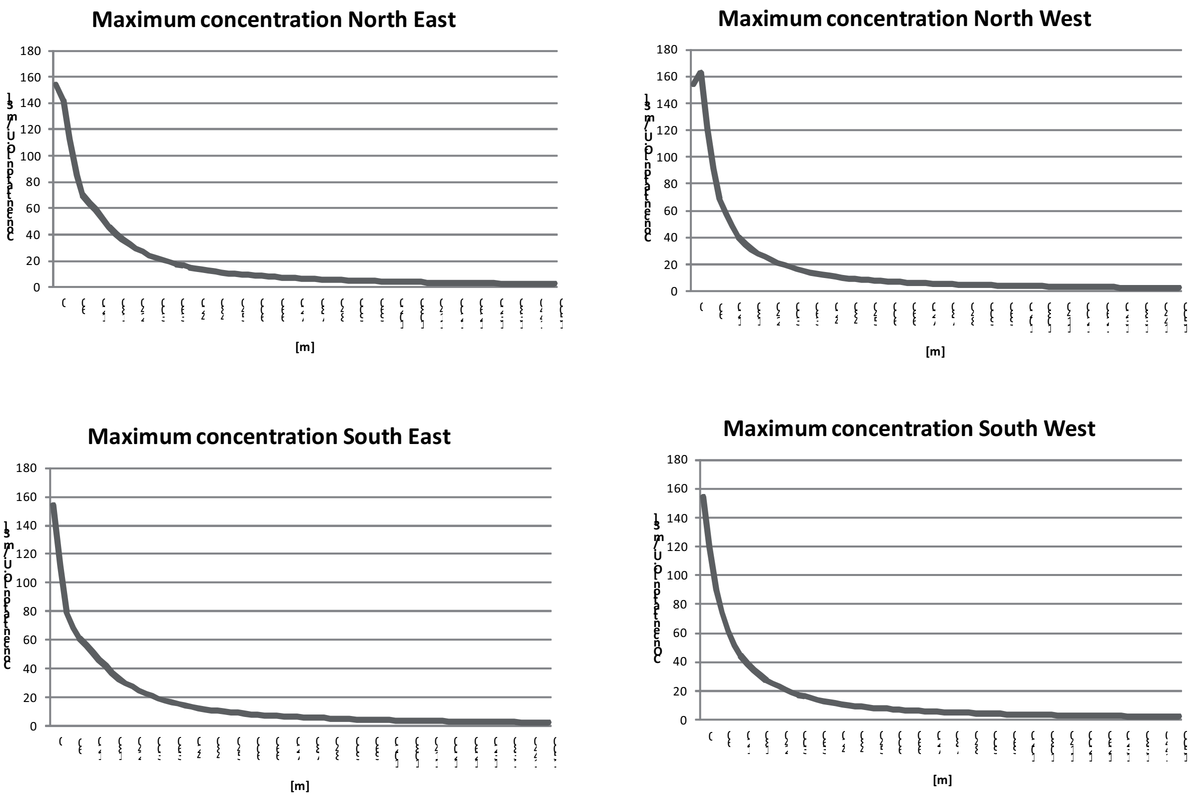


Figure 1 Maximum concentrations of odor along 8 directions (biofilter at ground level)

For a better understanding of the phenomenon, a map with isoconcentration lines (step = 1 OU_E/m^3) is presented in Figure 2. It must be pointed out that at the borders of the studied area the values are at least equal to 1. That means that the impact of the plant is not negligible and doesn't comply with the Lombardy regulations.

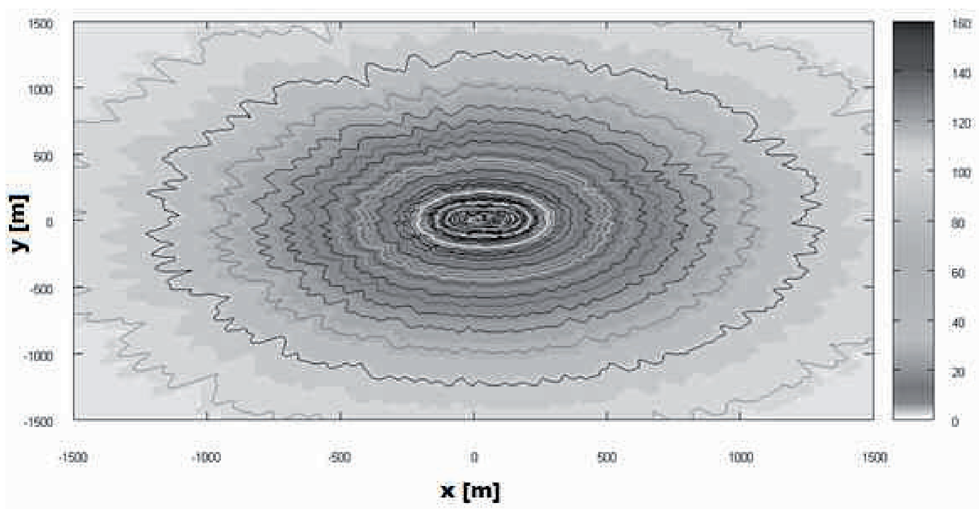


Figure 2 Isoconcentration of maximum hourly values (yearly basis; biofilter at ground level)

3.2 Bio-drying plant with biofilter located on the roof of the plant

Also for the second proposed scenario the odor dynamics in all directions are presented in Figure 3.

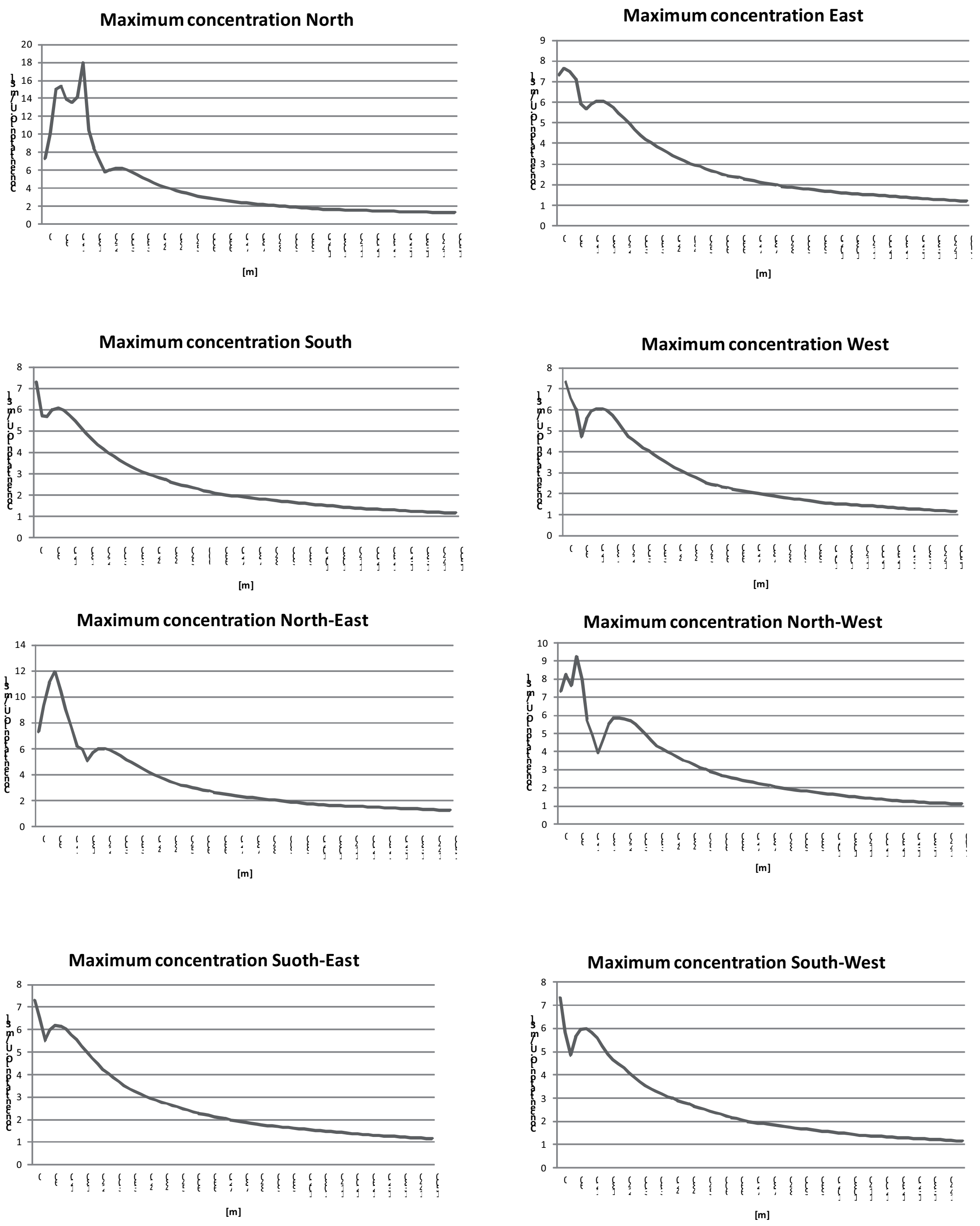


Figure 3 Maximum concentrations of odor along 8 directions (biofilter on the roof)

In case of biofilter at roof level the impact is much smaller than in the first case, with maximum values, close to the plant, slightly lower than 20 OU_E/m^3 compared to 160 OU_E/m^3 of the previous configuration. An overview of the phenomenon is given in Figure 4. In spite of a significant decrease of the impact close to the plant, at the borders of the studied area the odor concentration is still not optimized if compared with the Lombardy regulations as odor concentrations are still higher than 1.

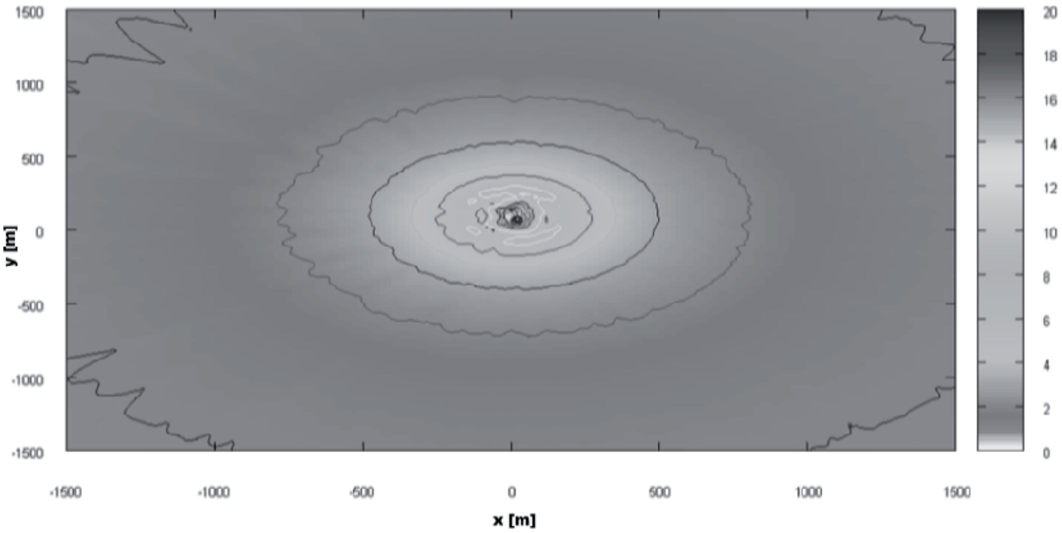
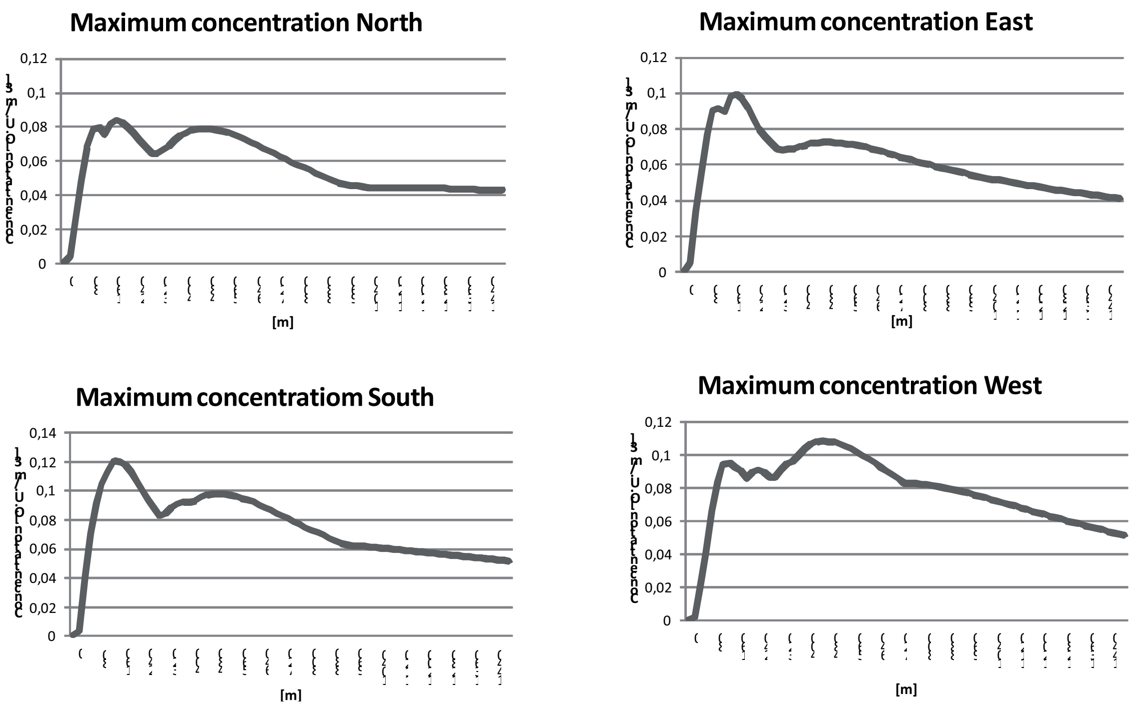


Figure 4 Isoconcentration of maximum hourly values (yearly basis; biofilter on the roof)

3.3 Bio-drying plant with RTO system and stack 25 m high

In the case of RTO (Figure 5) it can be observed that the maximum values are lower of orders of magnitude, slightly above 0.12 OU_E/m^3.



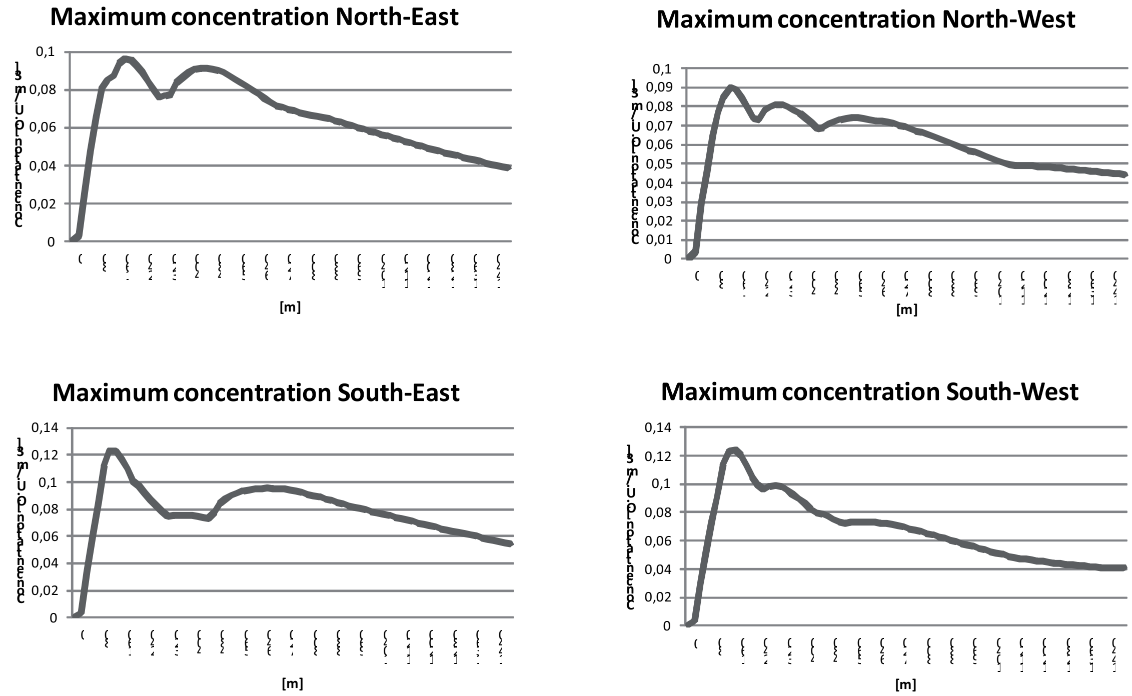


Figure 5 Isoconcentration of maximum hourly values (yearly basis; RTO)

The map with isoconcentration lines has not been made for the RTO scenario because the concentrations are all below one unit. The adoption of the RTO technology solves the odor problems as demonstrated also in Figure 6, showing the bigger advantage compared to the biofilter options.

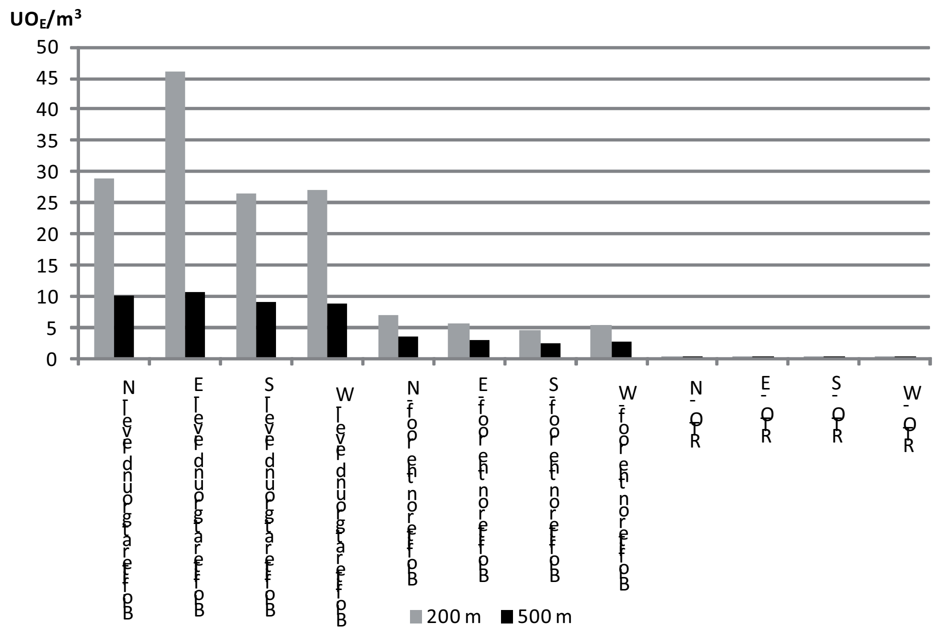


Figure 6 Odor concentrations at 200 m and 500 m from the plant

In Figure 6 the range 200 m - 500 m has been chosen for an easy comparison with the respective values in Table 1. However the solution with the biofilter at ground level never complies with the targets requested by the Lombardy regulation. The second scenario (biofilter on the roof) represent a better solution than the first one, but also in this case the residential and commercial area are not preserved from the odor point of view. Instead, for the second scenario, the agricultural or industrial areas are in part preserved. The case of RTO always complies with the regulation.

In the Table 2 the lowest distance for the first and second scenario needed for complying with the regulation are presented. The case of RTO is not reported as the targets can be reached in all the territory.

Table 2 Distances for complying regulation target when a biofilter is adopted

	Biof. at ground level	**Biof. on the roof**	**Biof. at ground level**	**Biof. on the roof**	**Biof. at ground level**	**Biof. on the roof**
	5 OU_E/m^3		**3 OU_E/m^3**		**1 OU_E/m^3**	
North	840 m	360 m	1,220 m	580 m	> 1,500 m	> 1,500 m
South	820 m	160 m	1,200 m	380 m	> 1,500 m	> 1,500 m
West	760 m	220 m	1,140 m	440 m	> 1,500 m	> 1,500 m
East	840 m	240 m	1,220 m	480 m	> 1,500 m	> 1,500 m
North-East	880 m	320 m	1,260 m	560 m	> 1,500 m	> 1,500 m
South-East	880 m	180 m	1,260 m	420 m	> 1,500 m	> 1,500 m
South-West	800 m	160 m	1,180 m	400 m	> 1,500 m	> 1,500 m
North-West	820 m	300 m	1,220 m	540 m	> 1,500 m	> 1,500 m

4 Conclusions

In this paper the optimal solution for minimization of the odor impact resulted the one with RTO option applied for air treatment. Biofilter costs less but this paper demonstrates that the impact of a plant adopting this option could not comply with the quality targets of modern regulations. The design strategy of placing a biofilter on the roof of the plant can guarantee a lower impact mainly in the surroundings of the plant. Of course the results are representative of areas with a climatology similar to the one of the case-study. In Italy flat zones as the studied one are typical, thus this paper is useful for pointing out the necessity of adequate studies on each case-study.

It must be remembered that smaller plants gives lower impacts.

In Italy RTO is scarcely adopted in spite of the local environmental advantages. The common adoption of biofilters without an adequate pre-study based on modeling causes big troubles in many cases. In the north of Italy two biological plants were recently closed because of the unhappy choice of biofiltration.

5 Acknowledgements

The Authors thank Mr. Stefano Bugna for the support in the calculations and the Environmental Protection Agency of the Province of Verona for the availability of the meteorological data.

6 Literature

He P., Tang J., Zhang D., Zeng Y., Shao L.	2010	Release of volatile organic compounds during bio-drying of municipal solid waste, Journal of Environmental Science, 22(5), 725-759.
Ragazzi M., Rada E.C., Antolini D.	2011	Material and energy recovery in integrated waste management systems : an innovative approach for the characterization of the gaseous emissions from residual MSW bio-drying, Waste Management, doi:10.1016/j.wasman.2011.02.024
DGR	2003	DGR 16 aprile 2003 n.7/12764 "Linee guida relative alla costruzione e all'esercizio degli impianti di produzione di compost"
EPA	2004a	User's Guide for the AMS/EPA Regulatory Model AERMOD. EPA-454/B-03-001. U.S. Environmental Protection Agency, Research Triangle Park, NC.
EPA	2004b	User's Guide for the AERMOD Meteorological Pre-processor (AERMET). EPA-454/B-03-002. U.S. Environmental Protection Agency, Research Triangle Park, NC

Author's addresses *:*

Dr.-Ing. Elena Cristina Rada
University of Trento
via Mesiano 77
IT-38122 Trento
Telephone: +39 0461 28 26 13
Email : Elena.Rada@ing.unitn.it
Website: http://www4.unitn.it/People/it/Web/Persona/PER0038284

Prof. Dr.-Ing. Marco Ragazzi
University of Trento
via Mesiano 77
IT-38122 Trento
Telephone: +39 0461 28 26 09
Email : Marco.Ragazzi@ing.unitn.it
Website: http://www4.unitn.it/People/it/Web/Persona/PER0003630

Emissionsspezifischer Verfahrensvergleich von MBA-Mieten in der Kompostierung

Aurel Lübke, Bernhard Gamerith, Roman Lugmayr

Compost Systems GmbH, Wels, Österreich

Emission-specific comparison of biological treatment technologies for organic waste streams

Abstract

In the process of aerobically biological treatment, microorganisms stabilize waste streams into compost or compost like products. If this process does not run securely aerobic, substances which are related to odor emission like (ammonia NH_3, hydrogen sulfide H_2S) and Methane can be emitted.

In the course of this study, odor samples and gas concentrations were taken and measured from a non aerated and aerated windrow over a period of 4 weeks and compared against each other. For detailed monitoring, gas composition was tested every second day and every week odor samples were taken.

In the non aerated windrow, Methane concentrations at considerable high levels (>35 %Vol) were measured within the first 3 weeks of the process. In the aerated windrows the conditions remained aerobic at all time and only shortly before the turning process small concentrations (max. 2 %Vol) were measured.

Based on the achieved data, a carbon footprint was calculated for an example plant with a capacity of 15.000 tons of waste per year. The study has proven, more than 44 % of the total CO_2 equivalent emissions could be saved by the aerated process technology. Comparing the aerated technology to Incineration, more than 52 % of the equivalent CO_2 emissions were saved.

Keywords

Climate-relevant gases, composting, aerated windrows, methane, CO_2 equivalent, CO_2 footprint

1 Introduction

1.1 Target

During the works of a Bachelor study of the University of Applied Science in Wels, odor and gas emissions of aerated and non aerated (compost like) piles were investigated for odor and climate changing gas emissions.

1.2 Description

Two piles, (aerated and non aerated) with the identical starting mixture and same treatment method (weekly turning) were compared against each other for odor emissions, gas-composition and temperature, during a testing period of the first 4 weeks in the process.

1.2.1 Dimensions, aeration process

The pile size was chosen and adapted to today common pile sizes with a width of 5 m a height of 2-2,5 m and a cross section of 6-7 m². The aerated pile was located over an aeration channel in the platform surface. The aeration was working discontinuously according to the PLC control software and taken to a Biofilter for gas cleaning. The aeration system works in conjunction with the natural breathing effect of the pile dynamics and consequently needs fairly low gas exchange rates of 2-4 times of the pile volume every hour.

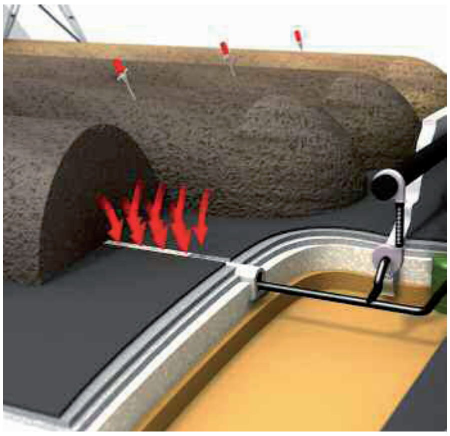


Fig. 1: negative aeration

1.2.2 Material composition

The tests were performed on piles consisting of source seperated kitchen waste with green waste as a bulking agent. The results however also apply to the dynamics of non source seperated organic waste (MSW) due to a very close biological characteristic. (MBT process)

1.2.3 Gas composition of the piles

Over the duration of 4 weeks, the gas composition of the gas within the piles was measured every other day on 5 locations of the windrow for CH_4, CO_2 and O_2.

2 Methane

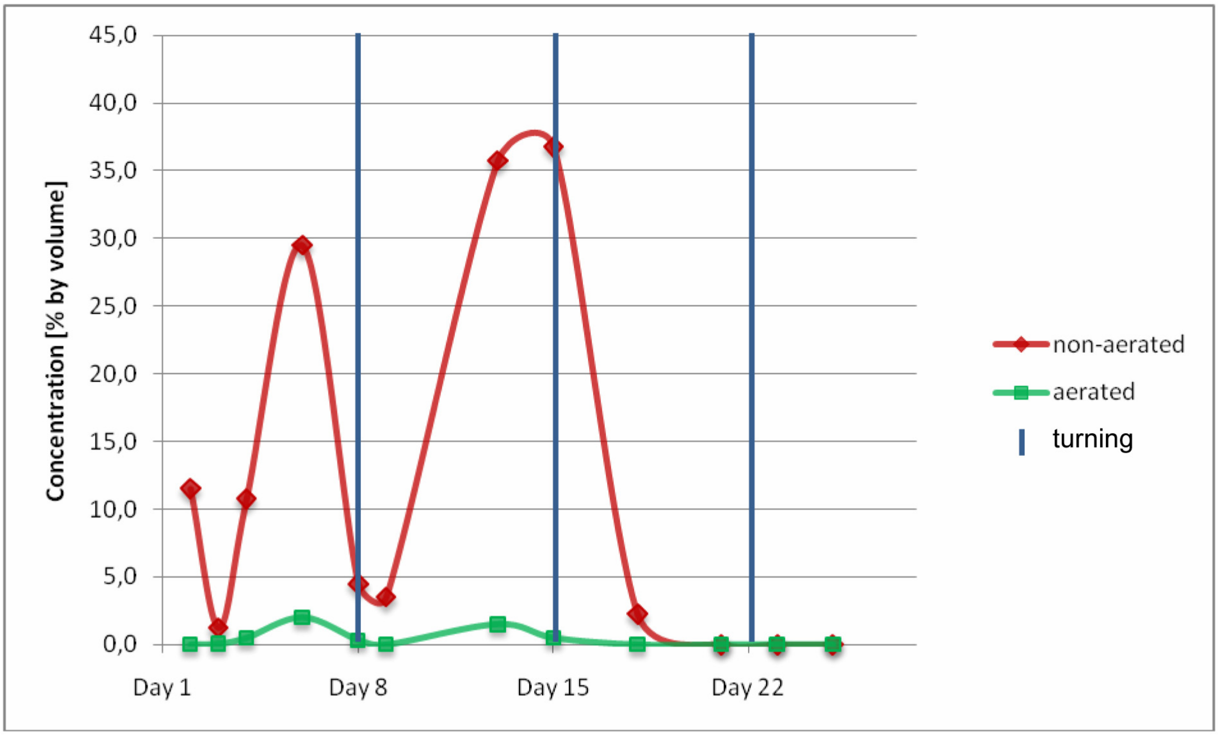


Fig 2: Methane concentration in non-aerated and aerated windrows

Affected by the method of collection, the supplied material may partly become anaerobic already before reaching the site. The first gas test was already performed about 6 h after the formation of the pile, meaning that the aerated pile had enough time to change the environment from anaerobic conditions to aerobic condition in the short given time. In comparison, the non-aerated piles had an average methane concentration of 11,5 %Vol. After about 3 days, the methane concentration also in the non aerated pile reduced due to slowly changing environment in the pile. However, shortly after the CH_4 levels in the non aerated piles went as high as 30 %Vol in average until the first turning took place.

After turning the methane concentration reduced, due to the high air exchange, to a level of 3,5 %Vol CH_4. The process activation due to the mechanical turning and the low supply of oxygen to the material however explain the further peak of 35 %Vol CH_4 in the following days. After the next turning process the production of methane was reduced and only levels of 3 %Vol were measured beyond. In the 4th week of the process no more methane was detected in the piles.

In the aerated pile also a slight level of methane was detected shortly before the turning. The detected peaks however were still less than 10 % against the non-aerated piles (max. 2-3 %Vol CH_4).

Due to the self compacting of the pile material, the mixing and loosening of the pile material is required on a weekly base was concluded.

2.1 Odor emission

Under anaerobic conditions, the building of odor intense substances are forced (NH_3, H_2S etc). Non aerated piles consequently show a higher potential of building odor substances than aerated piles.

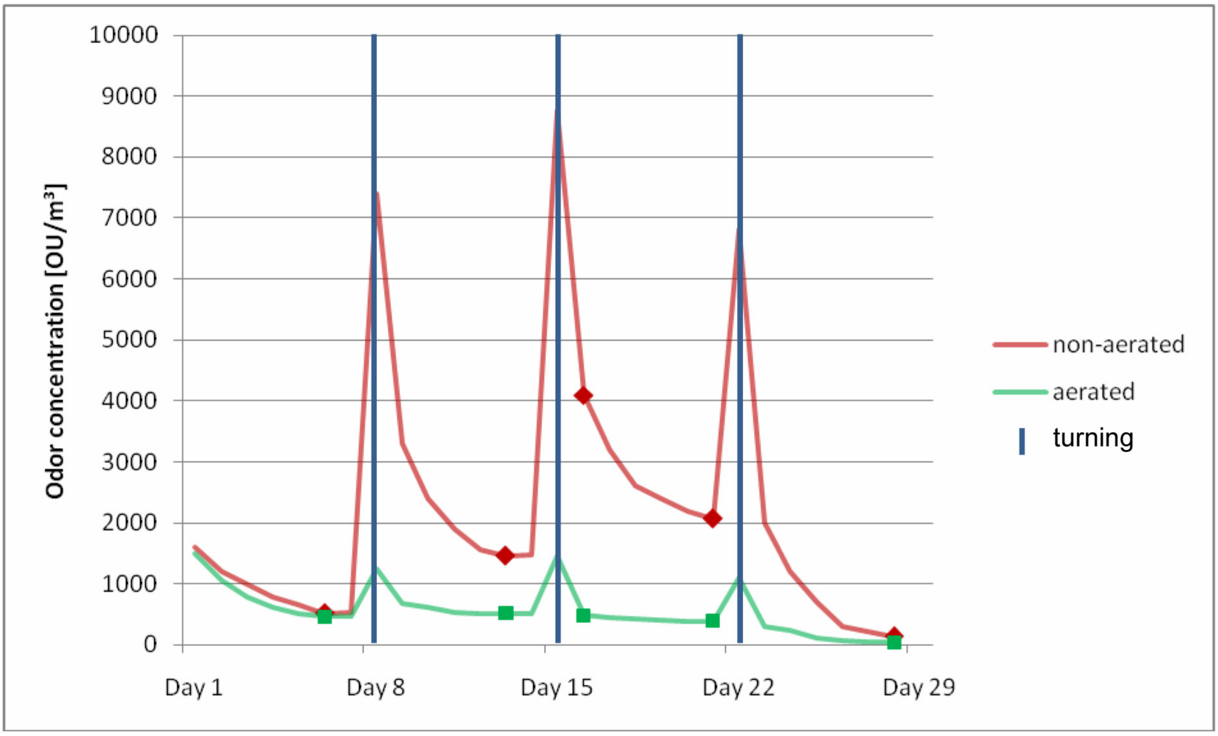


Fig. 3: Odor production in aerated and non-aerated windrows

The exceptional low level of the first odor test in the non aerated pile was explained by the slow start up phase of the non aerated pile. This was detected by the slow pickup of Temperature and the rather low production of CH_4 of the non aerated pile compared to the aerated pile.

In comparison the second odor sampling in the second week showed three times the concentration of odor of the aerated pile when the concentration in the third week went as high as 20.00O OU/m³ and did not reduce until the fourth week.

The odor tests during turning showed an odor concentration of 8.800 OU/m³, which came to a boost of 6x the odor concentration compared to the sampling just before the turning!

The aerobic conditions in the aerated piles were also proven in the continuously lower odor concentrations of the aerated piles.

The shock emissions during the turning of the piles only reached the level of emission of the aerated pile during the duration of the whole process at equivalent age.

The reduction of the odor emission by the aeration process was shown to be in the area of 70 to 80 % of the total emissions. Calculating the shock emissions during the turning process, the savings were proven to exceed 80%.

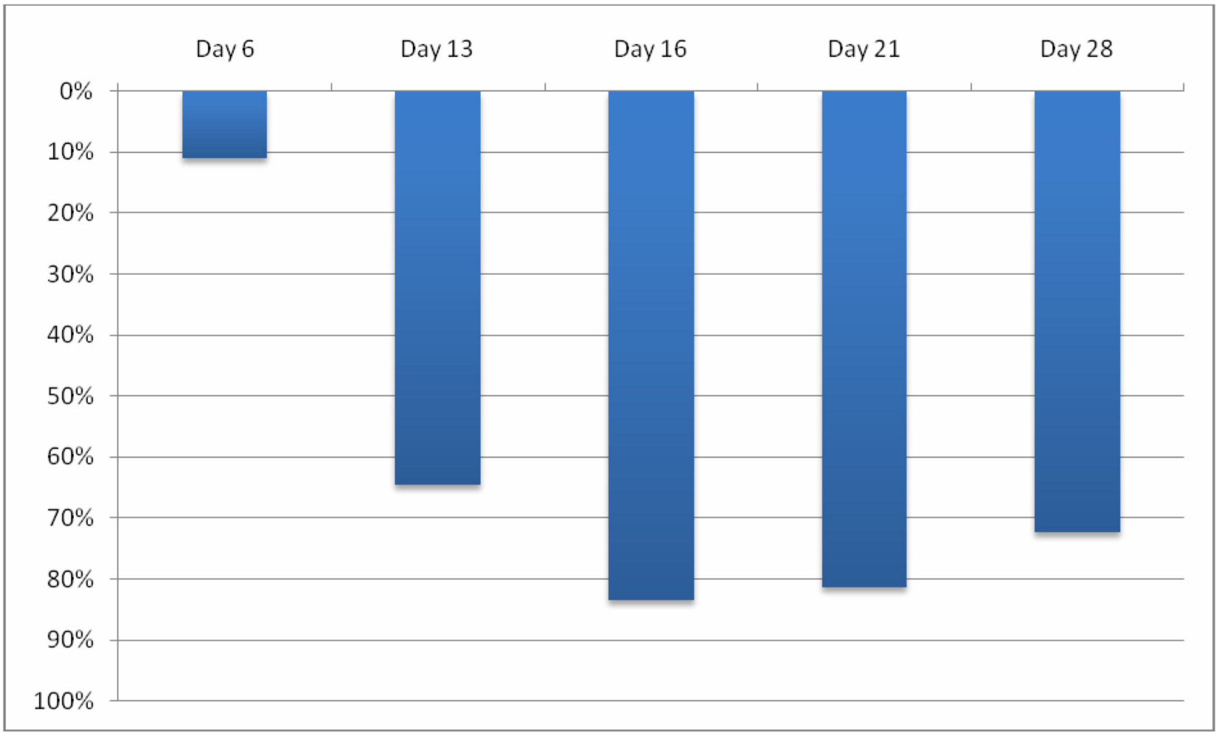


Fig. 4: Odor reduction by aeration

3 CO_2-Footprint

Based on the results of the Gas composition of the piles, a CO_2 footprint was calculated. As a base tonnage, a production facility treating 15.000 tons of organic waste as a feedstock was assumed.

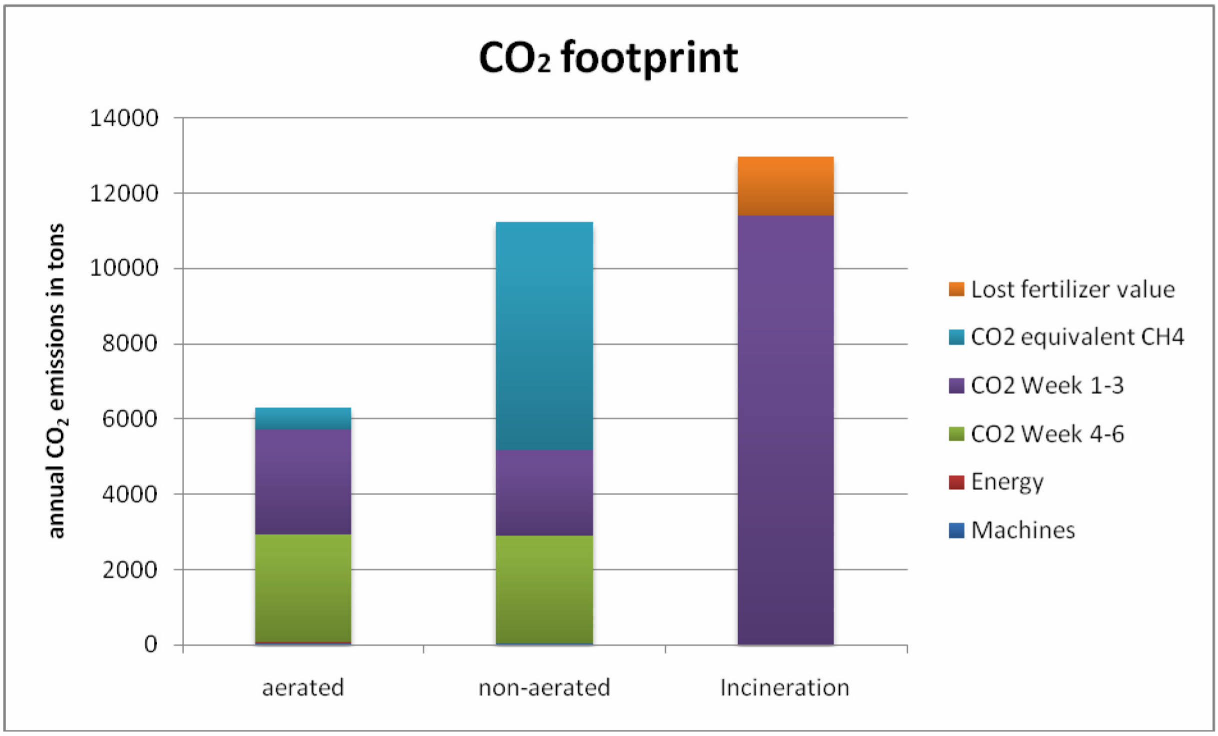


Fig. 5: CO_2-Footprint

While the aerated piles were able to stop the CH_4 production within a few days, the compared non aerated pile showed 11 times higher methane emissions. Consequently the non-aerated plant accumulates CO_2 equivalent emissions of 11.238 to/year, which is almost double the emission of the aerated comparison. The aerated plant would bring a reduction of CO_2 equivalent emissions of 4.953 tons/year (- 44 % CO_{2eq}).

Comparing these emissions to an incineration plant, an amount of 11.400 to CO_2 would be released. In addition the loss of valuable nutrients (NPK) must be considered which would cause additional carbon emissions during the production or the mining of fertilizer. The securing of the nutrients during the production of compost or a “CLO - compost like output”, would secure an additional reduction of produced CO_2 equivalents in the amount of 1.561 tons per year. So in comparison to incineration the aerated system shows a reduction of 6.670 to (-52 %) of carbon equivalent emissions to the environment.

4 Literature

Comitée Européen de Normalisation (CEN)	2006	EN 13725: Luftbeschaffenheit – Bestimmung der Geruchsstoffkonzentration mit dynamischer Olfaktometrie, 2006

Author's addresses:

Aurel Lübke
Compost Systems GmbH
Maria-Theresia-Straße 9
A-4600 Wels
Telefon: +43 7246 350 777-20
Email: aurel.luebke@compost-systems.com
Website: www.compost-systems.com

Ing. DI Bernhard Gamerith
Compost Systems GmbH
Rainharter Straße 137
A-3571 Gars/Kamp
Telefon: +43 2985 27 220
Email: bernhard.gamerith@compost-systems.com
Website: www.compost-systems.com

Roman Lugmayr, B.Sc.
Compost Systems GmbH
Maria-Theresia-Straße 9
A-4600 Wels
Telefon: +43 664 44 95 729
Email: roman.lugmayr@compost-systems.com
Website: www.compost-systems.com

Efficient Desulphurization of Biogas based on a newly developed technology

Joerg Stockinger

S&H Umweltengineering Vertriebs GmbH, Nauen, Germany

Abstract

AD (anaerobic digestion) technology and biogas plants have been a great success in the near past and it will continue. This development is accompanied by an increasing relevance of the topic “desulphurization”. Ongoing tightening of emission restrictions as well as increasing usage of sulphur containing input materials for AD plants raise the question on hydrogen sulfide (H_2S) contents in the biogas. H_2S and its combustion products are known for causing considerable operational problems. For this reason an efficient desulphurization is inevitable for modern biogas plants. The challenge here is to find the appropriate system considering the wide range of possible technologies. The following paper gives a brief overview of the most proven technologies and introduces the nearly waterfree SulphPur desulphurization newly developed by S&H.

Keywords

SulphPur, Desulphurization, Sulphur Removal, Hydrogen Sulfide, Biogas, Biogas Purification

1 Desulphurization – General Introduction

In the last years an increasing global effort in substituting fossil energy sources (oil, gas) by alternative, regenerative energy resources can be noticed. An additional driving force is the trade policy and the common political situation in the supplying countries.

One main pillar of regenerative energy sources is biogas produced from renewables (e.g. maize). In Germany the number of such biogas plants will exceed 6,000 soon. Outside Germany also biowaste, MSW and/or food waste are used for comparable biogas plants. Multiple investigations have shown the advantages and benefit of the biogas resp. AD technology. For this reason also the global number of AD plants increases steadily. Many countries promote the energy production based on renewables by special state funding programmes (D: EEG, UK: ROCs, etc.).

Biogas produced with renewables has, depending on the used input material, varying compositions. Beside the main components, like methane and carbon dioxide, numerous trace components can be found in biogas.

Within these trace components hydrogen sulfide (H_2S) has an outstanding procedural relevance. Biogas contains typically between 100 to 5,000 ppm H_2S, in special cases also more than 10,000 ppm. The concentration of H_2S is mainly depending on the sulphur content of the input materials. Higher contents of H_2S in biogas are caused by sulphur containing amino acids as well as through the desulphurication of sulphates.

The impacts of hydrogen sulfide are manifold. The odour threshold of H_2S is between 0.025 and 8 ppm. The odour is known unpleasant and like that of bad eggs. Already at concentrations of above 100 ppm irritations, over 500 ppm cramps are caused. Contents of approx. 1,000 ppm result in death in minutes, contents of approx. 5,000 ppm result in death in seconds. Beside the toxicological impact of H_2S, this compound and its combustion products have a high importance for the plant equipment. H_2S is highly corrosive and is, when using biogas for energy production (e.g. CHP), oxidized to SO_2. As a result of the chemical exposure engine oils acidify and this leads directly to a significant reduction of oil change intervals. In worst cases engine damages have been caused by high H_2S contents. If catalytic converters have to be used to clean the CHP exhaust (e.g. when low formaldehyde limits (Germany, Italy) are to be kept), H_2S has a special importance due to its impact as catalyst poison.
The above mentioned shows clearly that an effectivd removal of H_2S from biogas is necessary if not mandatory.

2 Strategies for Desulphurization

The removal of H_2S from biogas can be achieved in many ways. The main point is to find the adequate treatment for your special requirements. The following chapters give a brief overview of possible technologies.

2.1 Physico-chemical Processes

Precipitation by iron compounds

Inorganic iron chemicals are able to fix sulphur, produced within the biological anaerobic degradation process, and therefore inhibits the production of hydrogen sulphide. The ferrous sulphide (FeS), produced by this treatment, will be oxidized to water-soluble sulphate immediately under aerobic conditions. Such conditions are typical e.g. for aeration steps (AD-MBT). If then the process water is recovered by drying steps (optimization of a plants water balance) the sulphate is re-cycled in the plant and increases as a consequence the sulphur load of the plant. In such cases the demand for chemicals increases steadily.

The big advantage of the iron dosage are the comparable low CAPEX (capital expenditure). For this reason this technology is commonly used by some plant builders. At the end the client has to pay the bill because iron chemicals have to be used in a more than stoichiometric ratio, which leads directly to higher OPEX (operational expenditure).

Adsorption Systems

Iron containing materials and active carbons are able to adsorb H_2S. This capability is used for removal of residual contents (fine cleaning). Active carbon filters are often used for such a fine cleaning because they can remove H_2S almost completely. But as active carbons cause considerable operation costs at higher H_2S contents, these systems are only economically reasonable for the above mentioned fine cleaning of biogas with low H_2S concentrations. The disposal of consumed active carbons is done by the dealer or specialized disposal contractors.

Alkali Scrubber

Scrubbers using alkaline chemicals in a kind of trickling column can wash out H_2S quantitatively. Further usage of chemicals (high OPEX) helps producing elementary sulphur and sulphate. More often alkali scrubber are combined with an add-on biological treatment of the scrubber discharge and an air treatment step. The operational costs can be reduced compared to the pre-mentioned processes, but the CAPEX are significantly higher.

2.2 Biological Methods

General Introduction

All biological treatment systems are based on the same process. They are using naturally existing sulphur bacteria (Thiobacillus) to remove H_2S from biogas. This microbiological oxidation takes place in two steps:

$$2\,H_2S + O_2 \longrightarrow 2S + 2\,H_2O \qquad \textit{reaction (1)}$$

$$2\,S + 2\,H_2O + 3\,O_2 \longrightarrow 2\,H_2SO_4 \qquad \textit{reaction (2)}$$

The biological biogas cleaning requires following minimum settings:

- contaminates need to be biological degradable
- sufficient amount of degrading microorganisms
- good oxygen and nutrient provision to microorganisms
- stable and controlled process conditions (moisture, temperature, etc.)
- non-critical concentration of inhibitors / toxic substances

To reach and ensure a high density of microorganisms in the reaction zone the reactor is equipped with special support/filling material to immobilize the microorganisms.

Figure 1 illustrates the microbiological transfer of H_2S.

The microorganisms need oxygen for the transformation of hydrogen sulphide. Against the general opinion this intake of oxygen does not reduce the value of biogas used for the production of electricity. CHP plants detect the oxygen by the lambda probe and adjust the combustion air respectively.

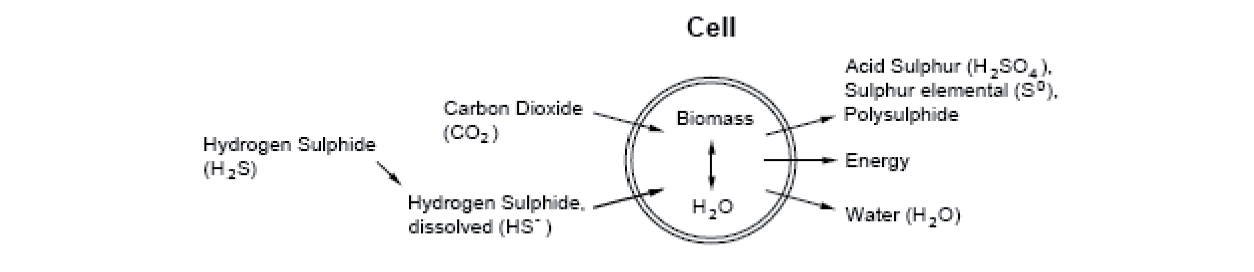


Figure 1 microbiological transfer of H_2S

Internal Desulphurization

This commonly used kind of biogas desulphurization at German biogas plants, fed with renewable according to the German EEG, is sufficient for very low to low sulphur contents. Air is blown directly into the head room of the digester. As growing material nets are installed in the roof structure or a floating layer is used. This process is not controlled and often sparsely stable. For this reason it is only usable for low sulphur loads. A permanent removal of H_2S from biogas is usually not ensured.

Biotrickling Reactor

If an efficient and stable removal of H_2S is required, biotrickling filter have been the standard solution. In contrast to the internal desulphurization in the head room of the digester, an external reactor can ensure the oxidation of H_2S by microorganisms at stable and controllable conditions (pH, T, growing surface). The discharge of such a classical biological desulphurization is sulphuric acid. This product can be used as fertilizer in agriculture. The biotrickling process is well-engineered. It is globally accepted and established as crude respectively mass desulphurization. S&H itself has already installed over 200 plants in more than 20 countries. Finally the key advantage and decisive reason for the broad acceptance of this technology is the very low OPEX compared to all above mentioned treatment systems.

SulphPur

SulphPur is a newly developed desulphurization technology based on the long-time experience of the S&H Umweltengineering Vertriebs GmbH on the field of biological desulphurization systems. Optimized operation conditions combined with a new technological concept are the key points, on which a process has been developed that remedies the few disadvantages of biotrickling filters (water and energy demand) to a far extend. With this the biological desulphurization is not longer limited to plants with higher sulphur contents. Now it is also interesting for smaller plants with less sulphur containing feeding substrate. On the other hand at plants with higher loads of sulphur the

SulphPur process scores with significantly reduced OPEX. The next pages will give a comprehensive introduction to the SulphPur technology.

3 Development of a new biological technology for sulphur removal

In the last 2 years S&H Umweltengineering Vertriebs GmbH put a lot of effort in the development of a new concept for the desulphurization of biogas. Our background knowledge regarding biological desulphurization systems helped us to realize the new SulphPur technology. It all started with the idea to produce elementary sulphur when removing H_2S from biogas. This is a totally different approach compared to the classical biotrickling process. The way to reach this aim is given by the microbiological process itself (see reaction (1) and (2)). The challenge was to inhibit the fully oxidation of sulphur. The microbial reaction steps show that this can be achieved by a process running short of oxygen and water. Such a process will automatically produce elementary sulphur.

A further challenge was found on the engineering side. The production of elementary sulphur in the classical biotrickling reactor could lead - worst case - to a blocked column due to its special construction. It was necessary to prevent this and give sulphur the chance to fall downwards into the pump sump by gravity. From there it can be removed by special pumps. In most cases the sulphpur containing sludge can be discharged into the digestate storage.

The whole development was accompanied and supported by Envitec, a biogas plant builder and operator. Now we are able to present a staple process that brings our initial idea to reality. This process brings multiple advantages for operators and owners of such plants. Figure 2 shows a simplified flow sheet of the SulphPur desulphurization.

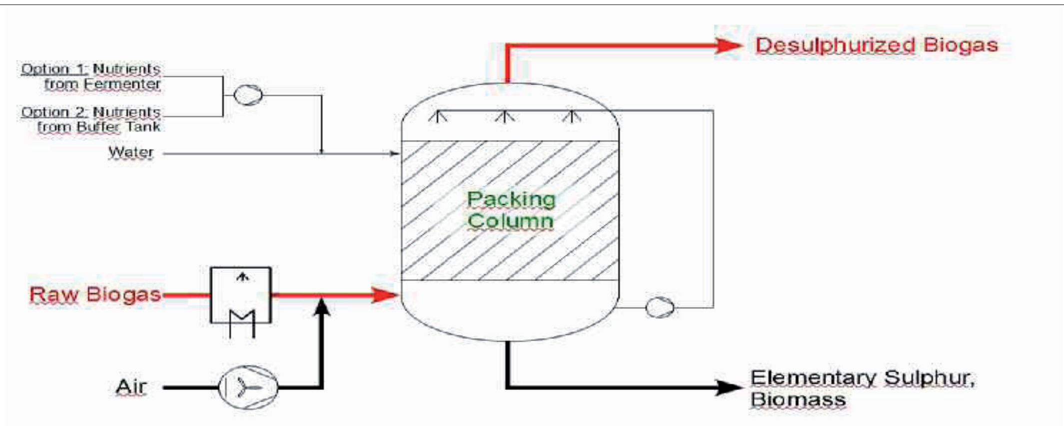


Figure 2 simplified flow diagram of the SulphPur process

In a 1 year lasting test and optimization period a pilot plant was operated on a 500kW biogas plant. As a result the standard operation conditions have been found. A significant difference to our classical biological desulphurization was for example found in a tighter temperature range for an optimized desulphurization. For this reason a heat scrubber (see fig. 2) is used to stabilize the seasonally caused variations. The pilot plant showed throughout the whole trial period (with a lot suboptimal test and operation conditions) an average removal of >90% and not uncommonly 95%. Results of the trials are shown in figure 3.

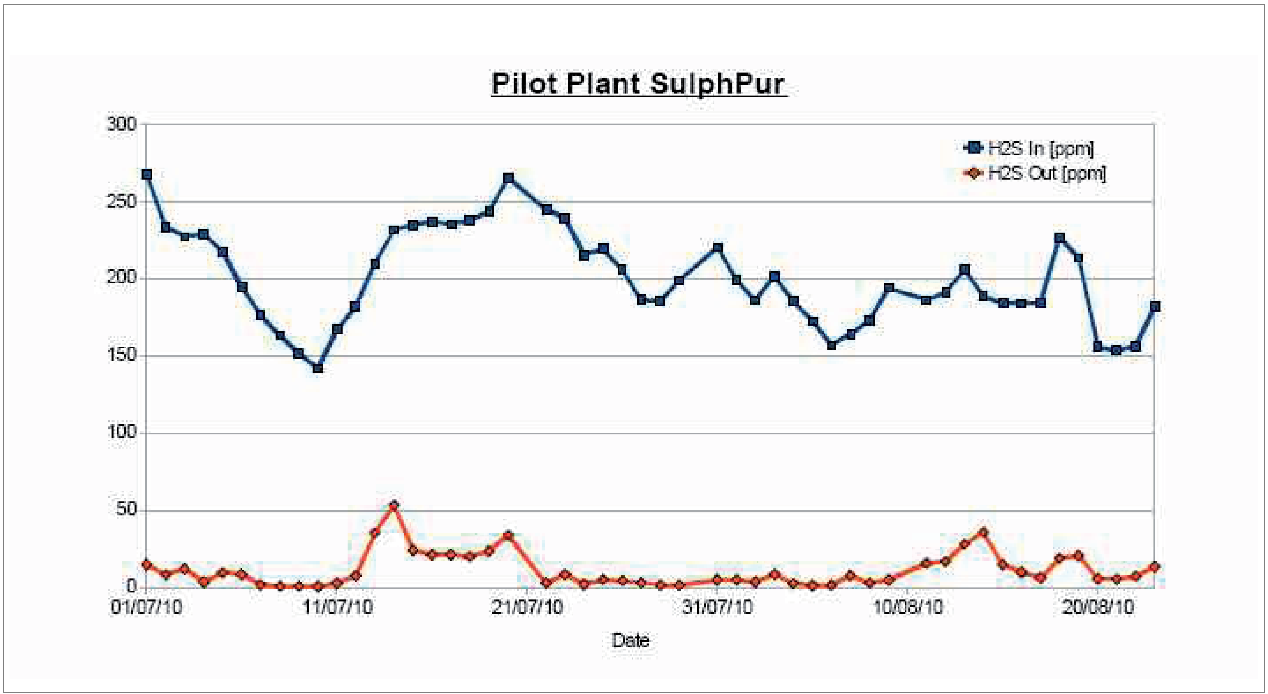


Figure 3 Results of the SulphPur trials

The market entrance in 2010 was a great success for S&H. The first commercial SulphPur plants are already installed and successfully commissioned at biogas plants and further plants are presently installed at further biogas plants and a AD-MBT (mechanical biological waste treatment plant based on anaerobic digestion). Additional SulphPur plants are in the planning stage for this year.

The changes in operating a SulphPur plant compared to the classical desulphurization led to positive economical savings at the end of our trial period. While a classical biotrickling filter needs partly huge amounts of water in order to secure a stable sulphur removal, a SulphPur plant needs nearly none water. The main reason for the high water demand of the classical desulphurization is the production of sulphuric acid. This causes a steady decrease of pH. But as the efficiency of the sulphur removal drops at pH below 1.3 potable water is used to stabilize the pH (above 1.3). In contrast to this the SulphPur technology works with comparable low moisture. Together with further changes made this new process produces elementary sulphur. Advantage of this is that no pH changing compounds (like sulphate) are produced. Consequently no additional water is needed to stabilize the pH. Secondary and significant economical advantage is the extensively reduced sprinkling of the microorganisms inside the SulphPur column. Only once a day the bacteria are provided with moisture. The remaining moistening is done by the biogas. Compared to the classical desulphurization, where the water supply is done on a 24/7 basis, the SulphPur technology shows only minor pump run times. This additionally reduces the energy demand significantly and extends the maintenance period. Above mentioned is a strong indication for a process that hardly needs maintenance and care.

4 Summary

The awareness of the needs for an effective sulphur removal from biogas was steadily increasing in the past and will become more and more a topic for all international plants producing biogas (agricultural and commercial biogas plants, AD-MBT, food and bio-waste treatment plants, etc.). Not only plant builder and consultants know that but also customers and operators of such plants. In former times very often the expense for a good desulphurization was shunned. Nowadays the demand for an effective removal of sulphur is obvious and beyond question. An adequate technology exists for every requirement (fine or mass cleaning). When selecting the desulphurization technology not only the CAPEX but also the OPEX need to be considered. The latter was not uncommonly disregarded and the operators had to pay dearly. Chart 1 is not only a short and comprehensive overview but also a comparison of the main desulphurization technologies and the newly developed nearly water-free S&H SulphPur process. This innovative system combines the known advantages of the well-engineered biotrickling process offered by S&H Umweltengineering Vertriebs GmbH for many years and the benefits arising from a newly designed process. The SulphPur technology has a significantly reduced water demand (up to 90%). The energy demand can usually be reduced by more than 60%. Considering also the reduced maintenance demands the SulphPur technology can reach a significant reduction of the annual operational expenditures.

Chart 1 Comparison of the main desulphurization processes
[(empty) = not applicable; ◖ = partly applicable; ● = applicable]

Characteristic	Internal Desulphurization	External Desulphurization	
	adding of iron compounds and usage of activated carbon filter	conventional bio-trickling systems	SulphPur® Dry Bio-Reactor
Sulphuric Acid as By-Product discharged into Digestate Storage		●	
Elementary Sulphur as By-Product discharged into Digestate Storage			●
Low Energy Consumption	●		◖
Maintenance-friendly System		◖	●
Low Corrosion Potential at biogas plant (pumps, pipes, tanks)		◖	●
Low Discharge Quantities, saving of CAPEX/invest costs for larger digestate storage tanks	●		●
Low annual Operational Costs		◖	●
High Hydrogen Sulphide Reduction Performance	●	◖	●

The SulphPur process has many advantages for biogas plants and is now also for such smaller biogas plants economically interesting, where in the past the relation between CAPEX and OPEX militated against a biological desulphurization. Below the main attributes of the SulphPur technology are listed to express in short the qualities of this newly developed technology:

- ✓ very low energy demand
- ✓ minimized water demand
- ✓ continuous process with nearly no respectively very short down times
- ✓ no waste water and no dangerous waste products (e.g. sulphuric acid with low pH)
- ✓ minimized operational expenditures
- ✓ very low maintenance requirements and costs
- ✓ minimized need of control
- ✓ saving of cost intensive sulphur reduction agents (e.g. FeCl, FeOH, etc.)
- ✓ longer lifetime of activated carbons
- ✓ longer lifetime of CHP plants at biogas plants without activated carbon filters
- ✓ secured operation and production of electricity according to TA Luft/EEG (formaldehyde)

The above mentioned shows that the S&H SulphPur technology is a new and cost-effective way of removing sulphur from biogas.

Author's address:

Dr.-Ing. Dipl.-Chem. Dipl.-Ing. Jörg Stockinger
S&H Umweltengineering Vertriebs GmbH
Schwanebecker Weg 1
D-14641 Nauen
Telefon: +49 3321 744 20 0
Email: stockinger@sh-umwelt.de
Website: www.sh-umwelt.de

Economic Comparison of Landfilling with and without Anaerobic Pre-Treatment

Gerd Burkhardt, Nina Müller, Ludwig Streff

ICP Ingenieurgesellschaft Prof. Czurda and Partners mbH, Karlsruhe, Germany

Abstract

Up to the present most development banks (such as the World Bank or the German KfW) have sponsored in particular the fundamentals of waste management such as collection, transport and the orderly depositing of waste. The German Ministry of the Environment would like in future, however, to sponsor rather more advanced techniques for waste treatment, also in countries where this has hardly been considered before. Up to now the general opinion was that such higher quality waste treatment techniques (such as e.g. using biogas facilities, compost plants or waste incinerating plants) are still too expensive for most countries in the world. On closer inspection, however, it emerges that there are hardly any differences in the overall costs for waste disposal through cost reductions when landfilling and possible proceeds from various treatment systems. The consortium IGIP / L.e.e. / ICP has now developed a calculation tool with which different waste management scenarios can be compared relatively easily.

Keywords

Landfilling, cost calculation, cost comparison, investment costs, operational costs, dynamic prime costs, anaerobic digestion, fermentation

1 Introduction

The introduction of proper and environmentally compatible waste management is supported financially with the aim of fundamentally improving the infrastructure in many developing and emerging countries by numerous development banks, such as, for example, the German KfW bank group, the EBRD or EIB (development banks of the EU) or by the World Bank. Until a few years ago, fundamental waste management measures such as collection and transport of the waste as well as proper landfilling were sponsored here by the FRG through the KfW bank group and the Gesellschaft für Internationale Zusammenarbeit (giz).

These measures can in general be borne economically by the populations in these states, whereas higher quality waste disposal systems including technically more sophisticated facilities, such as e.g. a mechanical-biological treatment plant (MBA), composting or a fermentation plant, seem too expensive.

The basis used for this assessment is the principle that the costs of waste disposal should not be more than approx. 1 % of the average income of the population. If it can be seen that waste management measures are too expensive and cannot be borne by the population in the long run, such projects are usually not sponsored either, since this sponsoring would not be sustainable.

The new guidelines of the environmental and development policies in the FRD go beyond simple waste disposal, however. Where possible, recycling and climate-friendly technologies should be given attention. This certainly seems possible in emerging countries such as Turkey, for example, if the economic conditions are favourable.

The KfW has published the following figures for the projects it has sponsored in Turkey.

Table 1: Costs of waste management plants in Turkey, sponsored by the KfW development bank, in comparison with figures from Germany /1/

			Investment costs		Dynamic prime costs	Costs per household (in % per income)	
Country	**Region / City**	**Inhabitants**	**million €**	**€ per capita**	**€ / Mg**	**Average income**	**Income of the poorest 20 %**
Turkey	Denizli	330.000	11,0	33,0	24,0	0,60%	1,10%
	Samsun	380.000	17,6	46,0	26,0	0,60%	1,10%
	Erzurum	330.000	14,2	43,0	32,0	1,00%	2,00%
	Trabzon/Rize	601.000	27,1	45,0	36,0	0,80%	1,50%
Germany					150 - 180	0,30%	1,00%

Table 2: Cost comparison of different waste treatment systems (all figures in €/Mg waste) /1/

Waste Treatment / Disposal	**Sanitary Landfill**	**Biological Treatment (Stabilisation)**	**Fermentation**	**Incineration**
Total costs	12 - 20	25 – 60	60 – 90	120 - 180
Benefit by electric power generation	4 - 6	-	8 - 14	18 - 35
Benefit of CDM	4 - 5	8 – 10	10 – 11	12 - 14
Net costs (without utilisation of heat)	4 - 8	17 – 50	45 - 65	90 - 130

The figures given for the overall costs of fermentation of 60 – 90 €/Mg seem too high here. Presumably these figures are based on the relatively expensive, high tech facilities in Germany. On the one hand the authors also know of definitely lower figures, on the other hand the costs for a waste management concept have to be seen as a whole and not only in terms of the individual type of plant. Cost advantages (when landfilling or during transport) might result through the comparatively expensive treatment of waste at other sites.

It was for this reason that the consortium of companies IGIP / L.e.e. / ICP[1] decided to pool the experiences of the firms and to carry out a cost comparison for a specific example. As a basis, a project was chosen where the costs had already been calculated for a landfill (currently under construction) as well as for an MBA (aerobic treatment of the organic components of waste). The firm L.e.e. has in addition planned a fermentation plant of a relevant size which is already in operation, so that confirmed figures for the construction of such a facility are also available. Using this sample project we intend to investigate to what extent the costs differ for disposal systems with a deposit of non-treated waste and the costs of deposit after anaerobic treatment. A project in Tunisia was chosen for this, as this project was one of those being sponsored by the KfW and the costs calculation for the construction had already been confirmed by an invitation for tenders. Moreover, Tunisia is a relatively highly developed country in North Africa, where without doubt higher quality waste treatment plans could be put into operation.

In order to make the cost calculations comparable, an Excel tool was developed at the same time, which automatically calculates the specific dynamic prime costs or draws up a business plan suitable for bank approval from the usual costs calculations of the planners (investment costs, re-investment costs and operating costs). Due to the structure of this tool even sensitivity analyses may also be carried out very easily.

[1] IGIP (Ingenieurgesellschaft für Internationale Planungen mbH), Darmstadt; L.e.e. s.a.r.l, Junglinster/Luxemburg; ICP (Ingenieurgesellschaft Prof. Czurda und Partner mbH), Karlsruhe

2 Description of the waste management situation in Tunisia

In the project for which the cost comparison calculations were carried out, we are dealing with the waste management concept for Greater Tunis with ca. 2 million inhabitants. Besides an optimized collecting and re-loading of the waste, in particular a second regulated landfill was to be planned to reduce strain on the landfill Jebel Chékir, constructed in 2000.

Tunisia may be described (not only) from a waste management point of view as the most advanced country in North Africa. One after the other, modern waste management systems have been and are still being developed all over the country. Here, first the most populated cities and governorates along the coast were supplied with modern waste collection, re-loading points and a regulated landfill. The first of these landfills thus developed was Jebel Chékir, mentioned earlier, which was sponsored by the World Bank. Up to now 10 regular landfills for 9 governorates have been developed (see Figure 1).

The lines with a light grey background are those governorates already equipped with a modern landfill; the first 4 governorates form the greater Tunis area.

Thus in the foreseeable future ca. 7 million inhabitants in Tunisia (ca. 68%) will be connected with a regular landfill. The planning of three further landfills in Medjerdatal (Governorate Béja, Jendouba, Le Kef and Siliana) is under way at present and further projects are planned for the near future.

In Table 4 the most important figures concerning Tunisia are compared with those of Turkey and Germany.

The 9 new landfills (without the landfill Jebel Chékir) were only surveyed last year and correspond completely both in construction as well as in operation to European standards, even if due to lack of experience there were initially (and at some sites still are) problems with the disposal of leachate and at present still no degasification is installed. This is planned, however, at all landfills and will be installed soon.

Table 3: Basic Data on the Governorates of Tunisia

Nr.	Governorate	Area	Inhabitants(2009)	Inhabitants per km² (2009)
		km²	Capita	Capita/km²
1	Tunis	346	994 900	2 875.4
2	Tunis Ariana	482	485 700	1 007.7
3	Tunis Ben Arous	761	567 500	745.7
4	Manouba	1 137	364 600	320.7
5	Nabeul	2 788	743 500	266.7
6	Zaghouan	2 768	169 100	61.1
7	Bizerte	3 685	542 400	147.2
8	Béja	3 558	304 600	85.6
9	Jendouba	3 102	421 200	135.8
10	Le Kef	4 965	256 100	51.6
11	Siliana	4 631	233 100	50.3
12	Kairouan	6 712	555 900	82.8
13	Kasserine	8 066	428 300	53.1
14	Sidi Bou Sid	6 994	408 800	58.5
15	Sousse	2 621	602 300	229.8
16	Monastir	1 019	504 700	495.3
17	Mahdia	2 966	392 900	132.5
18	Sfax	7 545	917 000	121.5
19	Gafsa	8 990	334 900	37.3
20	Tozeur	4 719	102 300	21.7
21	Kebili	22 084	149 100	6.8
22	Gabès	7 175	357 400	49.8
23	Médenine	8 588	451 200	52.5
24	Tataouine	38 889	145 000	3.7
Total		**154 591**[2]	**10 432 500**	**67.5**

[2] According to the source, different figures are given for the area. Figures concerning population density thus very accordingly.

Table 4: Comparison of Economic Data of Tunisia, Turkey and Germany /2, 3, 4/)

Country	**Tunisia**	**Turkey**	**Germany**
Description			
Area	ca. 160.000 km^2	ca. 814.578 km^2	357.104 km^2
Inhabitants (2008)	10.432.500	73.914.260	82.110.000
Inhabitants per km^2	ca. 65 E/km^2	ca. 91 E/km^2	ca. 230 E/km^2
GDP 2009 (IMF)	3.852/capita	8.723 $/capita	40.875 $/capita
Human Deve-lopment Index	98	79	22
IMF Ranking No.	Position 95	Position 75	Position 16

3 Brief description of the sample project

It is intended that the second planned landfill „Kabouti" for the greater Tunis area should take in exactly half of the waste generated there. The volume of waste in the first year of operation (estimated at the beginning of 2012) will be approx. 350,000 Mg and because of the rapidly increasing population and specific waste amount reach ca. 600,000 Mg in the year 2030. The overall volume is planned for maximally ca. 10 mill. Mg or resp. up to 23 operating years. The deposit surface of the landfill is approx. 22.5 hectares. All details in the following text are based on a feasibility study which was sponsored by the KfW. /5/.

The figures 1 and 2 show the simplified site plan of the landfill Kabouti as well as the basis sealing system used, where a combination sealing was chosen.

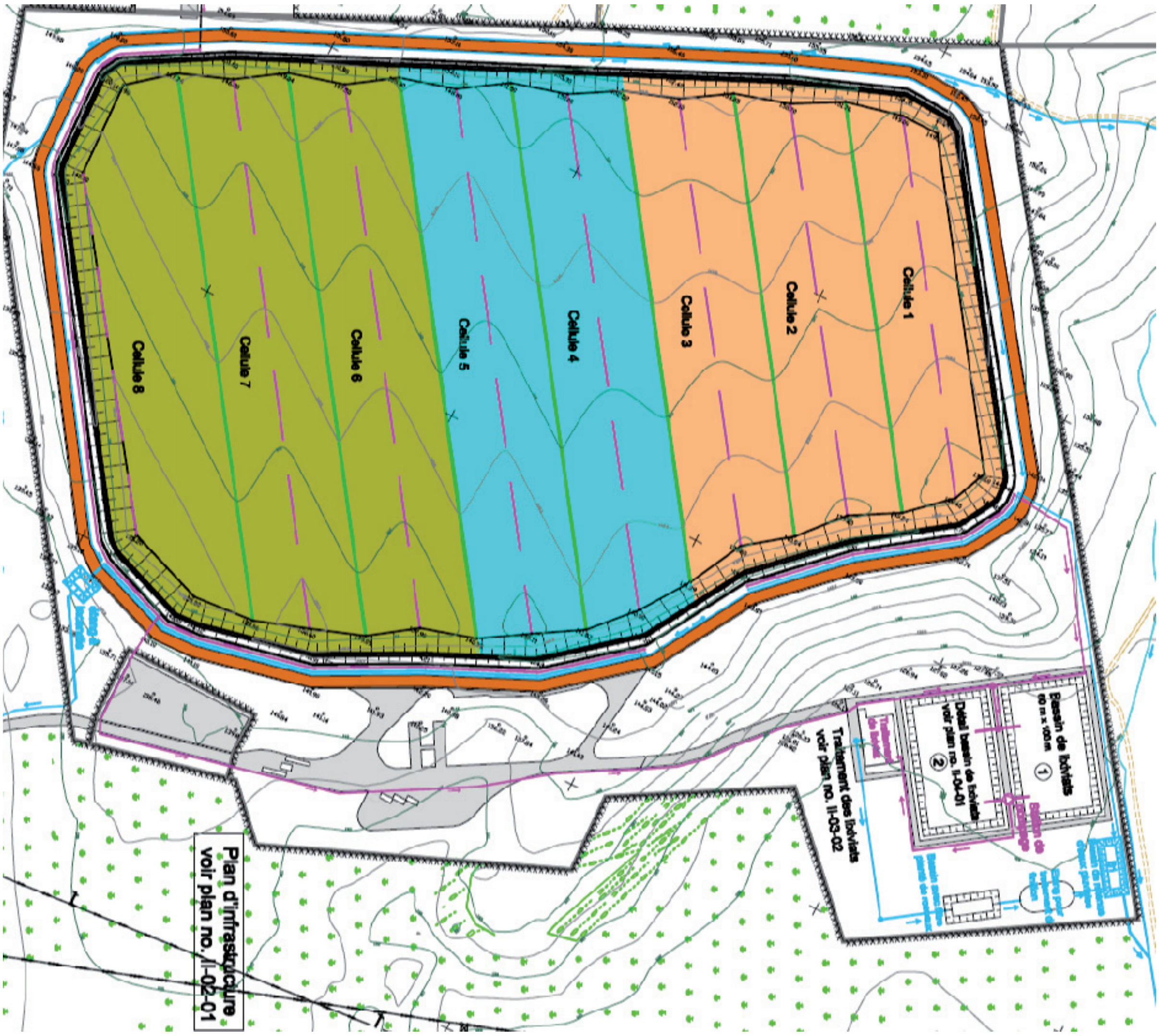


Figure 1: Layout of sanitary landfill „Kabouti“ /4/

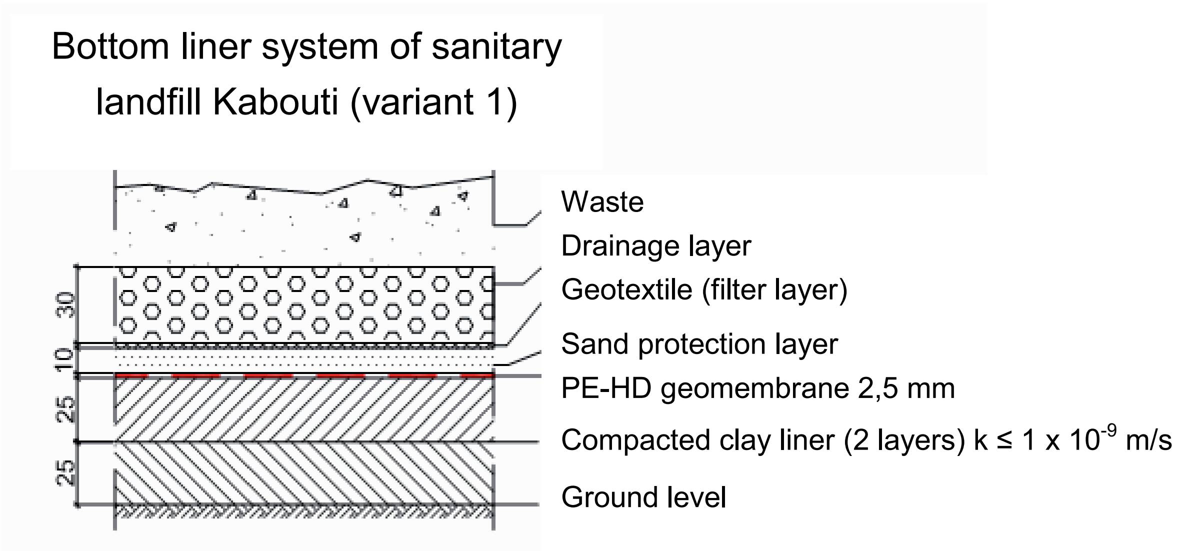


Figure 2: Bottom liner system of landfill „Kabouti“ (variant 1)

The investment costs of this landfill can be seen in Table 5.

Table 5: Investment costs of the landfill Kabouti (landfill sections 1 to 3 without surface sealing)

	Landfill section 1 and infrastructure	Landfill section 2	Landfill section 3
Investment costs[3] (without equipment)	about 14 million €	about 3.1 million €	about 5 million €
Investment costs equipment	about 2.2 million €	Re-investment after period of amortiza-tion	Re-investment after period of amortization

The specific dynamic production costs for the landfill described are calculated on the basis of the investment costs shown in Table 5, the re-investment for equipment etc. over the operating period and the operating costs at around ca. 12.57 €/Mg. A fixed rate of interest of 3% was assumed for the calculation. Proceeds from landfill gas use (production of electrical energy) were not taken into consideration here. If the costs for collection, re-loading and transport are also added, this results in total dynamic production costs of 36.88 €/Mg for 50% of the waste amount dealt with in the investigation /4/ for the settlement area of Tunis. If revenue from the conversion of landfill gas into electricity is taken into account, then the above costs are reduced to 10.38 €/Mg for the landfill or resp. 34.69 €/Mg for the overall disposal. The amount of gas extracted and the energy obtained is estimated quite conservatively, since it has been shown that the prognoses for this in the past were usually calculated much too optimistically and could not be realized in practice.

4 Comparison of the systems

4.1 Comparison of the landfills in the variants considered

In the following the fundamentals of the planning for the two landfills in the variants under investigation are briefly described.

Variant 1

The landfill Kabouti mentioned before was planned as a crude waste landfill taking account of the EU landfill directive /6/. In the first landfill section almost all the infrastruc-

[3] Without surface sealing (capping system)

ture of the landfill was developed, e.g.: access road and internal road, all buildings, weighing machine, leachate storage basin, surface drainage with retention. This planning thus corresponds to the basic variant 1 of the following comparison.

In the case of the waste quantities described above, the costs were calculated over the whole period of the landfill operation and on the basis of the detailed planning of the landfill as well as on costs calculation carried out and meanwhile verified through the invitation for tenders and allocating of contracts for the construction.

Likewise taken into consideration were the costs incurred in the after-care phase, assuming that the landfill was equipped with leak-proof surface sealing after filling and that thus the leachate amount is reduced to zero in the after-care phase. These costs were used as a basis for comparison for the second scenario developed – fermentation of waste and the subsequent deposit on a thus reduced-size landfill.

Variant 2

For the alternative variant it was simply assumed that the fermentation plant was designed for the medium amount of waste, so that in the real case it would be underdimensioned from start to finish. This assumption is certainly greatly simplified, but the planning with a modular structure would have involved too much effort for this costs comparison.

For variant 2 it is assumed that the organic waste and recyclable waste will be removed from the overall waste stream and that only the remainder will reach the landfill.

Due to the pre-treatment of the waste, the amounts to be deposited are reduced considerably. On average only ca. 156,000 Mg per annum are to be deposed of over the period under consideration. The landfill in the comparison variant 2 can, for the same disposal period, thus be developed to a considerably lesser extent. The following table shows the main differences between the landfills under consideration.

In addition to the differences described in Table 6, a reduced amount of equipment and personnel is required for the residue landfill in Variant 2. A simple surface sealing was planned for both landfill variants, which for both was calculated at 35/€/m^2.

The dynamic prime costs of both variants can be seen in Table 6. Here it should be noted that the costs of both variants refer respectively to the total waste quantity occurring in the period under consideration.

Table 6: Comparison between the crude waste landfill in Variant 1 and the residual waste landfill in Variant 2

	Landfill Variant 1	**Landfill Variant 2**
Operating time	23 years	23 years
After-care period	30 years	30 years
Area	22,5 ha	14,0 ha
Bottom lining system	Composite liner	Single liner
Degasification necessary	yes	no
Average quantity of leachate	about 90.000 m^3/a	about 45.000 m^3/a
Leachate treatment	3 step treatment plant	1 step treatment plant
Investment costs[4]	about 22.1 million €	about 10 million €
Dynamic prime costs without benefits of landfill gas utilization[5]	12.57 €/Mg	5.63 €/Mg

4.2 Costs of waste treatment

It is not only the costs of depositing waste at the landfill which are to be compared, however. In Variant 2, the costs for waste treatment have to be added, of course. These are made up of the costs for the pre-treatment of the waste before fermentation and the costs for the fermentation plant. The pre-treatment of the waste is essential, as collection is of mixed waste, so that first the recycling waste and also the contaminants have to be sorted out. The pre-treatment consists of sieving (drum screen) as well as hand sorting on a conveyer belt.

Further processing of the waste (e.g. using a pulper) was added to the costs of fermentation. Here, the scenario being considered was based on the actual composition of the waste.

The calculation shows that the dynamic prime costs for Variant 2 are - without taking the revenues into account - in the area of costs specified by the KfW (see Tab. 2). Thus the fermentation alone including the accompanying pre-treatment of the waste incurs costs of ca. 33.24€/Mg (in terms of the total amount of waste involved). The specific costs according to the amount of the waste treated are of course higher, as waste had already been sorted out in the pre-treatment phase (either as recycling materials or as contami-

[4] Without equipment and surface sealing

[5] In terms of the total amount of waste occurring

nants which had to be deposited. The costs area of 60 – 90 €/Mg depicted in Table 2 for fermentation seems despite this very high, but nevertheless still lies in the range of the costs calculated, if one relates this only to the waste amount treated.

The investment costs for pre-treatment amount to 23 million Euros (construction costs and costs for equipment), those for the fermentation plant to a total of 43 million Euros. As in the case of the landfill, the plant operating times were estimated at 23 years, so that the systems could be kept comparable in the time axis too.

The actual costs of the treatment plants depend quite considerably on the proceeds acquired from recycling materials and resp. the energy produced. To demonstrate this, the dynamic prime costs were calculated respectively both for the sorting as well as for the fermentation, depending on the amount of the proceeds. For this see figures 3 and 4.

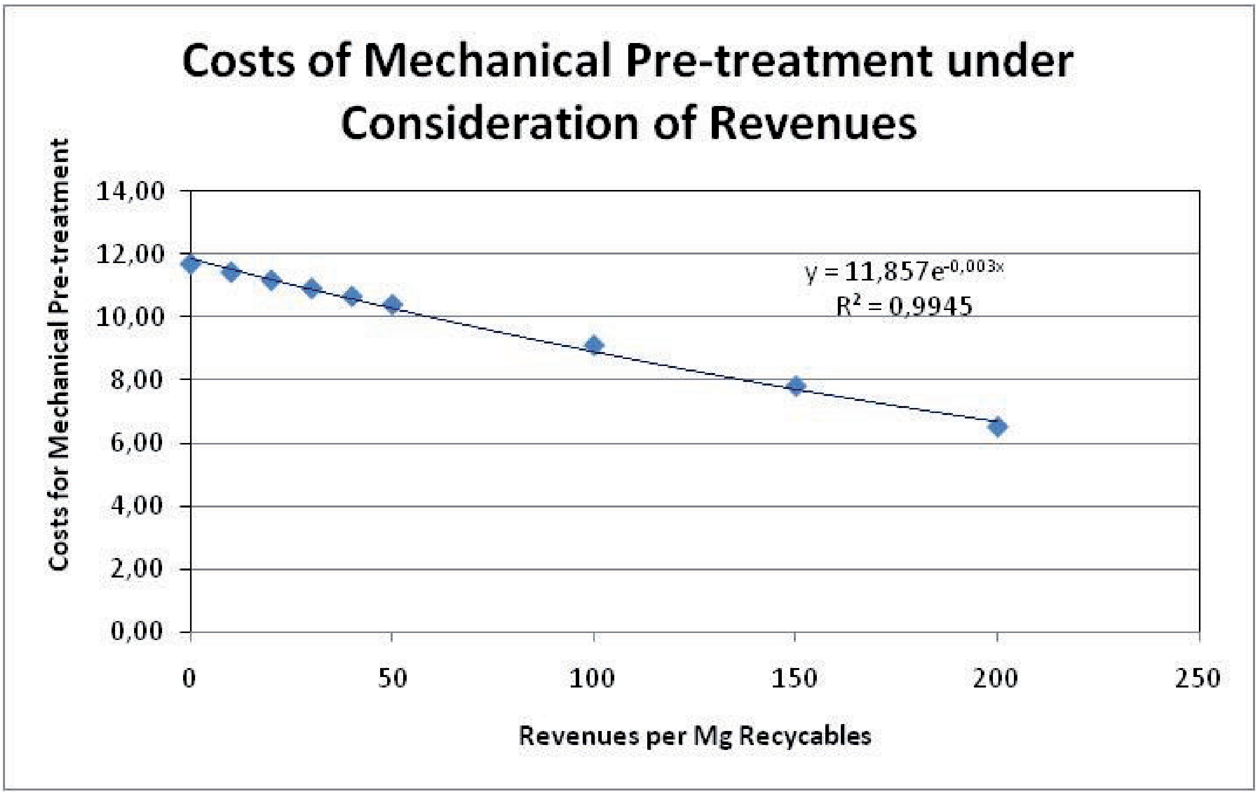


Figure 3: Costs for pre-treatment / sorting depending on the amount of achievable proceeds for the recyclable materials in €/Mg

Figures 3 and 4 demonstrate that when the proceeds for the materials obtained or energy produced are higher, then the treatment costs for pre-treatment of waste are distinctly reduced. It is also evident, however, that taking into account the proceeds for recyclable materials on the world market today and in the near future, the costs for sorting cannot be reduced as desired. This pre-treatment is, however, necessary in any case in a mixed waste collection before higher quality measures such as fermentation can be carried out. This can even provide profit through the production of energy if the payment for the electricity fed into the mains supply is approx. 12 €-cent per kWh.

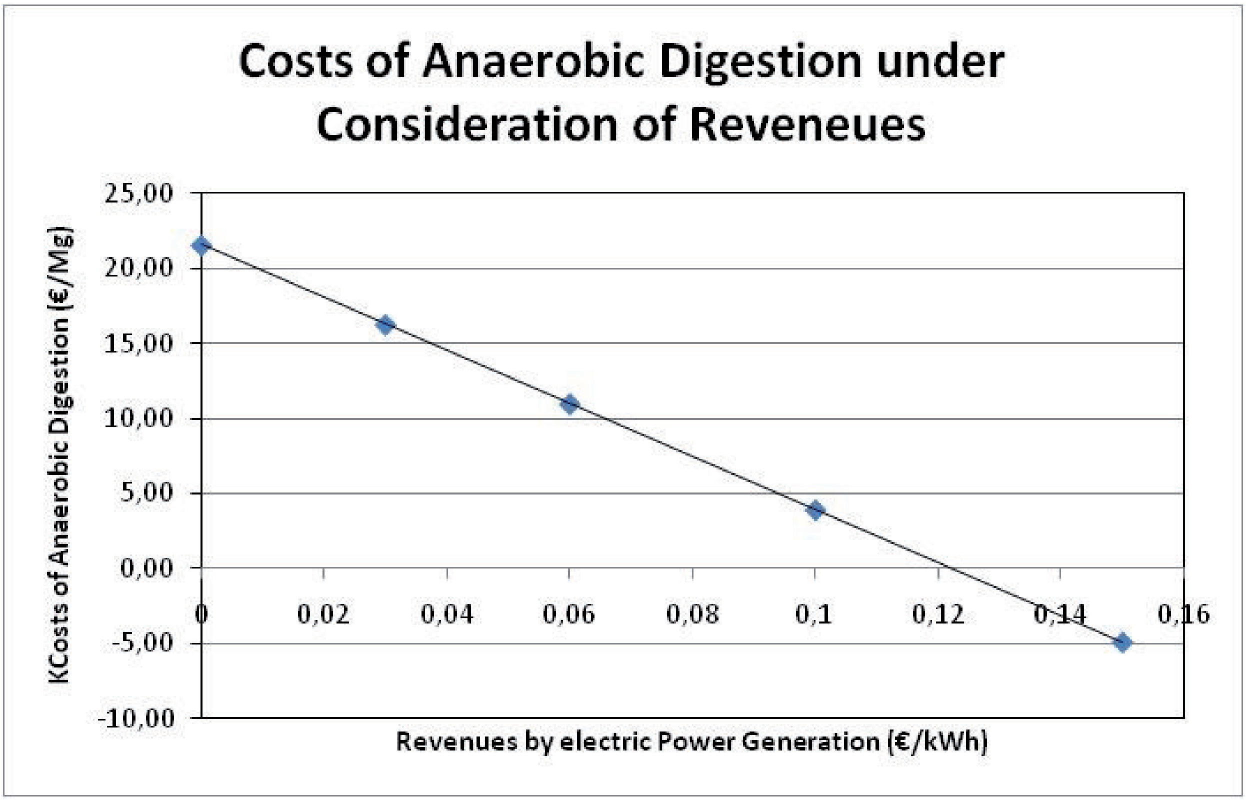


Figure 4: Costs for the fermentation depending on the amount of achievable proceeds for the electrical energy produced

4.3 Cost comparison of the two systems under consideration

In Table 7 a clear overview of the costs for the systems under consideration (variants 1a to 1b, also 2a to 2d) is given. First the costs for both variants were calculated, without taking into account payment for recycled materials acquired or energy produced (variants 1a and 2a). In the next step, the costs when estimating realistic profits (30 € / Mg recycled materials; 0.11 €/kWh electrical energy) were calculated (variants 1b, 2b and 2c). Since in the fermentation process a fertilizer or compost is also produced, a further variant 2c was considered for the sale of these products (for 10 €/Mg). It becomes evident, however, that in many countries the problematic sale of fertilizer/compost does not contribute much to reducing costs. Finally, yet another estimate was calculated, based on the approach that the proceeds from recycled materials as well the energy produced develop differently compared to all other costs of living. For this an annual increase in proceeds of 1% was estimated (variant 1c and 2d).

The transport costs were not calculated for variant 2 because they are subject to location. To simplify matters the costs of Variant 1 were adopted.

The comparison of systems thus reveals that higher quality waste disposal systems with a fermentation plant compared to the simple disposal of the mixed waste on a landfill are economically also clearly justifiable. If profits are estimated from CO_2 trading - although this has not yet been done in the investigation above – then financial advantages even result for the Variant 2.

Table 7: Costs comparison between the depositing of waste without previous anaerobic treatment (Variant 1) and depositing after previous anaerobic treatment (Variant 2)

Basic data	Interest	3,00	%
	First year	2009	-
	Design phase	2005 - 2009	-
	Commencement of w landfill construction	2010	-
	End of disposal at Kabouti (Variant 1):	2032	-
	Revenues by recyclables	30	€/Mg
	Revenues by electric power generation	0,11	€/kWh
	Revenues by fertilizers / compost	10	€/Mg
	Increase of revenues per year	1	%

All figures in €/Mg	**Variant 1** **landfill without pre-treatment**			**Variant 2** **landfill with pre-treatment (biogas generation by anaerobic degestion)**			
	Variant 1a	**Variant 1b**	**Variant 1c**	**Variant 2a**	**Variant 2b**	**Variant 2c**	**Variant 2d**
	without landfill gas utilization	**with landfill gas utilization and revenues for electric power generation**	**with landfill gas utilization and increase of revenues**	**Without any revenues**	**With revenues for electric power generation and recyclables**	**With revenues for electric power generation and recyclables and fertilizer**	**Like variant 2c but with an increase of revenues**
Waste collection	11,90	11,90	11,90	11,90	11,90	11,90	11,90
Waste transfer	7,09	7,09	7,09	7,09	7,09	7,09	7,09
Transportation	5,32	5,32	5,32	5,32	5,32	5,32	5,32
Mechanical pre-treatment	0,00	0,00	0,00	11,67	10,82	10,82	10,82
Anaerobic degestion	0,00	0,00	0,00	21,57	2,13	1,01	-1,91
Landfilling	12,57	10,38	9,94	5,63	5,63	5,63	5,63
Sum	36,88	34,69	34,25	63,18	42,88	41,76	38,85
	Dynamic prime costs without collection, transfer and transportation						
Mechanical pre-treatment	0,00	0,00	0,00	11,67	10,82	10,82	10,82
Anaerobic degestion	0,00	0,00	0,00	21,57	2,13	1,01	-1,91
Landfilling	12,57	10,38	9,94	5,63	5,63	5,63	5,63
Sum	12,57	10,38	9,94	38,87	18,57	17,45	14,54

5 Conclusions

In the considerations above we are dealing only with hypothetical models of course. The models are based on real figures, however, and also on the construction of a landfill and a fermentation plant. The fermentation plant is a very good size as it should treat all the remaining waste after pre-treatment (i.e. without recycled materials and without contaminants) (ca. 250,000 Mg/a). This size of course results in relatively low specific treatment costs. The specific costs for fermentation will be somewhat higher for smaller facilities. It is assumed that all waste to be deposited will be pre-treated, so that there is a considerable reduction in costs for the landfill.

It is desirable that after a phase in which first pilot plants with a performance of less than 100,000 Mg/a in countries such as Tunisia or Turkey are built and successfully operated, then the waste quantities of whole regional authorities should be treated before they are deposited on landfills. In addition to purely monetary considerations, the other advantages of such a high quality waste disposal - such as environmental, ecological and social aspects - should also to be taken into account.

The increasing scarcity of raw materials as well as the rise in energy prices will in future be a factor in making higher quality waste disposal systems of interest when compared to just depositing the waste without treatment. Probably even financial advantages will be possible. An important pre-requisite for this in particular is reliable legislation, for example for the feeding of electrical energy into the national grid(s) of a country. This contributes quite considerably to a long term certainty in planning. The corresponding legislation in Germany can here serve as an example.

The costs for varying waste disposal systems can be drawn up relatively quickly using the Excel tool developed and can be subjected to a sensitivity analysis.

6 Literature

Schenk, B. und Pfaff-Simoneit	2008	"KfW's Support for Turkey's Evolving Waste Management System", Lecture on the Conference "Towards a Clean Environment in Turkey – Challenges & Financing Options", Nov. 4th and 5th 2008 in Ankara, Turkey
World Bank	2010	World Development Indicators, http://data.worldbank.org
Wikipedia	2010	(www.wikipedia.com)
Institut National de la Statistique	2009	Tunisia
Consortium IGIP / IU / ICP	2008	Feasibility study on the waste management for Greater Tunis, by the, elaborated for ANGeD (Agence National de la Gestion des Déchets), Tunis
EU-Landfill Directive	1999	Directive 1999/31/EG as of April 26th 1999

Authors' addresses:

Dipl.-Ing. Gerd Burkhardt, Dipl.-Ing. Nina Müller, Dr.-Ing. Ludwig Streff
ICP Ingenieurgesellschaft Prof. Czurda and Partners mbH
Eisenbahnstraße 36
D-76229 Karlsruhe
Phone +49 721 94477-0

Email icp@icp-ing.de Website: www.icp-ing.de

Potential of the Microbial Methane Oxidation to Mitigate Low Gas Emissions of Mechanically and Biologically Treated Waste

Sonja Bohn, Johannes Jager

University of Technology Darmstadt, Institute IWAR, Department of Waste Management

Abstract

Mechanical and biological treatment (MBT) of waste is among others an appropriate method to diminish landfill gas production. In this study, lysimeter experiments were carried out to determine the gas production rate of MBT waste of different treatment intensities, different water content and changing ambient temperature. A very low gas production rate (1.0 ml gas kg DM^{-1} d^{-1}) was confirmed for intensive treated MBT waste. Water content above 30 mass-% and ambient temperature higher than 8 °C support the gas production rate. Lysimeter results were validated through a study at a test field on an operating MBT landfill. Measurements by the use of special underground chambers verify the low gas production potential of MBT waste (0.7 ± 0.8 l CH_4 m^{-2} h^{-1}). Extraction and treatment of landfill gas at such a low emission rate require sophisticated techniques thus very expensive. The use of methanotrophic bacteria in landfill top cover systems is a natural and sustainable way for complete mitigation of such low gas emission. Provided that the soil material is thoroughly chosen and the top cover system is well designed. Some criteria for an adopted top cover system are given.

Zusammenfassung

In the framework of the MiMethox-project, financed by the Federal German Ministry of Education and Research, a process study on a MBT landfill is done. The results of a lysimeter study for qualitative and quantitative MBT landfill gas analyzes are introduced. The gas production rates were validated at a test field on an operating MBT landfill. The natural potential of the microbial methane oxidation is described and the adaptability on low gas emission landfills is shown. Further, some criteria for an optimized landfill cop cover system adopted for the microbial methane oxidation are listed.

Keywords

MBA, Gasbildung, Lysimeter, Testfeldstudie, Mikrobielle Methanoxidation, Aufbau von Methanoxidationsschichten

MBT, gas production, lysimeter, test field study, microbial methane oxidation, criteria for methane oxidation layer

1 Introduction

Landfills are the second largest source of atmospheric methane emissions (Kreileman & Bouwman 1994) and responsible for about 26 % of the anthropogenic caused greenhouse effect (Butz 1997). In accordance with the EU Landfill Directive (Council Directive 99/31/EC), since 1st of June in 2005, only waste of low biological activity, e.g. mechanically or biologically treated waste is allowed to be deposited on German landfills to reduce environmental impacts caused by leachate or gas emission. A criteria catalogue was established to evaluate the residual biological activity of MBT waste. The most important parameters are the total organic carbon (TOC < 18 mass-%) or the heating value (H_0 < 6.000 kJ kg^{-1}), the static respiration index (AT_4 < 5 mg O_2 g DM^{-1}), the gas production potential (GB_{21} < 20 N l kg DM^{-1}) and the dissolved organic carbon (DOC ≤ 300 mg l^{-1}) (Verordnung über Deponien und Langzeitlager, DepV, annex 3).

MBT integrates a number of technical processes with the objectives of material recovery, refuse derived fuel production, as well as volume reduction by mechanical separation and sorting. Disposal of these pretreated materials result in significantly reduced landfill gas production. Untreated waste has a gas production rate at around 200 – 250 m^3 t^{-1}. MBT material, complying with disposal criteria, produce only about 40 m^3 t^{-1} (Berger 2008). Nevertheless, even by the use of state-of-the-art techniques for active or passive gas recovery, still a substantial amount of methane escapes to the atmosphere and thus negatively contribute to global warming.

Methane has the second largest radiative forcing of the long-lived greenhouse gases (Forster et al. 2007), being 25-fold more radiatively active than carbon dioxide on a molar basis over a 100-year period (IPCC 2007). Recorded in database of an IPPC inventory in 2006, a projection of methane emission by the waste sector gives about 640 Mt CO_2-eq in 2010 (Bogner et al. 2007).

To prevent methane emission from landfills into the atmosphere, the application of the sustainable methane oxidation potential of methanotrophic bacteria is a sustainable and inexpensive method. A community of methanotrophic bacteria occurs naturally where methane and oxygen are available in a suitable proportion. The chemical reaction for oxidizing methane to CO_2 in the presence of O_2 is shown by the following equation:

$$CH_4 + 2\ O_2 \Rightarrow CO_2 + 2\ H_2O + 883\ kJ/mol$$

For the oxidation of methane, the bacteria mainly need oxygen, water and nutrients at an appropriate ratio. However, the substrate supply is often limited by soil physical properties such as soil texture, pore size distribution and degree of compaction, which determines the air capacity and therewith the soil diffusivity (Gebert 2008). Also, moisture and temperature determine the activity of the methane oxidizing bacteria.

In the beginning of 2007, the project “MiMethox – Microbial Oxidation of Methane in Landfill Cover Layers” financed by BMBF (Federal German Ministry of Education and Research) started with a duration of six years. The project aims are the development of optimized landfill top covers for a suitable microbial methane oxidation as well as the remediation of hotspots, which refer to small areas with high landfill gas fluxes in the top cover. In the framework of the MiMethox project, the following two technical guidelines are in progress:

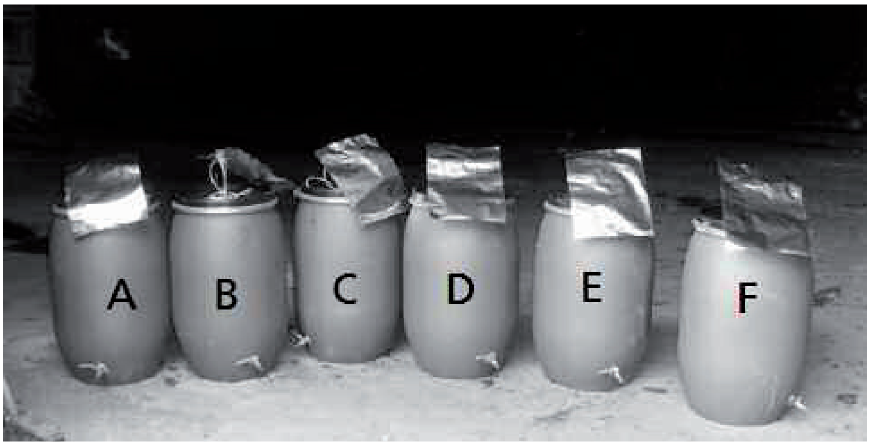
- Development of landfill cover designs suited for the inexpensive and sustainable reduction of methane
- Development and validation of a method to balance the methane budget of the entire landfill

In framework of the MiMethox-project Darmstadt University of Technology, Institute IWAR, Department of Waste Management has been working on the work package “Process study on a MBT landfill”. The aims of this workpackage are quantification of methane production in the MBT waste, methane oxidation in the top cover and remediation of hotspots to diminish residual methane emission.

2 Methods

2.1 Lysimeter experiments

Eight lysimeter experiments are carried out to investigate the gas production rate as well as gas composition of MBT waste with different levels of organic substances, different water content, and the influence of the changing ambient temperature. The lysimeter experiments were developed in cooperation with the “Abfallwirtschaftszentrum Rhein-Lahn” in Rhineland-Palatinate, Germany (AWZ). The AWZ treats the residual municipal solid waste of 550.000 habitants in the “Rhein-Lahn Kreis”, “Rheingau-Taunus-Kreis” and “Altenkirchen”. The mechanical treatment of this plant consists of a shredder, a classification (< 150 mm) in a drum sieve, and a magnet. The biological treatment of the fine organic fraction includes a five-week intensive composting process in containers with active aeration and watering and a nine-week of compost maturing process in open roofed piles.



Picture 1 Lysimeter A-F

For the lysimeter experiments, MBT waste of different treatment levels were filled and compacted (density = 1.4 Mg m^{-3}) in 150 l gas-tight containers and weight with gravels for simulating the top cover. Each container has a valve for draining leachate and a valve for collecting gas on the top (picture 1). During the experiment, the lysimeters are stored in a hall where the inside temperature corresponds to the outside temperature, which is continuously logged. Table 1 gives the output parameter for the different type of waste.

Table 1 Lysimeter experiments. Types of waste pretreatment and output parameters

lysimeter no.	pretreatment	water content [mass-%]	GB_{21} [Nl kg DM^{-1}]	AT_4 [mg O_2 g DM^{-1}]	DOC [mg l^{-1}]	TOC [mass-%]
1	MT+14w BT	33.5[1]	14.9[1]	3.6[1]	277[1]	12.9[1]
2	MT+14 w BT	26.4	14.9	3.6	277	12.9
A	MT	40.5	70.1	70.5	2415	26.9
B	MT+9 w BT	41.0	57.2	17.3	483	16.4
C	MT+14 w BT	21.9	7.8	3.4	226	16.0
D	MT+14 w BT	21.5	6.5	4.0	214	14.2
E	MT+14 w BT	30.5	18.3	4.3	255	16.2
F	MT+14 w BT	34.5	7.6	3.3	220	18.1

[1] lysimeter 1 was belated watered with 10 mass-% water

GB_{21} [gas production in 21 days], AT_4 [respiration index], DOC [dissolved organic carbon], TOC [total organic carbon]). MT: Mechanical Treatment (= shredder + drum sieve [150 mm]), BT: Biological Treatment.

During the experiment, the gas produced in each container is collected in a TECOBAG® (Tesseraux Spezialverpackungen GmbH, Bürstadt). At an interval of a week, the collected gases are analyzed qualitatively by gas chromatography-flame ionization detector / thermal conductivity detector (GC-FID / TCD) for the permanent gases CO_2, O_2, N_2 and CH_4. Further, the gas volume is measured by a digital vacuum pump DESAGA® (DESAGA GmbH, Wiesloch).

2.2 Process study on a MBT landfill

Since the end of 2007 a field study has been performed on an operating MBT landfill at the AWZ. The test field with a dimension of 20 m x 30 m was constructed to monitor gas production in MBT waste and microbial methane oxidation processes in the recultivation layer.

Dimension of the test field (from top to bottom):

- 0.3 m top soil layer
- 0.7 m subsoil layer (clayey silt)
- 0.4 m capillary layer (sand NK 0/2)
- 0.2 m capillary block (gravel NK 2/4)
- 20 – 25 m MBT waste

For investigation of landfill gas fluxes out off the waste body, six underground, open-bottom chambers (1.0 m x 1.0 m x 0.2 m) are installed in the gas distribution layer (figure 1). The CH_4-flux out of the MBT waste body is analyzed by flushing the underground chambers with inert nitrogen gas and measuring the time depending re-increase of CH_4-concentration in the chamber using a flame ionization detector (FID) (R53-T Ratfisch Analysensysteme GmbH, Poing).

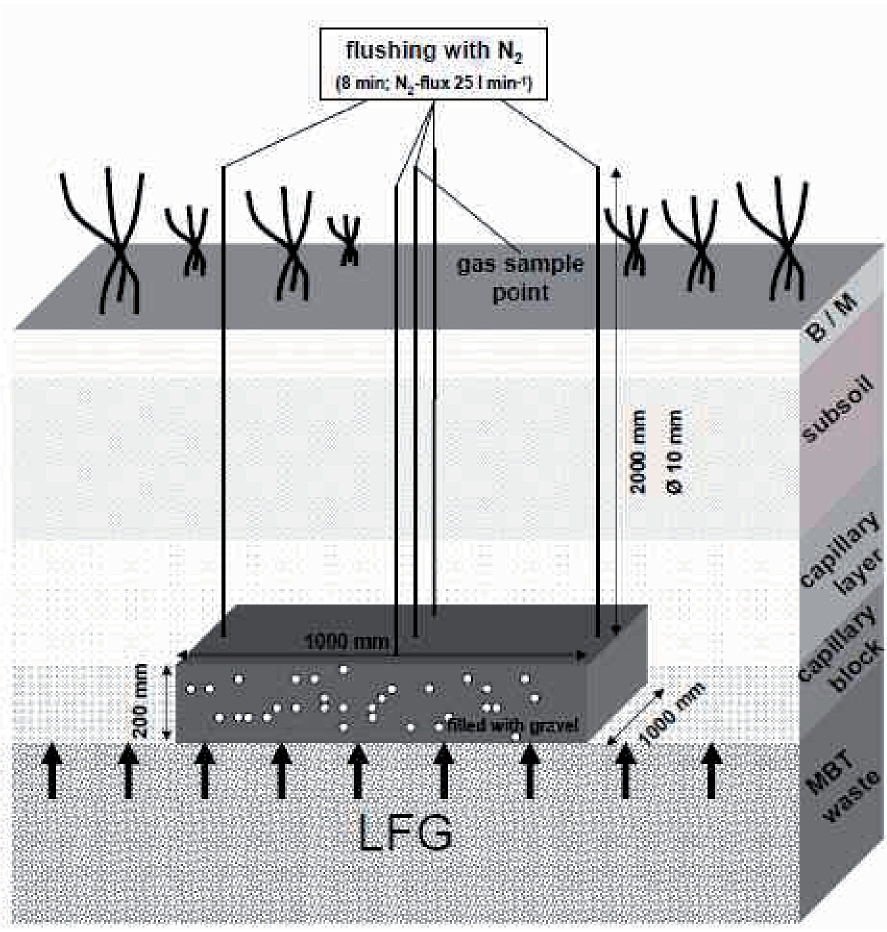


Figure 1 Design and installation of the underground chambers in the test field cover system

3 Results and Discussion

3.1 Lysimeter experiments

Figure 2 shows the cumulated gas production rates [ml gas kg DM^{-1} d^{-1}] over a time period of 900 days of the eight lysimeters. A large difference was observed in gas production of lysimeters with waste of no or low-level biological treatment (lysimeter A and B) and in lysimeters containing waste of a 14-week, intensive biological treatment (lysimeter 1, 2, C and D).

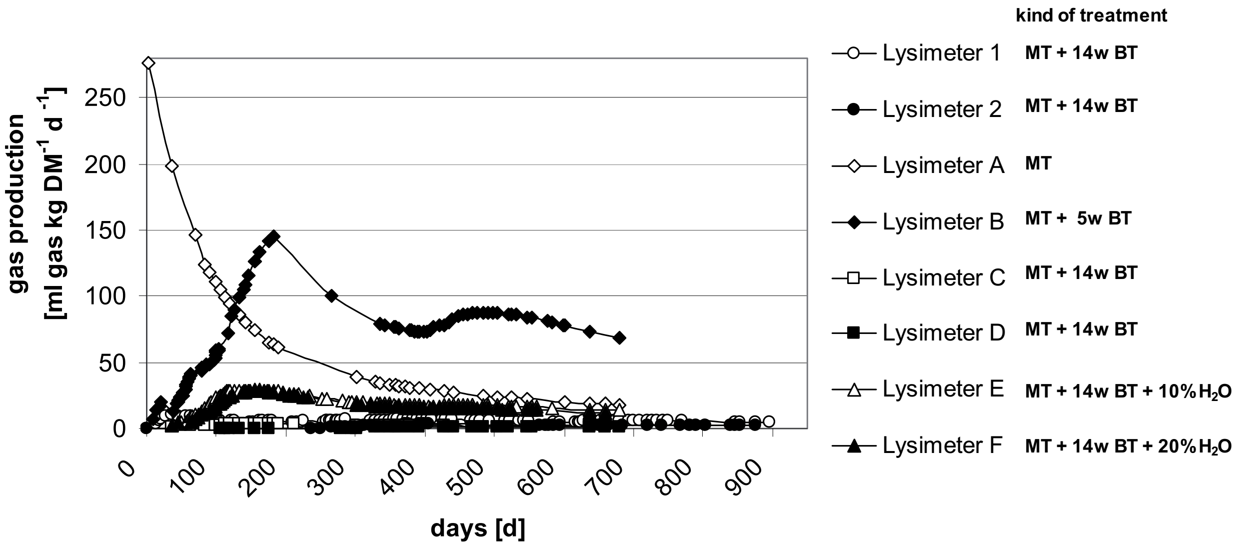


Figure 2 Gas production rate [ml gas kg DM^{-1} d^{-1}] of the eight lysimeters

After 900 days of investigation, the highest gas production still occurs in lysimeter B (60 ml gas kg DM^{-1} d^{-1}) with the highest CH_4-content of 64 vol-% (figure 3). During the short biological treatment of 5 weeks, the organic compounds have been solubilised, i.e., cleavage of organic polymers (e.g. cellulose) must have been taken place. However, the treatment was too short for complete biological degradation. Therefore, the degradation of the waste is in progress in the lysimeter B, leading to the high gas production rate. Lysimeter A shows the second highest gas production rate (18 ml gas kg DM^{-1} d^{-1}). And the level of DOC of the input material (only MT waste) is the highest (2415 mg l^{-1}; table 1). Yet, since the input material was not treated biologically, the organic compounds in the material must have maintained the original forms, i.e., are to be biologically degraded in the lysimeter.

Lysimeters 1, 2, C and D contain similarly treated wastes (MT + 14 weeks BT), representing typical low calorific MBT waste according to the criteria of landfilling (DepV). The average gas production rate after 900 days is about 1.0 ml gas kg DM^{-1} d^{-1} in these lysimeters. It is because of the low organic fraction (DOC < 277 mg l^{-1}) and the lower water content (< 30 mass-%), which constrains the microbial activity.

Water was added to the MBT waste for lysimeter E and F to 10 mass-% (E) and 20 mass-% (F), respectively, before installation in the lysimeters. The effect was observed at an increased gas production rate of 14 and 12 ml gas kg DM^{-1} d^{-1}, respectively. The biological activity can be optimized by an appropriate water content, which dissolves the nutrients and improves its availability. Because a lack of water often results in a reduction of gas production, the leachate re-infiltration is a well-known technology to shorten the aftercare phase of landfills.

Further, the gas production activity is influenced by temperature. As seen in figure 3, there is no gas production below a ambient temperature of 8°C. Above the critical temperature, the increase and decrease of gas production is proportional to the changing of the ambient temperature.

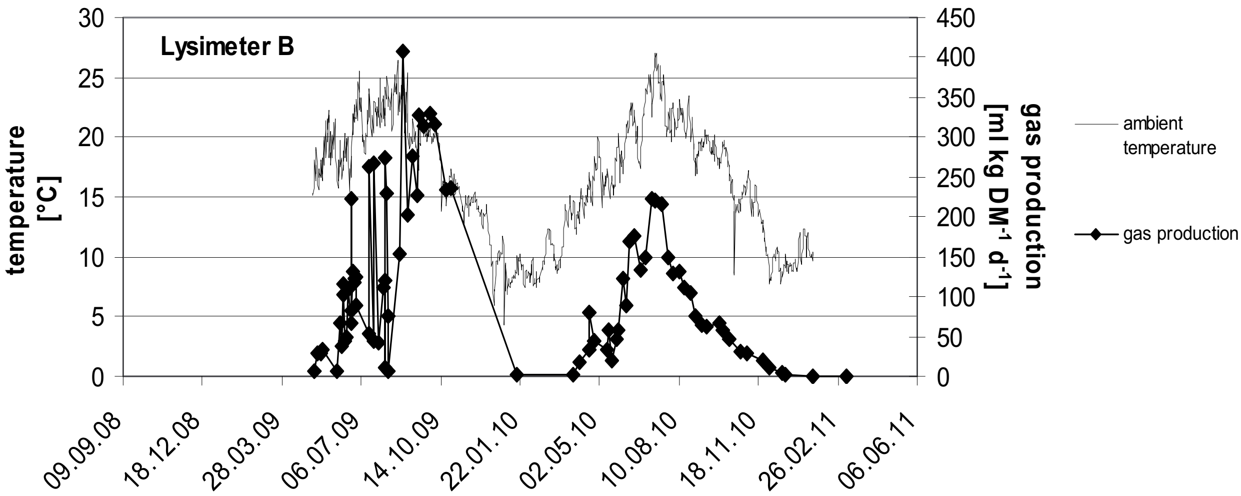


Figure 3 Influence of ambient temperature on gas production

Beside quantitative gas production rate, the qualitative gas composition was analyzed. Figure 4, 5 and 6 show the changes in gas composition over the time in lysimeters B, C and E. The initial phase is always formed by a high CO_2-concentration (Rettenberger & Mezger 1992), due to the biodegradation of easy biodegradable substances by consumption of oxygen. Followed by an increase of methane concentration, which is the transition from the aerobic biological respiration process into the anaerobic methane production phase. Both, lysimeter B and E show a good similarity in their gas composition patterns, although the organic compound in B is twice as high, but E has extra water addition (table 1). Lysimeter E by contrast of lysimeter C shows that at high water contents (> 30 mass-%) a faster degradation of biodegradable substances can be achieved.

In summary, the gas production rate and the CH_4-concentration is highly influenced by the organic mass and the biological availability determined by the stage of pre-treatment as well as the water supply.

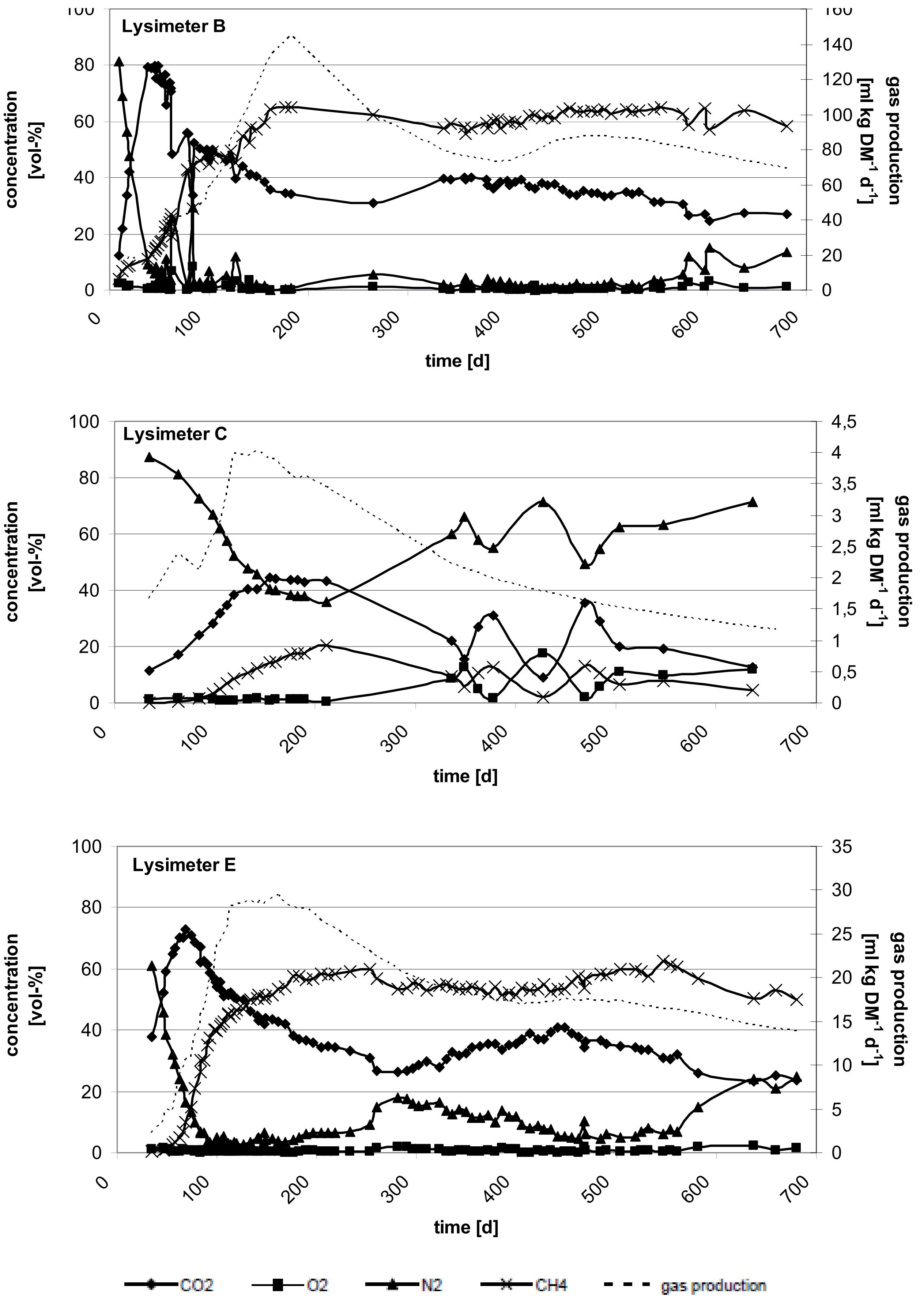


Figure 4, 5, 6 Qualitative gas composition and quantitative gas production rate of the lysimeters B, C und E.

3.2 Validation of methane production on the test field

The waste of the lysimeters 1, 2, C and D presents MBT waste ready for landfilling (DepV, annex 3) and therewith the determined gas production rate of 1.0 ml gas kg DM^{-1} d^{-1} should represent the gas production in a real MBT landfill. Taking this result for a conservative estimation, the CH_4-flux off the MBT waste body into the cover system of the test field can be calculated. Taking into account the dimension of the waste body under the test field (30 m x 20 m x 25 m [l x b x h]), the density (1.4 Mg m^{-3}), the typical water content of waste disposal at the AWZ (around 35 mass-%) and the measured CH_4-concentration (60 vol-%), the expected CH_4-flux of the waste body into the cover system can be estimated about 0.6 l CH_4 m^{-2} h^{-1}.

This estimation was validated on the test field by the use of underground chambers, which are installed in the gas distribution layer (capillary block) for collecting the upward migrating landfill gas (figure 1). Figure 7 gives the CH_4-fluxes into the underground chambers. The fluxes are between 0.6 and 3.5 l CH_4 m^{-2} h^{-1}, on average of 0.7 ± 0.8 l CH_4 m^{-2} h^{-1}. This value confirms very well the conservative estimation, calculated based on the lysimeter experiment, where a CH_4-flux of 0.6 l CH_4 m^{-2} h^{-1} for the test field was predicted.

In conclusion, both the underground chamber measurement and the lysimeter experiment are suitable methods to describe the methane production rate and methane flux of the MBT low gas production system.

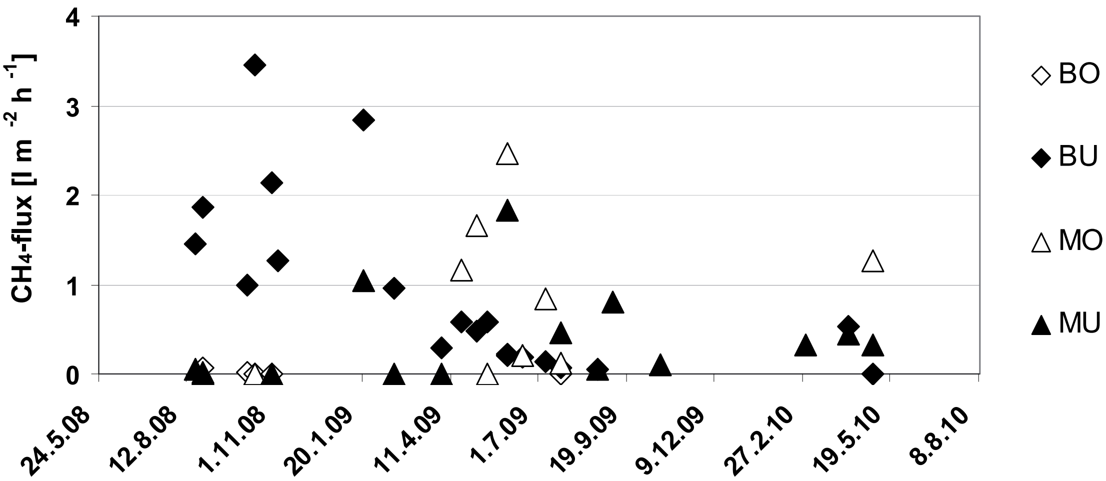


Figure 7 CH_4-flux measurement in the underground chambers (BO, BU, MO and MU define the position on the test field)

3.3 Potential of the microbial methane oxidation

The microbial oxidation of methane in cover soils bears great potential for an inexpensive and sustainable reduction of methane emission from landfills particularly for sites with low gas production potential i.e. MBT landfills or old landfills.

Determined by the exposition to methane and availability of oxygen, a very active population of methanotropic bacteria can be developed in a top cover system. In the framework of the MiMethox-project analyses of the methane oxidation rate in top cover systems of five old landfills were done by Gebert (2010). Figure 8 shows potential CH_4-oxidation rates up to 137 l CH_4 m^{-2} h^{-1}, 5 l CH_4 m^{-2} h^{-1} on average.

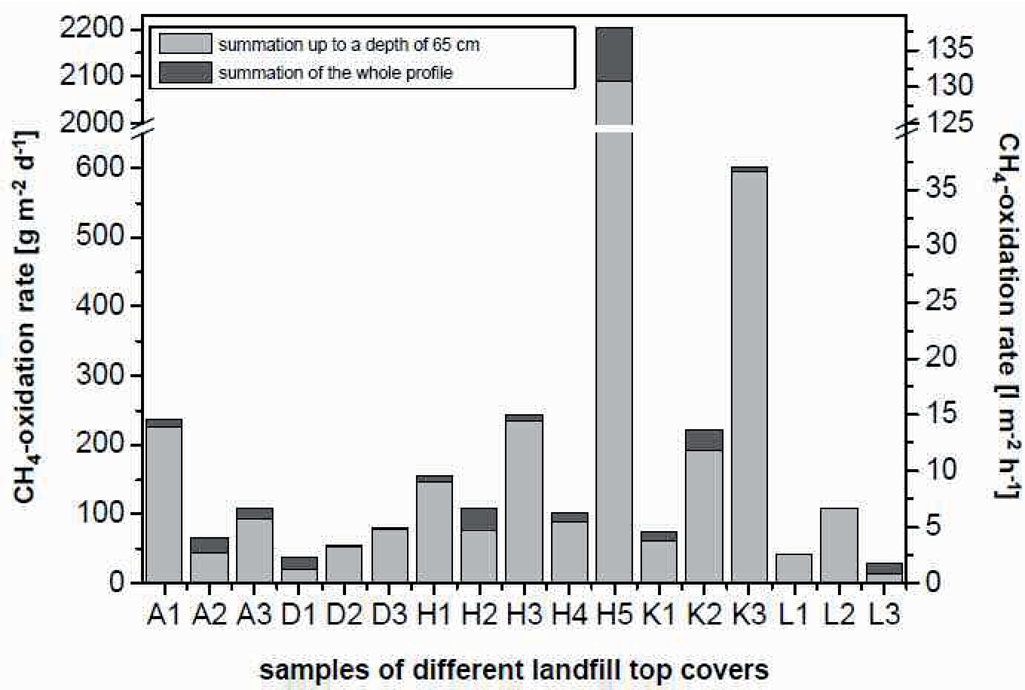


Figure 8 Methane oxidation potential in the cover system of five old landfills in northern Germany. Analyzed in batch tests (Gebert 2010)

The calculated CH_4-load based on the lysimeter experiments (0.6 l CH_4 m^{-2} $h^{-}1$) and the validation on the test field using the underground chambers (0.7 ± 0.8 l CH_4 m^{-2} h^{-1}) demonstrate a very low methane emission of MBT landfills. With regard on the demonstrated high methane oxidation potential, the methane emission of MBT waste can be fully oxidized by methanotrophic bacteria. However, a designed cover and a thoroughly choice of material are required.

3.4 Criteria for an optimized methane oxidation layer

- Gas distribution layer of coarse material (0.2 m at least)
- Thickness of recultivation layer 0.5 – 1.0 m

Characteristics of the recultivation layer:

- Long term stability of soil material; not biodegradable
- High field capacity to maximize evatranspiration („water balance layer“)
- Sum of clay and silt content: 17 – 40 mass-%
- Qualified soils are: sands, loamy sand, sandy loam or coarsely textured loams
- Construction without compaction (no heavy construction machine)
- Average density 1.4 g cm-3
- Air capacity of 17 vol-% at least

  (Gebert et al., 2010)
- Site-specific vegetation is essential especially at low qualified soil material to improve soil aeration by spreading roots, which built up secondary macro pores and dewater the water filled pores blocked for gas transportation

4 Acknowledgements

The MiMethox-Project is funded by the German Federal Ministry of Education and Research (BMBF) within the subsidy program “klimazwei”.

Special thanks to the “Abfallwirtschaftszentrum Rhein-Lahn” for supporting the project.

Further information and contact: www.mimethox.de.

5 Literature

Berger, J.	2008	Biologische Methanoxidation in Deponieabdeckschichten. In: Schriftenreihe WAR, Band 198, Verein zur Förderung des Instituts WAR (Publ.), Darmstadt University of Technology, Germany.
Bogner, J. E. & Matthews, E.	2003	Global methane emissions from landfills: new methodology and annual estimates 1980-1996. Global Biogeochemical Cycles, 17 (2), p. 1065-1083.
Butz, W.	1997	Klimarelevanz von Deponiegasemissionen. In: Rettenberger/Stegmann (Publ.): Neue Aspekte bei der Deponiegasnutzung. Trierer Berichte zur Abfallwirtschaft Bd. 11. Economica Verlag, Bonn, 9-21.

Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Fahey, D.W., et al.	2007	Changes in atmospheric constituents and in radiative forcing. In: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M., Miller, H.L. (Eds.), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on climate Change. Cambridge University Press, Cambridge, UK and Now York, NY, USA.
Gebert, J.	2008	Gas Diffusivity as Limiting Factor for Methane Oxidation in Landfill Cover Soils. In: Matthias Kühle-Weidemeier (Publ.): 3. Praxistagung Deponie 2008 Zwischenlager – Deponien – Nachsorge. 2th – 3th December 2008. Cuvillier Verlag. p. 326-335.
Gebert, J.	2010	Mikrobielle Methanoxidation in Deponie-Abdeckschichten: Das Projekt MiMethox. In: Mikrobielle Methanoxidation in Deponie-Abdeckschichten; Tagungsband zum Workshop 29.-30.04.2010 in Hamburg, Gebert, J. & Pfeiffer E.-M. (Hrsg.),Hamburger Bodenkundliche Arbeiten, Bd. 63, ISSN 0724-6382
Gebert, J., Groengroeft, A. Pfeiffer, E.-M.	2010	Relevance of soil physical properties for the microbial oxidation of methane in landfill covers. Soil Biology and Biochemistry, article in press doi:10.1016/j.soilbio.2010.07.004
IPCC	2007	Climate Change 2007: Mitigation. Contr. Working Group III to the 4th Assess Report of the IPCC. In Intergovernmental Panel on Climate Change, Cambridge.
Kreileman, G. J. J. & Bouwman, A. F.	1994	Computing land use emissions of greenhouse gases. Water, Air and Soil Pollution, 76, p. 231-258.
Rettenberger, G. & Mezger, H.	1992	Langzeitphasen des Deponiegeschehens bei Altablagerungen, Industrial waste management, waste reduction and treatment; Envirotech, S. 487-494.
Verordnung über Deponien und Langzeitlager (DepV)	2009	Ausfertigungsdatum: 27.04.2009; Stand: Zuletzt geändert durch Art. 5 Abs. 11 V v. 26.11.2010 I 1643; www.juris.de.

Author's addresses:

Dipl.-Biol. Sonja Bohn, Prof. Dr. Johannes Jager
Technical University of Darmstadt
Institute IWAR, Department Waste Management
Petersenstr. 13
D-64287 Darmstadt
Telephone: +49 6151 16 4901
Email s.bohn@iwar.tu-darmstadt.de
Webseiten: www.mimethox.de
www.abfalltechnik.net

Neue Erkenntnisse zur Chloranalytik von Ersatzbrennstoffen

Sylvia Schade-Dannewitz, Jürgen Poerschke, Sebastian Döring

Fachhochschule Nordhausen

New findings regarding the analysis of chlorine in waste-derived fuels

Abstract

We are aware of the current strong interest in the energetic utilisation of waste-derived fuels (WDF). Rising energy costs are also boosting the substitution of fossil fuels with WDF. Sampling, preparation and splitting are key factors determining the analysis result. In consideration of this, Nordhausen UAS has developed a promising method – the “pressing-drill method”. Especially inorganic chlorine salts lead to high-temperature corrosion in the combustion of waste-derived fuels. Compared to standard methods, the pressing-drill method can be used for the simple and low-cost extraction of a fluid that can be analysed precisely with ion chromatography. An additional aim is move away from the single specification of the total chlorine content, which also includes a subdiagnosis of unknown dimension.

Zusammenfassung

Bei der Qualitätssicherung von Ersatzbrennstoffen ist der Chlorgehalt von besonderem Interesse. Grundsätzlich lassen sich die Chlorverbindungen in organische wie z. B. PVC und anorganische Formen unterscheiden, welche sich im thermischen Prozess unterschiedlich freisetzen. Die hohen Ablagerungsraten von anorganischen Salzen wie NaCl und KCl führen zur Hochtemperaturkorrosion. Mittels Pressbohrmethode (PBM) besteht neben der Gewinnung repräsentativer Feststoffproben die technisch einfache und ökonomisch günstige Möglichkeit zur Erzeugung von Pressflüssigkeit. Der Vergleich von Analysenergebnissen anorganischer Chlorfrachten zwischen den DIN-Verfahren Elution und Extraktion und der Analyse der Pressflüssigkeit ergibt eine sehr gute Korrelation. Die neuen Möglichkeiten der differenzierten Analytik sollen den Summenparameter Cl relativieren und Indikator für das Korrosionspotential des eingetragenen Cl sein. Zudem wird angestrebt von der singulären Angabe eines wenig aussagekräftigen Gesamtchlorgehaltes abzugehen und eine funktional zusammengesetzte Chlorkennziffer zu entwickeln.

Keywords

Ersatzbrennstoff (EBS), Chlor, Probenahme, Pressbohrmethode, Analyse

Waste-derived fuel (WDF), chlorine, sampling, pressing drill- method, analysis

1 Einleitung

Wichtige Voraussetzung beim Einsatz von EBS ist die Einhaltung der vereinbarten Qualitäten (z. B. Heizwert, Chlorgehalt- organisch/anorganisch und biogener Anteil). Insbesondere die Probenahme, die Probenaufbereitung und die Probenteilung bzw. -verjüngung üben einen entscheidenden Einfluss auf das spätere Analysenergebnis aus, so dass Fortschritte und Standardisierungen auf dieser Ebene Fehlerquellen und Abweichungen deutlich minimieren. An der FH Nordhausen ist eine völlig neue Methode zur Probenentnahme und Gewinnung von Analysenproben aus heterogenen Schüttgütern geringer Dichte entwickelt worden, die sogenannte Pressbohrmethode (Patent 10 2007 021 145).

2 Pressbohrmethode

2.1 Verfahrensaufbau

Nach der Probenahme vom Band wird die Stichprobe von etwa 10 Liter in eine Pressvorrichtung überführt, wobei die Befüllung des Presszylinders in mehreren Befüllungsschritten erfolgt. Hierbei wird zunächst eine durchschnittliche Verdichtung des Materials um den Faktor 6 - 8 realisiert, so dass im Presszylinder ein komprimierter Körper entsteht. In der Probe enthaltene Flüssigkeit wird durch kleine Öffnungen in der Form ausgepresst, sog. Pressflüssigkeit. Die Entnahme von Proben erfolgt nunmehr durch wahrscheinlichkeitsproportionale bzw. zufällige Beprobung mittels Werkzeug über Bohrlöcher. Das Stoffsystem liegt durch den Pressdruck als kompaktes Stoffgefüge vor, so dass bei der Probenentnahme Entmischungserscheinungen aufgrund verschiedener Stoffdichten, breiter Korngrößenverteilung sowie differierender Geometrie vermieden werden. Bei der Pressbohrmethode handelt es sich demzufolge um eine Quasi-Festkörperbeprobung, welche den speziellen Anforderungen an die zu beprobenden Stoffsysteme gerecht wird. Eine je nach Zylindergeometrie durchzuführende Vorzerkleinerung der Probe und insbesondere die Auslese nennenswerter Störstoffe ist und bleibt obligatorisch.

2.2 Probenentnahmeregime

2.2.1 Zuordnung der Volumenelemente

Grundlage der PBM ist die zufällige Entnahme von Volumenelementen aus dem verpressten Material. Durch die Probenentnahme mittels Bohrer ist die Masse bzw. das Volumen eines jeden Volumenelementes vom Durchmesser des verwendeten Bohrers und der frei vorgebbaren Länge bzw. Tiefe des zylindrischen Elementes abhängig. Als praktikabel hat sich eine Elementlänge von 10 mm erwiesen, wodurch sich die Abhängigkeit auf den Bohrerdurchmesser reduziert. Die Gesamtprobenmenge besteht also aus der Summe mehrerer zufällig zu entnehmender Volumenelemente die beim Vorgang der Entnahme mittels Bohrer als Bohrelemente anfallen. Die Anordnung der Bohrlöcher im Zylinder ist so gewählt, dass nahezu jedes der Volumenelemente als Bohrelement ausgewählt werden kann. Das Bohrbild, Gesamtheit der Bohrungen auf der Mantelfläche des Zylinders, ergibt sich also in Abhängigkeit der Durchmesser der Bohrungen und der für die Stabilität des Zylinders verbleibenden Stege.

2.2.2 Dimensionen der Volumenelemente

Die eindeutige Zuordnung eines Volumenelementes wird durch drei Dimensionen bestimmt. Bei der Übertragung auf den Presszylinder gilt folgende Zuordnung:

1. Dimension: Höhenlinie der Bohrlöcher (Ebene)
2. Dimension: Bohrloch- Nummer (Winkel)
3. Dimension: Bohrlochtiefe

Bei der zufälligen Auswahl wird der Besonderheit des Kreises mit der Berücksichtigung von Wichtungsfaktoren für die Zufallszahlen Rechnung getragen. Damit ist ein Volumenelement durch die Angabe von drei Zahlen, entsprechend der drei Dimensionen, eindeutig bestimmt.

2.2.3 Probenentnahmeplanung

Entsprechend der im Voraus zu berechnenden Probenmenge wird der Probenentnahmeplan erstellt. Aus den feststehenden Parametern der Geometrie (Anzahl der Höhenlinien, Bohrlöcher je Höhenlinie und dem Zylinderdurchmesser) und der gewünschten Anzahl der Bohrelemente je Bohrloch steht die Anzahl der zu entnehmenden Bohrelemente fest. Mit diesen Angaben erhält man interaktiv am PC den für die Methode elementaren zufallsgenerierten Probenentnahmeplan. In *Abbildung 1* sind beispielhaft zwei zufällig ausgewählte (hintereinander liegende) Volumenelemente für ein Bohrloch angegeben:

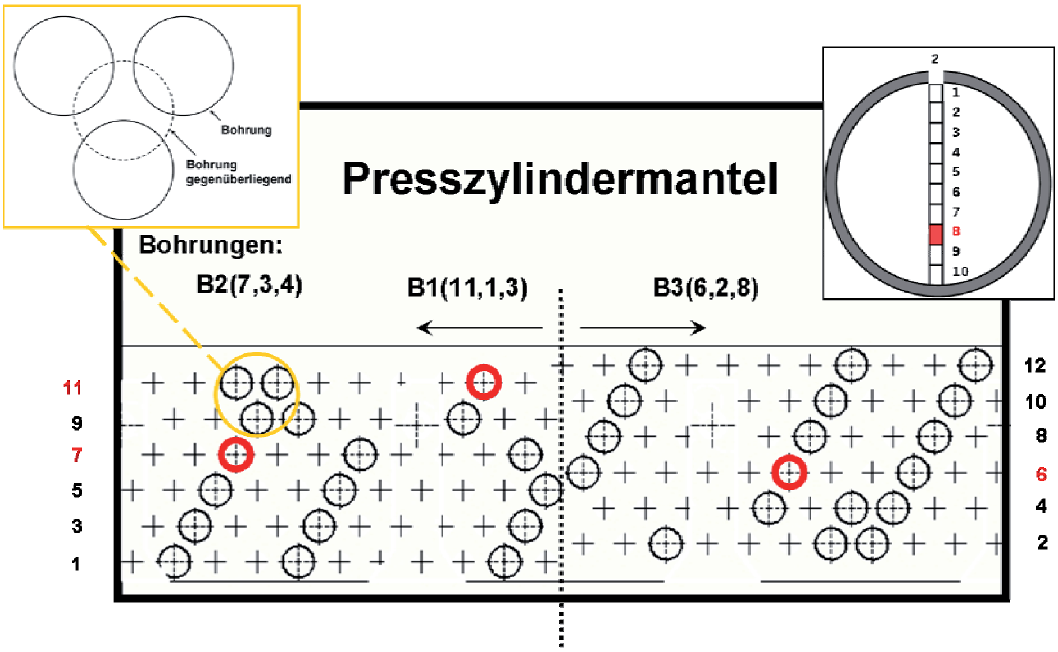


Abbildung 1: *Vereinfachtes Bohrbild (für nur drei Bohrungen je Höhenlinie)*

Die Reihenfolge für die Entnahme der Bohrelemente ist so ausgewählt, dass die ursprüngliche Zuordnung der Bohrelemente zu den Volumenelementen im Pressling durch die Entnahme von Bohrelementen nicht verändert wird bzw. ungestört bleibt. Es sollen, wie aus *Abbildung 1* ersichtlich, B(5,3,2) und B(5,3,4) entnommen werden. Der Probenentnahmeplan berücksichtigt nach analogem Prinzip auch die beiden anderen Dimensionen durch Sortierung. Ebenso werden durch den Zufallszahlengenerator (Microsoft Office Excel 2003) doppelt bestimmte Elemente zugleich durch andere ersetzt. Ein Probenentnahmeplan besteht aus den geometrieabhängigen Eingabedaten laut *Tabelle 1*, mit denen der Zufallsgenerator Bohrelemente generiert, welche in *Tabelle 1* ausgegeben werden. Die fett/rot markierten Elemente entsprechen dabei denen des Beispiels aus der *Abbildung 1*.

Tabelle 1: *Probenentnahmeplan Teil I – Eingabedaten*

aktuelle Geometrie	
Anzahl der Bohrlochebenen	***12***
Anzahl der Bohrlöcher je Ebene	***3***
Anzahl der Elemente je Bohrloch	***10***
Durchmesser des Zylinders in cm	***10,00***
Länge eines Bohrelementes in cm	***1,00***
Anzahl der gewünschten Bohrelemente	***10***

Tabelle 2: *Probenentnahmeplan Teil II – zu entnehmende Bohrelemente*

	Bohrelemente		
Lfd. Nr.	Bohrlochebene	Bohrloch Nr.	Element Nr.
1	12	1	1
2	12	1	2
3	7	1	1
4	7	2	10
5	***5***	***3***	***2***
6	***5***	***3***	***4***
7	2	3	2
8	2	3	3
9	2	3	7
10	1	3	8

Bei Parallelanalysen oder mehreren Analysenparametern wie z. B. die Erfordernis neben der klassischen Doppelbestimmung des Heizwertes und des Chlorgehaltes auch Schwermetalle, den Aschegehalt oder den anorganischen bzw. wasserlöslichen Chlorgehalt über Extraktion zu bestimmen, reicht der einfache Probenentnahmeplan nicht aus, ohne das Bohrgut willkürlich teilen zu müssen. Daher wurde der Probenentnahmeplan zum Kombiplan erweitert, welcher unter Berücksichtigung der Zylindergeometrie und der Anzahl unabhängiger Analysenproben zufallsgenerierte Element nach Probe (Plan Nr.) sortiert ausgibt.

Die Funktionsfähigkeit und Praktikabilität der Pressbohrmethode unter Anwendung des erarbeiteten Probenentnahmeregimes konnte vielfach nachgewiesen werden und es zeigte sich, dass die Fehler im Vergleich zu den bisherigen Standardmethoden erheblich geringer bzw. die erzeugten Analysenproben um ein Vielfaches repräsentativer sind. Die Ergebnisse an zahlreichen realen Sekundärstoffsystemen belegen deutlich die geringeren Streuungen innerhalb der Doppelbestimmungen und der **Datenkollektive** und damit die genaueren Ergebnisse. Vor allem der Vorteil der geringen Entmischung und der Ausschluss von subjektiven Einflussnahmen bei der Teilchenzuordnung verringern die systematischen Fehlerquellen bei der Erzeugung repräsentativer Analysenproben erheblich.

3 Analytische Möglichkeiten zur Chlorbestimmung unter Anwendung der Pressbohrmethode

Von besonderem Interesse ist der Chlorgehalt. Grundsätzlich lassen sich die Chlorverbindungen in organische und anorganische Formen unterscheiden, welche sich aus Abfällen und Abfallkomponenten im thermischen Prozess unterschiedlich freisetzen. Demzufolge ist es sinnvoll und notwendig, die Chlorbindungsformen zu ermitteln.

Chlor liegt in der biogenen Fraktion von Ersatzbrennstoffen hauptsächlich in Form von wasserlöslichen anorganischen Salzen wie Natrium- und Kaliumchlorid vor, bei denen ein Ionenaustausch erfolgen kann. Durch die Bestimmung des wasserlöslichen Natrium- und Kaliumgehaltes ist zusätzlich eine Abschätzung des aggressiven Anteils dieser Elemente in Bezug auf eine mögliche Verschlackung und Verschmutzung möglich. Die hohen Ablagerungsraten von z. B. KCl und NaCl an Dampferzeugern führen zu Korrosion unter den Belägen, so dass besonderes Augenmerk auf diesen anorganischen Chlorgehalt am Gesamtchlorgehalt gelegt werden muss. Folgerichtig ist die Kenntnis über den Anteil anorganisch gebundener Chlorfracht ein wichtiger Indikator für das Korrosionspotential des EBS. Aufgrund des mehrfach nachgewiesenen Minderbefundes der Chlorfracht bei der Bestimmung mittels Aufschluss im Kalorimeter, wird die Notwendigkeit der differenzierten Analyse unterstrichen.

Die Hochtemperaturchlorkorrosion kann grob in die folgenden zwei Problemkreise unterteilt werden:

a) Ablagerung

Wie Untersuchungen der Reaktionsflächen zeigten, beinhalten die Ablagerungen hohe Konzentrationen von Chloriden und Sulfaten, die eutektische Schmelzen bilden und Ursache der Salzschmelzenkorrosion sind. Unter den Ablagerungen auf den Dampferzeugerheizflächen wurden Abtragungen durch Eisenchloridbildung und die Auflösung der Oberflächen in Salzschmelzen gemeinsam beobachtet [Born, 2005]. Es kommt also letztlich zur Hochtemperaturchlorkorrosion durch Anlagerung bzw. die Aufkonzentrierung von Chloriden durch den Eintrag vor allem der Alkalichloride NaCl und KCl.

b) Abgas

Bei der Chlorwasserstoffkorrosion hängt die Korrosionsgeschwindigkeit von den HCl-Konzentrationen im Rauchgas und von der Oberflächentemperatur der Heizflächen ab. Je höher die Oberflächentemperatur ist, desto schneller laufen die Korrosionsreaktionen zwischen Chlorwasserstoff und dem Rohrwerkstoff ab. HCl wird hierbei durch die thermische Zersetzung insbesondere der PVC-Fracht im EBS gebildet.

Unter Berücksichtigung der vielfältigen Einflussfaktoren auf das Korrosionsrisiko eines Brennstoffs ist die gängige Praxis der singulären Angabe eines Chlorgrenzwertes als Summenparameter für EBS unzureichend. Vielmehr muss vom wenig aussagekräftigen Gesamtchlorgehalt zu einer nach Bindungsform differenzierten Betrachtung übergegangen werden.

Die Pressbohrmethode ermöglicht neben der Gewinnung von festen Analysenproben, dem Bohrgut, auch die Gewinnung einer flüssigen Phase, der Pressflüssigkeit (vgl.

Abbildung 2). Diese kann alternativ zu den gängigen DIN-Verfahren Elution und Extraktion zur Bestimmung des Anteils anorganischer Chlorfracht am Gesamtchlorgehalt genutzt werden.

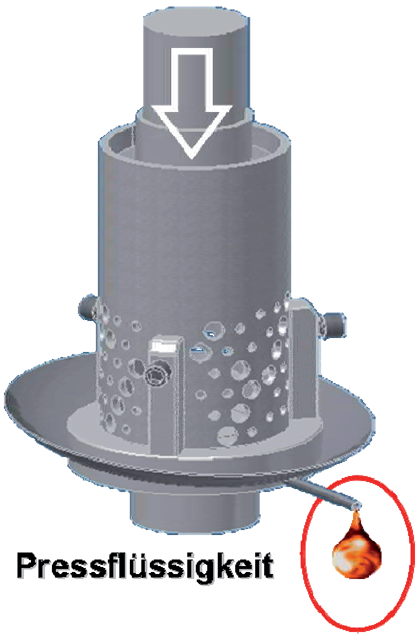


Abbildung 2: *Gewinnbare flüssige Phase mittels Pressbohrmethode*

3.1 Untersuchungen zum Nachweis des Minderbefundes anorganischer Chlorfracht durch Kalorimeteraufschluss

In den Probenahme-, Probenaufbereitungs- und Analysenvorschriften für Sekundärbrennstoffe im Rahmen des RAL-Gütezeichens 724 der BGS [BGS, 2008] wurde zur Chloranalyse fester Brennstoffe der Kalorimeteraufschluss mit anschließender Ionenchromatographie festgelegt. Dabei handelt es sich bei dieser Standardmethode um eine zweistufige Kombination aus Verbrennungsaufschluss im Bombenkalorimeter nach DIN 51900-2:2003-05 zur Zerstörung der organischen Matrix und anschließender Analyse der in wässriger Matrix absorbierten Chloride mittels Ionenchromatographie nach DIN 51727:2001-06. Zur vollständigen Erfassung der Chlorfracht ist zwischen diesen beiden Stufen eine Gaswäsche vorgesehen. Eine eingehende Literaturrecherche ergab, dass durch den unvollständigen Kalorimeteraufschluss mit einem Chlor- Minderbefund zu rechnen ist. Der in den Verbrennungsrückständen verbleibende nicht erfasste Chloranteil, der bei der Analytik mittels IC fehlt, führt also bei der konventionellen Feststoffanalyse unweigerlich zu einem Minderbefund mit einem unbekannten Betrag (siehe *Abbildung 3*).

Mit der Differenzierung in brennbare und nicht brennbare Anteile, lassen sich qualitative Aussagen zu Chlorgehalten in Abfällen ableiten. Rückschlüsse auf die Bindungsform lassen sich treffen, indem man den brennbaren Anteil der organischen Bindungsform gleichsetzt und den nicht brennbaren Anteil entsprechend der anorganischen. Da in großtechnischen Feuerungen höhere Temperaturen als 600 °C vorliegen, lassen sich die Bezeichnungen brennbar und nicht brennbar nicht direkt auf die Praxis übertragen. Dennoch stellt diese Methode einen richtigen Ansatz zur differenzierten Betrachtung des Gesamtchlorgehaltes und zum qualitativen Nachweis des Minderbefundes von Chlor durch den Kalorimeteraufschluss dar.

Wenn dieser Minderbefund also auf die Verbrennungsrückstände zurückzuführen ist, liegt nahe diese eingehender zu betrachten. Als Analyseverfahren zur qualitativen Bestimmung der in den Verbrennungsrückständen verbleibenden Chlorfracht eignet sich in besonderem Maße die Röntgenfluoreszenzspektroskopie. Die *Abbildung 3* zeigt das dabei angewandte Vorgehen zum qualitativen Nachweis des Chlor- Minderbefundes durch den Kalorimeteraufschluss. Dazu wurden mittels PBM unter Anwendung eines Kombi-Probenentnahmeplans 5 Parallelproben aus einer EBS- Stichprobe entnommen. Anschließend wurden diese getrocknet und mittels Ultrazentrifugalmühle (Retsch ZM 100) auf 1 mm zerkleinert. Die Gefahr eines Verlustes an flüchtigen chlororganischen Verbindungen während der Trocknung und Zerkleinerung wurde als vernachlässigbar angesehen. Nach dem separaten Aufschluss jeder der 5 Analysenproben von jeweils 0,9 - 1,2 g TS im Bombenkalorimeter (IKA C2000 basic), wurden die Verbrennungsrückstände aus den Quarztiegeln vereint um eine genügend große Probe zur RFA (Spectro iQ2) zu erhalten. Anschließend wurden die Verbrennungsrückstände getrocknet und mittels Scheibenschwingmühle (Retsch RS 200) pulverisiert.

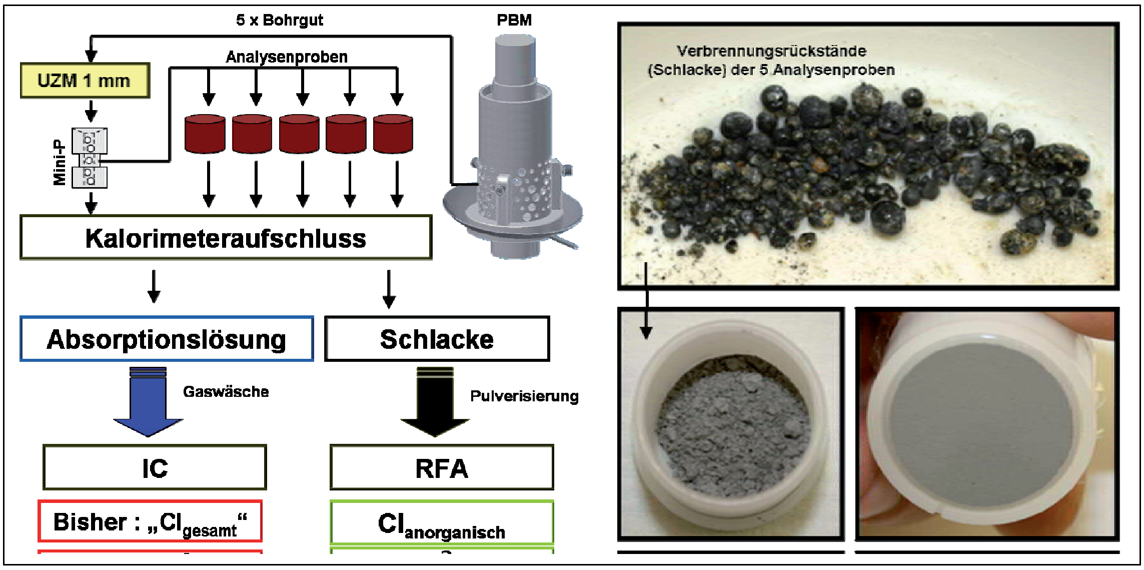


Abbildung 3: *Qualitativer Nachweis von $Cl_{anorg.}$ im Verbrennungsrückstand*

Die anschließende Messung der feinstzerkleinerten Verbrennungsrückstände mittels RFA ergab nach dem Schüttelvorgehen, d. h. Mehrfachmessung mit zwischenzeitlicher Umwälzung der Probe zur Veränderung der gemessenen Oberfläche, eine marginale

Spannweite von 0,0002 M.-% Cl. Es ist also relativ sicher, dass eine homogene Probe erzeugt werden konnte. Da mittels RFA Chlor elementar gemessen wird und durch den Kalorimeteraufschluss alle brennbaren bzw. organischen Chlorverbindungen fehlen, ist der an dieser Stelle gemessene Chlorgehalt von 0,433 M.-% TS als Mittelwert mit großer Sicherheit anorganischen Ursprungs. Dabei wurde der Rückschluss des Mittelwertes mit dem Aschegehalt auf die Trockensubstanz der Probe vorgenommen. Der RFA-Mittelwert der fünf Bohrgüter vor der Verbrennung im Kalorimeter ergab 0,828 M.-% TS. Da die mittels RFA- Messung erhaltenen Chlorgehalte aufgrund der matrixbedingten Methodenauswahl und Kalibrierung nicht direkt vergleichbar sind, ist eine stichfeste Ableitung von Ergebnissen sehr schwierig. Es kann jedoch gefolgert werden, dass ein beträchtlicher Anteil der Gesamtchlorfracht anorganisch gebunden vorliegt und bei der Bestimmung von „$Cl_{ges.}$“ über Ionenchromatographie nach Kalorimeteraufschluss nicht erfasst wird.

$$"Cl_{ges.}" = Cl_{IC} \qquad \text{ist unrichtig.} \tag{1}$$

Somit ist die bisherige Vorgehensweise $Cl_{ges.}$ mittels IC nach Kalorimeteraufschluss nachzuweisen, unzulässig und muss kritisch hinterfragt werden. Es lässt sich ableiten, dass sich der Gesamtchlorgehalt eher aus dem mittels IC nach dem Verbrennungsaufschluss im Kalorimeter ermittelten, fast ausschließlich organisch gebundenem und dem anorganischen Chlorgehalt additiv zusammensetzt. Dann ergibt sich nach obiger Beziehung:

$$Cl_{ges.} = Cl_{org.} + Cl_{anorg.} \tag{2}$$

Der Minderbefund von Chlor bei dem Standard-Aufschluss im Kalorimeter konnte über die Spektroskopie der Verbrennungsrückstände bestätigt werden. Die Neubewertung der bisherigen Standard- Chloranalytik in Bezug auf den Parameter Gesamtchlorgehalt erscheint somit zwingend erforderlich.

3.2 Analytik anorganischer Chlorfrachten

Aufgrund des Minderbefundes anorganischer Chlorfracht bei der Bestimmung mittels Aufschluss im Kalorimeter, wird die Notwendigkeit der differenzierten Analyse unterstrichen. Die zwei gängigen DIN-Verfahren zur Quantifizierung des Gehaltes anorganischer Chlorfracht beruhen auf der Auslaugung der löslichen Chlorfrachtanteile mit Wasser als geeignetes Unterscheidungskriterium. Die wasserlösliche Chlorfracht entspricht also nach beiden DIN-Verfahren im weiteren Sinn der anorganischen. Immer mehr

EBS-Verwerter gehen derzeit dazu über, die anorganische bzw. wasserlösliche Chlorfracht über die Auslaugung nach DIN 38414-S4:1984-10 Bestimmung der Eluierbarkeit mit Wasser bzw. DIN EN 12457-4:2003-01 oder DIN CEN/TS 15105:2005-10 Extraktion, separat zur erweiterten Qualitätsbeurteilung bestimmen zu lassen, um der technisch weitgehend unbeherrschten Hochtemperaturchlorkorrosion entgegen zu wirken bzw. diese durch entsprechende Maßnahmen auf ein vertretbares Maß zu reduzieren. Insbesondere mit steigendem Organikanteil im Brennstoff und somit steigenden Anteilen anorganisch gebundener Chloride, ist die vollständige und differenzierte Kenntnis der Chlorfracht von Interesse.

3.2.1 Analytik der Pressflüssigkeit

Pressflüssigkeit kann mittels Pressbohrmethode bei EBS ab einem Wassergehalt von 25 M.-% und einer Verdichtung von ~ 3,6 MPa ohne weiteres gewonnen werden. Ist Pressflüssigkeit für Analysenzwecke gewünscht und der Wassergehalt der Probe reicht für deren Gewinnung nicht aus, so kann der Wassergehalt der Probe operativ so eingestellt bzw. konditioniert werden, dass sicher Pressflüssigkeit anfällt. Nach *Formel 3* kann mit Kenntnis des Wassergehaltes, die der Originalprobe zuzugebende Wassermenge zur Erreichung des Wassergehaltes, der Pressflüssigkeit garantiert, errechnet werden.

$$m_{H_2O} = \frac{WG_{soll} \cdot m_{TS}}{100 - WG_{soll}} - \frac{WG_{ist} \cdot m_{TS}}{100 - WG_{ist}} \qquad (3)$$

m_{H2O}	Masse der Wasserzugabe in g;
WG_{soll}	der einzustellende Wassergehalt in M.-% OS;
m_{TS}	Masse der Trockensubstanz der zu befeuchtenden Originalprobe in g (m_{OS}*((100-WG_{ist})/100);
WG_{ist}	gemessener Wassergehalt in M.-% OS.

Ist der Austritt von Pressflüssigkeit mit oder ohne vorherige Konditionierung des Wassergehaltes gegeben, so kann diese, wie aus *Abbildung 4* ersichtlich wird, zur Analyse von $Cl_{anorg.}$ eingesetzt werden.

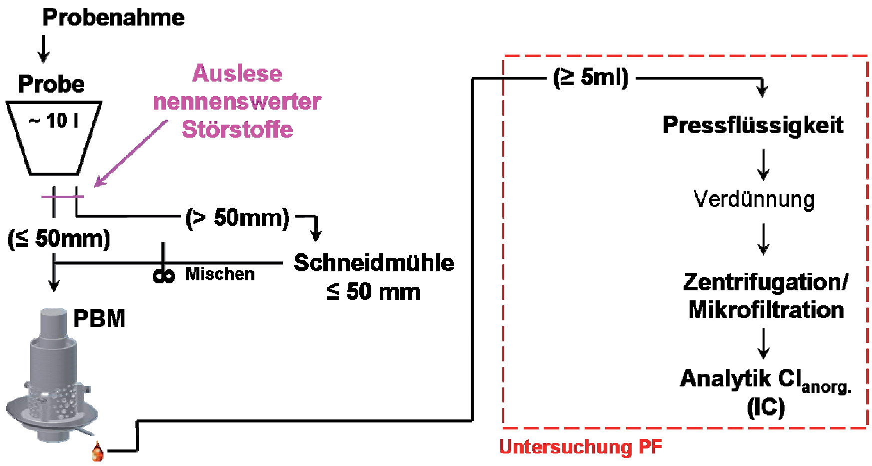


Abbildung 4: *Analysenregime Pressflüssigkeit*

Die aufgefangene Pressflüssigkeit kann also nach entsprechender Verdünnung zwischen V_f = 250 - 1000 direkt in den Ionenchromatograph mit integriertem Probenvorbehandlungsmodul (Dialysezelle) oder nach manueller Mikrofiltration, z. B. mittels Spritzenfilter, analysiert werden. Wurde der Wassergehalt der Probe konditioniert, muss das Zugabewasser als Verdünnung berücksichtigt werden. Die Pressflüssigkeit, die einer solchen Vorverdünnung unterliegt, wird daher als PF^+ bezeichnet. Die Berücksichtigung dieser, im Vorfeld der Gewinnung der Pressflüssigkeit verursachten Verdünnung, findet nach der folgenden *Formel 4* statt.

$$c_1 = \frac{c_2 \cdot V_2}{V_1} \quad (4)$$

c_1	Konzentration in der ursprünglichen PF in mg/l
c_2	Konzentration in der (durch Wasserzugabe entstandenen) PF^+ in mg/l
V_2	Volumen des Gesamtwassers, d. h. ursprünglich enthaltenes- plus zugegebenes Wasser in ml
V_1	Volumen des ursprünglich enthaltenen Wassers in ml

Die in der Pressflüssigkeit gemessenen Gehalte an anorganisch gebundener bzw. wasserlöslicher Chlorfracht liegen zunächst mit der Einheit mg/l vor. Um die Vergleichbarkeit der Ergebnisse mit denen der Elution und Extraktion zu ermöglichen, deren Umrechnung auf mg/kg_{OS} bzw. mg/kg_{TS} erfolgt, muss auch hier umgerechnet werden. Dies erfolgt nach *Formel 5*.

$$\omega_{TS} = \frac{(c - c_0) \cdot V_{H_2O}}{m_{TS}} \quad (5)$$

ω_{TS} Massenanteil des Stoffes in der Trockensubstanz in mg/kg TS

c_0 in der Blindwertbestimmung vorhandene Konzentration des Elementes im Zugabewasser in mg/l

c In der Pressflüssigk. vorhandene Massenkonzentration des Elementes in mg/l

V_{H2O} Volumen des Gesamtwassers, d. h. ursprünglich enthaltenes- plus zugegebenes Wasser in l

m_{TS} Masse der Trockensubstanz der verpressten Probe in kg TS

Analog kann der Massenanteil des betreffenden Stoffes in der Originalsubstanz errechnet werden, indem man in der *Formel 5* anstelle der Trockenmasse die Masse der verpressten Probe im Originalzustand einsetzt. Dabei ist unbedingt die ursprüngliche Masse der Originalsubstanz einzusetzen, da das zugegebene Wasser nicht Bestandteil der eigentlichen Originalsubstanz ist. Bei den Berechnungen ist zudem darauf zu achten, dass bei einer Konditionierung des Wassergehaltes entweder das Volumen des ursprünglich enthaltenen Wassers und die entsprechend korrigierte Elementkonzentration der PF oder das Volumen des Gesamtwassers aus ursprünglichem- und Zugabewasser und die Elementkonzentration der PF^+ eingesetzt wird.

3.2.2 Verfahrensvergleich

Mittels Pressbohrmethode besteht neben der Gewinnung von repräsentativen Feststoffproben die sowohl technisch einfache als auch ökonomisch günstige Möglichkeit zur Erzeugung von Pressflüssigkeit. Im Rahmen der Praxiseinsätze zur Integration der Pressbohrmethode in die Routineanalytik zwei der größten deutschen Labordienstleister konnte unter anderem, nach vorheriger Konditionierung der Wassergehalte, Pressflüssigkeit gewonnen werden. Der Vergleich der Analysenergebnisse anorganischer Chlorfrachten zwischen der Extraktion nach DIN CEN/TS 15105:2005-10 und der Analyse der Pressflüssigkeit ergab eine ausgesprochen gute Korrelation. Im Weiteren soll auf den folgerichtigen Vergleich der Bestimmung von $Cl_{anorg.}$ über die Pressflüssigkeit mit der Bestimmung aus dem aufwändig hergestellten Eluat bzw. Extrakt der DIN-Verfahren Elution und Extraktion eingegangen werden. Die Praxis in den Analyselaboratorien zeigte, dass es einerseits zum Teil Defizite bei den Messmethoden selbst gibt. Andererseits interessierte die Frage, wie schnell und genau die Analysen vorgenommen werden können. Zudem spielt sowohl der monetäre als auch zeitliche Aufwand bei den zur Verfügung stehenden DIN- Verfahren eine immer bedeutendere Rolle. Der Methodenvergleich zur Erzeugung von Proben zur Analyse anorganischer Chlorfrachten und die Einordnung der Pressbohrmethode gehen zusammenfassend aus der *Abbildung 5* hervor. Die *Tabelle 3* beinhaltet dazu einen Überblick des jeweiligen Vorgehens mit entsprechender Angabe der Dauer.

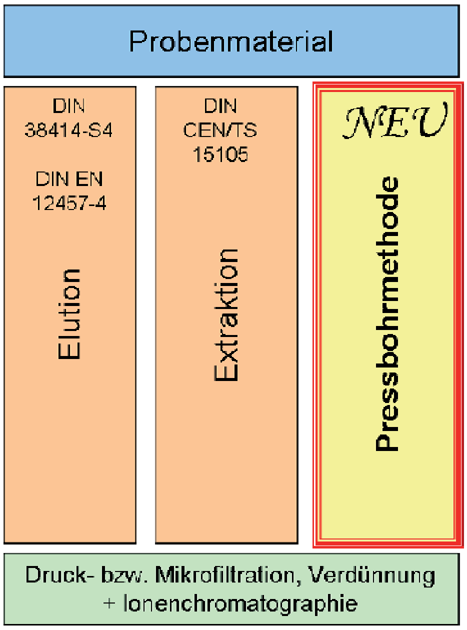


Abbildung 5: *Einordnung der Pressbohrmethode als Basis zur Analyse von $Cl_{anorg.}$*

Tabelle 3: *Vergleich der DIN-Verfahren Extraktion und Elution mit der PBM*

DIN CEN/TS 15105 **(Extraktion; Oktober 2005)**	**DIN 38414-S4; DIN EN 12457-4** **(Elution; Oktober 1984; Januar 2003)**
- Zerkleinerung mittels Schneidmühle auf ≤ 10 mm. - Einwaage von **1,0 g Analysenprobe.** - Zugabe von 50,0 ml Wasser. - Vermischung durch Schwenken. - Geschlossenes Gefäß **60 min bei 120 °C erhitzen.** - **Abkühlung** auf Raumtemperatur. - Inhalt in einen 100 ml Messkolben überführen, Innenseite des Gefäßes mit einer geringen Menge Wasser waschen und hinzugeben. - Messkolben auf 100 ml mit Wasser auffüllen. - Einen Teil der Lösung Mikrofiltrieren (Membranfilter oder Spritzenfilter; Porengröße 0,45 µm)- dabei ist der erste Teil des des Filtrates zu verwerfen	- Zerkleinerung mittels Schneidmühle auf ≤ 10 mm. - Einwaage von **100 g Trockenmasse als Originalsubstanz**. - Zugabe von 1 l Wasser in die Weithalsflasche (Feststoff Flüssigkeits-Verhältnis 1:10). - Flasche **24 h langsam über Kopf drehen** (~10 U/min). - Abtrennung des ungelösten Rückstandes durch Filtrieren oder Zentrifugieren. - Bestimmung von pH-Wert und elektrischer Leitfähigkeit im Filtrat/ Zentrifugat. - Volumen des Eluats auf 10 ml messen. - Bei Stoffen, die schwer löslich sind bzw. zu großen Massenanteilen in der Probe vorhanden sind oder sich deren Lösungsverhalten während der Untersuchung verändert, ist mehrmalig zu eluieren (der Rückstand der behandelten Probe wird erneut mit 1 l destilliertem Wasser versetzt und 24 h über Kopf geschüttelt). einstufige Elution
Probenvorbereitung: ~ 1 h Durchführung: ~ 2 h Gesamtdauer: ~ 3 h	Probenvorbereitung: ~ 1 h Durchführung: ~ 25 h Gesamtdauer: ~ 26 h
Pressbohrmethode	
- Befüllung des Presszylinders (ggf. nach Konditionierung des Wassergehaltes) - Verpressung der Probe und Abführung der Pressflüssigkeit - Auspressen der Probe und Reinigung des Zylinders	
Probenvorbereitung: keine (ggf. Vorzerkleinerung bei > 50 mm; ggf. Konditionierung Wassergehalt) Durchführung: ~ **15 min** Gesamtdauer: ~ **20 min**	

Wie aus der vergleichenden Gegenüberstellung deutlich wird, sind die Standard- DIN-Verfahren zur Erzeugung einer flüssigen Analysenprobe zur ionenchromatographischen oder titrimetrischen Bestimmung von anorganischer bzw. wasserlöslicher Chlorfracht ungleich aufwändiger und durch die notwendigen Verbrauchsmaterialien deutlich teurer als die direkte Analytik der Pressflüssigkeit. Insbesondere die Gewinnung der zur Elution/ Extraktion erforderlichen repräsentativen Analysenproben bzw. Einwaagen von 100 g/ 1 g ist nach dem Stand der Technik mit einem unbekannten Fehlerbetrag behaftet.

Das *Diagramm 1* zeigt exemplarisch an Mittelwerten von drei Einzelmessungen einer Probe, ähnlich den Vergleichsanalysen der Praxiseinsätze, eine sehr gute Übereinstimmung der Messwerte von $Cl_{anorg.}$ über die Pressflüssigkeit mit den Standard DIN-Verfahren. Zudem weist die Dreifachbestimmung von $Cl_{anorg.}$ über die Pressflüssigkeit die deutlich kleinste Streuung bzw. Spannweite auf.

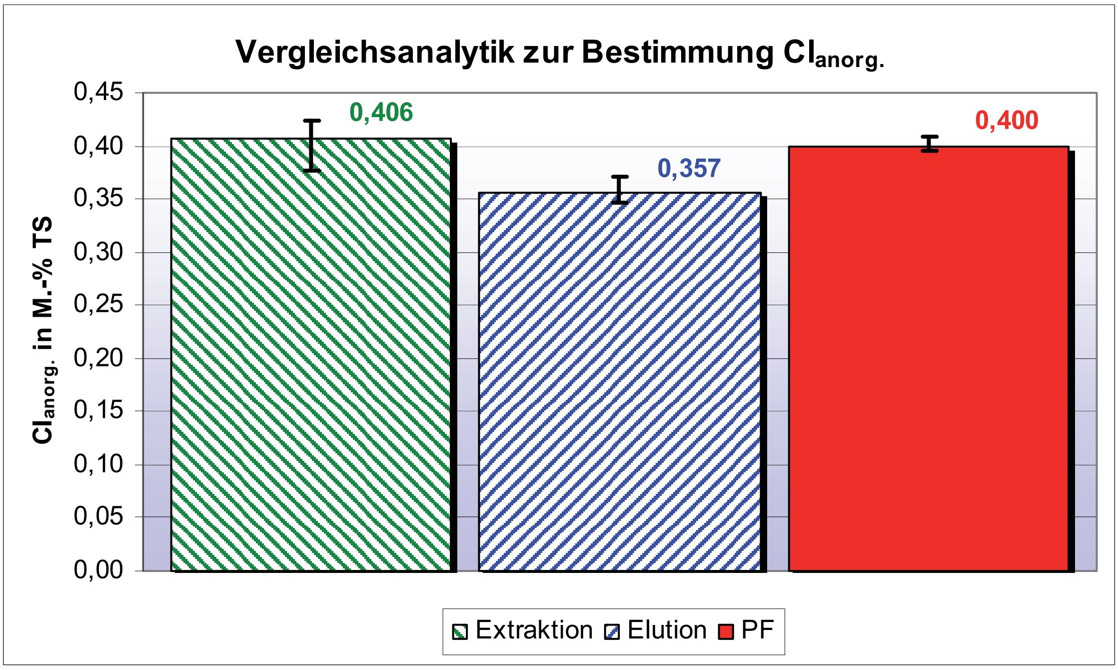


Diagramm 1: *Vergleichsanalytik zur Bestimmung von* $Cl_{anorg.}$

Das *Diagramm 2* belegt die Gleichwertigkeit der Analytik anorganischer Chlorfracht über die Pressflüssigkeit im Vergleich mit den DIN-Verfahren Extraktion und Elution. Untersuchungsgrundlage waren dabei 13 EBS- Proben verschiedener Herkunft. Auffällig ist dabei die Spannweite der anorganischen Chlorfracht innerhalb der Probenserie mit bis zu 0,4 M.-% TS und die gute Übereinstimmung der DIN-Verfahren Extraktion und Elution mit der direkten Analytik der Pressflüssigkeit. Unter Anbetracht der Heterogenität sind zudem die geringen Messwertschwankungen zwischen den angewendeten Verfahren beachtlich.

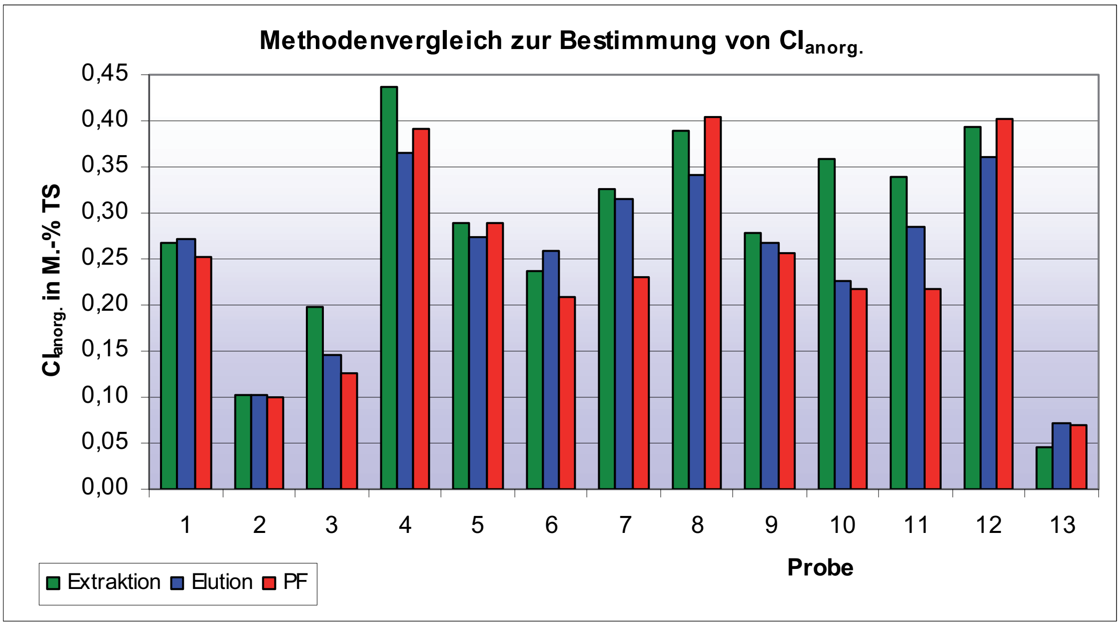


Diagramm 2: Methodenvergleich zur Bestimmung von $Cl_{anorg.}$

Die Analyse der Pressflüssigkeit zur quantitativen Bestimmung des Gehaltes an anorganischer bzw. wasserlöslicher Chlorfracht kann somit als gleichwertige und deutlich schnellere Alternative zu den aufwändigen DIN-Verfahren der Feststoff- Elution und -Extraktion gesehen werden.

Die neuen Möglichkeiten der differenzierten Chloranalyse unter Verwendung der Pressbohrmethode sollen letztendlich den Summenparameter Chlor relativieren und Auskunft über das Schadpotential des eingetragenen Gesamtchlorgehaltes geben. Zudem sollten die erzielten Ergebnisse dazu beitragen von der singulären Angabe eines wenig aussagekräftigen Gesamtchlorgehaltes, der zudem einen Minderbefund unbekannter Dimension beinhaltet, abzugehen.

Literatur

BGS	2008	Probenahme-, Probenaufbereitungs- und Analysenvorschriften für Sekundärbrennstoffe im Rahmen des RAL-Gütezeichens Sekundärbrennstoffe (RAL-GZ-724) Stand 31.10.2008
Born, M.	2005	Wissenschaftliche Grundlagen der rauchgasseitigen Dampferzeugerkorrosion. In: Born, M. [Hrsg.]: Rauchgasseitige Dampferzeugerkorrosion, Saxonia Standortentwicklungs- und Verwaltungsgesellschaft mbH, Freiberg

Anschrift der Verfasser:

Prof. Dr.-Ing. Sylvia Schade-Dannewitz
Dr. rer. nat. Jürgen Poerschke
Dipl.-Ing. (FH) Sebastian Döring
Fachhochschule Nordhausen
Weinberghof 4
D-99734 Nordhausen
Telephone: +49 3631 420 300
Telephone: +49 3631 420 402
Telephone: +49 3631 420 743
E-Mail: schade@fh-nordhausen.de
poerschke@fh-nordhausen.de
doering@fh-nordhausen.de
Website: www.fh-nordhausen.de

Für weiterführende Informationen stehen wir Ihnen gern zur Verfügung!

HEATING VALUE OF RESIDUES AND WASTE DERIVED FUELS FROM DIFFERENT WASTE TREATMENT METHODS

I.-S. Antonopoulos*, A. Karagiannidis*, E. Kalogirou**

* Aristotle University, Department of Mechanical Engineer - ** Waste to Energy Research and Technology Council, Greece

Abstract

Prevention of waste production at source, recycling of packaging waste and processing the organics are the main parts of the Hellenic waste management strategy. In the meanwhile recycling of packaging wastes may be compatible with incineration within integrated waste management systems. In order to estimate and calculate the energy potential of the Municipal Solid Wastes a mathematical model was structured taking into consideration the existing legislation and infrastructure on waste management plants and their residuals. Initial goal of this paper was the formulation of an appropriate model for forecasting the waste generation till 2030 taken into account the restrictions of the Landfill Directive 1999/31/EC. Afterwards, the recycling impact and the organic waste diversion in the heating value of the MSW were investigated.

Keywords

heating value, MSW, recycling, diversion, Directive 1999/31/EC

1 Introduction

In EU-27, 524 kg of Municipal Solid Waste (MSW) was generated per capita in 2008. Of the total amount of MSW in EU-27, 40% was landfilled, 20% incinerated, 23% recycled and 17% composted (EUROSTAT, 2010). In Greece in the year 2000, approximately 4.6 million tons of MSW was generated, which is an increase of 50% compared to 1990 (PAPACHRISTOU ET AL., 2009). In figure 1 is illustrated the waste generation in the Hellenic regions for the year 2006 (TEE, 2006), with the municipalities to be mostly responsible for collection, treatment and final disposal of the MSW. According to the Hellenic Technical Chamber, MSW in 2007 consisted of 40% organic material, 29% paper and cardboard, 14% plastic, 3% metal, 3% glass, 3% inert waste, 2% leather-wood-textiles and 6% other waste (TEE, 2006). In the same year, the collected recyclable materials were approximately 1050 kt, 38% of which were paper and cardboard, 28% plastics, 14% glass, 13% metals and 7% leather-wood-textiles. The main policy orientation in Greece is the maximization of material recovery through the implementation and extension of recycling programs with source separation in all the large municipalities, in addition to the construction of Material Recovery Facilities (MRF).Absolute priority is the remediation of the old open dumps and the construction of new sanitary landfills. Currently, 63 sanitary landfills exist, but only three of them are equipped with biogas system collection and flaring. According to the Directive 1999/31/EC considering waste landfilling, EU-countries are obliged to reduce the amount of landfilled Biodegradable Municipal Waste (BMW) to: i) 75% of the total amount of BMW generated in 1995 by 2010 (this target won't be achieved basing on the current situation and facts), ii) 50% of 1995 levels by 2013 and iii) 35% of 1995 levels by 2020. Moreover, the amendment of the Directive 2004/12/EC, 94/62/EC, obliges that no later than 31 December 2008, 60% by weight for glass, paper and cardboard, 50% for metals, 22.5% for plastics and 15% for wood should be recycled. Regarding to BMW management, currently 3 Mechanical Biological Treatment (MBT) plants operate in Greece (Liossia, Chania and Irakleio). Additionally until the end of 2010 1 more will start their operation, in Ditiki Elllada and the second in Peloponnisos (table 1). These 5 plants will have a total treatment capacity of 766.5 kt of residual MSW in 2010. Even though Regional Planning studies in Greece have proposed the construction of a new MBT or Waste-to-Energy (WtE) plants; at the moment (July 2010) plants seem to stall and if this situation remains no new plants are expected to operate before 2013. As a result of this situation, no new residual waste treatment will be constructed and all residual MSW will finally be disposed to sanitary landfills. Considering packaging wastes, the legislative framework (HELLENIC LAW 2939/2001, JOINT MINISTERIAL DECISION 9268/469 and DIRECTIVE 94/62/EC) set new recycling targets resulting into increase of recycling rates from 42.8% in 2006 to 44% in 2008 (EUROSTAT, 2007). Figure 2 illustrates the location and the number of the MRF. In this paper a mathematical model is presented which calculates the MSW composition applying different recycling rates of packaging materials or different diversion rates of the organic waste in order to identify the recycling impact in the heating value of the MSW.

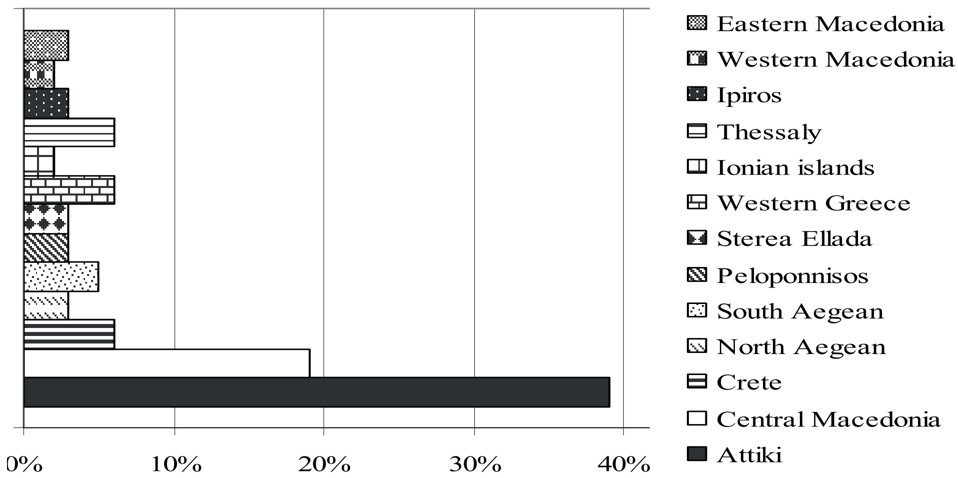


Figure 1 Waste generation in the Hellenic regions.

Table 1 MBT plants – current status in Greece, in combination with the map in Figure 2.

MBT	Capacity (kt)	Implementation year	Technology
Liossia	301	2004-2006	Composting
Chania	70	2005	
Peloponnisos	255	1997	
Irakleio	70	2010	Biodrying
Ditiki Ellada	70,5	2009	
To be constructed			
Attiki (I)	495	2010	Composting
Thessaloniki (SE)	120	2010	It isn't decided yet
Imathia	50	2010	
Serres	90	2010	
Thessaly	80	2010	
Eastern Macedonia-Thrace	60	2010	
Western Macedonia	106	2011	
Attiki (II)	660	2013	
Pella	30	2013	
Pieria	30	2013	
Ipiros	55	2013	
Kilkis	35	2020	

Figure 2 MRF and MBT plants – current status in Greece; in italics are the MBT plants which are planned to be constructed in accordance to table 1 and in bold are the MRF plants. The MBT plants location is referred to each region.

2 Methodology

2.1. Model overview

Figure 3 depicts an integrated waste management model taking into consideration the existing infrastructure in Greece. The described model (figure 3) combines the following attributes:

- separate collection at source, which depends on the mass fraction of each waste material,

- recycling of packaging materials and paper/cardboard,
- organic waste diversion and
- potential incineration of residues from MRF and MBT plants.

Main output of this model is the calculation of the heating value of the residuals MSW applying different diversion rates of each waste fraction.

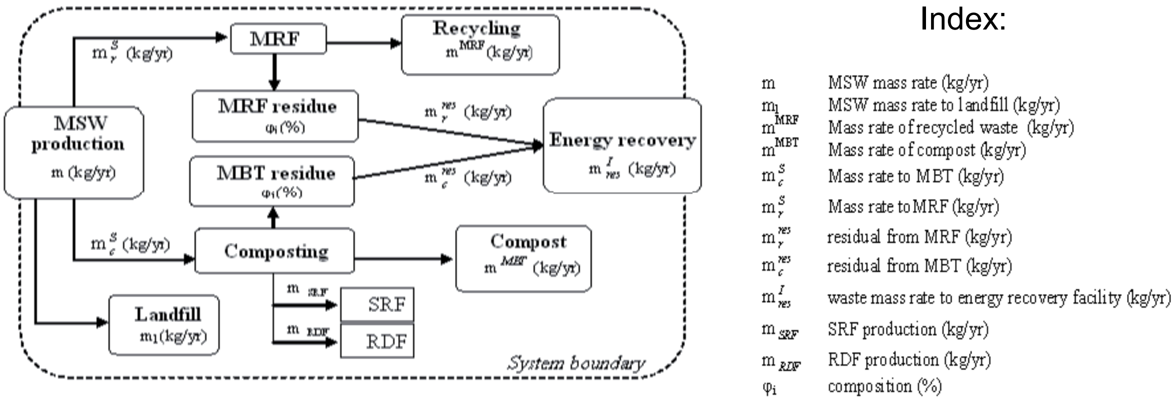


Figure 3 Model overview

In order to calculate the whole waste management system, the first step was to model the existing recycling and organic waste treatment plants and formulate their mass balance. The main target of modelling MBT and MRF plants was to estimate the amount of the residues and their composition in order to estimate then their heating value. Then the second step was to calculate the heating value of i) the MSW and ii) the residuals from the MRF and the MBT plants through appropriate mathematical equations. Especially for the MBTs, the produced quantities of Solid Recovered Fuels (SRF) and Refuse Derived Fuels (RDF) were taken into account together with various scenarios on the technology of the MBT plats which are planned to be constructed in the next years according to the National Planning (YPECHODE, 2007). Model's function is based on the following equations:

$$m = m_l + m_r^S + m_c^S \quad [1]$$

$$\phi_{i(i=c,r)} = \frac{\sum_{i=c,r} m_i^{res}}{m_r^S + m_r} \quad [2]$$

$$m_c^S = m_{SRF} + m_{RDF} + m^{MBT} + m_c^{res} \quad [3]$$

$$m_r^S = m^{MRF} + m_r^{res} \quad [4]$$

$$m_{res}^I = m_r^{res} + m_c^{res} \quad [5]$$

2.2 Waste predictions

For the estimation of the amounts of MSW disposed to sanitary landfills and trace out all the waste flows until 2030, it was assumed that new waste treatment plants according to National Regional Planning will be constructed with sufficient capacity to treat all residual MSW in Greece in order to diverse BMW from landfills and the targets of the Directive 1999/31/EC achieved. Moreover, it was assumed that recycling rate of packaging waste will increase gradually by 2011 in order to meet the revised targets of the Packaging Waste Directive (2004/12/EC), namely 55% w/w recycling of packaging waste and from then onwards packaging waste recycling will increase gradually every year. As far as other than packaging waste materials, it was assumed that recycling rate will increase gradually until 2030. Despite the aforementioned assumptions, at the moment (July 2010) in Greece there is no national waste strategy with specific targets on recycling after 2011. Figure 4 depicts the MSW Management in Greece until 2030, according to proposed model and aforementioned assumptions, taking into consideration a constant waste growth rate 1.1%, whilst figure 5 illustrates the BMW production and diversion that are described from the Directive 1999/31/EC.

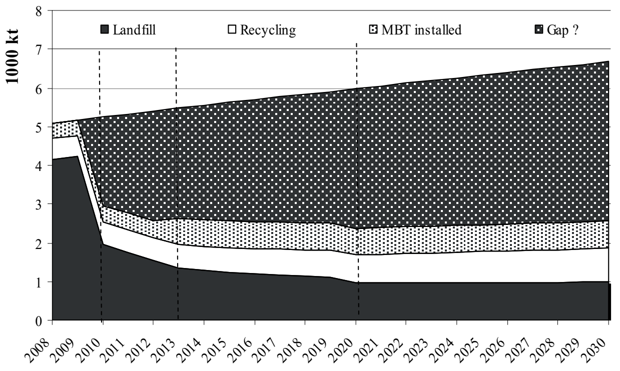


Figure 4 Predictions on waste management treatment methods.

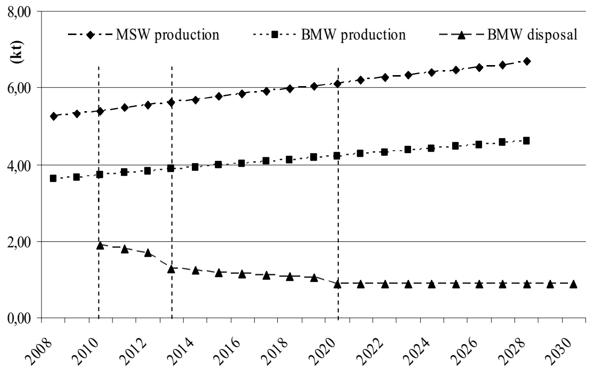


Figure 5 BMW disposal and diverted quantities according to Directive 1999/31/EC.

2.3 Modelling of waste management plants

2.3.1 MRF modelling

In order to calculate the final residues from the MSW and the recovered materials it was necessary to model the sorting process, which takes place in sorting plants. Figure 6 illustrates the total mass balance of a sorting plant on a Life Cycle Analysis (LCA) approach taking into consideration the operation of these plants in Greece. For instance residuals are approximately 30% of the inserted waste with a mixed composition of organics, inert, light plastics fractions and paper/cardboard.

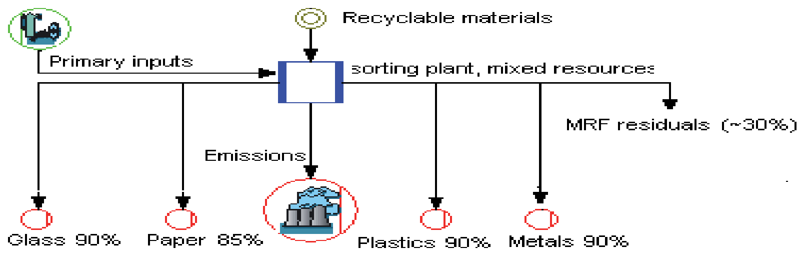


Figure 6 MRF Input/Output modelling.

2.3.2. MBT modelling

MBT reduces the mass and volume of wastes, due to the removal of recyclable materials and both carbon and moisture losses. The amount of reduction is very dependent on the design and technical characteristics of each plant (composting process or biodrying). MBTs which are equipped with biodry technology produce SRF, while composting plants produce RDF. Figure 7 illustrates the total mass balance for a composting plant (left figure) and biodrying plant (right figure) including RDF and SRF quantities, residuals and compost respectively. In case the proposed MBT plants indicated in Table 1 will be constructed, the total potential RDF/SRF quantities are those illustrated in figure 8 considering the installed technology on these plants.

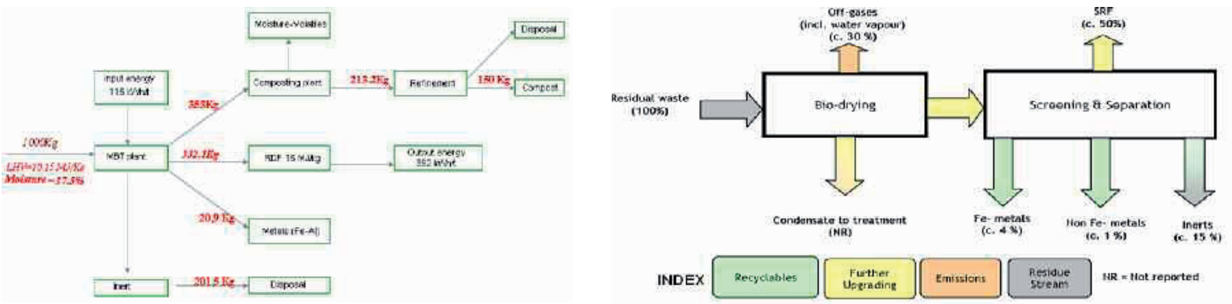


*Figure 7 MBT input/output modelling (*SCOULLOS ET AL.*, 2009 and* JUNIPER*, 2005).*

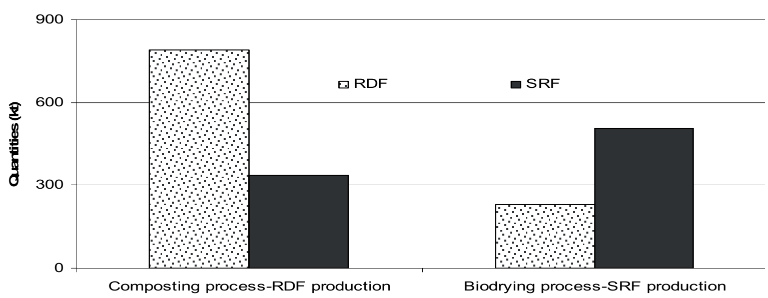


Figure 8 RDF and SRF quantities considering that scheduled MBT plants will be constructed taking into consideration the two scenarios: i) MBT plants with composting process and ii) MBT plants with biodrying process.

2.4 Heating value calculations

An interesting option in waste management and energy recovery is the MSW incineration. Apart from the produced energy, thermal process also reduces MSW mass by as much as 70% and MSW volume by up to 85%. Higher Heating Value (HHV) and Lower Heating Value (LHV) are important knowledge for judging it's worth using waste as fuel. In practice, the HHV of a solid mixture, candidate to use as fuel in a thermal process, is determined by a calorimetric test bombing. On the other hand, it is possible to calculate HHV and/or LHV by using appropriate mathematical equations which are based on the chemical parameters of the waste in a wet or in dry basis respectively (MERAZ ET AL., 2003). Dulong in the early 1800s demonstrated that the heating value of a solid mixture could be determined from its chemical composition, making certain assumptions about the heat released from each of the element by using appropriate coefficients (CHANG ET AL., 1997). Afterwards, Lloyd and Davenport, De Boie and Wilson formed other mathematical equations so as to obtain better results in calculating HHV. Table 2 illustrates the results of using each of the aforementioned equations compared by experimental results bringing the most accurate mathematical form. LHV is calculated by using appropriate mathematical forms or by subtracting from HHV the moisture together with the hydrogen contents. In this study, Dulong equation was used to determine the HHV and LHV was calculated by subtracting the moisture and hydrogen contents from each waste fraction (equation 1 and 2). Table 3 summarizes the chemical waste composition in a dry basis and the HHV and LHV for each waste fraction and table 4 illustrates the physical waste composition in combination with the LHV and HHV.

Table 2 MSW HHV calculation using published mathematical forms; in italics are depicted the most accurate results compared with experimental results.

Waste fraction	Lloyd and Davenport	De Boie	Wilson	Dulong	Experimental
Paper/cardboard	17.41	16.44	15.33	*14.81*	**15.8**
Food waste	6.44	6.11	5.81	*5.57*	**5.51**
Plastic	27.16	26.4	26.37	*25.77*	**32.56**
Textile	22.33	21.48	20.77	*20.14*	**17.24**
Rubber	27.15	26.81	27.25	*26.77*	**25.33**
Leather	38.59	*38.4*	40.14	39.69	**36.24**
Glass	0.26	0.25	0.25	*0.24*	**0.14**
Metal	1.88	1.76	1.63	*1.55*	**0.7**
Yard waste	8.37	7.93	7.46	*7.14*	**6.51**

3 Results and Discussion

In order to examine the influence of the diversion rates on the heating values of the MSW it is a prerequisite to calculate/estimate the physical MSW composition. LHV of the residual MSW applying different recycling and diversion rates for packaging materials and biodegradable waste respectively. The effect of varying the recycling and diversion rates of all the waste fractions simultaneously is displayed in figure 9. The recycling of paper packaging reduces the LHV of the residual waste but only 14% (when recycling rate is 100%). Although the plastic packaging percentage in the MSW composition is much smaller than that of paper packaging (see table 4), the recycling impact in LHV is much more (about 60% reduction of the LHV).

Table 3 Chemical waste composition, HHV and LHV values in a dry basis.

Waste fraction	Content (%)							(MJ/kg)	
	Moisture	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur	Ash	HHV	LHV
Paper/cardboard	70	48	6.4	37.6	2.6	0.4	5	7.08	3.96
Food waste	6	43.5	6	44	0.3	0.2	6	14.49	13.03
Plastic	2	60	7.2	22.8	0	0	10	26.11	24.48
Textile	10	55	6.6	31.2	4.6	0.2	2.5	20.17	18.47
Wood waste	20	49.5	6	31.2	4.6	0.2	2.5	15.96	14.16
Yard waste	60	47.8	6	38	3.4	0.3	4.5	7.94	5.16
Glass	2	0.5	0.1	0.4	0.1	0	98.9	0.23	0.16
Metal	3	4.5	0.6	4.3	0.1	0	90.5	1.55	1.35
Other	20.5	20.91	2.39	12.78	0.4	0.1	42.93	6.72	5.69

Table 4 Waste Heating Value and physical waste composition.

Waste fraction	Composition (%)	HHV (MJ/Kg)	LHV (MJ/Kg)
Organics	40	3.00	1.82
Paper/cardboard	29	4.20	3.78
Plastic	14	3.66	3.43
Glass	3	0.01	0.00
Metal	3	0.05	0.04
Leather-Wood-Textile	2	0.36	0.33
Inert	3	0.01	0.00
Other	6	0.40	0.34
Total		11.69	9.75

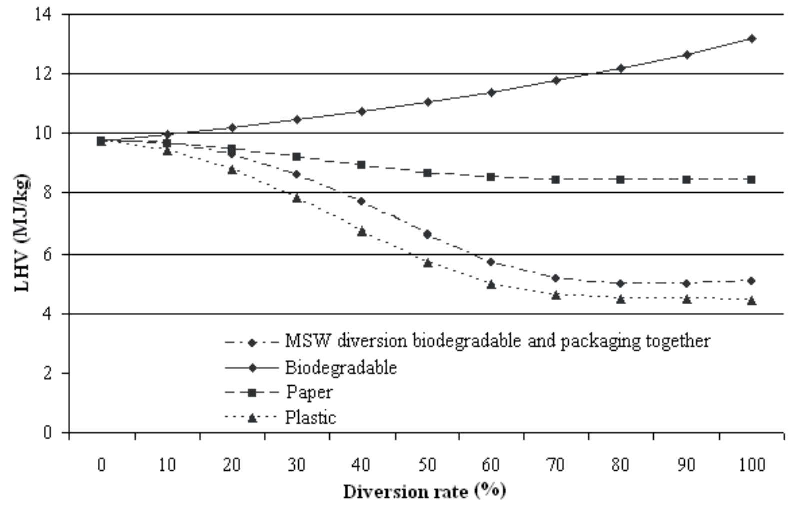


Figure 9 MSW heating value applying different diversion rates and recycling rates in biodegradable and packaging waste respectively.

The separate collection of biodegradable waste and packaging materials has a strong negative impact on the LHV of the residual waste because of the high moisture content. On the opposite, the diversion of the biodegradable waste has a positive impact on the LHV of the residual waste due to the low moisture content in that fraction.

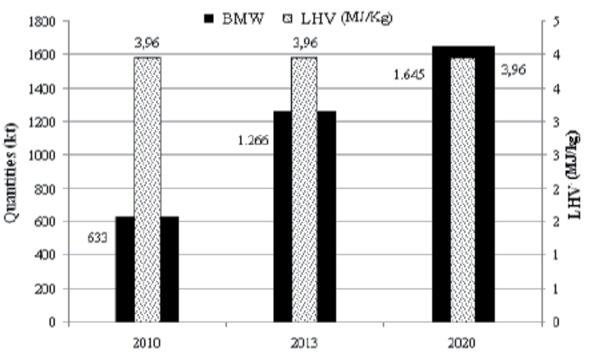


Figure 10 BMW diversion in combination with LHV and targets set by 1999/31/EC.

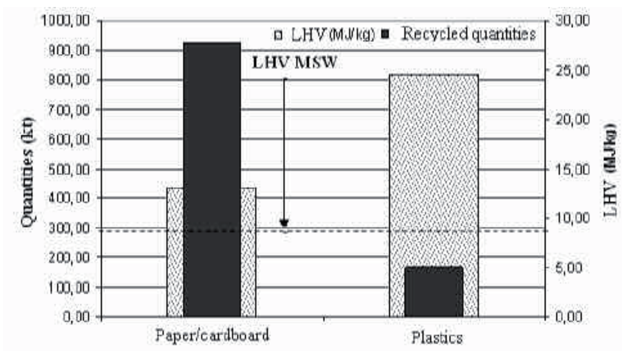


Figure 11 Packaging materials recycled in combination with LHV and targets set by 2004/12/EC.

As far as MBT and MRF residuals heating values are concerned, figures 12 and 13 illustrate the aforementioned comparison, taking into account two different scenarios depending on the MBT technology; whether the new MBTs have composting or biodrying technology. SRF can be distinguished from RDF in the fact that it is produced to reach an international standard (CEN/343 ANAS) and its heating value is estimated around 15 MJ/kg, whilst RDF heating's value is 18 MJ/kg. As it was previously stated in § 2.3.1 and 2.3.2, MRF residuals are approximately 30% of the inserted waste and its heating value is estimated to be about 5MJ/kg whereas MBT residuals which are consisted of mixed plastics, paper, organics and inert waste in a percentage of 15% of the inserted waste, with a heating value of 10.5 MJ/kg. Considering MBT residuals, when residual paper and light plastics fractions cannot establish a suitable RDF, then these fractions will be landfilled, increasing residual's heating value. Only a small account of the BMW content of the input waste is reduced in the biodrying process (less than with alternative composting processes that seek to fully biostabilise the waste). This is not an issue when the SRF is utilized as a fuel, but it would be if the SRF had to be landfilled or used in a WtE plant together with the residuals of the plant.

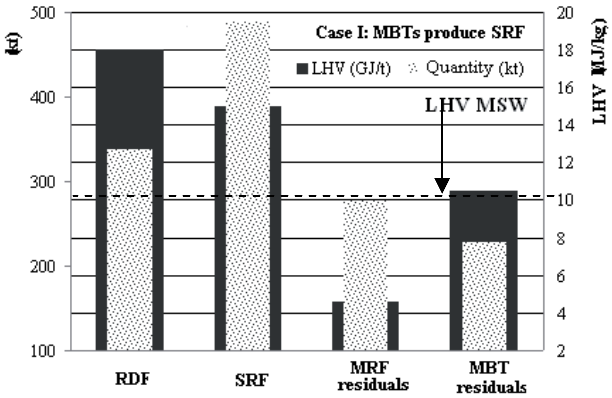


Figure 12 Heating value of SRF/RDF and residuals from MBT and MRF plants; Case I: MBTs with biodrying technology.

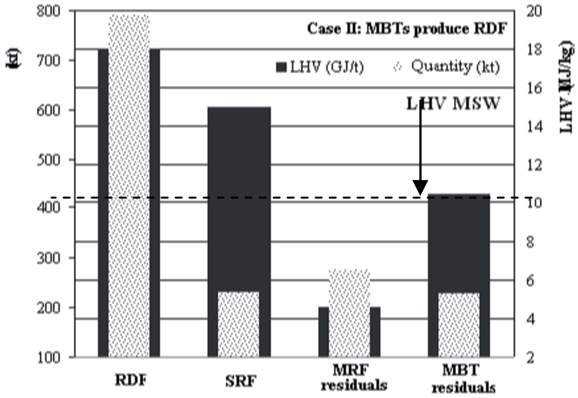


Figure 13 Heating value of SRF/RDF and residuals from MBT and MRF plants; Case II: MBTs with composting technology.

In addition to the aforementioned results, a supplementary valorisation of the produced SRF/RDF took place by using the Tanner graphic method (figure 14).

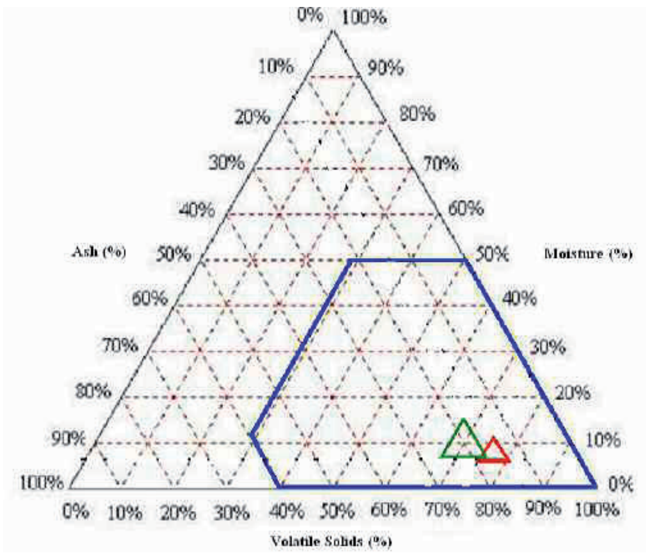


Figure 14 Tanner charts on the current Hellenic RDF/SRF: average content of RDF/SRF physical-chemical parameters. With blue line is depicted the self sustainable combustion area blue line, red line RDF, green line SRF.

4 Conclusions

In Greece about 85% of the generated MSW is disposed of in landfills or in open dumps which are still open in some municipalities. Landfill Directive 1999/31/EC demands the reduction of the biodegradable waste fraction which is sent to landfills, meaning that a national strategy on waste management should be followed. By implementing the aforementioned Directive, food waste will be diverted from the mixed waste stream, increasing the LHV of the residual waste and as a result increasing its potential use as a supplementary fuel in WtE plants or in existing industries such as cement industry etc. Recycling of packaging materials has a negative impact on LHV, but this will be compensated with the recovery of food waste and the recycling of the glass and metals. The aforementioned compensation will then increase the LHV of the residual waste. On the other hand, construction barriers of WtE plants exist in Greece; the main problem is due to political conflicts and/or high bureaucracy. In addition, the RDF/SRF market is very sensitive and flexible and its dependence from the low gate fees of the sanitary landfills creates barriers in the development of WtE practices and plants. Concluding, the landfill Directive sets crucial restrictions regarding waste management for the next years. A national strategy should be carried beginning from the implementation of regional planning (constructing of waste management plants), combining recycling and food waste recovery implementing the international WtE practices in order to structure an integrated waste management system.

5 Acronyms

BMW	Biodegradable Municipal Waste	MBT	Mechanical Biological Treatment
HHV	Higher Heating Value	MRF	Material Recycling Facility
LCA	Life Cycle Analysis	MSW	Municipal Solid Waste
LHV	Lower Heating Value	RDF	Refuse Derived Fuel
SRF	Solid Recovered Fuel	WtE	Waste-to-Energy

6 References

CEN/TC 343. Technical Committee on Solid Recovered Fuels.

Chang Ni-Bin, Chang Y.-His and Chen W.-C. 1997 Evaluation of heat value and its prediction for refuse-derived fuel. The Science of the Total Environment, 197, 139-148.

Directive 2004/12/EC 2004 Amending Directive 94/62/EC on packaging and packaging waste. Statement by the Council, the Commission and the European Parliament, 11 February.

European Commission	1999	European Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste. Official Journal L 282, 05/11/1999.
Eurostat	2007	Packaging waste database, available in: http://appsso.eurostat.ec.europa.eu/nui/submitModifiedQuery.do, (last assessed at 8 July 2010).
Eurostat	2010	Environment in the EU-27. Half a ton of municipal waste generated per person in the EU27 in 2007. Eurostat news release, 43/2010.
Joint Ministerial Decision 9268/469/2007	2007	Quantitative objectives of recycling fixed by the harmonization of the Hellenic legislation in line with the European Directive 2004/12/EC that modified the European Directive 94/62/EC.
Juniper	2005	Technology and Business Review MBT: Mechanical-Biological Treatment: A guide for decision makers, processes, policies and markets. Annex D, Process review G-J, Juniper Consultancy Services Ltd.
Law 2939	2001	Packaging and alternative management of packaging and other waste. Foundation of National Organization of Alternative Management of Packaging and other waste. Issue no. 179, 6 August, Athens.
Magrinho A. and Semiao V.	2008	Estimation of residual MSW heating value as a function of waste component recycling. Waste Management, 28, 2675-2683.
Meraz L., Domínguez A., Kornhauser I. and Rojas F.	2003	A thermochemical concept-based equation to estimate waste combustion enthalpy from elemental composition. Fuel, 82, 1499-1507.
Papachristou E., Hadjianghelou H., Darakas E., Alivanis K., Belou A., Ioannidou D., Paraskevopoulou E., Poulios K., Koukourikou A., Kosmidou N. and Sortikos K.	2009	Perspectives for integrated municipal solid waste management in Thessaloniki, Greece. Waste Management, 29, 1158-1162.
Scoullos M., Siskos P., Zeri C., Skordilis A., Ziogas Ch., Sakellari A., Giannopoulou K., Tsiolis P., Mavroudeas S., Argyropoulos I., Roumeliotis Th. and Skiadi O.,	2009	Composition and chemical properties of RDF product at a MSW mechanical separation plant in Greece. Conference on thermal processing of MSW, National Technical University of Athens.
TEE	2006	Solid Waste Management in Greece: Attica case. Hellenic Technical Chamber, November.
YPECHODE	2007	Anex II «Accounting and estimating needs on Waste Management plants», Corporate Programme Environment.

Author's addresses:

Dr. I.-S. Antonopoulos

Laboratory of Heat Transfer and Environmental Engineer

Department of Mechanical Engineer

Aristotle University,

Box 483

54124 Thessaloniki, Greece

Telephone: +30 2310 994181

E-mail: jantonop@aix.meng.auth.gr

Dr. Avraam Karagiannidis

Laboratory of Heat Transfer and Environmental Engineering

Department of Mechanical Engineering

Aristotle University of Thessaloniki

54124 Thessaloniki, Greece

Telephone: +30 2310 994165, Fax: +30 2310 996012, Mobile: +30 6973425422

E-mail: makis@aix.meng.auth.gr

Dr. Efstratios Kalogirou

Waste to Energy Research & Technology Council (WTERT) for Greece

Physical and chemical assessment of the stabilization of residual household waste before landfilling at Alveol, a French MBT plant (Bellac, Haute Vienne)

CHANTOU Thouraya[*], FEUILLADE Geneviève[*], MAUSSET Denis[**], MATEJKA Guy[*] and BOUZID Jalal[***]

Research Group Water Soil and Environment (GRESE), Limoges University - ** SYDED, Union County for disposal of household and assimilated waste in the Haute-Vienne - * Laboratory of Water, Environment and Energy (LEEE), Sfax University*

Abstract

An evaluation of the mechanical biological treatment (MBT), used at center Alveol (Bellac, France) was performed in terms of mass decrease, of biogas emission reduction and of biologically treated waste stability. The MBT process, including as mechanical sorting of waste the shredding and magnetic separation of the iron, the aerobic biodegradation of organic fraction of waste in the windrow aerated by air depression (6 weeks), and the maturation on a platform in the open air for 12 weeks, is followed by landfilling in tight cells. To evaluate the efficiency of treatment, a waste characterization campaign was conducted at each step. Samples taken at four steps of MBT have been sorted by size (>100 mm, <100-20mm>, <20 mm) and category (12 types in which putrescibles, plastic, paper, cardboard, textiles, glass, inert materials etc.). The main measured parameters indicating the increase of waste stability were the followings: lost of putrescibles, decrease of organic matter of RI_4 (respirometric index after 4 days), increase of fine particles <20mm. Moreover, in view of assessing the degradation of waste leaching tests were also used. In these tests the leachate was analysed in terms of COD, BOD_5, TOC and of Suva index.

Keywords

Solid Wastes, mechanical-biological treatment, leaching test, organic matter, Respirometric Index.

1 Introduction

In France, in 2006, 26 million tons of Municipal Solid Waste (MSW) were produced and the major part (39%) is landfilled. In order to reduce the amount of the biodegradable matter in the landfilled waste and as an alternative for residual MSW incineration, Mechanical and Biological Treatment (MBT) has been recently considered in France with a first experience in the site of Mende (BAYARD ET AL.,. 2010). This process was developed and applied firstly, since 1999, in other European countries, mainly Germany and Austria. Some studies proved that methane emissions were limited, the pollution potential of landfill leachates reduced and the mass and the volume of the landfilled waste minimized (LEIKAM AND STEGMANN, 1995), due to the biological treatment before landfilling.

Many research studies presented biological indicators of the SW stability that allow the prediction of their behavior in landfills (PARODI, 2010). The knowledge of the organic matter contained in the leachate could for instance be used as an indicator of waste degradation (BERTHE ET AL., 2008) by the assessment of the TOC amount in waste or in the eluate of a leaching procedure. COSSU AND RAGA., (2008) proposed the evaluation of the waste biodegradability by the determination of the ratio of BOD_5 to COD (BOD_5/COD) after a leaching procedure.

Respiration index such as the “Atmungsaktivität” test with 4 days of aerobic incubations (AT4) developed in Germany and in Austria, the dynamic respiration index developed in Italy (ADANI ET AL., 2004), the BP test, corresponding to the measurement of biogas production under controlled anaerobic conditions and the “Gasbildung” GB21 test, designed to measure biogas production over 21 days after the lag period, were used to define the waste biological stability (BINNER., 2003). Some other researchers used both types of indicators (respiration index and other stability parameters) to provide an assessment of the waste stability (FRICKE ET AL., 2005).

The MBT French experience is recent and it began in 2003 with a first industrial plant in the site of Mende (DE AURAJIO ET AL., 2008). Since no stability criteria have been defined for the evaluation of the stability of the treated waste, numbers of the indicators listed in table 1 were applied and an assessment of the organic carbon balance and the reduction of biogas and bio-methane potentials had a special attention (BAYARD ET AL., 2010). These parameters have been measured on the solid matrix. PARODI ET AL., (2010) have established an optimized leaching test that would be used to assess the performance and the efficiency of the waste pre-treatment mode via the fast and slow mobilized organic matter fractions assessment.

The present paper reports the results of the application of a number of the stability indicators on samples of the ALVEOL plant in Bellac (Limoges Metropole), France throughout the pretreatment process.

2 Description of MBT plant, Alveol

2.1 ALVEOL site

The site of PTMB in Bellac (Haute-Vienne) operates since March 2009. It receives the OMR (household waste after separate collection of packaging) of 184 municipalities in the department Haute Vienne.

After a door to door collection, the OMR are transferred to four transfer centers where they are compacted; the OMR are then transferred to Alveol and landfilled after an intensive aerobic treatment process. The site receives near 80,000 tons per year at a rate of 100 tons per day, five days a week.

2.2 Mechanical pre-treatment

At first, the wastes are passed through a grinder (a Hammer mill) in order to aid the opening of waste bags and to partially reduce particle size. This step is followed by a metals recovering step using an electromagnetic separator. Finally, the wastes are mixed and sprinkled with water to be stored, thereafter, in the biological pretreatment platform.

2.3 Biological stabilization

The wastes are stored in confined modules equipped with forced ventilation via air exhausting for a period of 7 weeks. During this period, windrows are turned twice to ensure a best homogenization of the waste by having an equal distribution of the air. This first phase of degradation can reduce the maximum of the easily degradable organic matter. At the end of this phase, the waste is transported to a maturation area in order to to hone their stabilization for about 8 to 10 weeks.

3 Materials and methods

3.1 Sampling operations

The samples were taken at four stages of the pretreatment plant. Quantities of 400 kg were taken at different emplacements of the windrows. Thereafter, they were quartered to acquire the necessary amount for the analysis. The first sampling is performed in the storage box after the mechanical pretreatment of the waste –MPW-. The other samples were taken at three stages of the biological process. The first one was taken after three (3) weeks of the beginning of the pretreatment -FW1-, the second after seven (7) weeks –FW2- and the last one after 16 weeks –MW-.

Samples were stored in airtight plastic bags. Their physical characterization (sorting per size and per category, moisture, RI_4) was performed after less than 24 hours. After sorting, the fines were stored in closed bags for a period less than a week before being analyzed.

3.2 MODECOM characterization

Samples were characterized according to the MODECOM procedure developed by the French Environmental Protection Agency (ADEME, 1993).

The sampling and analyzes of the samples were realized according the MODECOM procedure.

- Dry Matter content, DM%

The DM content was measured on samples by the measure of the water loss after the dry at 80°C. This parameter is measured on category samples separately and on a waste samples that is quartered from the original samples before the MODECOM sorting.

- Organic Matter content, OM%

The OM content (or loss on ignition) was measured on categories that contain organic matter after calcination at 550°c for 4 hours. Dried samples of the categories containing Organic matter are weight, calcinated and weight again. Measurements were performed in triplicate (AFNOR, NF U44-160, 1985).

- Oxidable Organic Matter content, OOM%

OOM content was determined on the fine fraction (<20 mm) by the gravimetric procedure AFNOR, XP U44-164 (2004) used for the quantification of inert materials (plastic, glass, paper, cardboard, gravels and sand) in urban compost. The organic part of waste undergoes a chemical oxidation using the sodium hypochlorite. The OOM content is considered to be representative of the potentially biodegradable. The other components of the samples are identified after the sieving and the weighing. Measurements were repeated three times on 100 g (dm).

- pH, u. pH

pH was measured on three types of waste: the fine fraction (<20 mm), the extra-fine fraction (<10 mm) and the reconstituted waste. Samples are grounded to 10 mm. The aqueous suspensions are made with a (1/5) Liquid/Solid ratio. This ratio was not appropriate to the fine fraction and the reconstituted waste, therefore, it was modified.

- Respirometric test (RI4), mg O_2 g^{-1} (dm)

The RI4 test consists in the determination of the oxygen consumption over 4 days of incubation at 20°C. The tests were performed on the coarse waste and on the fine fraction obtained by sieving at 20 mm.

A mass of 20 g of moist wastes were directly placed into 500 mL hermetically closed bottles equipped with OXITOP® kit in order to measure oxygen consumption by the assessment of pressure changes. Carbon dioxide produced by organic matter biodegradation was fixed by a pellets of sodium hydroxide placed in a beaker inside the bottles that were incubated in the dark at 20°C. Values of RI_4 correspond to the oxygen consumption per kg of dry matter (dm) in the fourth day of incubation after the lag phase (BINNER, 2003).

- Leaching tests

Leaching tests were carried out with a liquid/solid (L/S) ratio of 10 during 168 hours with liquid renewal. PARODI ET AL (2010) optimized the L/S ratio in order to promote appropriate contact between waste and the distilled water chosen as the eluent.

The mixture of 100.0±0.1 g (dm) and 1±0.01 L of distilled water in 2 L bottle is agitated on a horizontal shaking system at 150 rpm. All experiments were carried out at ambient temperature (20±1°C).

Tests were performed on fines that were sorted by 20 mm meshes, quartered and dried at 80°C.

Analyses were carried out on leachates that have been centrifuged at 8000 g for 20 min in 4°C temperature and passed through a 0.45 µm cellulose nitrate filter.

4 Results and discussion

4.1 Waste characterization results

Table 2 shows the results of the physicochemical characterization of the samples.

The major part of the waste (50%) is represented by the medium fraction (20-100 mm). the greater fraction (>100 mm) decreased during the treatment process while the finest one increased.

Regarding the changes in waste composition during the process of stabilization, the putrescibles steadily decreased (2.7% to 0.1%). This evolution is related to the biological degradation that affected biodegradable categories, mostly putrescibles and secondarily paper-cardboard of about 50% at the end of the process. Plastics, glasses, metals, hazardous, Misc.C and Misc.I have increased, due to the decline of the organic fraction.

Table 1 : Results of the physicochemical sample characterizations during the process

Analysis	% (wm)	MPW[a]	FW1[b]	FW2[c]	MW[d]
Size particle	**>100 mm**	31,6	16.1	17.0	12.4
	100 -20 mm	49.5	57.7	60.2	50.4
	<20 mm	19.0	26.2	22.8	37.2
	Total	100.0	100.0	100.0	100.0
Categories	**Putrescibles**	2.7	0.9	0.4	0.1
	C. Putrescibles[e]	7.5	20.5	12.5	12.5
	Paper	15.2	9.0	14.5	9.0
	Cardboards	7.9	3.9	4.6	3.6
	Tetrapack	1.5	1.1	1.7	1.0
	Textile	5.5	4.5	6.3	5.3
	Sanitary textile	12.8	10.5	7.0	2.8
	Plastics-bags	9.2	11.4	7.4	6.0
	Plastics-Packaging	6.9	5.0	12.5	12.1
	Plastics-Recyclable	2.7	1.5	1.5	1.9
	Plastics-PS	0.4	0.1	0.6	0.1
	Glass	1.5	2.1	1.2	2.9
	Metals-Iron	2.1	1.1	0.7	1.4
	Metals-aluminium	0.8	0.4	1.7	0.8
	Misc.C[f]	3.6	0.9	3.3	0.3
	Misc.I[g]	0.7	0.9	1.0	1.4
	Hazardous	0.2	0.0	0.3	1.5
	Fines <20 mm	7.8	11.6	9.2	6.0
	Extra-fines <10 mm	11.1	14.7	13.6	31.3
	Total	100.0	100.0	100.0	100.0
Physicochemical parameters	**H % (wm)**	30.7	50.6	40.1	23.3
	OM %(dm)	39.9	28.3	25.0	16.2
	$OOM_{<20\ mm}$ %(dm)	23.4	22.1	19.0	14.5
	$OOM_{<10\ mm}$ %(dm)	39.2	42.0	13.5	12.0
	$pH_{<20\ mm}$ R(1/10)*	6.9	6.5	7.7	7.0
	$pH_{<10\ mm}$ R (1/5)**	6.7	6.3	7.4	7.7
	$pH_{Reconstituted}$ R(1/15)***	7.2	6.8	7.7	7.4

a: Samples taken at the outlet of the Mechanical Pretreatment; [b] : Samples taken during the fermentation, 4 weeks after the MBT process beginning; [c] : Samples taken during the fermentation 7 weeks after the MBT process beginning; [d] : Samples taken at the outlet of the MBPT process in the maturation platform; [e]: contaminated putrescibles waste that are no more recognizable because of their degradation; [f]: Miscellaneous combustible; [g]: Miscellaneous Incombustible. *: the Liquid/Solid Ratio = 1/10; **: the Liquid/Solid Ratio = 1/5; ***: the Liquid/Solid Ratio = 1/15

Moisture is an important factor for microbial activity. The initial waste moisture (31%) is low so it has been optimized by watering before the fermentation beginning. During the MBT treatment, water generation and evaporation are both happened as a consequence, respectively, of the biodegradation reactions and the heat generation.

During the treatment, the organic matter content decreased from 40 to 16% (dm). This decrease is higher at the beginning of the biological treatment due to the mineralization of refractory compounds.

The oxidable organic matter content has decreased from the initial phase to the final phase of the process of stabilization (39.2% to 12.0%).

The pH values measured on the fine fraction (<20 mm), on the extra-fine fraction (<10 mm) and on the reconstituted were not very different and have similar evolution during the treatment process. This evolution is related to the waste degradation with an acidification phase followed by an alkalization phase. By the end of maturation, pH is supposed to reach 8, the actual value of 7.5 shows that maturation has not been ended yet.

4.2 Respirometric test

.The duration of the test was seven (7) days by tacking in to account the lag-phase (3 days). The bottle aerations during the tests, have contributed to avoid the negative suppressing effect by metabolic products as it was recommended by BÖHN ET AL (2009).

The figure 1 showed the evolution of the aerobic respirometric activity of the waste (a) and on the fine fraction (b).

According to the respirometric test on shredded waste, RI_4 values of samples pretreated mechanically (MPW), after 3 weeks of PTMB treatment (FW1), after 7 weeks of PTMB (FW2) and after 16 weeks of PTMB (MW) were 20, 18, 16 and 13 mg O_2 g^{-1} (dm), respectively. Those values were superior to those measured on the fines. For instance, the RI4 measured on samples taken in the maturation platform were 20 mg O_2 g^{-1} (dm) for the shredded waste and 6 mg O_2 g^{-1} (dm) for the fines. Those results could be affected by the size particle of the waste since the pore space, for fines, were reduced which hinders the flow of the air into the matter and induce a low RI.

Regarding the test on the shredded waste, the MPW and FW1 samples from their RI_4 values seem having a high biodegradable contents which induce a similar respirometric activity. By the end of maturation, this index decreased and reached 13 mg O_2 g^{-1} (dm) but was, still, under the Austrian limit value considered for the stabilized waste acceptance in landfills.

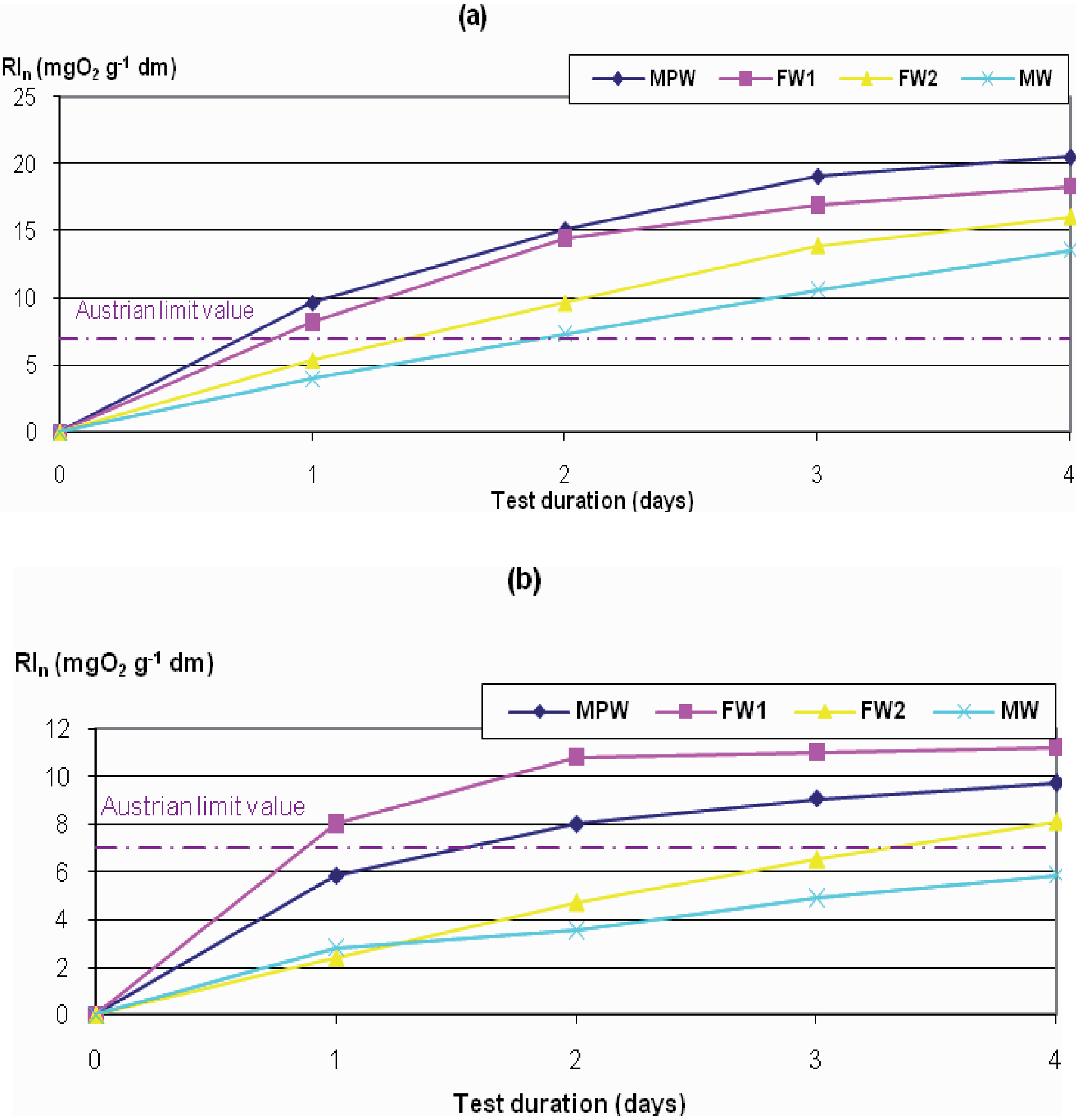


Figure 1 : Evolution of the respiration index of the samples taken in the MBT during 4 days, (a): test proceeded on the shredded waste; (b): test proceeded on the fines (<20 mm).

4.3 Leaching test

Leaching tests were performed in order to evaluate the maximum capacity of the waste to mobilize pollution in an unsaturated environment. The characterization of the eluates presents information that could define the pollution mobilization status during the leaching tests (Figure 2).

After 24 hours of leaching, pH of the waste eluates is slightly basic (7.3–7.7). At the end of the leaching test (168 hours), those pH values decreased (6.3 – 7.5) probably because of the leaching of the HCO_3^- ions.

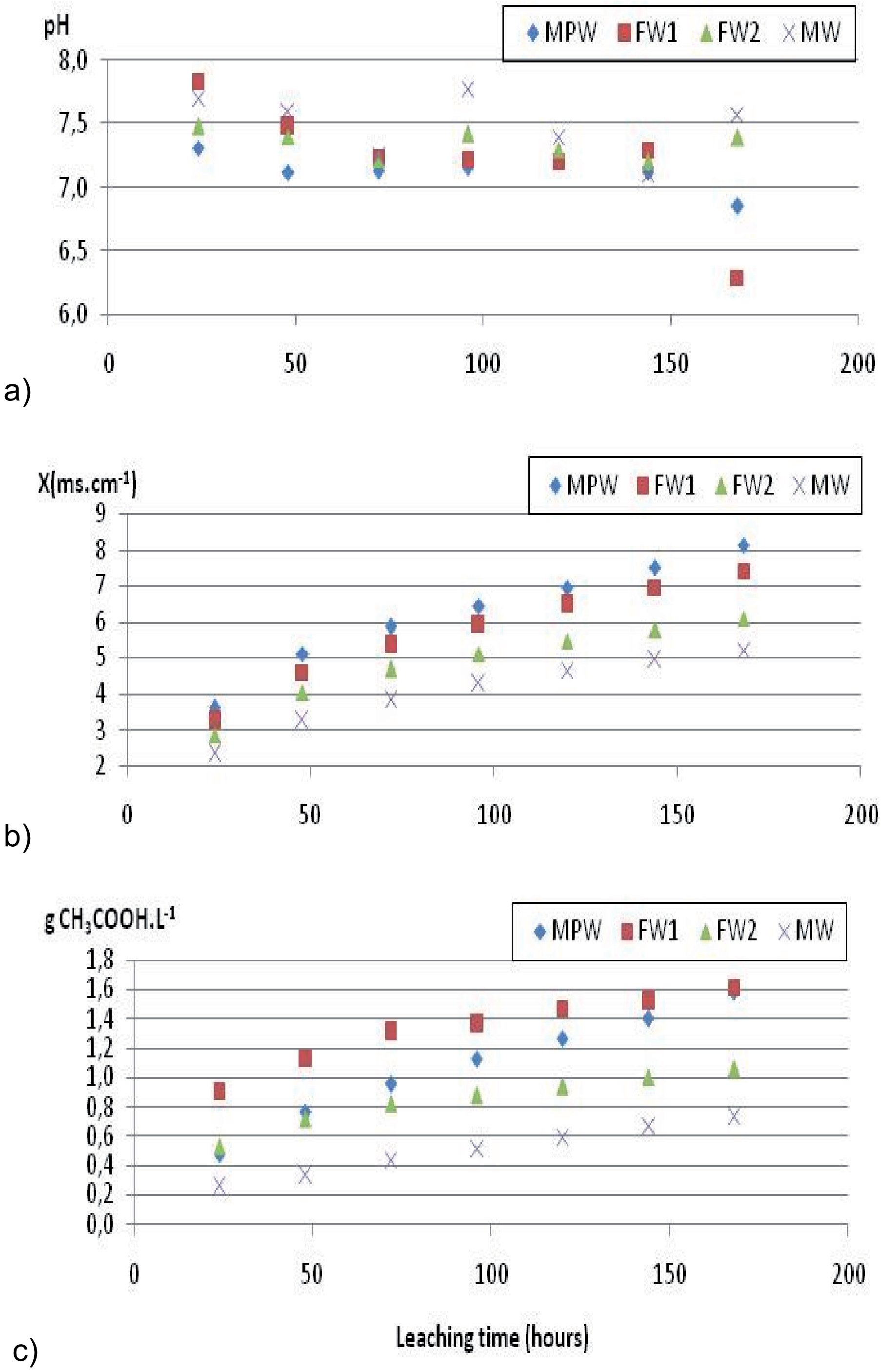


Figure 2 : Evolution of the pH (a), the Conductivity (b), and the Fatty Acids (c) in the leaching tests for the PTMB samples.

In the case of the (FW1) sample where pH passed from 7.8 to 6.3, the progressive release of the high content of fatty acids (9.12 $g.kg^{-1}$ dm) could explain the acidification of the eluate during the test. pH of the eluates after 168 hours of leaching showed a decrease at the beginning of the process in the same time as a slight increase in the concentration of the CH_3COOH. This phase of enzymatic degradation caused the temperature increase which establishes the thermophilic phase characterized by an increase of the pH and a decrease of the concentration of fatty acids (Figure 3).

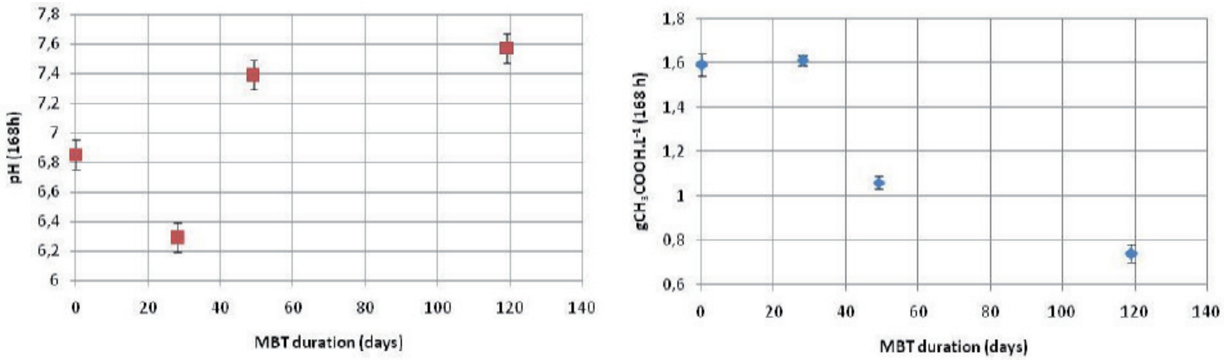


Figure 3 : pH and fatty acids evolutions after 168 hours leaching test with renewal during the MBT process.

Table 3 shows that the parameters related to the organic load evolved similarly: they increase during the test which is a leaching characteristic phenomenon.

Table 2 : COD, DOC and BOD_5 values after 24 and 168 hours of leaching.

	COD ($gO_2.kg^{-1}$ DM)		**DOC ($g\text{-}C.kg^{-1}$ DM)**		**BOD_5 ($gO_2.kg^{-1}$ DM)**	
	24 h	**168h**	**24 h**	**168h**	**24 h**	**168h**
PMW	69.8 ± 0.5	109.6 ±0.1	22.7 ±0.2	35.6 ± 0.2	35.0± 0.8	60.3 ± 1.4
FW1	32.2 ± 0.2	58.6 ± 0.5	10.2 ± 0.1	17.5 ± 0.1	17.0 ± 0.5	24.7 ± 2.8
FW2	36.2 ± 0.3	54.3 ± 0.8	10.7 ± 0.1	16.6 ± 0.1	18.5 ±0.6	23.1 ± 0.7
MW	17.0 ± 0.2	29.9 ± 0.9	5.4 ± 0.3	9.9 ± 0.2	6.0 ±0.1	10.0± 0.3

The mineral load in waste is not totally mobilized even after 168 hours of leaching. This load is difficult to eliminate by lixiviation and a constant residue of it continue to be released after each eluent renewal.

The main amount of organic matter is extracted after the third day of leaching (32 g C kg^{-1} dm, 98 gO_2 kg^{-1} dm, and 50 gO_2 kg^{-1}dm).

The organic load in the eluates could be evaluated by the measurements of COD, DOC and BOD_5. The COD, DOC and BOD_5 values obtained for the samples in the maturation platform have, clearly, decreased (table 3).

The BOD5 measurements allow the estimation of the percentage of the biodegradable organic matter. The highest values were measured for the PTM eluate indicating a high biological aerobic activity in the waste. The BOD_5 of samples FW1 and FW2 are similar and the measured values during the test are very close indicating slower degradation activities in the windrows probably because of air deficit. This was confirmed by the

DOC and DOC measurements which passed after 24 hours of leaching, respectively, from 10.2 to 10.7 gC kg^{-1}(dm) and from 32.2 to 36.2 g O_2 kg^{-1}(dm).Various ratios are used in researches to characterize the organic matter degradation status in the leachate. For instance the SUVA index was used as a relevant parameter to evaluate the waste degradation progress since it reflects the hydrophobicity and the aromaticity of organic compounds (FEUILLADE ET AL., 2009). Moreover, MILLOT (1986) used the BOD_5/COD ratio to evaluate the leachate maturity (Figure 5).

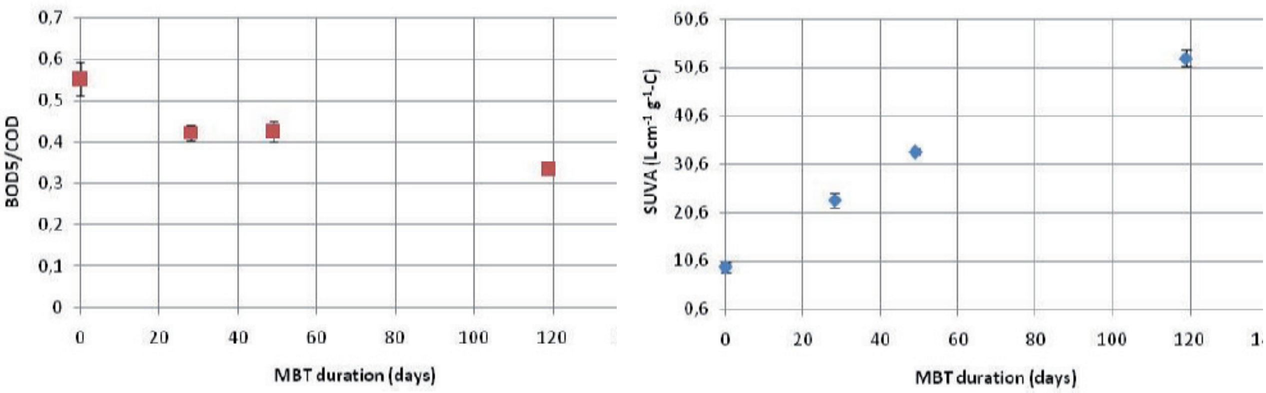


Figure 5: Evolution of BOD_5/COD ratio and SUVA index during the MBT process

BOD_5/COD ratio for the entrance waste is the highest. It is characteristic of untreated waste. The values of this ratio decreased during the process and the BOD_5/COD ratio of the stabilized waste is near 0.3 which indicates an intermediate stability status with a low biodegradability. SUVA index increased continuously during the process indicating that the organic compounds released in the leachates of the stabilized waste are more aromatic than those of the untreated waste. According to FEUILLADE ET AL (2009), the SUVA index of the MW (52 L.cm^{-1}g^{-1}C) is characteristics of matured waste.

5 Conclusion

Although some parameters measured were limited and did not reach the maturation values, the treatment conducted in the ALVEOL plant ensure relatively the stabilization of the waste. In a global point of view, it ensures the reduction of the particle size of the waste with an abatement of 62% of the waste having a size particle >100 mm, the oxidation of a large amount of organic matter (60%), the reduction of the biological activity (35%) and the diminution of the parameter values related to the organic matter load. However, some stages of the treatment specially the fermentation one was shown to need optimization. Indeed, FW1 and FW2 samples parameters (on solid and on leachate) do not show a clear evolution regarding the parameters used to evaluate the organic matter degradation of the waste. The slowdown of the degradation at this level can be caused by a lack of ventilation and/or watering. Hence, an improvement of the aeration and of the watering procedure is highly recommended during the fermentation stage.

6 References

Adani F., Confalonieri R., Tambone F. 2004 Dynamic Respiration Index as a descriptor of the biological stability of organic wastes, J. Environ. Qual. 33 1866–1876.

ADEME 1993 MODECOM,Méthode de Caractérisation des Ordures Ménagères, ADEME éditions,Paris.

AFNOR, XP U44-164 2004 Organic Soil Conditioners and Organic Material for Soil Improvement—Determination of Total Organic Matter—Calcination Method

AFNOR, NF U44-160 1985 Organic Soil Conditioners and Organic Material for Soil Improvement—Determination of Total Organic Matter—Calcination Method.

Bayard R., de Araújo Morais J., Ducom G., Achour F., Rouez M., Gourdon R. 2010 Assessment of the effectiveness of an industrial unit of mechanical biological treatment of municipal solid waste Hazardous Materials 175. 23-32.

Berthe C., Redon E., Feuillade G. 2008 Fractionation of the organic matter contained in leachate resulting from two modes of landfilling: an indicator of waste degradation, J. Hazardous. Materials. 154. 262–271.

Binner E. 2003 Assessment of MBP waste—misinterpretations of respiration activity, in: T.H. Christensen, Cossu R., Stegmann R. (Eds.), Sardinia 2003, 9th International Waste Management and Landfill Symposium, S. Margherita di Pula, Cagliari, Italy, 2003.

Böhn K., Smidt E., Binner E., Schwanninger M., Tintner J., Lechner P. 2009 Determination of MBT-waste reactivity- An infrared spectroscopic and multivariate statistical approach to identify and avoid failures of biological tests. Waste Management 30 (2010) 583-590. Corriger bohn 2010

Cossu R., Raga R. 2008 Test methods for assessing the biological stability of biodegradable waste, Waste Manage. 28, 381–388.

De Araújo Morais J., Ducom G., Achour F., Rouez M., Bayard R. 2008 Mass balance to assess the efficiency of a mechanical–biological treatment, Waste Management. 28, 1791–1800.

Feuillade-Cathalifaud G., Pallier V., Parodi A., Redon E. 2009 La matière organique du lixiviat comme indicateur de la stabilisation des déchets : application à des pilotes semi-industriels. GF-IHSS 2009 - Matières Organiques dans un Environnement en Evolution, Montpellier, France, 24 et 25 novembre 2009.

Fricke K., Santen H., Wallmann R. 2005 Comparison of selected aerobic and anaerobic procedures for MSW treatment, Waste Management. 25 (2005) 799–810.

Leikam, K., Stegmann, R. 1995 R., The emission behaviour of mechanically–biologically pretreated residual waste. Waste Reports Emissionsverhalten von Restmull, ABF-BOKU, Vienna, Austria.

Millot N.	1986	Les lixiviats de décharges contrôlées. Caractérisation analytique et études des filières de traitement. Thèse de doctorat, INSA de Lyon.
Parodi A., Feuillade-Cathalifaud G., Pallier V., Mansour, A.A.	2010	Optimization of municipal solid waste leaching test procedure: Assessment of the part hydrosoluble organic compounds, J. Hazardous. Materials.

Author's addresses

Dr. Guy Matejka, professor
GRESE, ENSIL, 16 rue Atlantis, Ester Technopôle
87068 Limoges Cedex, France
Telephone: +33 555 423 679
Email: matejka@ensil.unilim.fr
Website: www.ensil.unilim.fr

Dr. Geneviève Feuillade, professor
GRESE, ENSIL, 16 rue Atlantis, Ester Technopôle
87068 Limoges Cedex, France
Telephone: +33 555 423 695
Email: feuillade@ensil.unilim.fr
Website: www.ensil.unilim.fr

MAUSSET Denis
SYDED
Union County for disposal of household and assimilated waste in the Haute-Vienne
19 rue Cruveilhier BP 13114
87031 Limoges cedex, France.

MATEJKA Guy
Research Group Water Soil and Environment (GRESE)
Limoges University
E-mail: matejka@ensil.unilim.fr

BOUZID Jalal
Laboratory of Water, Environment and Energy (LEEE)
Sfax University, ENIS, National Engineering School of Sfax
BP: W 3038, Sfax, Tunisia

Stand und Perspektiven der Aufbereitungstechnik zur stofflichen und energetischen Verwertung von Gewerbeabfällen

Rüdiger Oetjen-Dehne, Manfred Kanthak

u.e.c. Berlin GmbH / Kanthak & Adam GbR Berlin

Status and prospects of treatment technology for material and energy recovery from commercial solid waste

Abstract

A research project on behalf of the Federal Office for Environmental Protection aims to assess the quantity, the management and the aspects of resource preservation of commercial solid wastes. This contribution summarizes substantial results concerning the material flow and describes the structure and efficiency of different sorting plants. So far the Commercial Wastes Ordinance only provides a mass-related rating which makes no difference between material recycling and energy recovery. A fast and viable concept of managing material flows is developed within the study. This concept seizes both the objectives of the EC Framework Directive on Waste and the draft Waste Avoidance, Recycling and Disposal Act and transfers them to the output flows of the pre-treatment plants for mixed commercial municipal waste.

Inhaltsangabe

Im Rahmen eines vom Umweltbundesamt beauftragten Projektes wurde das Aufkommen, der Verbleib und die Ressourcenrelevanz für die der Gewerbeabfallverordnung unterliegenden Gewerbeabfälle ermittelt. Der Beitrag fasst wesentliche Ergebnisse zu den Stoffströmen zusammen und erläutert den Aufbau und die Leistungsfähigkeit verschiedener ausgeführter und in Betrieb befindlicher Sortieranlagen. Um das Ressourcenpotential intensiver als bisher zu nutzen, werden verschiedene Optimierungsansätze und ein Konzept zur Stoffstromlenkung erläutert. Dieses Konzept greift die Ziele der Abfallrahmenrichtlinie sowie des Entwurfes des KrWG auf und überträgt diese auf die Outputströme der mechanischen Vorbehandlungsanlagen für gemischte gewerbliche Siedlungsabfälle.

Keywords

Ressourcenrelevanz, Gewerbeabfälle, Sortieranlagen, Stoffstromlenkung

resource preservation, commercial waste, sorting plants, managing material flow

1 Einleitung

Die gewerblichen Betriebe der Bundesrepublik Deutschland erfassen erhebliche Mengenanteile der anfallenden Abfälle getrennt und sortenrein, u.a. auf der rechtlichen Grundlage der bereits 2003 erlassenen Gewerbeabfallverordnung. Daneben fallen aber auch Abfallgemische an, die ebenfalls ein erhebliches Ressourcenpotential darstellen.

Der folgende Beitrag analysiert, ob und wie dies Potential bisher genutzt wird. Die Grundlage bildet ein im Auftrag des Umweltbundesamtes bearbeitetes Forschungsprojekt, mit dem Daten und Informationen zum Aufkommen und zum Verbleib von gewerblichen gemischten Siedlungsabfällen ausgewertet wurden (UMWELTBUNDESAMT 2011).

2 Aufkommen und Zusammensetzung von gemischten Gewerbeabfällen

Auf Basis der verfügbaren Informationen haben Gewerbebetriebe im Jahr 2007 rund 4,3 Mio. Mg gemischte Gewerbeabfälle sowie 2,1 Mio. Mg gemischte Verpackungen, die nicht aus der Sammlung von Leichtverpackungen im Rahmen der dualen Systeme stammen, in Summe also 6,4 Mio. Mg entsorgt.

Die Zusammensetzung dieser Abfallgemische ist ausgesprochen heterogen und wird von einer Vielzahl von Einflussgrößen beeinflusst. Im Rahmen des UFOPLAN-Projektes konnten sieben Untersuchungen aus dem Zeitraum nach 2002 für gemischte gewerbliche Siedlungsabfälle ausgewertet werden. Anhand dieser Daten kann die Zusammensetzung gemischter gewerblicher Siedlungsabfälle (Stand 2007), wie in Bild 1 gezeigt, geschätzt werden.

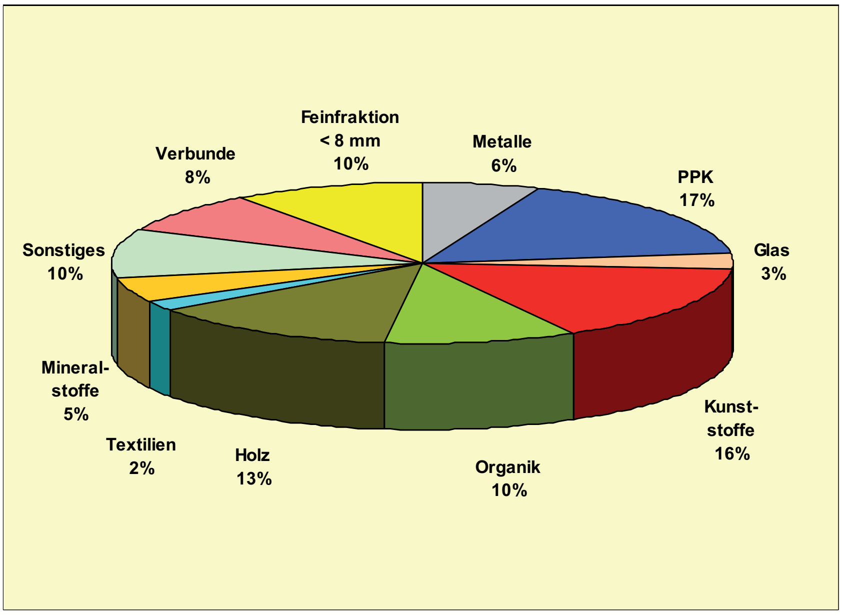


Abbildung 1: Geschätzte Zusammensetzung gemischter gewerblicher Siedlungsabfälle

Die Abfälle verfügen noch über ein hohes Wertstoffpotenzial, was darauf hindeutet, dass nicht alle Gewerbebetriebe die anfallenden Wertstofffraktionen separat erfassen und entsorgen, sondern diese nach wie vor als Gemisch an die Entsorgungswirtschaft abgeben.

Trotz des vorhandenen Wertstoffpotenzials wird der Großteil der gemischten gewerblichen Siedlungsabfälle (ca. 60 Ma.-%) allerdings direkt in thermischen Abfallbehandlungsanlagen entsorgt, nur rund 30 Ma.-% gelangen in Sortieranlangen. Für die Verpackungsgemische zeigt sich ein anderes Bild; hier werden rund 70 Ma.-% in Sortieranlagen aufbereitet. Vom Gesamtaufkommen der beiden Abfallgemische werden nur rund 43 Ma.-% bzw. 2,77 Mio. Mg einer Aufbereitung zugeführt.

3 Aufbereitungstechnik

3.1 Ziele und Verfahrensaufbau

Das Ziel der Gewerbeabfallaufbereitung ist es, aus den heterogenen Abfallgemischen vermarktungsfähige Produkte (Papier, Pappe, Kartonagen, z.T. in unterschiedlichen Qualitäten; Fe- und NE-Metalle (NE-Metalle auch sortenrein); Kunststoffe (verschiedene Kunststoffprodukte, wie Folien, Hartkunststoffe, bzw. verschiedene Kunststoffarten, wie PE, PP, PET) sowie Holz) abzutrennen, die definierten Qualitätskriterien entsprechen.

Daneben entstehen in Abhängigkeit von der verfahrenstechnischen Komplexität der Sortieranlagen eine oder zwei stofflich nicht verwertbare Outputfraktionen:

- Sogenannte Feinsiebreste, also das ausgeschleuste Unterkorn von Klassierprozessen, stellen eine mit mineralischen Bestandteilen angereicherte Fraktion dar. Untersuchungen solcher Unterkornfraktionen zeigen allerdings, dass der Anteil biologisch abbaubarer Komponenten durchaus relevant sein kann. Diese Fraktion ist deshalb i.d.R. nicht verwertbar, sondern muss einer Behandlung zugeführt werden (OETJEN-DEHNE et.al. 2010).
- Sortierreste fallen bei jeder Aufbereitungsanlage an und werden entweder direkt der energetischen Verwertung zugeführt oder zu Ersatzbrennstoffen verarbeitet. Zur Herstellung hochwertiger Ersatzbrennstoffe existieren je nach Einsatzzweck des EBS auch hochwertige Aufbereitungsanlagen (OETJEN-DEHNE, KALVELAGE 2009).

Die Verfahrenstechnik zur Aufbereitung von Gewerbeabfallgemischen wurde seit den späten 1980er Jahren kontinuierlich weiterentwickelt. Mittlerweile können die in der folgenden Tabelle dargestellten Subsysteme und Prozessschritte eingesetzt werden.

Tabelle 1: Gliederung der Sortieranlagen in Subsysteme und wesentliche Prozessschritte

Subsysteme		**Prozessschritte**
1	Annahme	- Wiegung - Datenaufnahme
2	Lagerung	- Flachbunker mit Radlader oder Greifbagger
3	Vorbehandlung	- Störstoffentnahme - Grobvorsortierung - ggf. Vorzerkleinerung
4	Materialtrennung	- Klassierung - manuelle Klaubung - automatische Klaubung - Magnetscheidung - Wirbelstromscheidung - Sichtung
5	Aufbereitung Sortierreste	- Nachzerkleinerung, - Metallabscheidung - Verdichtung

Stoffliche und/oder energetische Produktverwertung

Der Hauptprozess, also die eigentliche Materialtrennung, nutzt Trennmerkmale wie die Korngröße, die Dichte, die Form, die Magnetisierbarkeit und das Spektralverhalten (Sensortechnik). Nicht jede der in Betrieb befindlichen Anlagen nutzt jedoch alle 5 Subsysteme, vielmehr lassen sich verschiedene Anlagentypen differenzieren:

- „Einfachst"-Anlagen (Subsysteme 1 – 3) – Baggersortierung und Umschlag
- Anlagen einfacher Komplexität (Subsysteme 1 – 4) – manuelle Klaubung, ggf. Magnetscheidung
- Anlagen mittlerer Komplexität (Subsysteme 1 – 4) – Siebung, Magnetscheidung, manuelle Klaubung, ggf. Zerkleinerung (Subsystem 5)
- Anlagen hoher Komplexität (Subsysteme 1 – 5) – Zerkleinerung, Siebung, Magnetscheidung, Sensortechnik, manuelle Klaubung.

Analysen der verfahrenstechnischen Merkmale entsprechender Anlagen zeigen, dass zwischen 20 und 30 % als Anlagen höherer Komplexität eingestuft werden können. Ein Großteil der in Deutschland betriebenen Anlagen nutzt somit nicht die in den letzten Jahren weiterentwickelten technischen Möglichkeiten zur Verbesserung der Wertstoffausbeute.

3.2 Anlagen mittlerer Komplexität

Sortieranlagen mittlerer Komplexität (Bild 2) verfügen über Aggregate zur maschinell unterstützten manuellen Sortierung (zusätzlicher Einsatz von Siebaggregaten) und zur Metallaushaltung, zudem werden teilweise Nachzerkleinerer (Subsystem 5) eingesetzt. Diese Anlagen können gegenüber einfachen Anlagen höhere Wertstoffausbeuten erreichen.

Das der manuellen Sortierung vorgeschaltete Sieb trennt zur Entlastung der Sortierkräfte das manuell nicht sortierfähige Klein-Material ab. Durch die Klassierung werden somit eine höhere Produktivität bei der manuellen Sortierung und eine höhere Wertstoffausbeute erreicht.

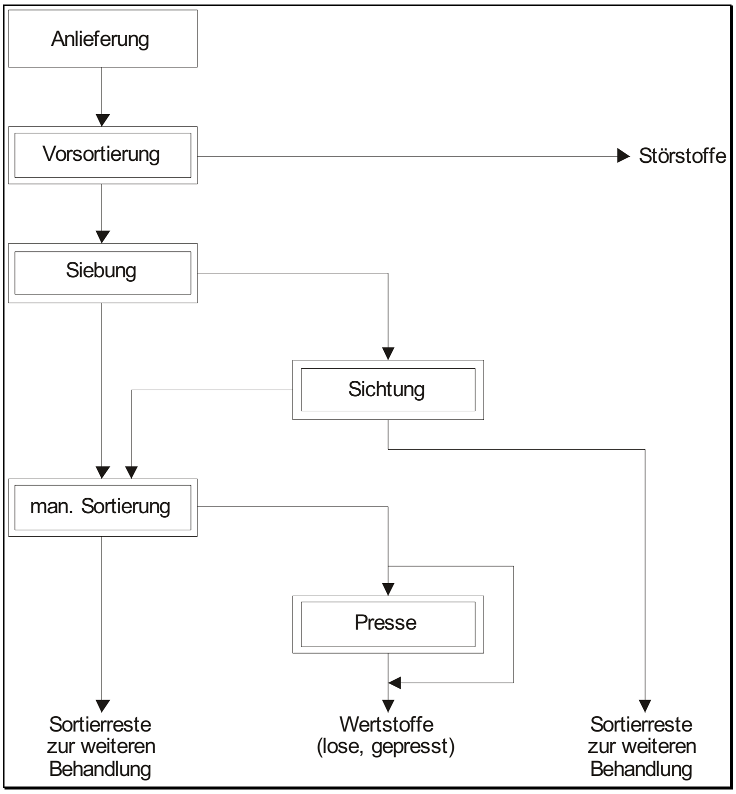


Abbildung 2: Blockschema einer Sortieranlage mittlerer Komplexität

Die Wertstoffausbeute der manuellen Sortierung wird vom Wertstoffgehalt und der Wertstoffbeschaffenheit (Korngröße, Stückgewicht) des Inputgemisches und den Sortierparametern (Anzahl der Sortierkräfte, Durchsatzleistung) geprägt. Bei einem zur manuellen Sortierung gelangenden Korn von > 100 mm errechnen sich theoretisch erzielbare Stundenleistungen von 48 bis 450 kg/Sortierer und Stunde, die praktisch realisierten Leistungen sind allerdings geringer. Selbst bei teilweise hoch wertstoffhaltigen gewerblichen Inputgemischen wurde bei Testfahrten eine mittlere Leistung je Sortierer zwischen 27 und 250 kg/h gemessen. Hohe Werte sind nur erreichbar, wenn das Aufgabegut auch eine Vielzahl von Stoffen mit hohen Stückgewichten (z.B. Metalle, Holz, Mineralien) enthält. Als praxisnaher Durchschnittswert bei der Entnahme von Mischkunststoffen, Kunststofffolien, PPK, Holz und Metallen kann für die manuelle Wertstoffentnahme eine Spanne von 100 – 160 kg je Sortierer und Stunde angesetzt werden. Bild 3 zeigt anhand von Versuchsergebnissen, dass mit steigendem spezifischen Inputdurchsatz die prozentuale Wertstoffausbeute tendenziell sinkt. Überlagert wird dieser Effekt aber stark von der Beschaffenheit des Aufgabegutes.

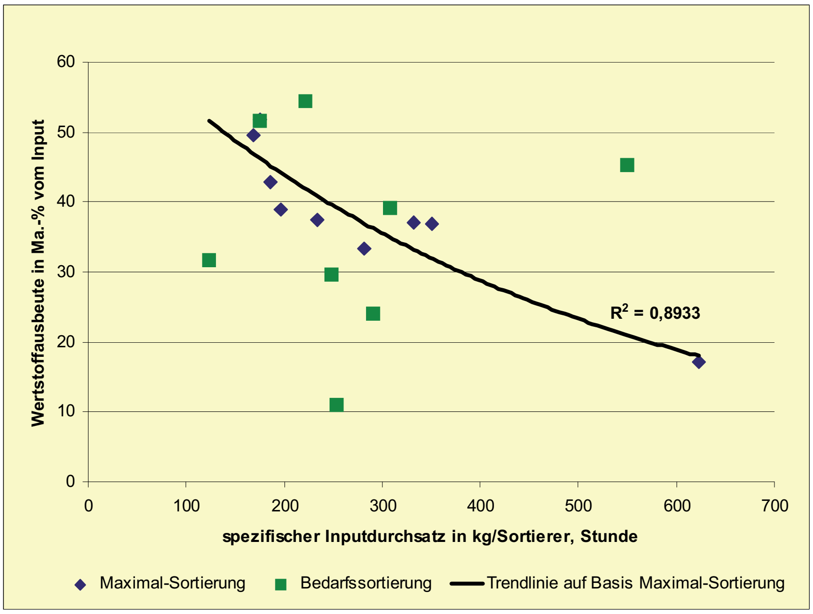


Abbildung 3: Wertstoffausbeute in Abhängigkeit vom spezifischen Durchsatz

Infolge des Kostendrucks sind Betreiber bemüht, den Durchsatz möglichst zu erhöhen und nur wenig Sortierpersonal einzusetzen; üblich sind deshalb spezifische Inputdurchsätze im Bereich von 1.000 – 1.200 kg/h, Sortierer. Dadurch sinkt die Wertstoffausbeute auf deutlich unter 20 Ma.-%. Es ist zusammenfassend davon auszugehen, dass je nach Aufgabegut und Marktbedingungen mit Sortieranlagen mittlerer Komplexität zwischen 5 und 20 Ma.-% als Wertstofffraktionen abgetrennt werden. Der danach verbleibende grobe Sortierrest ist oftmals visuell kaum vom Input zu unterscheiden. Durch die Entnahme von Metallen und Mineralien erfolgen i.d.R. jedoch eine Erhöhung des Heizwertes und eine Reduzierung des Aschegehaltes.

3.3 Anlagen hoher Komplexität

Anlagen hoher Komplexität trennen Wertstoffgemische zusätzlich mit automatischen Klaubungstechniken wie z.B. Nahinfrarot (NIR)-Geräte, Röntgensortiergeräten, Metallabscheider etc., nachdem das Abfallgemisch zuvor eine maschinelle Aufbereitung durchlaufen hat. Ein beispielhaftes Blockschema zeigt Bild 4.

Bei diesem Anlagentyp übernehmen Sortierkräfte vor allem die Nachsortierung der Wertstofffraktionen. Die Verfahrenstechnik dieser Vorbehandlungsanlagen ist so konzipiert, dass flexibel auf wechselnde Marktanforderungen reagiert werden kann. Dieses geschieht vornehmlich durch die individuelle Einstellung der NIR-Geräte und die Anzahl der Sortierkräfte. Wertstoffausbeuten können, je nach Aufgabegut und Marktbedingungen bis zu 40 Ma. % betragen.

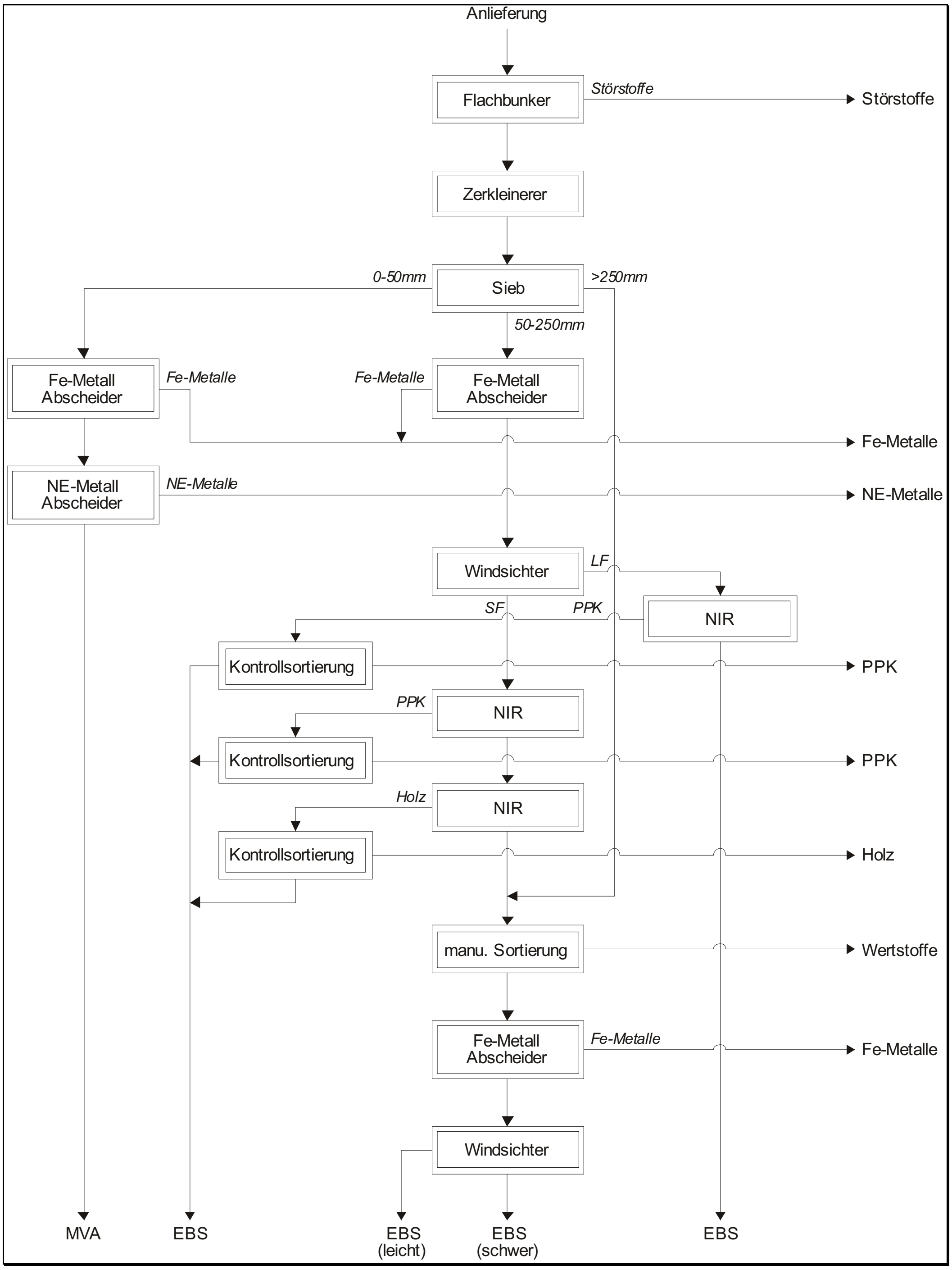


Abbildung 4: Blockschema einer Sortieranlage hoher Komplexität

Verfahrenstechnische Lösungen zur weitgehend automatisierten Trennung auch von Kunststoffarten wurden bislang für Gewerbeabfallgemische nur vereinzelt umgesetzt. Ursache ist vor allem die fehlende wirtschaftliche Basis für kapitalintensive Investitionen.

3.4 Sekundärrohstoffmengen aus der Sortierung gemischter Gewerbeabfälle

Im Rahmen des Forschungsprojektes für das Umweltbundesamt wurden Sortieranlagenbetreiber befragt, diese geben eine stoffliche Verwertungsquote von rund 17 Ma.-% für die separierten Wertstoffe PPK, Kunststoffe, Holz, Fe- und NE-Metalle an. Zur thermischen Behandlung gelangen rund 42 Ma.-% Brennstoffe (AS 191210), 21 Ma. % Sortierreste (AS 191212) und 4 Ma.-% umgeschlagene Abfälle. Nur ein geringer Teil wird als Sortierrest (AS 191212) an weitere Sortieranlagen abgegeben.

Je nach Anlage variiert der Anteil der aussortierten Sekundärrohstoffe stark. Tendenziell zeigt sich, dass selbst in einem Jahr mit vergleichsweise hohen Wertstofferlösen der Anteil der den Sekundärrohstoffmärkten aus der Sortierung gemischter Gewerbeabfälle zur Verfügung gestellten Stoffströme vergleichsweise gering ist. Dafür sind vor allem wirtschaftliche Überlegungen, vor allem niedrige Entsorgungsangebote der Betreiber thermischer Anlagen, verantwortlich.

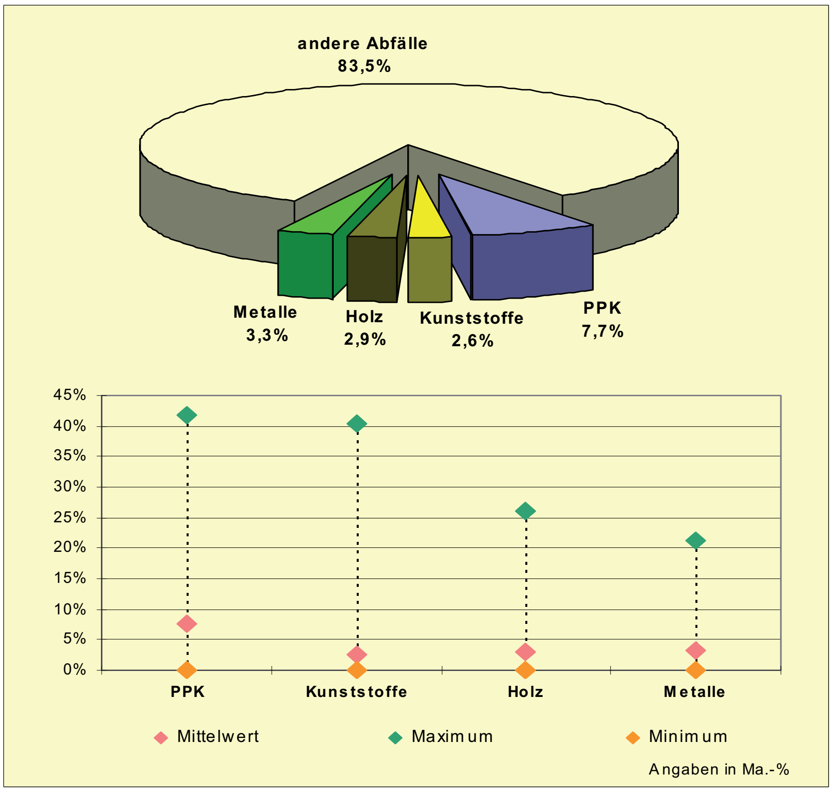


Abbildung 5: Verteilung des Outputs von 43 Sortieranlagen im Jahr 2007

4 Kostensituation

Können durch die getrennte Erfassung von Wertstoffen in den Betrieben oder durch die Sortierung von gemischten Abfällen keine Preisvorteile gegenüber der direkten energetischen Verwertung generiert werden, gelangt der Gewerbeabfall direkt in die Verbrennung. Gestützt auf Literaturdaten, die Ergebnisse einer Fragebogenerhebung sowie die Ergebnisse von Expertenpanels und Anlagenbesichtigungen zeigt sich, dass die Preissituation in Deutschland eine verstärkte Verbrennung induziert. So gaben rund 80 % der teilnehmenden Betreiber von Beseitigungsanlagen (MVA/MBA-Anlagen) Preise für gemischte gewerbliche Siedlungsabfälle bis 100 Euro/Mg, in über 50 % der Fälle Preise bis 70 Euro/Mg an. Im Vergleich dazu liegt das mittlere Preisniveau von Betreibern von Sortieranlagen rund 30 Euro/Mg höher, entsprechend gehen die akquirierten Mengen zurück.

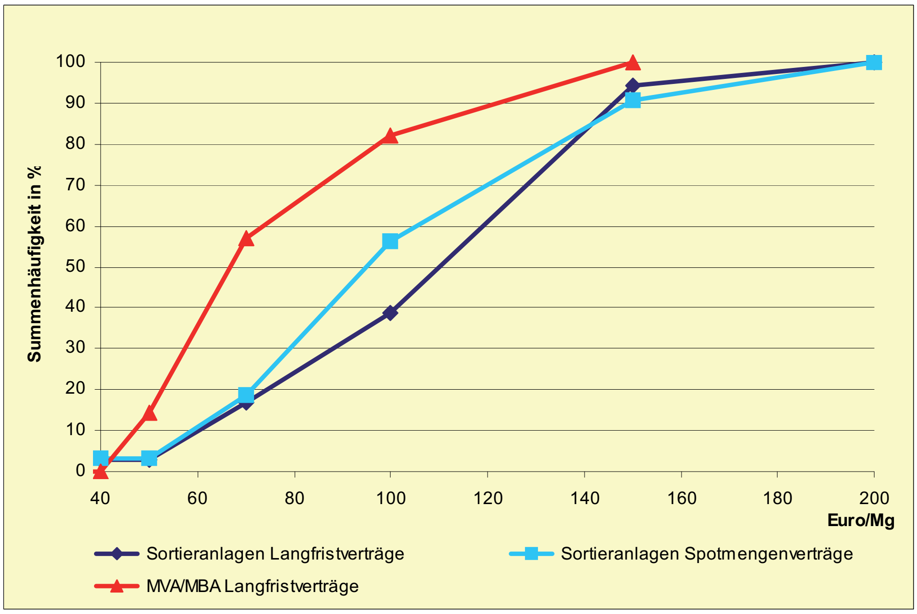


Abbildung 6: Entsorgungspreise für gemischte Gewerbeabfälle in Deutschland 2010 (n= 64)

Wenn trotz dieser Konkurrenzsituation das stoffliche Ressourcenpotential stärker als bislang genutzt werden soll, bedarf es künftig geänderter Rahmenbedingungen.

5 Optimierungsansätze für eine effizientere Nutzung der Ressourcen (Material und Energie)

Um das stoffliche und energetische Potential intensiver als bisher zu nutzen, damit vor allem Rohstoffe und dadurch auch Primärenergie aus fossilen Brennstoffen eingespart werden kann, können die folgenden Optimierungsansätze benannt werden.

- Alle entstehenden Gemische werden Sortieranlagen mit technischen Mindeststandards zugeführt.

  Dadurch hätte im Jahr 2007 der als Sekundärrohstoff nutzbare Anteil von ca. 0,46 Mio. Mg auf rund 1,1 Mio. Mg gesteigert werden können.

- Die Wertstoffausbeute der Vorbehandlungsanlagen wird gesteigert.

  Die Wertstoffgewinnung aus den in Vorbehandlungsanlagen angelieferten gemischten gewerblichen Siedlungsabfällen ist durch die Zusammensetzung und die Stoffcharakteristik technisch begrenzt, weil beispielsweise Feinkornanteile auch bei sensorgestützten Verfahren einer Sortierung von vornherein nicht zugänglich sind. Gegenüber der bisherigen mittleren Wertstoffausbeute von rund 16,5 Ma.-% sind jedoch Steigerungen auf bis zu 30 Ma.-% möglich. Würden zudem alle Gemische prinzipiell einer mechanischen Vorbehandlung zugeführt, wäre unter technischen Gesichtspunkten die Steigerung der Sekundärrohstoffmenge auf rund 1,9 Mio. Mg/a darstellbar. Dieses Potential wird bislang wegen der konkurrenzlos günstigen energetischen Verwertungswege nicht erschlossen.

- Die stoffliche Verwertung für (Misch-)Kunststoffe wird optimiert.

  Durch eine Steigerung der Wertstoffausbeute würden in zunehmendem Umfang Mischkunststoffe anfallen, die allerdings in den vergangenen Jahren zunehmend weniger stofflich verwertet wurden. Da die nachträgliche Aufbereitung und stoffliche Verwertung von Mischkunststoffen hinsichtlich des Treibhauseffektes und des Energieaufwandes günstiger als die energetische Verwertung der Mischkunststoffe beispielsweise in einem Zementwerk ist, müssen neue Aufbereitungskonzepte und Verwertungswege entwickelt und zur Anwendungsreife gebracht werden.

- Die Abtrennung von NE-Metallen wird optimiert.

  Aggregate zur NE-Metallabscheidung werden offenbar aus Kostengründen (Invest) bislang nur in wenigen Sortieranlagen eingesetzt. Um auch das nicht unerhebliche Metallpotential in den Gemischen, die als EBS der energetischen Verwertung zugeführt werden, zu reduzieren, sollte die NE-Metallaushaltung optimiert werden.

- Erzeugung hochwertiger und schadstoffarmer Sekundärbrennstoffe.

  Aus den nach der optimierten Wertstoffausbringung verbleibenden Sortierresten sind hochwertige und möglichst schadstoffarme Ersatzbrennstoffe zu erzeugen, anstatt wie bisher oft üblich die Sortierreste lediglich zu zerkleinern und allenfalls noch die Metalle auszuhalten. Je nach Qualitätsanforderungen können mindestens 30 Ma.-% der nach der Wertstoffausbringung verbleibenden Menge, also rund 2 Mio. Mg, als hochwertiger Sekundärbrennstoff erzeugt und hochwertig verwertet werden.

- Energetische Verwertung der verbleibenden Aufbereitungsreste.

  Erst die nach der Abtrennung stofflich verwertbarer Anteile und hochwertiger Sekundärbrennstoffe verbleibenden Aufbereitungsreste sind schlussendlich in den übrigen Verbrennungsanlagen (EBS-Rostfeuerungen, Müllverbrennungsanlagen) energetisch zu verwerten. Unterkornfraktionen aus Klassieraggregaten müssen entweder nachbehandelt, gemeinsam mit den Sortierresten energetisch oder anderweitig beseitigt werden.

Um angesichts der wirtschaftlichen Situation diese Maßnahmen in die Praxis umzusetzen, wird eine bewertende Quotierung vorgeschlagen, die in erster Linie die stoffliche Verwertung fördert, die Erzeugung hochwertiger Ersatzbrennstoffe aber nicht unberücksichtigt lässt. Diese Quote ist so festzulegen, dass den mechanischen Vorbehandlungsanlagen ein Spielraum bleibt, um auf die heterogene Zusammensetzung der Inputstoffe reagieren zu können. Vorgeschlagen wird deshalb, die bisher ausschließlich massenbezogene Gesamtquote der geltenden Gewerbeabfallverordnung für die stoffliche und energetische Verwertung in eine kombinierte qualitative und quantitative Quote abzuändern.

6 Literatur

Gewerbeabfallverordnung	2002	Verordnung über die Entsorgung von gewerblichen Siedlungsabfällen und von bestimmten Bau- und Abbruchabfällen (Gewerbeabfallverordnung)
Europäischen Union	2008	Richtlinie 2008/98/EG des europäischen Parlaments und des Rates v. 19.11.2008 über Abfälle und zur Aufhebung bestimmter Richtlinien (Abfallrahmenrichtlinie)
Oetjen-Dehne, R., Dehne, I, Döhle, G, Behr, G-R.	2010	Untersuchung von Stoffströmen der Abfallaufbereitungsanlagen in Sachsen-Anhalt, 15. Tagung Siedlungsabfallwirtschaft Magdeburg
Oetjen-Dehne, R, Kalvelage, M.	2007	Erfahrungen mit der Aufbereitung und Verwertung von Ersatzbrennstoffen aus Gewerbeabfällen, in: Internationale Tagung MBA, Hannover
Umweltbundesamt	2011	Abschlussbericht des Forschungsprojekts im UFO-PLAN des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit „Aufkommen, Verbleib und Ressourcenrelevanz von Gewerbeabfällen im Hinblick auf eine mögliche Novellierung der Gewerbeabfallverordnung“ (FKZ 3709 33 314)

Anschrift der Verfasser

Dipl.-Ing. Rüdiger Oetjen-Dehne
u.e.c. Berlin
Levetzowstr. 10 a
D-10555 Berlin
Telefon +49 30 3448039
Website: www.uec-berlin.de

Dipl.-Ing. Manfred Kanthak
Kanthak & Adam GbR
Achenseeweg 11
D-12209 Berlin
Tel.: +49 30 84709929
Website: www.kanthak-adam.de

Sensorbasierte Sortierung zur Erzeugung einer Deponiefraktion aus einer MBA-Schwerfraktion

Praxiserfahrungen und Vergleich verschiedener Aufbereitungsalternativen

Martina Meirhofer[1], Arne M. Ragoßnig[2], Manuel Sommer[1], Simone M. Pieber[1]

[1]BIOENERGY 2020+ GmbH, Forschungsstätte Pinkafeld, Österreich
[2]Fachhochschulstudiengänge Burgenland Ges.m.b.H, Pinkafeld, Österreich

Sensor-based sorting systems for the generation of a landfill fraction out of the heavy fraction of a MBT plant

Abstract

The processing of heterogeneous waste is a major challenge for waste treatment equipment used in mechanical-biological (MB) waste treatment plants. This conference contribution focuses on the technical feasibility and efficiency of different technologies for the processing of a heavy waste fraction from a MB-plant which contains a high portion of high caloric components. The aim is to meet the requirements for waste to be landfilled in Austria. Also economic considerations with regard to the implementation of an additional separation step and the resulting changes in the waste routing are discussed. The processing technologies looked at comprise sensor-based sorting technologies (NIR, X-ray transmission) as well as traditional mechanical density separation technologies such as a jigger and cross-flow air classification.

Inhaltsangabe

Die Behandlung von Abfallströmen einer MBA-Anlage stellt in der Regel durch deren heterogene Zusammensetzung besondere Anforderungen an Trennverfahren und Trennaggregate. Am Beispiel einer Schwerfraktion, welche hohe Anteile an brennbaren, energiereichen Bestandteilen enthält, sollen verschiedene Behandlungssysteme zur Erzeugung einer auf Deponien ablagerungsfähigen Fraktion erprobt werden und durch technische und wirtschaftliche Betrachtungen evaluiert werden. Die betrachteten Behandlungsverfahren umfassen sensorbasierte Verfahren, unter Anwendung von Nahinfrarot und Röntgentransmission, und klassische mechanische Dichtetrennverfahren wie Nasssetzverfahren (Jigger) und Querstromsichtung.

Keywords

Mechanisch-Biologische Abfallbehandlung, Schwerfraktion, Sensorbasierte Sortierung, Dichtetrennung, Wirtschaftlichkeitsbetrachtung, Sensitivitätsanalyse

Mechanical-Biological Treatment, Sensor-based Sorting, Density Separation, Economic Evaluation, Sensitivity Analysis

1 Einleitung

Vorrangiges Ziel der Abfallwirtschaft ist die Vermeidung und Minimierung von Abfällen. Sind Abfälle bereits entstanden, gilt es diese best möglich zu nutzen. Primär ist eine stoffliche Verwertung gewünscht, ist diese technisch wie wirtschaftlich nicht mehr möglich gilt oft die thermische Nutzung als Ersatzbrennstoff als Methode der Wahl. Für alle Verwertungsoptionen gilt, dass einerseits Ressourcen geschont und anderseits durch optimierte Abfallbehandlungsverfahren negative Umweltauswirkungen minimiert werden.

Nicht mehr nutzbare Abfallströme können unter strengen Auflagen einer Deponierung zugeführt werden. Aufgrund der rechtlichen Rahmenbedingungen, um Treibhausgasemissionen aus Deponien zu vermeiden, gilt in Österreich ein Deponierungsverbot für Abfälle mit einem organischen Anteil höher als 5% TOC (Total organic carbon), sofern sie zuvor keiner Behandlung unterzogen wurden. Neben der thermischen Behandlung wird von der Gesetzgebung auch die mechanisch-biologische Abfallbehandlung (MBA) als geeignetes Verfahren akzeptiert, wobei hier für zu deponierende Abfälle u.a. das Brennwertkriterium mit einem Grenzwert von 6.600 $kJ/kg_{TS(Trockensubstanz)}$ einzuhalten ist (DVO 2010).

In Zusammenarbeit mit einem Abfallbehandler wurde eine Schwerfraktion (20 – 80 mm) aus einer MBA-Anlage untersucht, welche große Anteile an inerten Bestandteilen jedoch auch mehr als 50% an energiereichen Materialien (wie Kunststoffe, Holz, Textilien) enthält und somit aufgrund der Nichteinhaltung der Kriterien für eine unmittelbare Deponierung eine Herausforderung in der weiteren Aufbereitung darstellt. Diese Schwerfraktion soll im Weiteren durch ein geeignetes Trennverfahren in eine deponiefähige (niederkalorische, weitgehend inerte) sowie eine thermisch zu entsorgende/verwertende (hochkalorische) Fraktion aufgetrennt werden. Der Fokus der Aufbereitung liegt auf der Erzeugung einer Fraktion, welche die Kriterien der Deponierung einhält. Hierfür wurden in der Forschungsarbeit sensorbasierte Trennverfahren sowie Dichtetrennverfahren für Aufbereitungsversuche ausgewählt und in Versuchsdurchführungen auf ihre Anwendbarkeit untersucht.

Das in Abbildung 1 dargestellte Stoffflussdiagramm zeigt die Behandlungsschritte des Anlageninputs bis hin zur betrachteten Schwerfraktion nach Trennsieb 2 (in der Darstellung grau hinterlegt).

Grob beschrieben besteht die Aufbereitung aus einer Zerkleinerung des Anlageninputs, mehreren Siebschritten sowie Stufen der ballistischen Separation zur Abtrennung von großflächigen (energiereichen) Bestandteilen sowie von mineralischen und biogenen Feinanteilen, Metallabscheidungsstufen (Eisen und Nichteisenmetalle) sowie einer dynamischen Vorrotte. Der Abfallstrom fällt mit rund 4.000 t pro Jahr an und macht einen Massenanteil am Anlageninput von rund 5,2% aus.

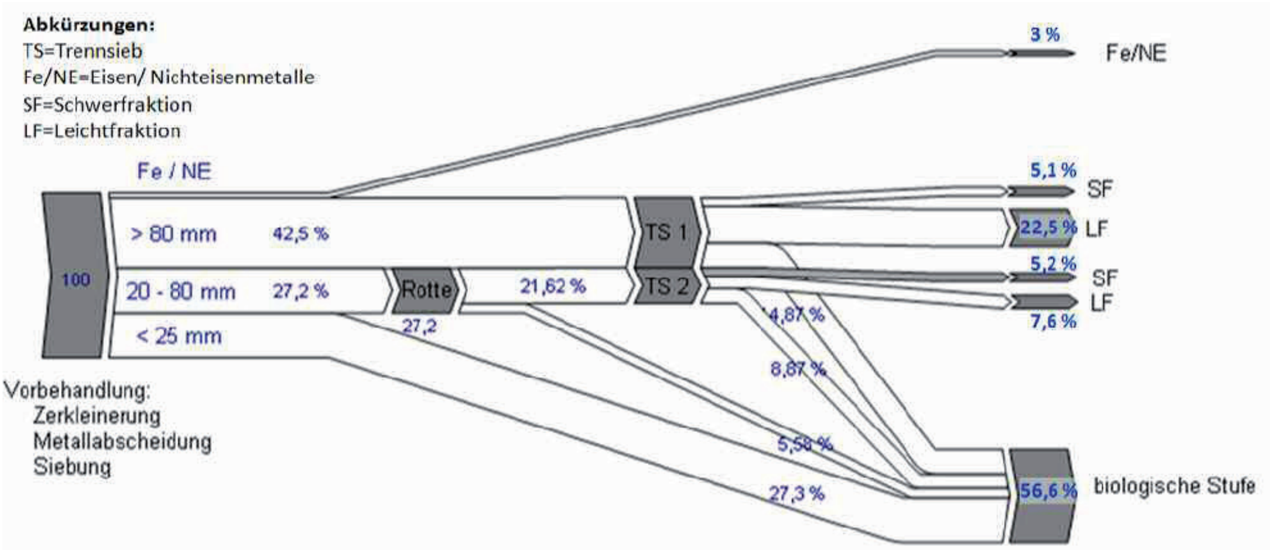


Abbildung 1 Stoffflussdiagramm der MBA-Anlage (UDB 2009)

2 Aufbereitungsversuche

2.1 Verwendete Aufbereitungstechnologien

Für die Durchführung von Aufbereitungsversuchen wurden sensorbasierte Sortierverfahren und mechanische Dichtetrennverfahren verwendet. Für die sensorbasierten Verfahren fiel die Entscheidung auf zwei verschiedene Nahinfrarotsysteme (NIR) und das Röntgentransmissionsverfahren, als Dichtetrennverfahren wurden eine Nasssetzmaschine, ein luftunterstütztes ballistisches Trennaggregat (Hartstoffscheider) und ein Querstromsichter ausgewählt. In Tabelle 1 werden die für die Auswahl der Trennverfahren wesentlichen Kriterien und Parameter zusammengefasst.

Für die Versuchsdurchführung mittels sensorbasierter Sortierung wurden zwei unterschiedliche Nahinfrarot Systeme (NIR) zum einen mit Multiplexer-Technologie (Wellenlängenbereich von 1.400 – 1.900 nm) (LLA 2010) und zum anderen mit Spectral Imaging (erweiterter Wellenlängenbereich bis 2.400 nm und Objekterkennung) (EVK 2008) verwendet. Als weiteres System wurde das Röntgentransmissionsverfahren ausgewählt. Als Dichtetrennverfahren wurden das Nasssetzverfahren (Jigger) sowie zwei luftunterstütze Trennverfahren (Hartstoffschieder, Querstromsichter) betrachtet.

Mit den oben erwähnten trockenen Dichtetrennverfahren und dem Röntgentransmissionsverfahren wurden bis zum gegenwärtigen Zeitpunkt nur orientierende Versuche durchgeführt, weshalb diese in der Vergleichsdarstellung (siehe Abbildung 3) nicht aufgelistet werden. Wissenschaftlich begleitete Aufbereitungsversuche mit diesen Verfahren sind in Vorbereitung.

Tabelle 1 Klassifizierung ausgewählter Trennverfahren für die vorliegende Trennaufgabe

Anlagentyp	Technischer Aufwand	Korngröße [mm]	Materialfeuchte	Variable Anlagenparameter	Anzahl Trenn-fraktionen
NIR-Sortierung (Optischer Multiplexer)	Hoch, durch Verwendung von Sensoren, EDV und mech. Komponenten	> 15	Problematisch, durch Veränderung der Reflexionsspektren	Abtastrate, Bandgeschwindigkeit, Druckluftmenge und Druckluftimpulsdauer	2
NIR-Sortierung (Spectral Imaging)	Hoch, durch Verwendung von Sensoren, EDV und mech. Komponenten	> 10	Problematisch, durch Veränderung der Reflexionsspektren	Abtastrate, Bandgeschwindigkeit, Druckluftmenge und Druckluftimpulsdauer	2
Röntgensortierung	Hoch, durch Verwendung von Sensoren, EDV und mech. Komponenten, Arbeitsschutz	15 - 250	Unproblematisch , möglicherweise Einfluss auf Austrageverhalten	Druckluftmenge und Druckluftimpulsdauer	2
Nasssetzmaschine (Jigger)	Gering, Trennung erfolgt durch Schwingungen	> 12	Unproblematisch	Hubhöhe und -zahl	2
Hartstoffscheider, luftunterstützte ballistische Separation	Gering; Trennung erfolgt durch mechanische Vibration und Luftunterstützung	20-80	Unproblematisch	Kaskadenförmig angeordnete Trennbleche sind in ihrer Neigung variabel	3
Querstrom-sichter	Gering, Trennung erfolgt durch horizontale Luftströmung	20-80	Unproblematisch	Luftdüsenwinkel, Volumenstrom; Paddelstellung	3

2.2 Beurteilung des Aufbereitungsergebnisses

Ziel der Versuchsdurchführungen war es die kohlenstoffreichen und somit hochkalorischen Abfallbestandteile von den niederkalorischen, inerten Abfallbestandteilen abzutrennen. Der Fokus der betrachteten Verfahren liegt dabei auf dem maximalen Ausbringen der hochkalorischen Bestandteile und der Reinheit der zu deponierenden Fraktion. Das Ausbringen stellt das Massenverhältnis des auszubringenden Materials im Auswurf bzw. der Leichtfraktion bezogen auf dessen Inputmasse dar. Die Reinheit stellt den Anteil des dem jeweils betrachteten Outputstrom korrekt zugeordneten jeweiligen Massenanteil dar. Die durch manuelle Sortierung erfolgten Beurteilungen werden für die niederkalorische / inerte Fraktion durch chemische Analytik (Parameter lt. Deponieverordnung) ergänzt (DVO 2010). Die Leichtfraktion wird basierend auf den Parametern der Abfallverbrennungsverordnung beurteilt (AVV 2010). Im mit brennbaren / energiereichen Materialien angereicherten Stoffstrom sollten sich sonstige Organik, Holz, PPK (Papier, Pappe, Karton)-Anteile, Kunststoffe (sowohl hell als auch dunkel), Textilien und sonstige Abfälle wiederfinden. Der inerte/energiearme Rest sollte sich aus Metallen, schadstoffhaltigen Abfällen, Inertmaterialien und der Feinfraktion zusammensetzen.

Bei den sensorbasierten Sortierungen, welche im Technikumsmaßstab durchgeführt werden, wurden in einem ersten Versuchsdurchlauf die Grundeinstellungen für ein vorerst ausreichendes Trennergebnis festgelegt und diese im Laufe mehrerer Versuchsdurchgänge variiert um die Qualität des Durchlaufes (inerte / niederkalorische Materialien, wie Steine, Glas, Keramik, Metalle, etc.), welche vorerst anhand manueller Sortierungen beurteilt wurde, zu optimieren. Um die Durchlaufqualität zu verbessern, können der Druck und die Dauer des Druckluftimpulses und je nach verwendetem Verfahren die Abtastgeschwindigkeit der Sensoren und das tolerierte Rauschen der reflektierten Spektren (NIR) variiert werden. Je Versuchsreihe wurden drei Durchgänge mit den jeweils selben Parametereinstellungen durchgeführt, um eine statistische Bewertung der Ergebnisse zu erlauben. Die Erprobung der Dichtetrennverfahren wurde als einmalige Versuche im großtechnischen Maßstab konzipiert. Auch hier wurden jeweils drei Proben der Output-Fraktionen charakterisiert.

Um Schwankungen in der Zusammensetzung des Versuchsmaterials nachvollziehen zu können wurden im Vorfeld über ein Jahr hinweg im Rahmen einer Charakterisierung des Stoffstroms (Sortierungen an zwei Tagen in einer ausgewählten Woche je Quartal) die Bandbreiten der Fraktionsanteile ermittelt (Abbildung 2). Damit eine Interpretation hinsichtlich der Vergleichbarkeit der Trennergebnisse der einzelnen Verfahren gewährleistet ist, wurde die Zusammensetzung des Abfallstroms auch bei den Aufbereitungsversuchen durch manuelle Sortierung ermittelt.

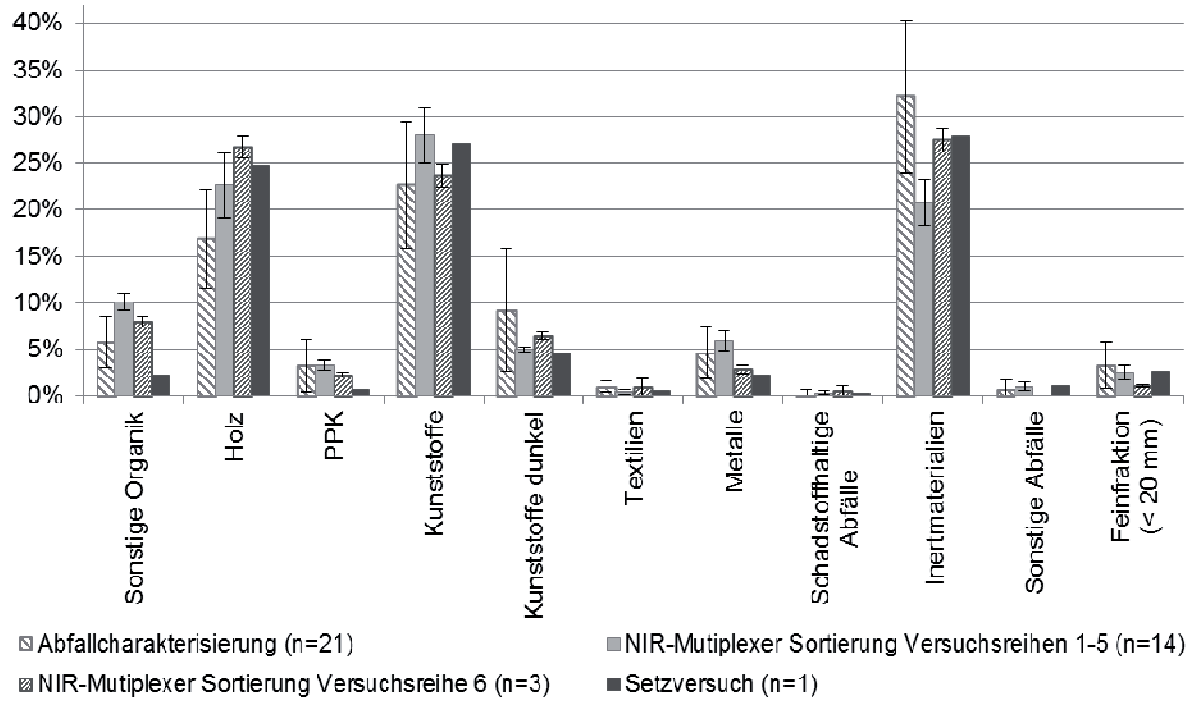


Abbildung 2 Gemittelte prozentuelle Materialzusammensetzung der Schwerfraktion nach Trennsieb 2, als Mittelwert ± Standardabweichung

Der Vergleich des verwendeten Probenmaterials bei der sensorbasierten Sortierung und dem Nasssetzversuch zeigt zum Teil erhebliche Abweichungen von den Ergebnissen der manuellen Sortierung auf. Es wird deutlich, dass der Anteil sonstiger Organik (im wesentlichen Vegetabilien), Holz und heller Kunststoffe erhöht und der Anteil der Inertmaterialien und zum Teil der Metalle bei den NIR-Sortierungen bei der Betrachtung der Mittelwerte stark reduziert war. Da die Probenahmen des Materials der Versuchsreihen 1 bis 5 und der Versuchsreihe 6 zu unterschiedlichen Zeitpunkten erfolgte, sind die jeweiligen Zusammensetzungen als getrennte Datenreihen dargestellt. Das Versuchsmaterial des Nasssetzversuches zeigte ein ähnliches Bild wie bei den Technikumsversuchen der sensorbasierten Sortierung, auch hier waren die Mittelwerte der Holz- und Kunststoffanteile erhöht und der Anteil an Inertmaterialien im Vergleich zu den manuellen Sortierungen an der Anlage etwas niedriger, jedoch ist zu beachten, dass das Probenmaterial aufgrund des Trennverfahrens einen deutlich höheren Wassergehalt aufwies und hierdurch Verschiebungen der Massenverhältnisse begründet sein können. Es ist aber festzuhalten, dass die bei den Aufbereitungsversuchen festgestellte Materialzusammensetzung basierend auf den Standardabweichungen der durchgeführten Stoffstromcharakterisierung in der zu erwartenden Bandbreite lag.

Dunkle Kunststoffe wurden bei der Charakterisierung des Abfallstromes wie auch der des Versuchsmaterials separat angeführt, da deren Massenanteil insbesondere bei der Beurteilung der sensorbasierten Sortierung (NIR), aufgrund ihrer schlechten Erkennbarkeit, von entscheidender Bedeutung sein kann.

2.3 Ergebnisse & Diskussion

Bei der Durchführung der NIR-Versuche mit der Multiplexertechnologie wurden insgesamt sechs Versuchsreihen zu je drei Versuchen durchgeführt (je Versuch ca. 20 kg_{FS} Probenmaterial). In den ersten fünf Versuchsreihen wurde schrittweise eine Parametervariation durchgeführt und die Ergebnisse der nachfolgenden manuellen Sortierungen evaluiert. Die optimalen Parametereinstellungen wurden in der vierten Versuchsreihe gefunden. Aufgrund des fortgeschrittenen Probenalters wurde die letzte Versuchsreihe (Versuchsreihe 6) als Wiederholung der Versuchsreihe 4 mit einer frischen Probe durchgeführt um eine realitätsnahe Bewertung der Aufbereitung zu ermöglichen.

Die Auswertung der manuellen Sortierung zeigte, dass insbesondere dunkle Kunststoffe aber auch sonstige Organik und Holz nicht in gefordertem Maße ausgebracht wurden. Durch den geringeren Anteil der Inertmaterialien im Input der Versuchsreihen, erhöhte sich darüber hinaus der Anteil auszubringender Masse was sich bei einer Negativsortierung (Ausschleusen nicht gewünschter Bestandteile) unvorteilhaft auf das Trennergebnis auswirkte.

Nach dem im großtechnischen Maßstab durchgeführten Setzversuch wurde ein repräsentativer Anteil der separat verladenen und verwogenen Produktströme einer manuellen Sortierung unterzogen. Die Detailauswertung der manuellen Sortierung der Produktströme des Setzversuchs zeigt einen geringfügig höheren Metallanteil in der Leichtfraktion, welcher durch die Ausschwemmung von Aluminium, insbesondere in Form von Verpackungsfolie, und anderen Metallen geringer Dichte resultiert und somit deren hohes Ausbringen begründet. Die hochkalorischen Bestandteile des Versuchsmaterials konnten im Allgemeinen mit hohen Ausbringraten abgetrennt werden. Die in der Schwerfraktion vorhandenen Kunststoffe, waren meist massive Abfallbestandteile oder in Materialverbunden integriert. Die Massenverhältnisse der hoch- und niederkalorischen Bestandteile in den Produktströmen zeigten für das Setzverfahren im Vergleich zur sensorbasierten Sortierung jedoch grundsätzlich ein besseres Trennergebnis.

In Abbildung 3 wird ein grafischer Vergleich der bisher in Versuchen erproben Trennverfahren (NIR-Multiplexer und Setzverfahren) angestellt. Dargestellt werden die Reinheiten der beiden Outputströme und das Ausbringen in die Leichtfraktion für beide Trennverfahren. Die niedrige Reinheit des niederkalorischen Stroms bei den NIR-Versuchen liegt darin begründet, dass große Anteile hochkalorischer / kohlenstoffreicher Bestandteile nicht ausgebracht werden konnten und im Durchlauf (d.h. der zu deponierenden Fraktion) verblieben, dies wird auch durch das niedrige Ausbringen untermauert. Das hohe Ausbringen hochkalorischer Bestandteile wirkte sich im Setzversuch deutlich auf die Reinheit der niederkalorischen Fraktion aus.

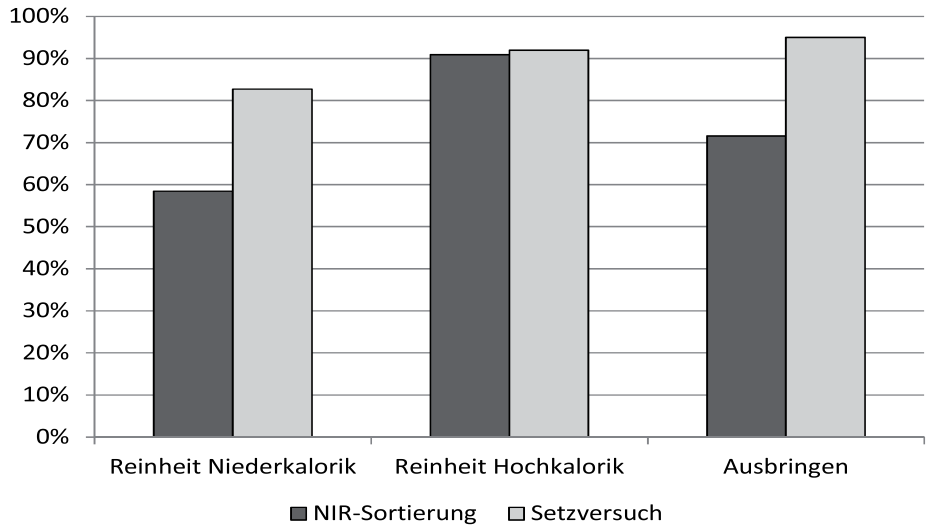


Abbildung 3 Vergleich der Trennergebnisse von NIR-Multiplexer Sortierung und Setzversuch, Angaben in Prozent

Gründe für das niedrige Ausbringen bei den NIR-Versuchen für einzelne Fraktionen sind ihre zum Teil schlechte Erkennbarkeit (zu geringe Reflexion), die teils geringe Partikelgröße und ungünstige -geometrie (rollendes Verhalten) sowie oberflächlich anhaftende Materialien und Verschmutzungen. Ein Einhalten des in der Deponieverordnung geforderten Brennwertes von unter 6.600 kJ/kg $_{TS}$ kann mit diesem Trennergebnis noch nicht gewährleistet werden. Weiterführende theoretische Betrachtungen zeigten jedoch, dass z.B. alleine bei einer Steigerung des Ausbringens dunkler Kunststoffe auf die Größenordnung des Ausbringens der Kunststoffe generell die Einhaltung des Brennwertkriteriums möglich wäre.

Über die Evaluierung des guten Trennergebnisses des Setzerfahrens hinausgehend ist jedoch eine Gesamtbewertung des Verfahrens durchzuführen. Hier ist jedenfalls die Notwendigkeit der Wasserhaltung negativ zu bewerten. Durch den intensiven Kontakt des Materialstromes mit dem Wasser werden anhaftende Schmutzpartikel und somit potentiell Schadstoffe und organische Fracht ausgewaschen. Diese finden sich nicht mehr im zu deponierenden bzw. thermisch zu behandelnden Materialstrom, da sie in die Wasserphase und in den ausgeschleusten Schlamm verlagert werden.

Um der Handhabe mit schadstoffbelastetem Prozesswasser und –schlamm zu entgehen wurden die Trockentrennverfahren der Querstromsichtung und das Röntgentransmissionsverfahren, welche ebenfalls die Dichte als Trennkriterium heranziehen, für weitere Versuche ausgewählt. Da die Materialerkennung bzw. -ausschleusung hier nicht durch oberflächliche Beschichtungen oder Materialanhaftungen beeinflusst werden. Zusätzlich wurde das Spectral Imaging Verfahren (NIR), welches durch den Einsatz einer Objekterkennung eine Zuordnung der Spektren zu Objekten ermöglicht und somit eine gezieltere Steuerung und Entscheidungsfindung für den Ausbringimpuls getroffen werden kann, ausgewählt. Indikative Versuche lieferten vielversprechende Ergebnisse, entsprechende wissenschaftlich begleitete Versuche befinden sich derzeit in Umsetzung.

3 Ökonomische Bewertung

Ein weiterer wesentlicher Schwerpunkt dieser Arbeit liegt in der detaillierten Darstellung einer gesamtwirtschaftlichen Betrachtung der jeweiligen Aufbereitungsalternativen. Basierend auf der gegenwärtigen Marktsituation sowie der Abschätzung möglicher Marktentwicklungen, wurde ein Kostenrahmen für die thermische Behandlung bzw. Verwertung der generierten Abfallfraktionen festgelegt, welcher als Ausgangsbasis zur Bewertung der Wirtschaftlichkeit diente. Das primäre Ziel liegt hierbei nicht nur in einer Betrachtung der wirtschaftlichen Rentabilität der jeweiligen Aufbereitungsoptionen, sondern in einem aussagekräftigen Vergleich der einzelnen Technologien.

3.1 Methodik

Das grundlegende Prinzip der wirtschaftlichen Auswertungen, welche in den nachfolgenden Abbildungen dargestellt werden, beruht zunächst auf einer Identifikation jener Parameter, welche den signifikantesten Einfluss auf die ökonomische Bewertung besitzen. Anhand eines vordefinierten Basisszenarios, in dem sämtliche Einflussgrößen einen wahrscheinlichen Ausgangswert besitzen, erfolgte systematisch die Variation jeweils eines Parameters (bzw. einer Einflussgröße), um sowohl deren Auswirkung auf die spezifischen Aufbereitungskosten zur Erzeugung einer deponierfähigen Schwerfraktion als auch auf das jährliche Einsparungspotential für die Entsorgung des betrachteten Abfallstroms im Falle der Implementierung einer entsprechenden zusätzlichen Aufbereitungsstufe zu untersuchen. An dieser Stelle sei zum besseren Verständnis angeführt, dass sich das Einsparungspotential aus der Differenz zwischen den anfallenden Behandlungskosten des gegenwärtigen Referenzszenarios (Kosten für die thermische Behandlung der Schwerfraktion) und den Gesamtkosten für den Betrieb der jeweiligen Aufbereitungsstufe (NIR-Sortierung bzw. Jigger) zuzüglich der Behandlungs- bzw. Entsorgungskosten für die aus dem zusätzlichen Aufbereitungsschritt resultierenden Abfallströme ergibt.

Anhand von Abbildung 4 wird nachfolgend das Prinzip der grafischen Darstellung der Wirtschaftlichkeitsbewertung erläutert. Untersucht wird hierbei der Einfluss einer Veränderung der Investitionskosten, des Strompreises sowie des jährlichen Durchsatzes auf die spez. Aufbereitungskosten der sensorbasierten Sortiermethode (NIR-Sortiertechnik). Die x-Achse dient hierbei der Darstellung der Parametervariation, wobei eine sich verändernde Bandbreite von -50 % bis +50 % gegenüber dem Basisszenario (0%) betrachtet wird. Die vertikale y-Achse stellt analog dazu die prozentuelle Erhöhung bzw. Verminderung der spezifischen Aufbereitungskosten dar.

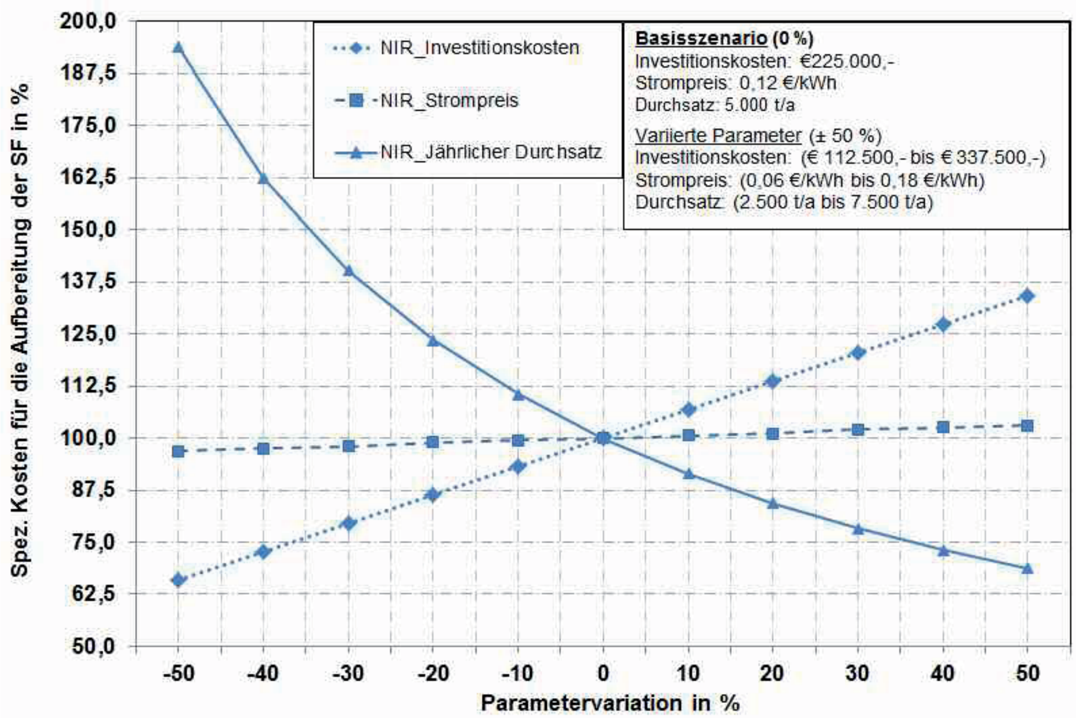


Abbildung 4 Einfluss der Parametervariation von Investitionskosten, Strompreis und jährlichem Durchsatz auf die spez. Aufbereitungskosten einer NIR-Sortierstufe

Wie in Abbildung 4 bereits sehr gut verdeutlicht wird, besitzen die einzelnen Parameter einen durchaus unterschiedlichen Einfluss auf die wirtschaftliche Rentabilität der Anlage. So zeigt eine Veränderung der Investitionskosten im gesamten Variationsspektrum eine deutlich höhere Signifikanz für die spez. Aufbereitungskosten als die Änderung des Strompreises. Werden die Investitionskosten beispielsweise um 50 % erhöht, bedeutet dies einen Anstieg der spezifischen Aufbereitungskosten pro Tonne Abfall um ca. 34 %. Dem gegenüber führt eine fünfzigprozentige Zunahme des Strompreises lediglich zu einer knapp dreiprozentigen Steigerung der spez. Kosten.

Die größte Bandbreite in Hinblick auf eine Veränderung der Aufbereitungskosten resultiert jedoch eindeutig aus einer Veränderung des jährlichen Durchsatzes, wie in Abbildung 4 anhand der Kostenkurve ebenfalls ersichtlich ist. So führt eine Halbierung der behandelten Abfallmenge annährend zu einer Verdoppelung der spez. Aufbereitungskosten, woraus eindeutig die Erkenntnis gewonnen werden kann, dass dieser Parameter das größte Einflusspotential besitzt und somit besondere Bedeutung für die wirtschaftliche Rentabilität der Anlage erlangt.

3.2 Vergleich der Aufbereitungsverfahren

Das selbe Auswertungsprinzip wie in Abbildung 4 erfolgte neben der sensorbasierten NIR-Methode auch für das Nasssetzverfahren mittels Jigger und zeigt nahezu identische Auswirkungen der einzelnen Parametervariationen auf die spez. Aufbereitungskosten. Von besonderer Bedeutung für einen aussagekräftigen Vergleich der einzelnen

Technologien ist hier jedoch die Tatsache, dass die spezifischen Aufbereitungskosten des Jigger-Verfahrens im Basisszenario um ca. 20 % über den spezifischen Aufbereitungskosten des NIR-Verfahrens liegen, was vor allem auf die Tatsache zurückzuführen ist, dass die wirtschaftliche Kalkulation unter Betrachtung zusätzlicher relevanter Kostenfaktoren (z.B. höhere Investitionskosten, Prozessschlammaufbereitungskosten, Kosten für Prozesswasser, Abwasserentsorgungskosten) durchgeführt wurde.

Abbildung 5 zeigt einen Vergleich der Auswirkungen der Parametervariationen auf das jährliche Einsparungspotential für die Entsorgung des betrachteten Abfallstroms in Bezug auf die aktuelle Situation (Referenzszenario) bei Implementierung einer zusätzlichen NIR-Sortierstufe sowie eines Jiggers. Dieser Vergleich setzt die Erreichung der gesetzlich festgelegten Kriterien für eine Deponierung bei beiden Aufbereitungstechnologien voraus.

Anhand der Bandbreite der y-Achse lässt sich hier ebenfalls erkennen, dass das jährliche Einsparungspotential, welches durch Implementierung der jeweiligen Aufbereitungstechnologie erzielt wird, maßgeblich von der Variation des jährlichen Durchsatzes beeinflusst wird. Abbildung 5 zeigt in einem direkten Vergleich beider Aufbereitungstechnologien ein höheres Einsparungspotential durch das NIR-Verfahren, was vor allem auf die Tatsache zurückzuführen ist, dass das Kalkulationsmodell des Jiggers höhere Investitions- sowie Entsorgung- bzw. Verwertungskosten der generierten Schwer- und Leichtfraktion (aufgrund der Massenzunahme durch erhöhten Wassergehalt) als auch die zuvor erwähnten Kostenfaktoren (für Prozessschlammaufbereitung usw.) berücksichtigt.

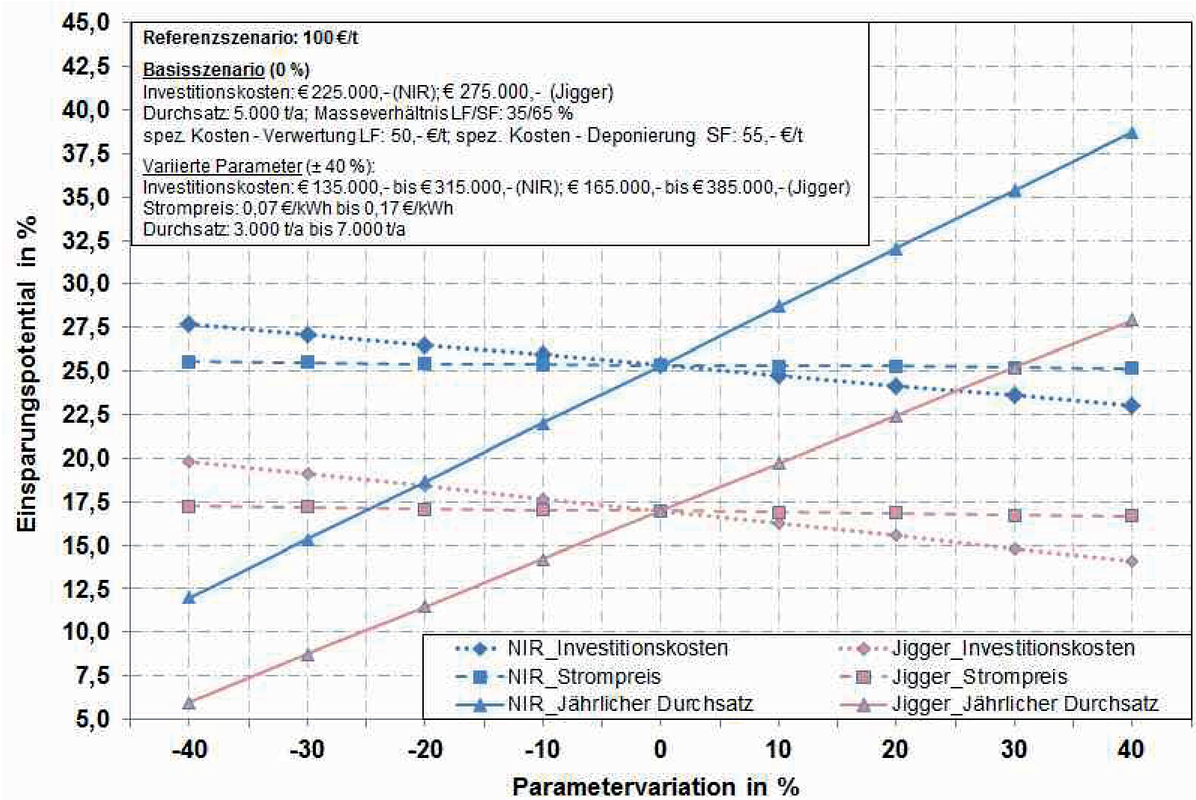


Abbildung 5 Vergleich des Einflusses der Parametervariation von Investitionskosten, Strompreis und jährlichem Durchsatz auf das jährliche Einsparungspotential bei Implementierung einer NIR-Sortierstufe bzw. eines Jiggers

Eine relevante Betrachtung liegt vor allem in der Parametervariation der spezifischen Entsorgungskosten der Deponiefraktion sowie der Kosten für die thermische Verwertung / Behandlung der heizwertreichen Leichtfraktion.

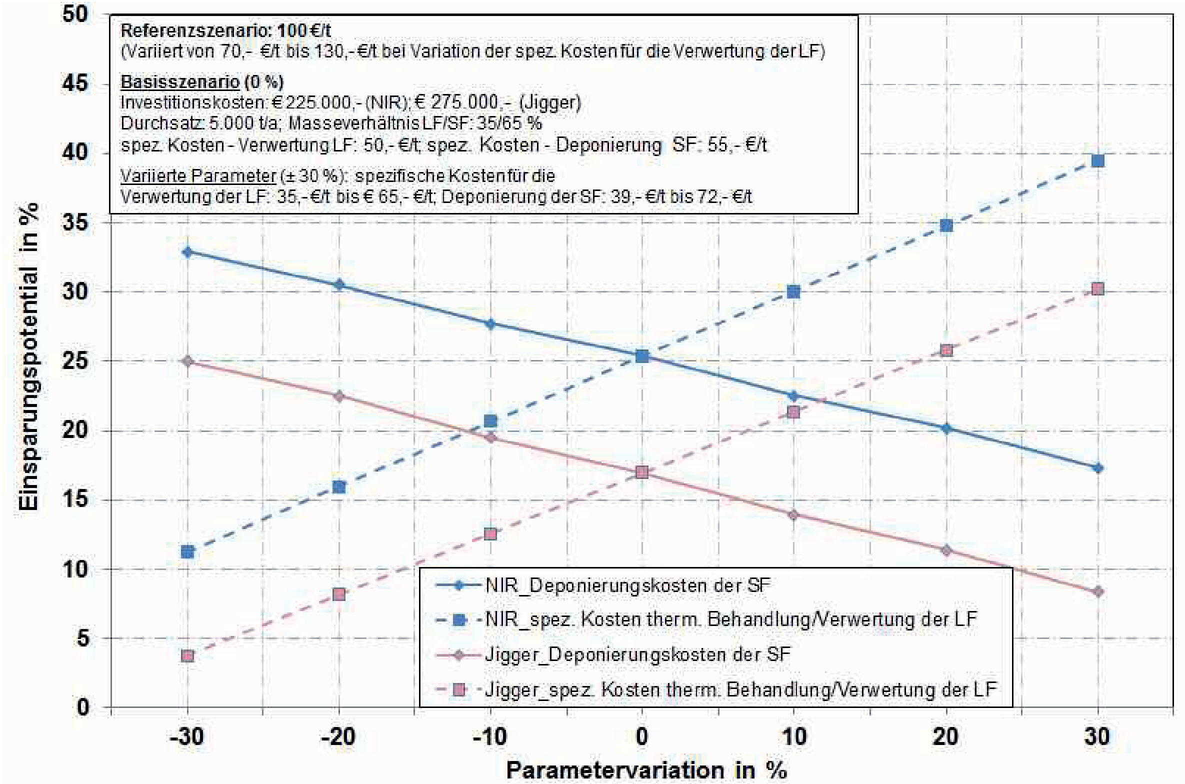


Abbildung 6 Vergleich des Einflusses der Parametervariation von Deponierungskosten der SF sowie der spez. Kosten für die thermische Verwertung der LF auf das jährliche Einsparungspotential bei Implementierung einer NIR-Sortierstufe bzw. eines Jiggers

Eine Erhöhung der spezifischen Deponierungskosten für die generierte Schwerfraktion führt zwangsläufig zu einer Reduzierung des Einsparungspotentials und stellt zudem einen signifikanten Einflussfaktor dar, wie aus Abbildung 6 hervorgeht. So bewirkt beispielsweise eine Reduktion der Deponiekosten um 30 % des Ausgangswertes einen Anstieg der ursprünglichen Einsparung im Basisszenario um 7,5 % sowohl für die NIR-Sortierstufe als auch den Jigger.

Die Variation der spez. Verwertungskosten der Leichtfraktion bewirken jedoch den signifikanteren Einfluss auf die Veränderung des Einsparungspotentials für beide Aufbereitungsverfahren. Der Verlauf des ansteigenden Einsparungspotentials bei einer Erhöhung der spezifischen Kosten für die Verwertung / Behandlung der heizwertreichen LF liegt in der Tatsache begründet, dass ein Kostenanstieg für die thermische Verwertung / Behandlung der LF jeweils auch mit einer entsprechenden Erhöhung der Kosten für die thermische Behandlung der Schwerfraktion im Referenzszenario (spez. Kosten für die thermische Behandlung der gegenwärtigen Schwerfraktion) einhergeht. Eine quantitative Erhöhung der spez. Kosten des Referenzszenarios steht wiederum in direktem Verhältnis mit einem linearen Anstieg des Einsparungspotentials.

4 Zusammenfassung und Ausblick

Generell scheinen die beiden bereits im Detail betrachteten Verfahren für die Lösung der dargestellten Aufbereitungsfragestellungen geeignet. Aus den zuvor erläuterten Ergebnissen wird deutlich, dass bei der Anwendung der NIR-Sortierung die Reinheit des Durchlaufes unter dem geringeren Ausbringen einzelner Materialien leidet. Grund hierfür sind die schlechte Erkennbarkeit von dunklen Materialien, organischen Bestandteilen (wie Vegetabilien) sowie oberflächliche Verschmutzung und der Umstand, dass bei der Versuchsdurchführung die Beruhigungsstrecke auf dem Transportförderband für stark rollende Partikel zu kurz war. Aus diesem Grund wurde das NIR-Spectral Imaging als weiteres Verfahren ausgewählt, da durch einen erweiterten Spektralbereich und eine Objekterkennung sowie des Scannens der Objekte im freien Fall, bessere Trennergebnisse zu erwarten sind. Orientierende Versuche mit diesem System zeigten bereits vielversprechende Ergebnisse. Auch das Röntgentransmissionsverfahren wurde als weitere sensorbasierte Sortiertechnologie ausgewählt, da hier die Materialerkennung über die Partikeldichte erfolgt und hier die Störfaktoren (Materialfeuchte, Schmutzanhaftungen, Oberflächenbeschichtungen) der NIR-Sortierung belanglos sind.

Das Setzverfahren weist nach der Beurteilung der Ergebnisse eine deutlich bessere Trennschärfe auf, jedoch ist hier zu beachten, dass Wasser als Trennmedium eingesetzt wurde, dies erfordert zusätzlich eine Beurteilung der Auswaschung von Organik und Schadstoffen. Orientierende Versuche mit einem Hartstoffscheider konnten für die betrachtete Schwerfraktion keine zufriedenstellenden Trennergebnisse liefern, da sich insbesondere die Partikelgeometrien unvorteilhaft auswirkten. Erste Versuche mit einem Querstromsichter erwiesen sich als erfolgreich – ein großtechnischer Versuch befindet sich in Vorbereitung.

Die wirtschaftliche Bewertung der einzelnen Varianten (inkl. Parametervariationen) hat deutlich gezeigt, dass selbst die Annahme verhältnismäßig ungünstiger wirtschaftlicher Bedingungen, wie beispielsweise hoher Entsorgungs- und Verwertungskosten, zu hohen Einsparungen gegenüber dem derzeit bestehenden Szenario führt. Ein direkter Vergleich zwischen der sensorbasierten Sortiermethode und dem Nasssetzverfahren zeigt aufgrund der unterschiedlichen Kostenstruktur klare wirtschaftliche Vorteile für das NIR-Verfahren.

5 Danksagung

Das Forschungsvorhaben „Waste as Renewable Energy Source“ wird im Rahmen des Forschungsprogramms des K1-Zentrums BIOENERGY 2020+ – gefördert durch Mittel aus dem durch die Forschungsförderungsgesellschaft abgewickelten Förderprogramm COMET – durchgeführt. Das K1-Zentrum BIOENERGY 2020+ wird neben Bundesmitteln aus Landesmitteln der Länder Burgenland, Niederösterreich und Steiermark finanziert. Die erforderliche Co-Finanzierung für das gegenständliche Forschungsvorhaben wird durch die Umweltdienst Burgenland GmbH, die Saubermacher Dienstleistungs AG sowie die BT-Wolfgang Binder GmbH bereitgestellt.

6 Literatur / Referenzen

AVV (Abfallverbrennungsverordnung)	2010	Bundesminister für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (Hrsg.), BGBl. II Nr. 389/2002 in der Fassung BGBl. II Nr. 476/2010, Wien
DVO (Deponieverordnung)	2010	Bundesminister für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (Hrsg.), BGBl. II 39/2008 in der Fassung BGBl. II 178/2010, Wien
EVK DI Kerschhaggl GmbH (Hrsg.); Kulcke A. et al.	2008	Sensorgestützte Sortierung 2008. 2D - NIR Spektroskopie und materialselektive induktive Metallerkennung im Recycling: Technologie und Praxisbeispiele
LLA Instruments GmbH (Hrsg.)	2010	http://www.lla.de/index.php/content/view/75/148
UDB	2009	Informationen bereitgestellt von Fr. Szabo, Umweltdienst Burgenland GmbH

Anschrift der Verfasser(innen)

Martina Meirhofer, BSc, DI Manuel Sommer und DI Simone M. Pieber
BIOENERGY 2020+ GmbH, Forschungsstätte Pinkafeld
Steinamagerstraße 21
A-7423 Pinkafeld
Telefon +43(0)3357/45370-1335
Email martina.meirhofer@bioenergy2020.eu
Website: www.bioenergy2020.eu

Prof.(FH) DI Dr. Arne M. Ragoßnig, MSc (OU)
Fachhochschulstudiengänge Burgenland Ges.m.b.H.
Steinamagerstraße 21
A-7423 Pinkafeld
Telefon +43(0)3357/45370-1070
Email arne.ragossnig@fh-burgenland.at
Website: www.fh-burgenland.at

Splitting of heterogeneous waste by sensor-based sorting as a basis for optimized material-specific waste-routing

Simone M. Pieber*, Arne M. Ragossnig, Manuel Sommer*, Martina Meirhofer*, Alexander Curtis***, Roland Pomberger*****

*BIOENERGY 2020+ GmbH, Pinkafeld Research Site, Austria

**Fachhochschulstudiengänge Burgenland GmbH, Pinkafeld, Austria

***Saubermacher Dienstleistungs AG, Graz, Austria

Abstract

In the presented work material-specific sensor-based sorting was evaluated for its technical application on heterogeneous wastes on a pilot and a large scale, in order to optimize the routing options of waste streams in an economically attractive way. Two sorting steps were conducted with the aim to process the specific waste streams and to generate value-added output streams. The first sorting step should allow for quality improvements (chlorine, heavy metal content) in the present waste streams in order to increase available options for industrial (co-)incineration. The second one aimed at increasing the biogenic carbon content, as the portion of biogenic CO_2 emissions gains in importance whenever waste is being co-incinerated in facilities subject to the EU emission trading scheme on CO_2.

The trials indicated that the application of sensor-based sorting for the splitting of the heterogeneous waste streams looked at is technically feasible as well as economically attractive.

Keywords

Sensor-based Sorting, Refuse Derived Fuel (RDF), Heterogeneous Waste, Material-specific Waste-Routing, Cement Industry, Near Infrared, Economic Evaluation

1 Introduction

Heterogeneous wastes, which consist of a material mix in varying composition and contain impurities, can only be material recycled and used for “waste-to-resources” with extensive processing. Therefore, “waste-to-energy” is one particularly relevant and often used option for heterogeneous waste. “Waste-to-energy” is, amongst others, the (co-)incineration of so-called “refuse derived fuel” (RDF) in industrial facilities like cement plants. One purpose thereby is to substitute fossil fuels. Nevertheless, specific quality requirements need to be met for waste to be used as energy source as well, in order to ensure that neither product quality nor environmental standards are being compromised. These quality criteria are different for the variety of potential “waste-to-energy” options and are therefore determining for the waste-routing.

The current widely applied approach to split heterogeneous solid waste streams to optimize their quality for the following energetic recovery or treatment is to perform very basic mechanical processing steps (crushing/shredding, classification and ballistic separation), using predominantly the particle size and density as separation criteria. The use of specific material characteristics which can be linked to specific chemical constituents, as separation criteria, is not yet widely applied, although previous research has demonstrated that basic mechanical processing steps are not sufficient for the required material-specific processing in e.g. RDF production. This is especially true for the chlorine content (e.g. ROTTER ET AL., 2004) which is a determining quality requirement in RDF co-incineration in the cement industry.

Material-specific characteristics can, on the other hand, be used as separation criterion by sensor-based sorting. Sensor-based sorting is the single particle separation on the basis of identifiable criteria which can be measured by suitable detectors. A specific object is notified by a detector, identified by a spectroscope, and ejected from the waste stream - usually by a pneumatic pulse. Material-specific characteristics for the identification are e.g. molecular characteristics and associated spectroscopic behaviour of e.g. polymeric material. Consequently, compared to above-mentioned separation technologies completely new sorting tasks increasing the functional efficiency of the separation can be fulfilled (see CHRISTIANI, 2006). First practical results (FAIST & RAGOSSNIG, 2009; TITECH, 2010) show that sensor-based sorting, which is a state-of-the-art technology for the processing of separately collected recyclables in material recycling, is potentially capable of splitting also heterogeneous wastes by material-specific characteristics.

Therefore, this conference contribution aims at exploring the technical feasibility and economic reasonability of the integration of NIR sensor-based sorting technology in a mechanical treatment plant to split heterogeneous – mainly commercial and pre-treated – solid waste. The additional treatment step should allow for refining the utilization, treatment or disposal options for the output streams generated by optimized separation of the present heterogeneous output streams. The analyses are based on extensive trials on a pilot scale and one indicative large scale experiment, both accompanied by material and chemical characterization of the products achieved. The evaluation of the technical feasibility encompasses the aim to (1) decrease the chlorine/pollutant content and (2) to generate one output stream with an elevated biogenic carbon content.

Both processing steps are assumed to increase the marketing opportunities for the waste contractor operating the mechanical treatment plant looked at. The first one with regard to the quality requirement in RDF co-incineration in the cement industry and the second one with regard to future developments in the energy and climate protection policy, referring to the CO_2 emission trading scheme within the EU and potential economic benefits for the waste contractor (e.g. POMBERGER ET AL., 2008). Concerning the RDF quality, in Austria the legal standards are defined in the Waste Incineration Directive (BMLFUW & BMFWJ, 2010) (e.g. heavy metal content) and further standards are required by the plant operators (e.g. limitations of the chlorine content, particle size).

The second part of this conference contribution aims at exploring the influence of different parameters on the economic feasibility of the additional separation step taking into consideration the new marketing opportunities based on the quality of the waste streams generated.

2 Study Design

2.1 Test Material

A mechanical treatment plant for the processing of commercial solid waste (60 kt/year in 2008) was addressed for analysis with regard to an optimized material-specific waste-routing. The following two main output streams were selected for further analysis:

- High calorific fraction (HC, particle size > 120 mm, lower heating value (LHV) > 20 MJ/kg_{dry}) used for RDF-production (RDF to be used as kiln burner fuel)
- Medium calorific fraction (MC, 20 – 120 mm, LHV < 20 MJ/kg_{dry}) used directly as RDF in the so-called “HOTDISC” process (calciner fuel)

These waste streams are gained from the input material after pre-sorting, metal separation, air classification and screening and contain mainly plastics, paper, cardboard, wood and textiles. The material composition was analysed four times over a one year period to account for seasonal variations. In addition, the material used for the sorting trials (three pilot scale test series and one indicative large scale test), was characterized, to confirm that the sorting trials were conducted with representative material. The HC contains mainly fossil materials (bright and dark plastics, about 40 to 80%) and a smaller part of biogenic materials (undefined organics, wood, paper and cardboard, about 20%) based on the wet mass (as received). The MC contains a high proportion of biogenic materials (undefined organics, wood, paper and cardboard, about 30%) as well as fossil materials (bright and dark plastics, about 20%). Up to 30 to 50% of the material was classified as “fine fraction” (< 30 – 60 mm for the MC) and not distinctly characterised concerning its material composition. Detailed information concerning the material composition is reported in literature (PIEBER ET AL., 2010; PIEBER, 2011).

2.2 Experimental Set-Up

The experiments were targeted on (1) the removal of chlorine and heavy metal bearing components followed by (2) the separation of biogenic material from the waste stream.

Plastics and biogenic material (e.g. paper) can be identified by near infrared (NIR) spectroscopy (Figure 1), using the material-specific absorption/reflection behaviour in the NIR wavelength range as identification criterion. Therefore, a NIR sensor-based sorting system (64 sensors, 1,400 – 1,900 nm, multiplexed, see LLA, 2010) was used in the trials.

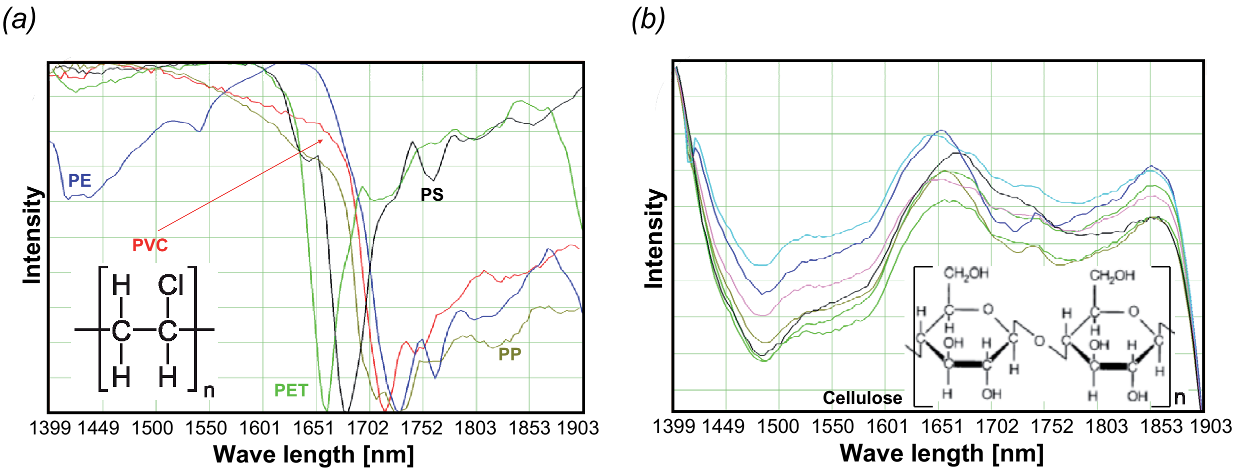


Figure 1 Reflected NIR material spectra (BTW-BINDER, 2010, modified). (a) Polyvinyl chloride (PVC), polyethylene (PE), polyethylene terephtalate (PET), polypropylene (PP), polystyrene (PS). (b) Spectra of different paper types.

In the processing trials, polyvinyl chloride (PVC) was ejected from the waste stream first. PVC contains 30 – 50 wt% chlorine (Cl) (CHRISTIANI, 2006) and was therefore chosen as target component. Additionally, (heavy) metals like Pb, Cd, Sn, Zn, Ba and Ca are used as PVC stabilizers in a range of 2 to 6 wt% (DOMININGHAUS, 2008). Consequently, the removal of PVC should be associated with a great reduction of the Cl and (heavy) metal content. Secondly, biogenic materials were ejected from this PVC-freed waste stream. Consequently, the sorting steps result in three output streams: Reject 1, Reject 2 and Passing 2 (Figure 2a).

To optimize the quantitative ejection of PVC (Reject 1) and the purity and yield of the biogenic reject (Reject 2) during processing of the waste streams, parameter-configurations (a.o. scanning speed of the sensor-system, pressure and duration of the pneumatic pulse, etc.) were varied in three test runs of threefold replicates (around 20 kg_{wet} each). Based on these results, one indicative test run on a large scale (Figure 2b) was conducted in order to get first results. The plant used for the large scale test run was optimized for a waste stream with different physical characteristics (particle density, geometry) and a different sorting task, namely packaging waste sorting ("Gelber Sack").

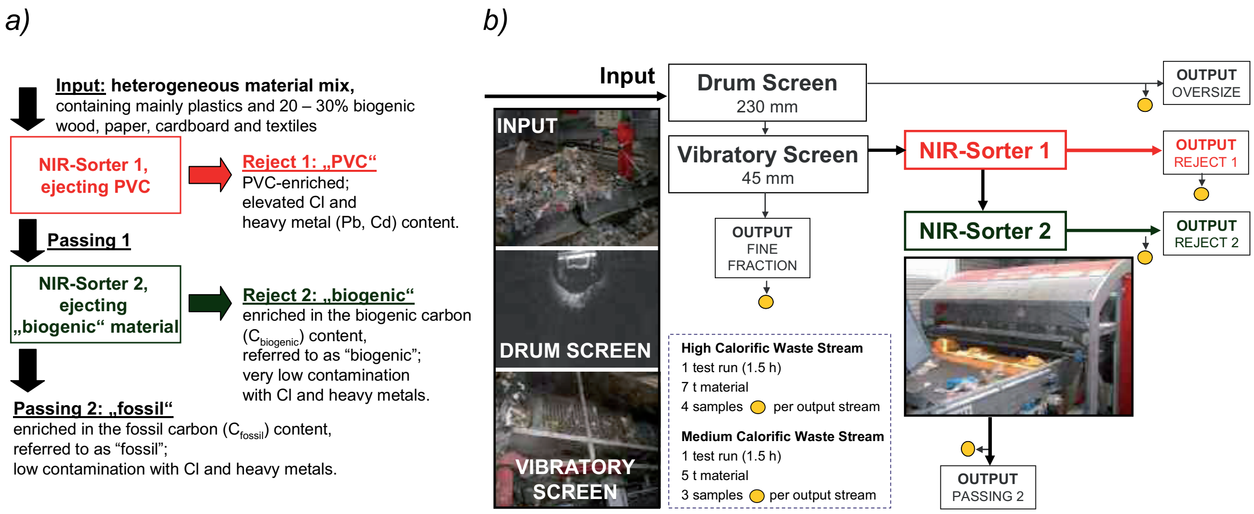


Figure 2 Processing scheme of the (a) pilot and (b) large scale experiments. Two “RED-WAVE” sorting devices of the BTW-Binder GmbH (Austria) with near infrared (NIR) sensors were applied. The first sorting device was separating PVC, the second one material with paper characteristics. On a large scale, additional processing steps (screening, NIR separation of Passing 2) had to be applied.

3 Technical applicability

3.1 Assessment Method

The functional efficiency of the separation steps (1) (yield, transfer coefficient) and the quality (2) (purity, absolute concentration) of the output streams with regard to further treatment, respectively utilization options were used to evaluate the processing steps.

Firstly, material characterisation of the output streams and their mass proportions were used for the evaluation. The material composition was analysed by manual sorting of the wet test material. Based on this analysis, the yield and purity for Reject 2 (biogenic output) and Passing 2 (fossil output) were determined. The yield represents the rejected mass proportion of material that is supposed to be rejected. The purity of a specific output stream is the mass proportion of material sorted correctly into that stream. The fine fraction was excluded from this evaluation, because it is a material mix and cannot be evaluated distinctly. Textiles were assumed to be of biogenic origin if found in the Reject 2, and assumed to be fossil if found in the Passing 2, due to a lack of evaluation methods by manual sorting. It was shown by PRETZ & KILLMANN (2007) that biogenic textiles are identified correctly by NIR sensors, making this assumption justifiable.

A further detailed evaluation was done using chemical quantification of the $C_{biogenic}$ content, the Cl content and heavy metal content (As, Pb, Cd, Cr, Co, Ni, Hg, Sb, Cu, Zn) as well as moisture, energy (lower heating value (LHV) and higher heating value (HHV)) and ash content as specified in the Waste Incineration Directive (BMLFUW & BMFWJ, 2010). Chemical quantifications were used to derive transfer coefficients, which represent the yield of a chemical component (Equation 1) and to evaluate the enrichment respectively depletion of a specific parameter's concentration (Equation 2).

$$X_{output}(i) = \frac{mass_{output} * concentration_{output}(i)}{mass_{input} * concentration_{input}(i)} * 100$$

Equation 1: Transfer coefficient X (%) of a specific chemical parameter i in the output stream (reject or passing) of a sorting process.

(a) $$E_{reject}(i) = \frac{c_{reject}(i) - c_{input}(i)}{c_{input}(i)} * 100$$

(b) $$D_{passing}(i) = \frac{c_{passing}(i) - c_{input}(i)}{c_{input}(i)} * 100$$

Equation 2: (a) Enrichment E (%) and (b) depletion D (%) of the concentration c of a specific chemical parameter i in the reject (a), respectively passing (b) of a sorting process.

3.2 Results

For the HC as well as the MC waste stream, an optimized parameter configuration of the pressure and duration of the pneumatic pulse and an appropriate NIR identification scheme were found in the pilot scale test runs for the assigned problem, as already presented in PIEBER ET AL., 2010.

For the HC waste stream, the optimized pilot scale test run no. 2 led to mass proportions of around 5% Reject 1 and 21% Reject 2 – with 74% of the total material mass staying in the Passing 2. The biogenic reject (Reject 2) was characterized by a yield and purity of about 88% both. The remaining material (74% Passing 2) had a purity of around 96%. In the indicative large scale test, around 3% of the total material mass was found in the Reject 1, similar to the pilot scale test run. In contrast, for the biogenic Reject 2, the yield (20%) and mass fraction (6%) were significantly decreased. Additionally, a lower purity was achieved for the biogenic Reject 2 and the remaining Passing 2 (79% respectively 72%).

Very similar results were achieved with the MC waste stream (Pilot scale: 4% Reject 1, 24% Reject 2 (yield: 79%, purity: 95%), 72% Passing 2 (purity: 84%); Large scale: 3% Reject 1, 5% Reject 2 (yield: 17%, purity: 87%), 52% Passing 2 (purity: 58%) - the remaining 40% were separated as fine fraction prior to entering the NIR sorting steps).

For both, the HC and MC waste stream, the yield of the Reject 2 (sorting step 2) was significantly decreased on a large scale (only around one fifth of the pilot scale test results). This was found to be a result of the mechanical treatment plant concept, which was designed and optimized for a waste stream with different physical characteristics (packaging waste, i.e. other particle density and geometry) and a different sorting task. An additionally determining criterion is the fact, that on a pilot scale 64 NIR sensors were applied per 1 m of band width. On a large scale in contrast, 64 sensors were applied per 2 m of band width – subsequently reducing the resolution.

For the first sorting step, in contrast, very satisfying results were achieved on a large scale concerning the transfer coefficient of Cl (Reject 1). Around 30% (MC, Figure 4a) to 41% (HC) of the total Cl freight were removed with only a very small material (around 3%$_{wet}$) and energy (3 – 4%$_{LHV,\ wet}$) loss. Additionally, up to 43% of the total Pb and Cd freight was removed (these heavy metals have been used as PVC-stabilizers, due to the life time of PVC-containing products these contaminants are still highly relevant in waste management) (Figure 4b-c). Consequently, large reductions in the Cl (> 30%) as well as Cd and Pb (up to 60%) concentration were achieved (Figure 3a).

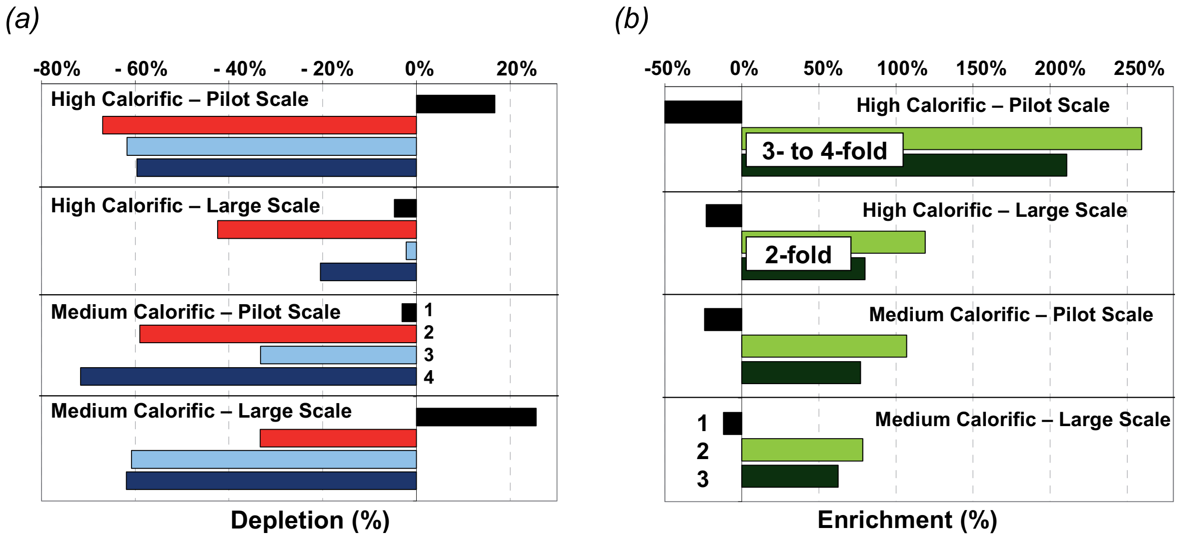


Figure 3 *Mean concentration enrichment and depletion compared to the input material of the specific sorting step. (a) Depletion of the Cl (2), Pb (3), Cd (4) concentration (dry) and energy content (1: lower heating value, LHV_{wet}) in the Passing 1 (b) Enrichment of the $C_{biogenic}$ concentration (2: based on the total carbon content, 3: based on the total mass) and energy content (1: LHV_{wet}) in the Reject 2.*

In the second sorting step, the $C_{biogenic}$ concentration was increased about 2- to 4-fold, compared to the Passing 1, with a final concentration in the Reject 2 in the order of 62 – 77%$_{dry\ Total\ Carbon}$ on a pilot as well as large scale; compared to around 16 – 47% in the input and 7 – 40% in the Passing 2. Consequently, around 62 – 77% of the CO_2 emissions resulting from energetic utilization would be of biogenic origin. The associated transfer coefficients ($C_{biogenic}$ based on the total carbon (TC) content) of this sorting step on a pilot scale were 49% (MC) and 72% (HC). On a large scale, the transfer coefficients were much lower, due to the low mass yield of the Reject 2 (about 17%). This is again due to the fact that the mechanical treatment plant used for the indicative large scale test is designed and optimized for a different waste stream and sorting task, as well as the number of sensors per band width.

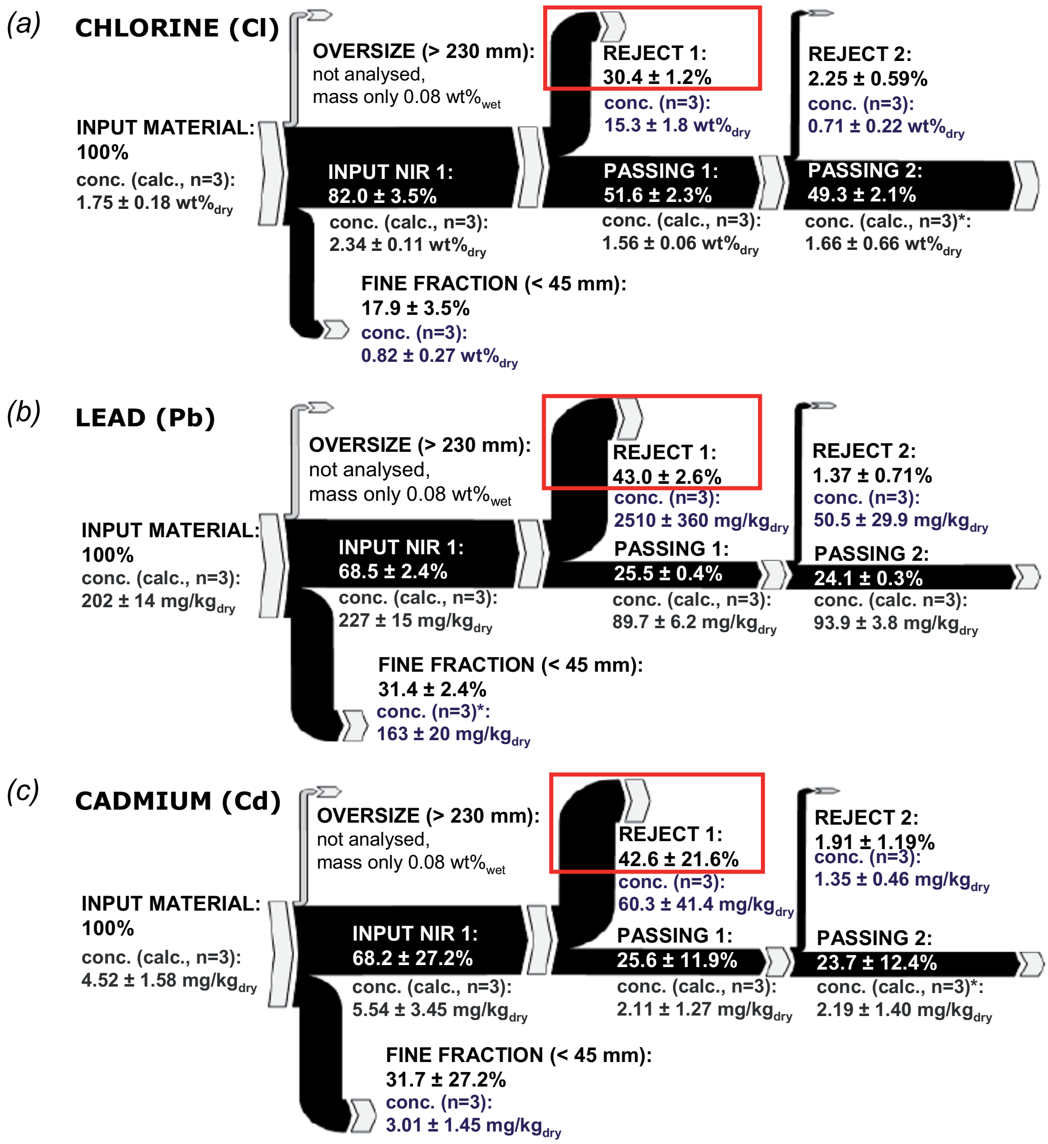


*Figure 4 Transfer coefficients and concentration of (a) Cl, (b) Pb and (c) Cd (MC, large scale test). Displayed data resemble mean values and standard deviation from chemical analysis of n samples and are marked * if they were corrected for extreme values. Data calculated from chemical analysis of resulting streams are marked with "calc.".*

4 Economic Viability

In order to evaluate the benefit of implementing a sensor-based sorting system, a scenario analysis with regard to the economic consequences has been performed. This analysis is based on a number of parameters including the operation costs of the processing system (e.g. investment costs, the electricity consumption, labour costs or the maintenance costs) as well as the specific costs/revenues for the treatment/utilization of the new waste streams obtained from the additional processing step. In consideration of the current market situation, a range was defined for various parameters looked at.

In the first step of the evaluation which is presented in this conference contribution, the economic scenario analysis shall demonstrate the influence of varying specific parameters on the reduction potential of the overall costs, which can be reached for the HC and MC waste stream compared to a reference scenario. The reference scenario represents the prevailing situation, in which the HC (further processing followed by the utilization as kiln burner fuel) and MC waste stream (direct utilization as calciner fuel via HOTDISC) are used as RDF for the cement industry. This reference scenario is compared to a scenario with the newly opened options for the utilization/treatment of the processed waste streams. This analysis aims to elicit the key parameters for an economically viable operation.

The general principle of the economic evaluation is to analyse the influence of varying specific parameters as for instance the specific treatment/utilization costs (Figure 5, x-axis) on the annual overall cost reduction that can be achieved compared to the reference scenario (y-axis). Compared to a defined basis scenario (starting point: 0% on the x-axis, Figure 5), only one parameter (e.g. the specific treatment/utilization costs / revenues for the “biogenic” Reject 2) is varied at a time (in a first step, a range of -50% to 50% on the x-axis is considered). Specific costs with values lower than 0 €/t (e.g. the specific treatment/utilization costs for Reject 2, Figure 5) represent revenues for the recovery of this waste stream for the waste contractor. The mass ratio of the output streams to each other (Reject 1 : Reject 2 : Passing 2) is defined based on the results of the pilot and large scale processing tests.

By analysing the influence of varying specific treatment/utilization costs for the Reject 1 (PVC), Reject 2 (biogenic) and Passing 2 (fossil) (Figure 5) on the costs for the management of both waste streams in detail, it was observed that a variation of the specific treatment/utilization costs for the fossil output has the largest influence on the economisation in both cases. This is caused by the fact that the mass content of the fossil fraction is much higher in comparison to the other fractions (PVC/biogenic output). Varying these treatment costs for an average mass content of about 75% in the HC waste stream by about -50% results in a cost reduction for the overall management which is about 8% larger than the cost reduction in the basis scenario (marked with a red square in Figure 5a).

Additionally it was found that for this specific case study the great range of treatment/utilization costs/revenues according to the current market situation of the PVC (Reject 1) and biogenic fraction (Reject 2) are both determining key factors for a beneficial economisation: Cost reductions between 5.1% and 6.1% for the HC waste stream compared to the basis scenario can be generated under optimised conditions which means -50% parameter variation for the specific treatment/utilization costs/revenues of the biogenic (Reject 2) and fossil (Passing 2) waste fraction.

The principle of the economic evaluation was the same for the MC waste stream (Figure 5b). Only the data for the basis scenario were different compared to the HC waste stream.

a) *b)*

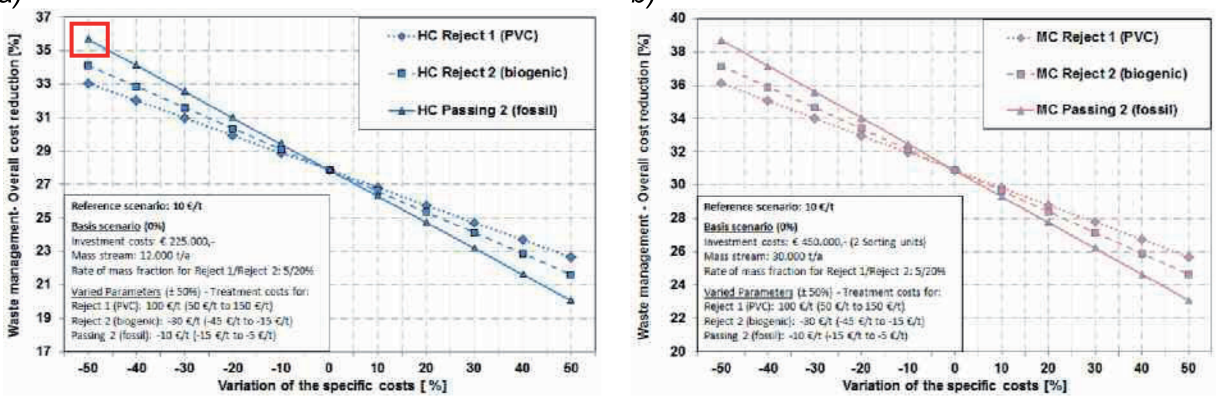


Figure 5 Influence of the variation of the specific treatment/utilization costs/revenues of the (a) HC and (b) MC waste stream, separated into Reject 1, Reject 2, and Passing 2 on the overall cost reduction compared to the reference scenario. (Data for basis scenario according to Curtis et al., 2010)

5 Discussion and Perspectives

Further processing of heterogeneous waste opens new possibilities for the (energetic) utilization of waste for waste management companies. Therefore, the opportunities of a MT plant regarding the application of sensor-based sorting technologies on specific heterogeneous waste streams were analysed. Sensor-based sorting experiments on a pilot and large scale were conducted in order to (1) remove contaminants (mainly Cl and heavy metal bearing components) and to (2) generate a waste stream with increased biogenic carbon content. The trials showed that the NIR-based sorting technology is generally applicable to gain waste fractions with the required characteristics, if the sensor systems are appropriately adjusted to the waste streams looked at.

The first sorting step should allow for quality improvements in the RDF output streams in terms of their Cl as well as heavy metal content, to increase their application potential in a variety of industrial (co-)incineration options (especially for the cement industry). The trials showed that the separation of around 3 to 5% (Reject 1) allows removing up to 40% of the total Cl freight on a large scale – reducing the Cl concentration in the RDF output stream (Passing 1) by around one to two thirds on a large respectively pilot scale. This separation step allowed for a simultaneous separation of up to two thirds of the Cd and Pb freight and reducing the respective concentrations in the RDF output stream (Passing 1) by up to two thirds as well.

The second sorting step was considered to broaden future marketing opportunities for the RDF produced concerning the relevance of the biogenic carbon content of RDF in the context of CO_2 emission trading in e.g. the cement industry but also waste management. The greatly increased biogenic carbon content in the “biogenic carbon enriched” Reject 2, compared to the input and especially the “fossil carbon enriched” Passing 2, is very promising (2- to 4-fold enriched concentration, pilot scale) in this regard. The biogenic carbon content based on the total carbon in the Reject 2 is in the order of 62 – 77%$_{\text{dry Total Carbon}}$. Consequently, around 62 – 77% of the CO_2 emissions in energetic utilization would be of biogenic origin.

In spite of these promising results concerning the purity and yield of the Reject 2 on a pilot scale, the yield has been comparatively small in the indicative large scale test. The challenges to be taken to increase the yield of the Reject 2 are mainly related to the overall plant concept, as the large scale plant used for the indicative test run was optimized for a waste with different physical characteristics and a different sorting task. Additionally, further issues concerning the condition of the sensors (maintenance) and the number of sensors per band width shall be addressed for an improved result. To test the assumed improvements, it is reasonable to integrate a NIR sensor-based sorting device at the mechanical treatment plant looked at and perform further test runs.

Besides the optimization and evaluation of the NIR-based sorting technology for application on the waste streams with current properties, possible changes in material composition, e.g. increased proportion of dark plastics contained in the waste - which could significantly decrease the efficiency of the NIR-based sorting technology - have to be kept in mind. Therefore, it should be assured that the applied technology can be adapted for changes in the input waste stream if required.

The financial benefits gained by implementing the sensor-based sorting system vary according to the determined figures chosen for the reference and basis scenario and their variation. The economic evaluation showed under optimized conditions (i.e. specific costs of 50 €/t for the PVC fraction, revenues of 45 €/t for the biogenic and 15 €/t for the fossil fraction) amortisations of 0.8 years for the HC waste stream and 0.6 years for the MC waste stream. Even when the economic evaluation is based on less optimal market conditions (i.e. spec. costs of 150 €/t for the PVC fraction, revenues of 15 €/t for the biogenic and 5 €/t for the fossil fraction) amortisations for the HC waste stream would be 4.5 years and 2.7 years for the MC waste stream, respectively.

6 Acknowledgement

This research was conducted within the K1-centre "BIOENERGY 2020+" promoted by the COMET funding scheme executed by the Austrian Research Promotion Agency and financed by national Austrian funds as well as funds from the provinces of Burgenland, Lower Austria and Styria. The co-financing from industry to be provided within the COMET funding scheme was granted by Umweltdienst Burgenland GmbH, Saubermacher Dienstleistungs AG and BT-Wolfgang Binder GmbH.

7 Literature

BMLFUW, BMWFJ (ed.)	2010	BGBl. II Nr. 476/2010 (Waste Incineration Directive (AVV-Novelle) 2010)
BTW-Binder GmbH	2010	Information and material provided by the BT-Wolfgang Binder G.m.b.H. Gleisdorf (Austria).
Christiani, J.	2006	Options and limits of waste material sorting. Processing of commercial waste and domestic refuse. Müll und Abfall 38, 532-536.
Curtis, A, Haider, R., Felber, J.	2010	Information provided by the Saubermacher Dienstleistungs AG Graz (Austria), Umweltdienst Burgenland GmbH Oberpullendorf (Austria), BT-Wolfgang Binder G.m.b.H. Gleisdorf (Austria).
Domininghaus, H.	2008	Kunststoffe, Eigenschaften und Anwendungen. Elsner, P., Eyerer, P. & Hirth, T. (eds.). Springer Verlag, Berlin Heidelberg.
Faist, V., Ragossnig, A.	2009	Sensorbased Sorting for the Reduction of the Upper Caloric Value in Mechanical-Biological Treatment Plants. Waste-to-Resources 2009, Wasteconsult, Hannover.
LLA	2010	LLA Instruments GmbH, online at: http://www.lla.de/, 2010-12-29.
Pieber, S. M.	2011	Alternative energy resources through advanced splitting of heterogeneous wastes by sensor-based sorting. Master Thesis. Fachhochschulstudiengänge Burgenland G.m.b.H.
Pieber, S., Ragossnig, A., Brooks, L., Meirhofer, M., Pomberger, R., Curtis, A.	2010	Advanced waste-splitting by sensor based sorting on the example of the MT-plant Oberlaa. DepoTech 2010, Montanuniversität Leoben.
Pomberger, R., Curtis, A.,	2008	Climatological relevance of waste management as

Scherübl, T.		seen by a collector. Österreichische Wasser- und Abfallwirtschaft 07-08, 113 - 122.
Pretz & Killmann	2007	Innovative sorting technologies for commercial waste. Müll und Abfall 11, 546-551.
Rotter, V. S., Kost, T., Winkler, J., Bilitewski, B.	2004	Material flow analysis of RDF-production processes. Waste Management 24, 1005 - 1021.
Titech	2010	TITECH sorting systems specified at world`s most modern municipal solid waste plant in Larnaca, Cyprus, online at http://www.titech.com/news/titech-sorting-systems-16281, 2010-12-29.

Author's addresses

Dipl.-Ing. Simone Pieber, Dipl.-Ing. Manuel Sommer & Martina Meirhofer, BSc.
BIOENERGY 2020+ GmbH, Pinkafeld Research Site
Steinamagerstraße 21
A-7423 Pinkafeld
Website: http://www.bioenergy2020.eu

Prof. (FH) Dipl.-Ing. Dr. Arne Ragossnig, MSc. (OU)
Fachhochschulstudiengänge Burgenland Ges.m.b.H.
Steinamagerstraße 21
A-7423 Pinkafeld
Telefon: +43(0)3357/45370-1070
Email: arne.ragossnig@fh-burgenland.at
Website: www.fh-burgenland.at

Dipl.-Ing. Alexander Curtis & Dipl.-Ing. Dr. Roland Pomberger
Saubermacher Dienstleistungs AG
Conrad-von-Hötzendorf-Straße 162
A-8010 Graz
Website: http://www.saubermacher.at

Self-Ignition of deposits containing recycling materials – an Underestimated Phenomenon

Anka Berger, Simone Krüger, Ulrich Krause

BAM Federal Institute for Materials Research and Testing, Unter den Eichen 87, 12205 Berlin, Germany

Abstract

Fires on waste dumps, surface landfills, underground stowing or storage facilities of recycling factories may have multiple harmful effects on individuals on site and on environment. Possibly several tens of thousands of tons flare up plunging vast areas in smoke and releasing large amounts of flue gases. Experience shows that fire fighting takes days or even weeks and moreover, as long as hidden glowing nests exist fires may break out repeatedly weeks or months later. In the light of this, fire prevention is much easier to manage than extinction. It is of interest to identify the geometrical and physical conditions under which the mid-term or long-term storage of recycling materials can be performed avoiding self-ignition. Our Guideline presents a novel method developed at BAM which combines experimental tests on lab-scale with numerical simulations in order to obtain permissible geometries of deposits and storage times at which self-ignition can be certainly avoided (Berger 2010).

Keywords

Self-ignition, hot storage tests, numerical simulations, FTIR spectroscopy, guideline

1 Introduction

Recycling- and landfill materials which contain often combustible or partial combustible fractions are present in large quantities and need to be stored in intermediate storages or land filling. The storage is available in loose bulks, as built-in special landfills or in the form of heaps, which are built of bales. During recent years in Germany several deposits of mixed wastes which have been left unattended over several years caught fire caused in an extreme heat release and excessive emissions of smoke and fire gases which may be carcinogenic and mutagenic substances, for instance, polyaromatic hydrocarbons, chlorinated monoaromatic compounds and polychlorinated biphenyls, polychlorinated dibenzo-dioxins and furans (PCDDs and PCDFs) (Ruokojärvi 1995). Although uninvestigated, it is highly probable that self-ignition was the main reason for the fires to break out. In heaps of combustible materials where the voids between the solid material are filled with air, always the hazard of self-ignition arises (Akgün 1994, Krishnaswamy 1996). Self-ignition in heaps of porous material occurs when the heat produced by chemical conversion of the materials is not dissipated completely. Mostly the combustible fraction is mixed with inert materials such as soil, sand or with shredded non-reactive fractions of construction wastes. A characteristic of self-ignition in big heaps or landfills is the long induction time. Due to the fact that the inner temperature gradient of such deposits is not measurable on the surface an early detection of the hot spot within the bulk is very difficult. Another disadvantage based on the early detection of self-ignition is the relative late appearance of fire and smoke gases out of the deposits. Lack of knowledge about the hazard of the deposits is often a reason for the occurrence of fires, especially self-ignition. The estimation of the existing risks, for instance the handling of substances which prone to spontaneous combustion and explosion, is very difficult and requires a high level of experience advance (Weise 1981, Schön 1974, Steen 2000). Therefore, a reliable risk prediction in fire prevention is a central task (Guideline). Such an analysis is based on the so called safety-related parameters of the fractions (for instance, the density, the specific heat capacity, the calorific value and the thermal conductivity), their reliable determination is of fundamental importance.

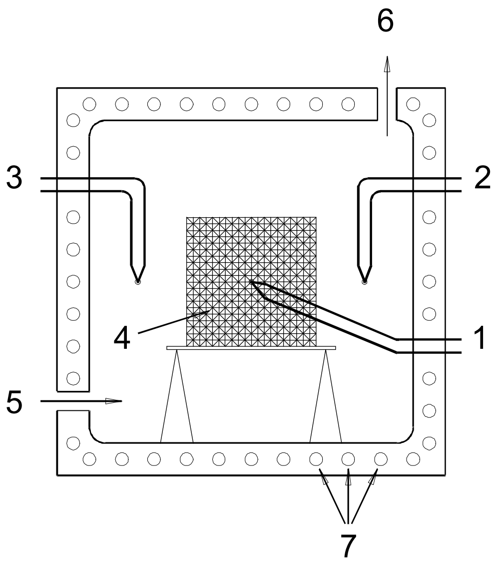
As real-scale self-ignition experiments on waste dumps or deposits of recycling materials are barely feasible, numerical simulations were performed to scale-up the laboratory results to the technical size (Berger 2008). In terms of physics, self-ignition and subsequent fire propagation in waste deposits are coupled heat and mass transfer phenomena. Thus, the general balance equations for heat and mass transfer are applied to model these phenomena, which have been described in detail by Krause et al. (Krause 2006).

Different lab-scale experiments (e.g. hot storage tests) were done to verify the model and the prediction of self-ignition of a real-scale waste dump. Furthermore, to receive information about the toxicity of the smoke emission and smoke gas composition during fires, chemical-analytical investigations were done. These experiments and their resulting conclusions are presented and discussed in this work.

2 Materials and methods

2.1 Experimental set-up

Self-ignition was investigated using the isothermal basket test method according to the European Standard Draft prEN 15188 (DIN EN 15188, 2007). The experimental set-up is shown in Figure 1. Sample volumes used in the tests were 31 mL, 100 mL, 400 mL and 800 mL. All baskets have the same diameter to height ratio of one (d/h = 1). The oven temperature and the temperature in the centre of the testing material are measured by thermocouples. The temperature signals are transferred to a data acquisition system. The output of the experiments is the self-ignition temperature (SIT), sometimes also called the critical ambient temperature in dependence on the characteristic length of the sample which is the volume-to-surface (V/S) ratio. The pre-exponential factor and the apparent activation energy may be derived from these data provided the physical parameter (bulk density, calorific value and the thermal conductivity) of the material tested are known.



1 = Thermocouples for measuring dust temperature

2, 3 = Thermocouples for measuring critical ambient temperature (CAT)

4 = Wiremesh cylinder with dust sample

5 = Air inlet (for natural convection)

6 = Air outlet (for natural convection)

7 = Heating elements

Figure 1 Experimental set-up to investigate the self-ignition behaviour of different fractions

Time-consuming was the preparation of the municipal solid waste (MSW), which was taken from a heap storing commercial waste, situated in a recycling facility. Because of the large particle size and the inhomogeneity of this commercial waste the arbitrary chosen sample had to be reduced to small particles to receive a homogeneous sample with a particle size of 1 mm and smaller. Therefore 25 kg of this MSW with a particle size between 10 and 25 mm were shredded in a Retsch Cutting Mill to get particle sizes of 5–10 mm (MSW-1). Thereafter the prepared sample was shredded in a Retsch Cross Hammer Mill SK 100 to obtain the desired particle size of 1 mm (MSW-2). Achieving a particle size of 200 µm (MSW-3), 5 kg of the 1 mm sample was embrittled with liquid nitrogen and shredded in the Ultra Centrifugal Mill ZM 2000.

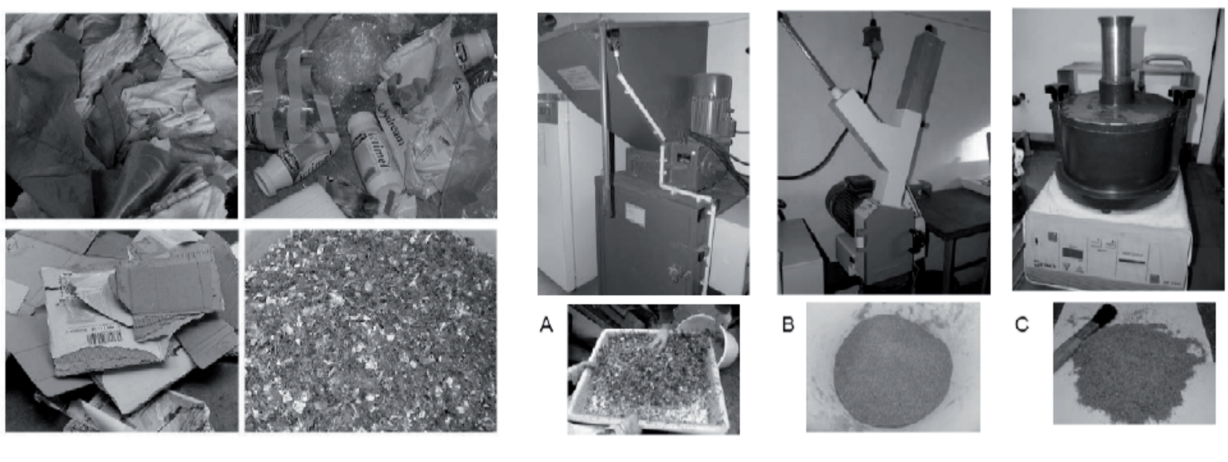


Figure 2 left: recycling materials, right: grinding and milling of the materials

2.2 Experimental investigations and results

In order to prevent self-ignition of recycled materials and waste materials, the information is needed on the fire behaviour under various conditions. In this regard, it was necessary to perform many different experiments.

2.2.1 Self-ignition temperature (SIT) in dependence on the combustible fraction

Mixtures of cellulose and diatomaceous earth have been stored in warm laboratory drying ovens at different temperatures. Figure 3 shows the dependence of the self-ignition temperature of the mass fraction of the combustible component. The SIT's increase when the mass fraction of the combustible decreases. It was interesting to note that even for a combustible fraction of 2.5% of mass fraction still self-ignition was observed despite of course exothermicity was much lower compared with 100% combustible. The isothermal hot storage tests showed the known dependence of the SIT on the V/A ratio. The larger the sample sizes the smaller the value of the SIT.

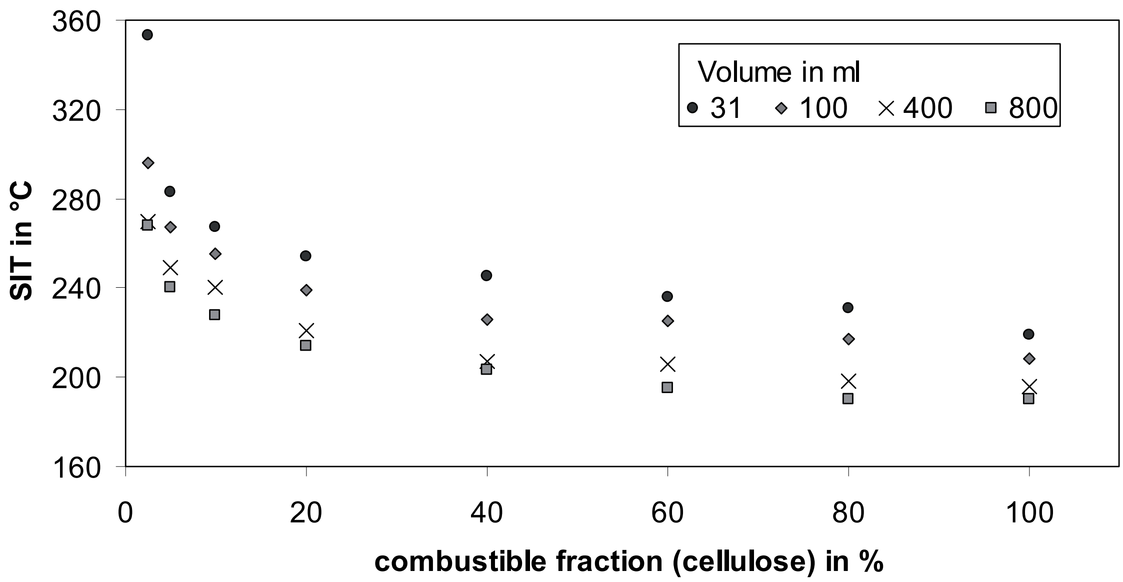
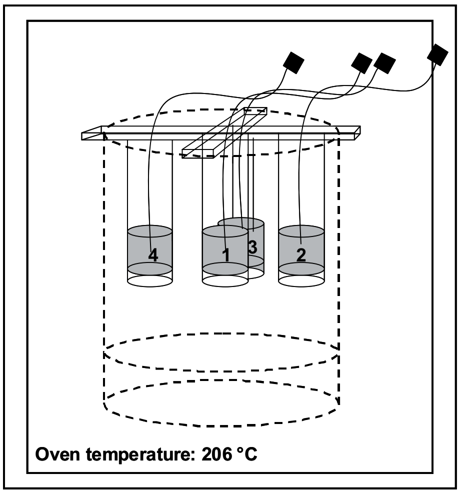


Figure 3 Self-ignition temperatures (SIT) in dependence of eight cellulose / diatomite mixtures

2.2.2 Model experiments for a construction waste dump

Investigations on not homogeneous distributed samples have been performed to construct a model rubble pile. Therefore, pockets of a combustible sample (cellulose) were embedded within in inert material (vermiculite). It was investigated if the transmission of heat from one of these pockets undergoing self-ignition through the inert matter into another pocket of combustible was sufficient to ignite the latter.



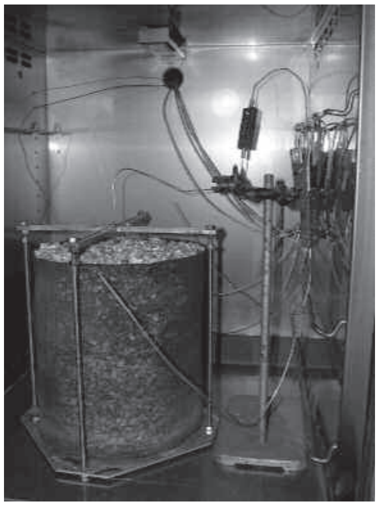


Figure 4 Experimental set-up, scheme (left), real-scale (right)

Figure 4 shows the experimental set-up of the four 100 ml cylinder filled with cellulose powder embedded in the insulation material vermiculite (in a 12600 ml cylinder). As a result of the experiments, the transmission of heat from the kernel cylinder 1 within the deposit through inert material to a second reactive kernel may be sufficient to ignite self-ignition in the latter one. The time distance for the transmission of heat from cylinder 1 to an adjacent cylinder is about half an hour. The experiments showed, although a material separation of the combustible fractions was present, there was still a thermal coupling. This explains why in such heaps often isolated from each location pocket of embers are found.

2.2.3 Exothermic behaviour of cellulose/diatomite mixtures

Figure 5 shows the time course of the temperature in the sample center for a volume of 400 ml at a storage temperature of 272°C for different compositions of the cellulose/diatomite mixtures. For a mass fraction of 2.5% cellulose, an increase in temperature led to more than 130°C above the storage temperature. According to the criteria contained in the DIN 15188, this is clearly to be interpreted as an ignition. Interesting is the fact that the maximum reaction temperature not occurred for pure cellulose but in mixtures with the same percentage of cellulose/diatomite. Starting from this maximum, the maximum reaction temperature decreased continuously in the direction of mixtures with higher or lower cellulose content. For this reproducible effect there is no conclusive explanation so far. However, the maximum reaction temperatures indicate a flaming combustion, while at 100% cellulose, a maximum reaction temperature was detected, as is typical for a smouldering fire.

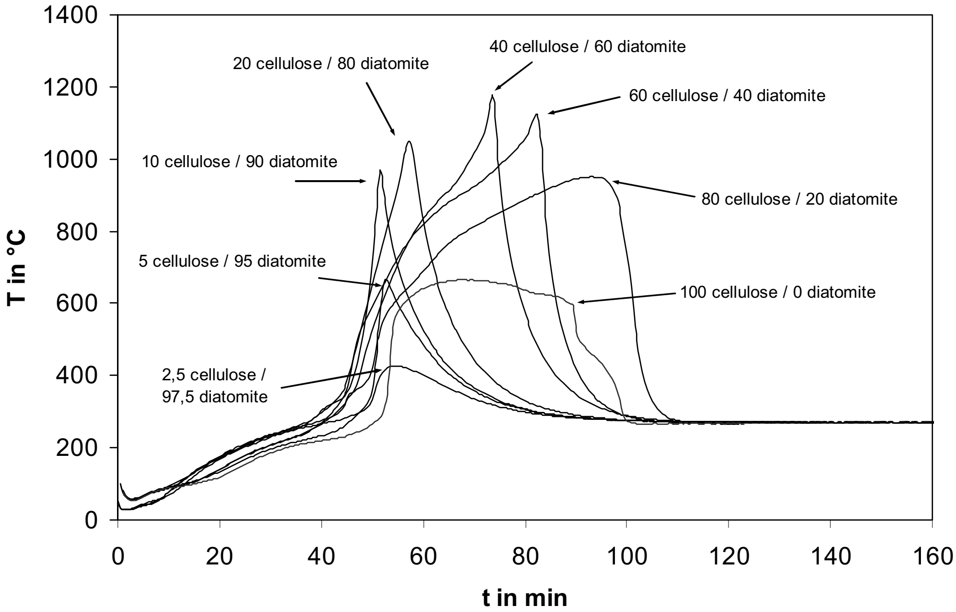


Figure 5 Time-temperature curves of different mixtures during the self-ignition

2.2.4 Self-ignition temperature (SIT) in dependence on an insulating layer

To receive information about the behaviour of self-ignition of combustible materials, in relation to the surrounding insulating layer (vermiculite), three reproducible experiments (A, B and C) have been carried out as shown in figure 6.

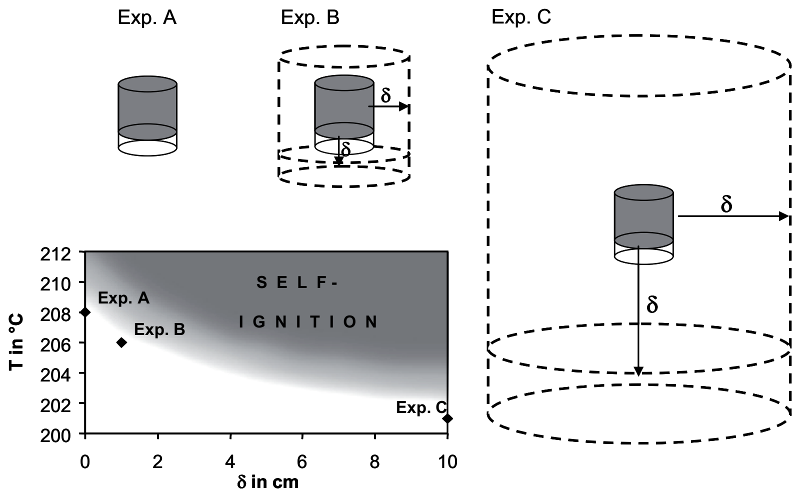


Figure 6 Self-ignition temperatures for the experiments A, B and C

It was interesting to investigate the influence of the thickness of insulating deposit (δ in cm) surrounding a single located cylinder on its self-ignition temperature. The self-ignition temperature of 208°C of experiment A with the not isolated 100 ml cellulose cylinder is 2°C higher than with an insulating layer of 1 cm (experiment B) and 7°C higher than with an insulating layer of 10 cm (experiment C). Therefore we can conclude, the thicker the insulating layer of a combustible enclosure is, the lower is the self-ignition temperature.

2.3 Chemical-analytical Investigations

Fires of recycling materials and deposits are characterized by an extreme heat release and excessive emissions of smoke and fire gases which contain toxic and hazardous materials depending on the output material.

2.3.1 Smoke gas analysis via FTIR spectroscopy in a DIN-tube

Smouldering tests were performed in the so-called DIN-tube according to DIN 53436-5 (DIN 53436-5, 2003). The DIN-tube consists of a horizontal quartz glass tube that is heated by a moveable electric furnace (Figure 7). The temperature of the furnace is adjustable in a range of 100 to 750°C. The shredded and reduced sample was placed as an elongated bulk in the DIN-tube and exposed to heat. The initial weight of the material per experiment was 4.8 g. The Experiments under smouldering conditions were carried out at temperatures of 100, 200, 300, 400, 500 and 600°C with an air flow of 300 l/h. During the experimental period of 30 min, the optical smoke density and the smoke gas composition at the respective temperature were measured.

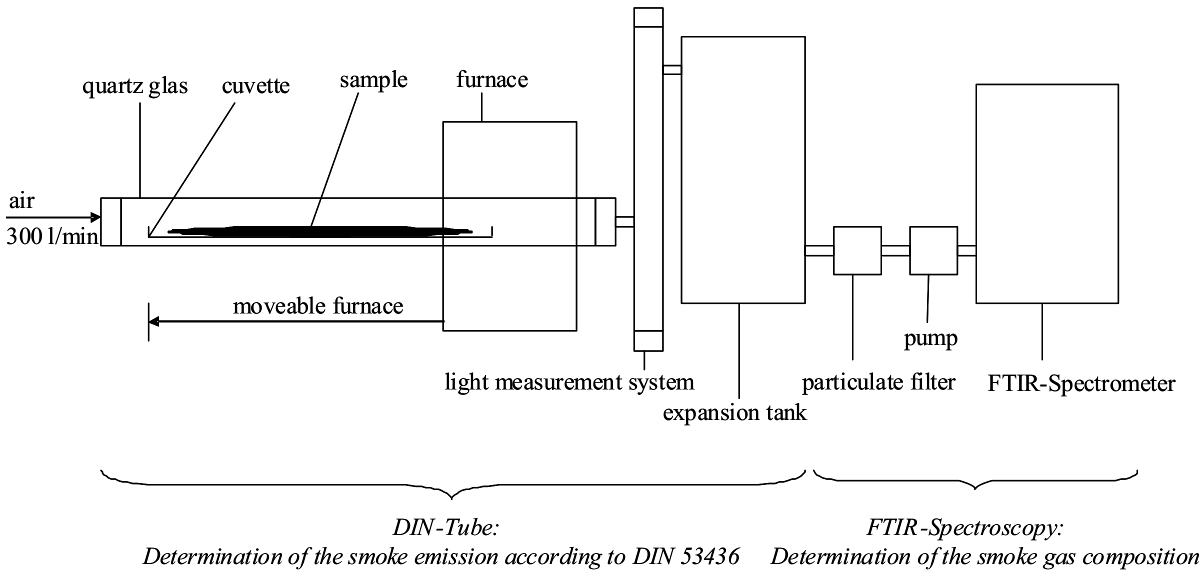


Figure 7 Experimental set-up for the determination of smoke gases in the DIN-tube

2.3.2 Composition of the smouldering gases

The smoke gas generation of the different fractions, paper/cardboard, textiles and plastics depends on the respective smouldering temperature. With increasing temperature, the smoke density increases and reaches its maximum at 300°C with 100% smoke density. At higher temperatures up to 600°C, the smoke gas density decreases slightly due to the increasing incineration. Another effect which could be observed with increasing smouldering temperature is the decrease in induction time for the smoke gas evolution. The higher the temperature the earlier it came to smoke or to the increase in smoke density. The largest mass loss occurs between the temperatures 200°C and 300°C and varies only slightly at higher temperatures. Exemplary, the Figures 8 and 9 show the concentration curves for the toxic components CO, CH_2O, HCN and HCl at 300°C for the waste fractions.

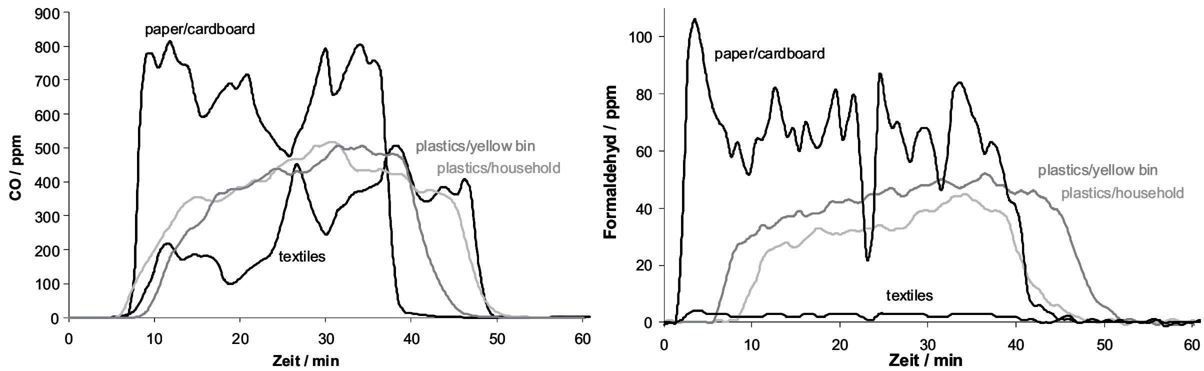


Figure 8 Concentration curves of carbon monoxide in ppm (left) and formaldehyde in ppm (right) during the smouldering of the fractions at 300°C in a DIN-tube

In all four diagrams, the concentration process during the 50 minute smouldering process at a temperature of 300°C is in the reaction zone. At a temperature of 200°C carbon monoxide in a concentration of 20 ppm could be detected. This concentration corresponds to the maximal accepted concentration. At a smouldering temperature of 300°C a carbon monoxide concentration of about 800 ppm was detected, which does not increase with increasing temperature (600°C). Therefore, at 300°C and higher there is a concentration limit value. However, the induction time reduced with rising the smouldering temperature. This also applies to the other components. The main components are carbon dioxide and water as well as carbon monoxide and formaldehyde. Furthermore, could be detected methane, ethane and acrolein as well as in dependence on the chemical composition of the starting materials HCN and HCl.

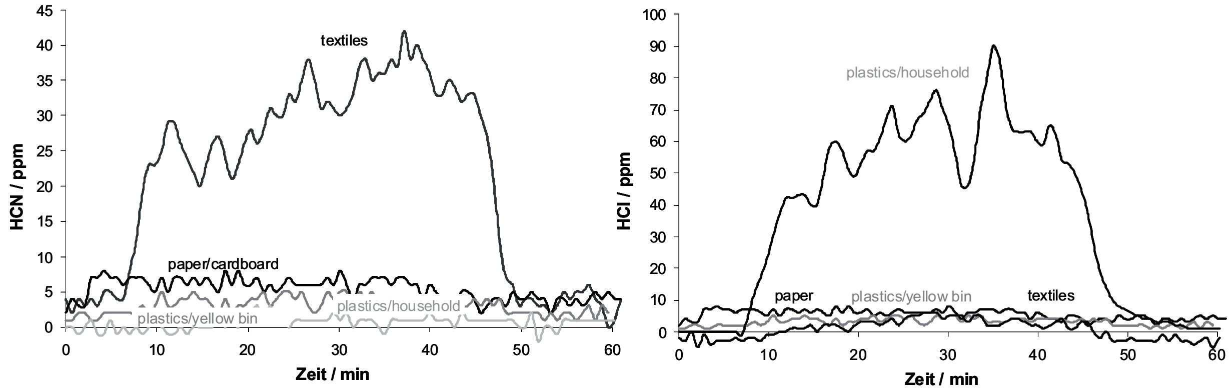


Figure 9 Concentration curves of hydrogen cyanide in ppm (left) and hydrogen chloride in ppm (right) during the smouldering of the fractions at 300°C in a DIN-tube

The highest concentration of CO is found during the smouldering process of paper and cardboard. Both plastic fractions showed about the same carbon monoxide concentration profiles. The lowest value for CO was found for the textile fraction. Similar results were detected for the emission of formaldehyde, with the difference that the textiles emitted only less formaldehyde concentrations. In contrast, the textiles showed during the smouldering process an increased concentration of hydrogen cyanide, while the other fractions issued no until very less HCN. Beside HCN high concentrations of ammonia could be detected, which did not have the other fractions. Cause of the emissions of ammonia and HCN is the composition of the textiles, consisting mainly of nitrogen-containing synthetic resins.

In Figure 9 are also shown the concentration profiles of hydrogen chloride. The fractions paper and cardboard, textiles and plastics (yellow bin) emitted during the smouldering process no HCl. In contrast, up to 90 ppm HCl were detected for the plastic fraction of the household. In this point there is a big difference in the both plastic fractions. This could be caused by the special composition of the plastic of the household. There are packagings, which consist of laminated film of polyethylene and polyvinyl chloride. These chlorine-containing polymers form during the smouldering process large amounts of hydrogen chloride.

Therefore, it is possible to detect mixtures of individual plastics via FTIR-spectroscopy. This could primarily very interesting for quality control of recycled products.

3 Numerical Simulations

As in the real scale fire tests at recycling dumps or landfills are not possible, the method of numerical simulation is used to predict the hazard of the self-ignition. Therefore, numerical simulations were performed to scale-up the laboratory results to the technical size. In terms of physics, self-ignition and subsequent fire propagation in waste deposits are coupled with mass and heat transfer phenomena. Thus, the general balance equations for heat and mass transfer are applied to model these phenomena. The model is based on a set of partial differential equations allowing computing the evolution with time of the multi-dimensional distributions of temperature and species concentrations within the deposit. It has been described in detail by Krause et al. (Krause 2006).

In Figure 10, as a result of the computation, the formation of the hot spot in the symmetry of the deposits at the bottom after about 5.8 years is shown. This composition (80% inert material and 20% combustible material) reflects a deposit of a typical building rubble heap.

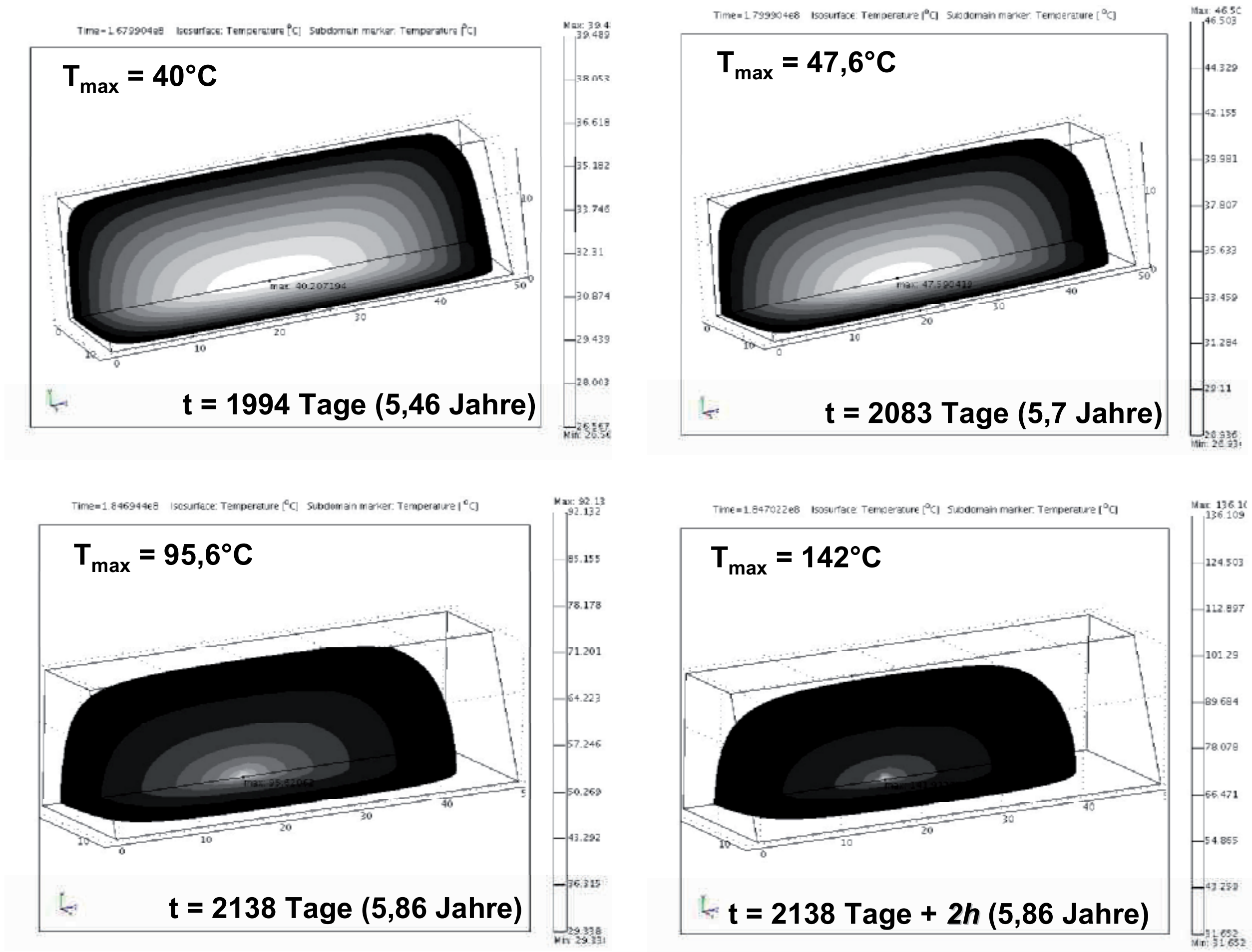


Figure 10 Simulation of a temperature distribution in a waste dump, 80% inert material and 20% combustible material (homogeneously mixed)

The reason for the temperature increase from 20°C to 40°C is the exothermicity of the ongoing reactions together with the restricted heat release to the environment. After 2083 days the temperature increased further to 47°C. Continued storage of the deposit under these conditions leads to the formation of a ‘hot spot’ within the deposit. After 2137 days the maximum temperature in the deposit has reached 92°C, but only about two hours later a level of 142°C was observed. This phenomenon is usually called ‘run-away’, which means the positive feed-back loop between temperature increase and reaction rate. The consequence of the ‘runaway’ is the breakout of an uncontrolled fire in the deposit.

4 Guideline

The aim of the guideline is to provide the basics of the self-ignition in landfills and intermediate storages in a concise form and to derive recommendations for the prevention of self-ignition in storages for recycling materials. The guideline contains a scientifically based method of risk assessment for self-ignition processes for the storage of recycling materials and deposits. This method includes three ingredients. The experimental determination of the relevant physic-chemical properties, the experimental determination of the reaction behaviour by thermal analysis and the prediction of the self-ignition and fire development by numerical simulation based on the real geometry of the storage arrangement.

5 Conclusions

As a result of the experimental and numerical investigations can be derived following practical conclusions. The tendency of self-ignition of plastic wastes increases by addition of inert materials. The highest fire temperatures occurred in mixtures with inert materials of plastic, despite the reduction in calorific value. Further, it could be shown that heaps also with a small fraction of combustible material can still undergo self-ignition. A dependence of the isolation deposit thickness on the SIT has been found. The thicker the isolation of the deposit around the combustible material is the smaller is the SIT. Via FTIR-spectroscopy it was possible to determine the composition of the smoke gas of the waste fractions under smouldering conditions. Toxic smoke gas components, such as carbon monoxide, formaldehyde, hydrogen cyanide and hydrogen chloride could be quantified. The investigated fractions differ essentially in their composition of the smoke gas components. Further, numerical simulation - using the thermo physical and kinetic data of the experimental studies – of the time-dependent distribution of the temperature during self-ignition and fire propagation within an example waste deposit has been predicted. The result of the computation reflects the fire propagation velocity, the hot spot generation and the induction periods. The practical fire fighting measures (safe storage geometry, safe storage times, additional fire protection measures) to prevent the self-ignition of waste and recyclable materials were summarized in a guideline.

6 Literature

Schön, G.	1974	Grundlagen des Explosionsschutzes. Arbeitsschutz. 1974, 2, 41-47.
Weise, E.	1981	Zum Verständnis von Sicherheit und Risikoerwartungen der Praxis an die Sicherheitswissenschaft. VFDB 1981, 4, 146-156.
Akgün, F.; Arisoy, A.	1994	Effect of particle size on the spontaneous heating of a coal stockpile. Combustion and Flame 1994, 99, 137-146.
Ruokojärvi, P.; Ettala, M.; Rahkonen, P.; Tahanen, J., Ruuskanen, J.	1995	Polychlorinated dibenzo-dioxins and furans (PCDDs and PCDFs) in municipal waste landfill fires. Chemosphere 1995, 30, 1697-1709.
Ruokojärvi, P.; Ruuskanen, J.; Ettala, M.; Rahkonen, P.; Tahanen, J.	1995	Formation of polyaromatic hydrocarbons and polychlorinated organic compounds in municipal waste landfill fires. Chemosphere 1995, 31, 3899-3908.
Krishnaswamy, S.; Bhat, S.; Gunn, RD.; Agarwal, PK.	1996	Low temperature oxidation of coal. Part 1: a single-particle reaction-diffusion model. Fuel 1996, 75(3), 333-343.
Steen, H.	2000	Handbuch des Explosionsschutzes. Wiley-VCH Verlag GmbH, Weinheim, 2000, 760.
	2003	DIN 53436-5, Erzeugung thermischer Zersetzungsprodukte von Werkstoffen unter Luftzufuhr und ihre toxikologische Prüfung. 2003.
Krause, U.; Schmidt, M.; Lohrer, C.	2006	A numerical model to simulate smouldering fires in bulk materials and dust deposits. Journal of Loss Prevention in the Process Industries. 2006, 19, 218-226.
	2007	DIN EN 15188, Determination of the Spontaneous Ignition Behaviour of Dust Accumulations. Beuth Verlag, Berlin, 2007.
Berger, A.; Krause, U.	2008	Investigations on the self-ignition of deposits containing combustibles. Fire and Materials. 2008, 32, 231-248.
Berger, A.; Schmidt, M.; Ferrero, F.; Krause, U.	2010	Ministerium für Umwelt, Gesundheit und Verbraucherschutz des Landes Brandenburg 2010. Leitfaden zur Brandvermeidung durch Selbstentzündung bei der Lagerung von Recycling- und Deponiestoffen, www.mugv.brandenburg.de

Author's addresses:

Dr. rer. nat. Anka Berger

Bundesanstalt für Materialforschung und –prüfung

Unter den Eichen 87

12205 Berlin

Telephone +49 030 8104 3402

Email: Anka.Berger@bam.de

Website: www.bam.de

Dr. rer. nat. Simone Krüger
Bundesanstalt für Materialforschung und –prüfung
Unter den Eichen 87
12205 Berlin
Telephone +49 030 8104 3324
Email: Simone.Krueger@bam.de
Website: www.bam.de

Dr.-Ing. habil, Dir. u. Prof. Ulrich Krause
Bundesanstalt für Materialforschung und –prüfung
Unter den Eichen 87
12205 Berlin
Telephone +49 030 8104 1740
Email: Ulrich.Krause@bam.de
Website: www.bam.de

Stationäre Druckluftschaum-Löschverfahren für den Einsatz in der Recyclingwirtschaft

Jörg Meyer

One Seven of Germany GmbH

Luckenwalde

Inhaltsangabe

Im Folgenden wird Die Situation stetig wachsender Anforderungen im Bereich der Abfall- Kreislaufwirtschaft aus Sicht des vorbeugenden Brandschutzes beschrieben.

Wir wollen damit Betreiber derartiger Unternehmen sensibilisieren, das Bewusstsein für dieses Thema stärken und im speziellen Lösungswege aufzeigen den Problematiken zu begegnen.

Dies soll der Förderung des Umweltschutzes, der Sicherheit der Unternehmen, der Bevölkerung und der Einsatz- und Rettungskräfte dienen.

Schlagwörter

Vorbeugender Brandschutz, Brandschutzkonzepte, Stationäre Löschanlagen, Innovative Löschverfahren, Druckluftschaum-Löschanlagen, Abfallwirtschaft, Recycling, Müllverbrennung, Heizkraftwerke, CAF, CAFS, Sprühflutlöschanlage, Sprinkleranlage, Wassernebellöschanlage

1 Grundgedanke

In den letzten Jahren gewinnt das Thema effiziente Materialausnutzung und Optimierung eines technologischen Kreislaufes zunehmend an Bedeutung.

In diesem Zusammenhang entstehen immer größere Anforderungen an Recyclingunternehmen. Aus betriebswirtschaftlichen Gründen wird oft versucht, Lagerflächen und Lagerhöhen zu vergrößern.

Leider wachsen damit nicht immer die Vorkehrungen für den Brandschutz.

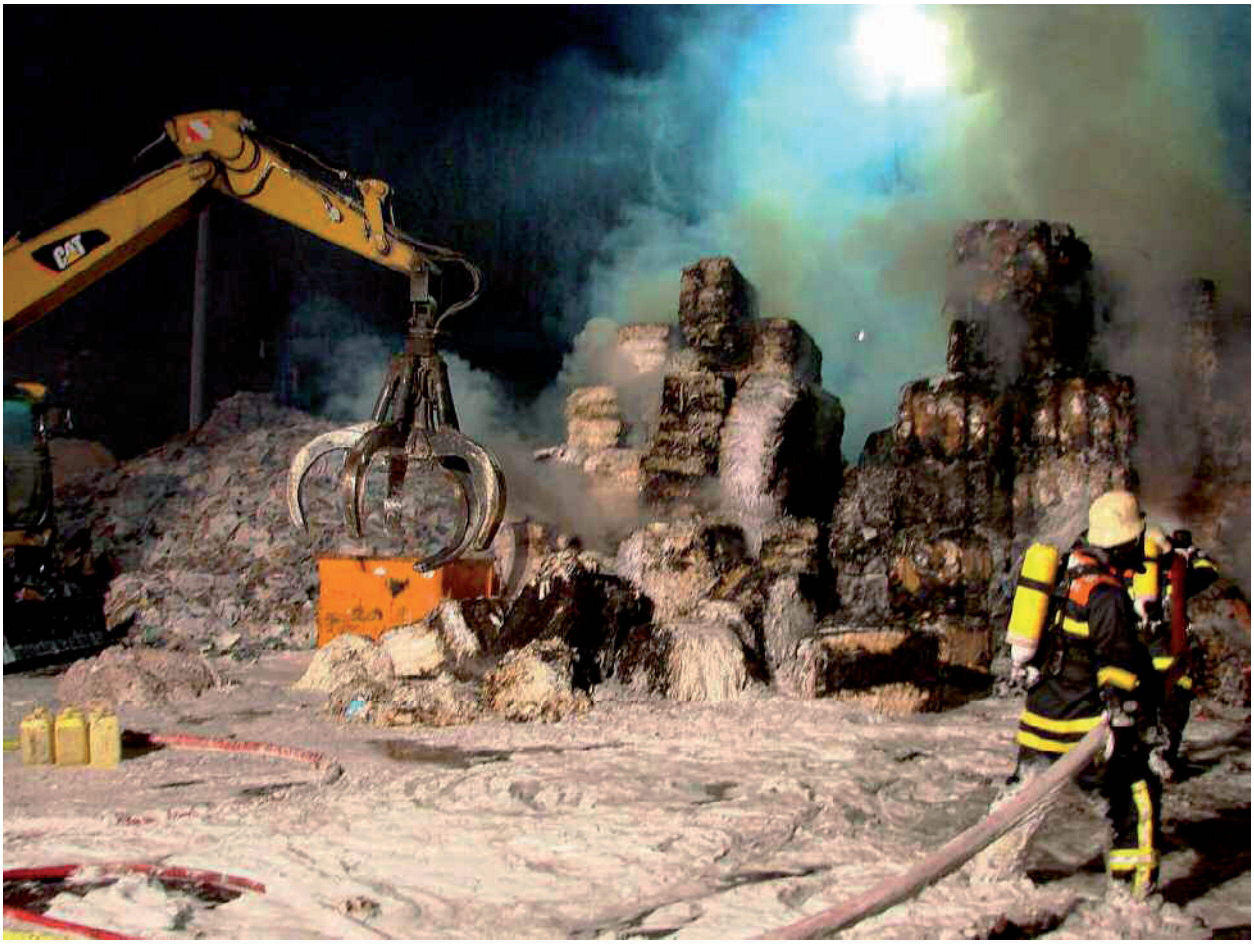


Abbildung 1 - Brand im Recyclingunternehmen

2 Situation

Verpackungsabfälle sind mit Hinblick auf den Brandschutz als problematisch einzustufen. Brandeinbringung von außen, Selbstentzündung bis hin zur Brandstiftung sind oft Ursache für katastrophale Brände. Untersuchungen von FM Global, einer der weltweit führenden Sachversicherer, ergaben, dass nach einem Brand 43% aller Unternehmen den Betrieb nie wieder aufnehmen, 28% der betroffenen Unternehmen innerhalb von 3 Jahren ihren Betrieb endgültig einstellen müssen und 6% gezwungen sind zu fusionieren oder aufgekauft werden. Nur 23% der von einem Schadensfeuer betroffenen Unternehmen sind hinterher wieder voll geschäftsfähig, wobei auch hier der entstandene Produktionsausfall ein großes Loch hinterlässt, welches durch die einmalige Investition in eine wirkungsvolle und automatische Brandbekämpfungsanlage nicht hätte entstehen müssen.

3 Kompetenzen bündeln

Brandschutz beginnt mit der Planung und einem sinnvollen Konzept zur Vermeidung von Brandereignissen.

Im Interesse des Betreibers sollten möglichst alle am Geschehen Beteiligten wie: Fachplaner, Feuerwehr, Brandschutzbeauftragte des Unternehmens, Genehmigungsstellen und natürlich auch der Versicherer, beteiligt werden.

4 Sinn und Ziel einer stationären Löschanlage

Unter Berücksichtigung verschiedener Faktoren, wie u.a. Lagergrößen, Stapelhöhe oder Anrückzeit der Feuerwehr, ist eine stationäre LA eine wirkungsvolle Maßnahme, einem Brand schnell zu begegnen und den Eintritt in eine schwer zu kontrollierende Vollbrandphase zu verhindern. Ist der Brand erst in die Vollbrandphase eingetreten, bleibt oft nur die Ausbreitung des Brandes zu verhindern, technische Anlagen und Gebäude sind zumeist kaum zu retten. Die Löschmaßnahmen der Feuerwehr finden mit großem personellen- und fahrzeugtechnischem Aufwand statt, dauern Stunden, oft Tage, manchmal Wochen.

Fazit - das schnelle Erkennen eines Entstehungsbrandes, eine unmittelbare Auslösung der LA und eine effektive Brandbekämpfung sind wichtige Punkte zur Schadensminderung. Eine automatische Erkennung und Auslösung sollte hierbei unbedingt in Betracht gezogen werden. Die Ausbreitung des Brandes sowie die Konzentration toxischer Stoffe, Größe der toxischen Rauchgaswolke, Größe der Brandfläche, Temperatur und Wärmestrahlung können durch die den Einsatz einer LA minimiert werden.

5 Löschanlagenauswahl

Das Thema Investition in eine stationäre LA und die Frage – welche LA zum Einsatz kommen soll – bringen oft einen gewissen Interessenkonflikt mit sich. Der Betreiber wird in erster Linie die Sicht auf ein betriebswirtschaftlich vertretbares Budget richten. Fachplaner und insbesondere Versicherer richten Ihren Focus auf einen optimalen Schutz.

Unterschiedliche Löschanlagenarten von unterschiedlichen Herstellern findet man heutzutage am Markt.

Nach VDS sind das:

Sprinkleranlagen, Sprühwasser-Löschanlagen, Schaum-Löschanlagen und Co_2-Feuerlöschanlagen.

Als Hersteller und Errichter von Druckluftschaum-Löschanlagen fallen wir natürlich in die Kategorie Schaum-Löschanlagen. Jedoch handelt es sich beim Druckluftschaum neben Leicht-, Mittel- und Schwerschaum um ein vollkommen eigenständiges Lösch-medium. (letzte Ausgabe der NFPA 11)

6 Das Druckluftschaum-Prinzip

6.1 Erzeugung des One Seven® Druckluftschaums

Durch definierte Zugabe von Druckluft und One Seven Schaummittelkonzentrat zum Löschwasser, werden aus dem Volumen eines Wassertropfens sieben Schaumblasen gebildet.

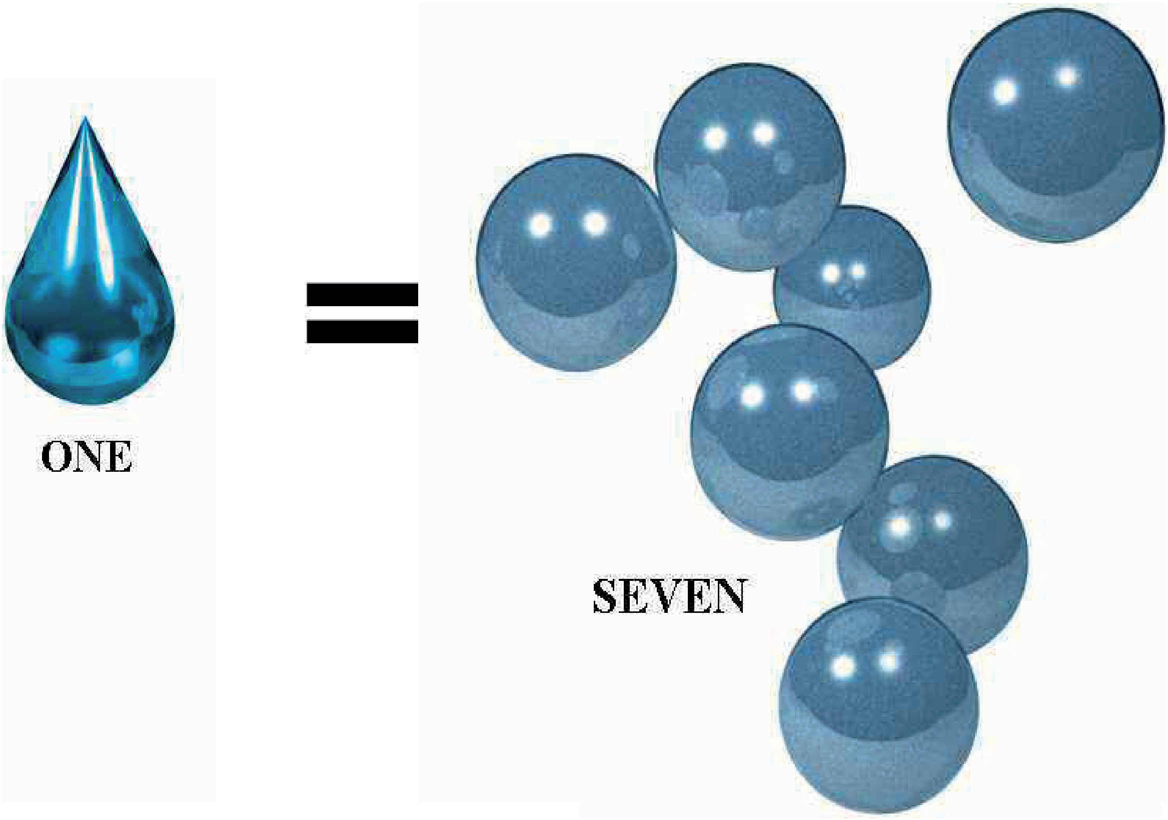


Abbildung 2 – one→seven

Die Struktur des One Seven Druckluftschaums ist ein kleinblasiger homogener Schaum mit enormer Löschwirkung. Die durchschnittliche Blasengröße beträgt 0,5mm. Der Druckluftschaum kann je nach Anwendungsfall von trocken/klebend bis nass/fließend hergestellt werden.

Modulare Anlagentechnik und fest eingestellte Parameter garantiert die Herstellung des gewünschten Druckluftschaums und schließen menschliche Bedienfehler aus. Eine genau berechnete Rohrsymmetrie garantiert, dass der außerhalb des Brandortes produzierte Schaum, zum jeweilig detektierten Löschbereich geleitet wird

Grafik Druckverluste Rohrlängen

Die Vorteile des Druckluftschaumverfahrens gegenüber anderen Schaumlöschverfahren liegen in der Erzeugung in dessen Folge die Qualität, die Wasserhalbwertzeit und die Löschwirkung von den o.g. Schäumen unterscheiden.

Eigenschaften

- Filmbildende Wirkung
- Hohe Eindringtiefe (geringe Oberflächenspannung)
- Hohe Anhaftung
- Ungiftig (biologisch abbaubar)

One Seven® -Löscheffekte

- Kühleffekt
- Stick- und Trenneffekt – Hauptlöscheffekt

6.2 One Seven Komponenten

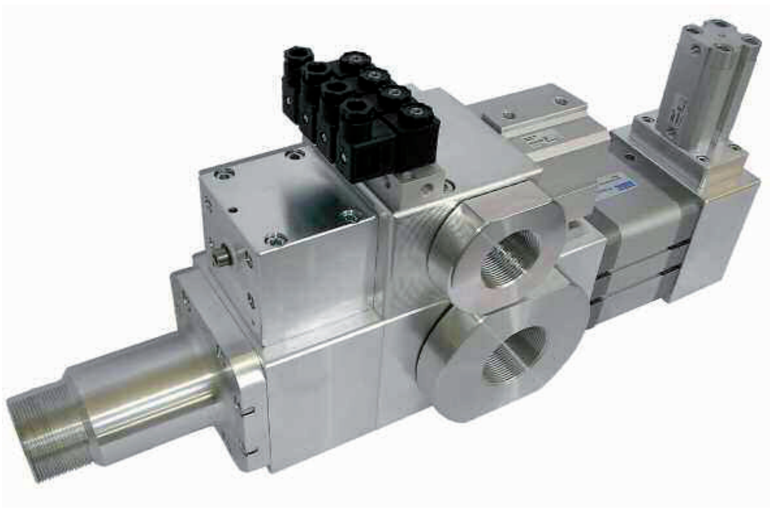


Abbildung 3 - One Seven® Kompaktschaumerzeuger der 3. Generation

Abbildung 4 - One Seven® Verschäumungsmodul

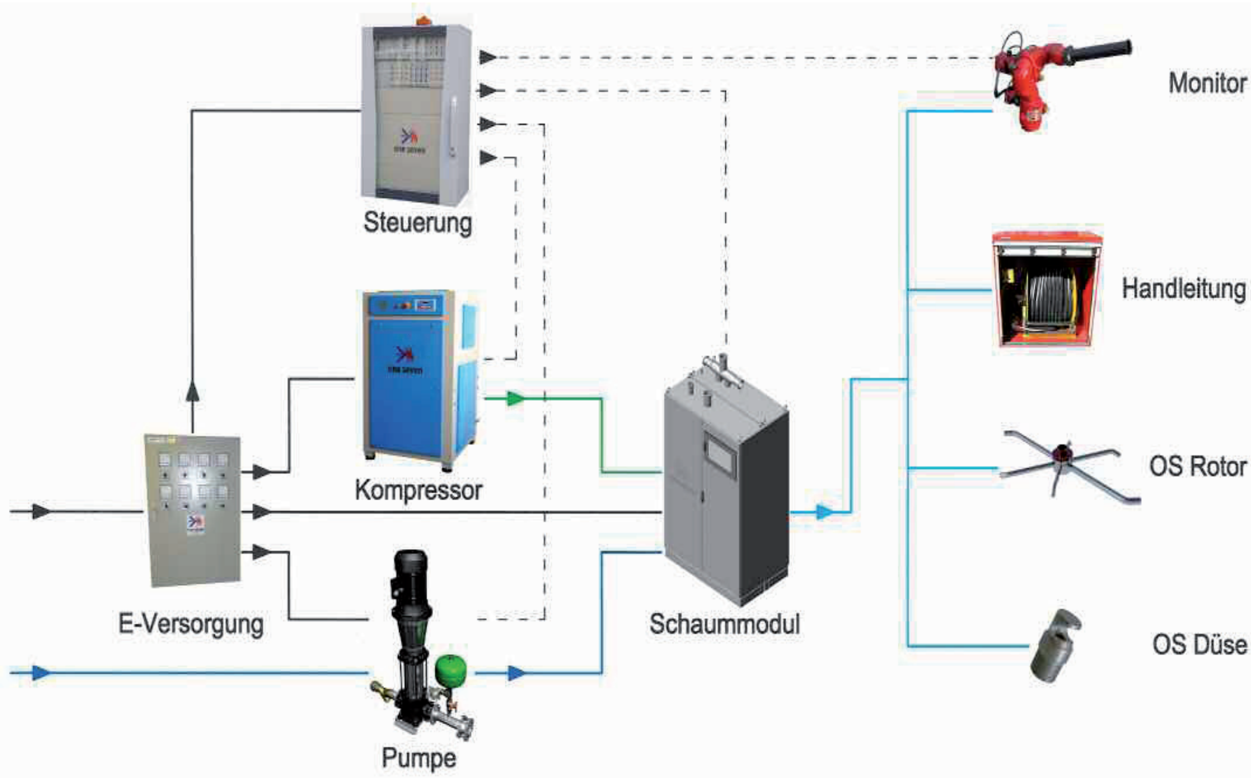


Abbildung 5 - Schema One Seven® Anlagekomponenten

Abbildung 6 - One Seven® Löschanlagenzentrale in einem Container

Video – Menston

Video – Schweden Holzhaus

6.3 Vorteile

- KURZE LÖSCHZEITEN
- Sehr geringer Schaummittelverbrauch
- Klasse A 0,3%

  Klasse B AFFF 0,5 %

  Klasse B AFFF-AR 0,6%
- verhältnismäßig geringe Löschwasserbevorratung
- weniger zu entsorgendes kontaminiertes Löschwasser
- lange Benutzungszeit des Schaumittels >15Jahre
- lange Wasserhalbwertzeit des One Seven Schaums, ca. 20min
- nur ca. 20-30mm Schaumteppich genügt um den Stickeffekt zu gewährleisten und das Brandgutes vom Sauerstoff zu trennen (Stickeffekt)

- trockene Leitungen im Ruhezustand
- große Entfernungen zwischen Löschanlagenzentrale und Löschbereich (bis 1000m) möglich
- geringes Gewicht → große Höhen > 400m erreichbar
- hohe Wurfweiten >50m
- Hohes Penetrationsverhalten/Eindringtiefe (Dreves-Test)
- Ideal bei Einsatz in Industrie/Lagerhallen mit Deckenhöhen > 12m und Decken mit wenig Tragkraft (Atrien)

  =< 12m für Sprinkler- u. Wassernebelanlagen (VDS)

  One Seven = 25m

Video – Einsatz OS

7 Anwendungsbeispiel

Recyclingunternehmen im süddeutschen Raum.

Schutzfläche:	ca. 6.600m^2
Applikationsrate:	4,0l/m^2/min
Verschäumungszahl:	8
Auswurfvorrichtung:	92 Rotore 1,5“, 52 Flachstrahldüsen, Zusätzlich Handleitungen mit 30m,60m u. 90m Schlauchlängen
Wasserverbrauch:	90m^3/h
Wasserversorgung:	7,5m^3 Tank mit automatischer Nachspeisung
Schaummittel:	One Seven® Klasse B 0,5%
Auslösung:	manuelle Auslösung über Druckknopfmelder und automatische Auslösung durch BMA

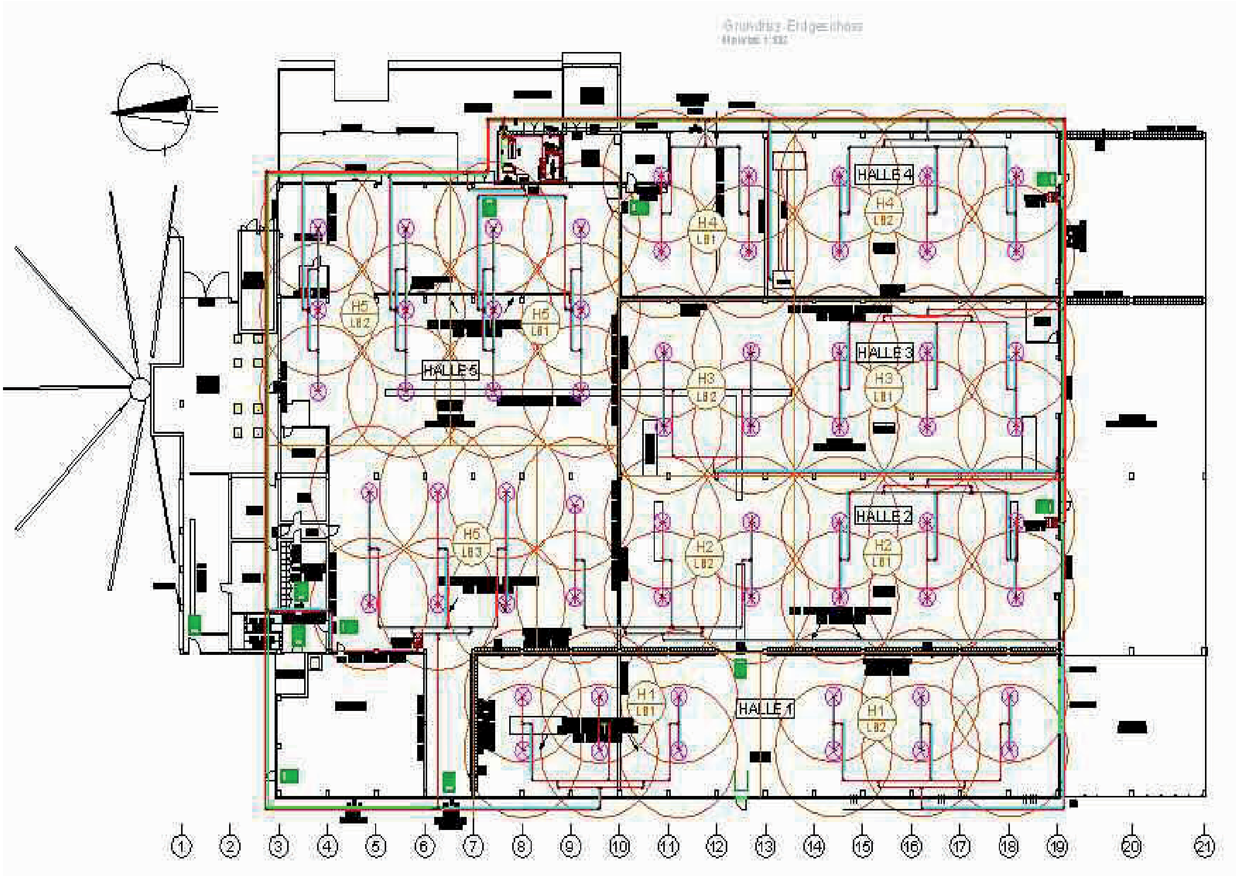


Abbildung 7 - Recyclinghalle

Abbildung 8 - One Seven® Rotore im Einsatz

8 Schlusswort

Es wurden von der One Seven of Germany GmbH bereits umfangreiche Erfahrungen im Bau und Betrieb von Löschanlagen gem. nationalen und internationalen Richtlinien und Standards (i.e. VdS, DIN, EN, FM, NFPA) gesammelt.

One Seven Brandmeldesysteme und Löschanlagensteuerungen sind VDS anerkannt. Derzeitig befindet sich eine stationäre Anlage in der FM-Zulassungsphase.

Unser Unternehmen ist nach der ISO 9001 zertifiziert und ausgezeichnet mit dem Innovationspreis 2008 des Landes Brandenburg.

Quellenangabe:

Abbildung 1 Quelle Google

Abbildung 2 Quelle One Seven®

Abbildung 3 Quelle One Seven®

Abbildung 4 Quelle One Seven®

Abbildung 5 Quelle One Seven®

Abbildung 6 Quelle One Seven®

Abbildung 7 Quelle One Seven®

Abbildung 8 Quelle One Seven®

Adresse des Autors:

Jörg Meyer
One Seven of Germany GmbH
Rudolf-Breitscheid-Straße 78
D-14943 Luckenwalde
Telefon +49 3371 – 69 13 – 76
Email joerg.meyer@oneseven.de
Website: www.oneseven.de

Aufbereitung und energetische Verwertung der heizwertreichen M(B)A-Fraktionen in Deutschland

Michael Nelles, Michael Balhar, Jennifer Grünes und Sabine Flamme

Zusammenfassung

In Deutschland werden derzeit 46 MBA-Anlagen und etwa 20 bis 30 MA-Anlagen mit einer Gesamtkapazität von rund 8 Mio. Mg betrieben. Die meisten Anlagen verfügen inzwischen über fast 6 Jahre Betriebserfahrungen und haben sich zu einer wichtigen Säule in der Abfallwirtschaft entwickelt. Es gibt aber noch eine ganze Reihe von Möglichkeiten zur Optimierung und im vorliegenden Beitrag werden die aktuellen Entwicklungen in den Bereichen Anlageninput, mechanische Aufbereitung, biologische Behandlung, Abluftreinigung, Reststoffe sowie die Aspekte Energieeffizienz, Klimaschutz und Wirtschaftlichkeit erläutert. Anschließend wird detaillierter auf die energetisch verwertbaren Reststoffe eingegangen, wobei die Möglichkeiten der Aufbreitung und Verwertungsoptionen beschrieben werden und der Stand bei der Qualitätssicherung von Ersatzbrennstoffen erläutert wird. Auf dieser technologischen Basis wird die MBA als umweltverträgliche integrierende Option der Abfallbehandlung, insbesondere im internationalen Bereich künftig weiter an Bedeutung gewinnen.

Abstract

In Germany, there are currently 46 MBT-Plants and about 20 up to 30 MT-Plants operating a total capacity of around 8 million tons. Most of the plants meanwhile possess about almost 6 years operating experience and became an important part of Germany's waste industry. But there still is a great range of possibilities to optimize the MBT-Technology. This review describes the current developments in the areas of system inputs, mechanical treatment, biological treatment, air purification, waste materials, as well as the aspects of energy efficiency, climate protection and economic efficiency. Afterwards the energetic recyclable waste materials are assumed in detail, where at the possibilities of the conditioning and utilization are described and the status of the quality management of refuse derived fuel will be discussed. On this technological basis the MBT-Technology as an environmentally-friendly integrating option of the waste treatment will gain in importance, especially in the international area.

Schlüsselwörter, Keywords

Mechanisch-biologische Abfallbehandlung (MBA), technische Optimierung, Energieeffizienz, Wirtschaftlichkeit, Klimaschutz, energetische Verwertung, hochkalorische Reststoffe

Mechanical-biological-treatment (MBT), technical optimization, energy efficiency, economy, climate protection, energetic utilization, high caloric waste materials

1 Einleitung

Derzeit sind in Deutschland 46 MBA-Anlagen mit einer Kapazität von ca. 5,5 bis 6 Mio. Mg in Betrieb und in diesen werden ca. 25 % der anfallenden Siedlungsabfälle mechanisch-biologisch behandelt [3]. Die realisierten Verfahrenskonzepte sind sehr unterschiedlich und nur schwer vergleichbar. Grundsätzlich lassen sich vor dem Hintergrund der rechtlichen Rahmenbedingungen, das waren primär die Anforderungen der AbfAblV und die 30. BImSchV, zwei Extremvarianten unterscheiden. Bei den Endrotteverfahren wird das Ziel verfolgt möglichst viel Deponiematerial zu erzeugen und bei den Trockenstabilisierungsvarianten sollen im Idealfall alle entstehenden festen Reststoffe einer energetischen bzw. stofflichen Verwertung zugeführt werden (siehe Abb. 1). Darüber hinaus werden derzeit in Deutschland rund 20 bis 30 Anlagen mit einer Kapazität von 2 bis 3 Mio. Mg/a betrieben, die die angelieferten Abfälle mittels mechanischer und physikalischer Verfahren (MPS-Anlagen) zu Ersatzbrennstoffen (EBS) aufbereiten [3]. Diese werden anschließend in Kohlekraftwerken, in der Zementindustrie oder immer häufiger in speziell für die energetische Verwertung von EBS errichteten industriellen Abfallverbrennungsanlagen energetisch verwertet.

Die meisten der heute betriebenen MBA-Anlagen wurden in den Jahren 2001 bis 2005 konzipiert und häufig unter hohem Zeitdruck errichtet. Seit Mitte 2005 müssen sich die MBA-Anlagen am Markt bewähren und die hohen Anforderungen der AbfAblV und der 30. BImSchV in der betrieblichen Praxis dauerhaft und sicher erfüllen. Vor diesem Hintergrund wurden und werden die MBA-Anlagen in den letzten 5 Jahren stetig optimiert, die Kinderkrankheiten auskuriert und die Verfahrenskonzepte an die sich ständig verändernden Rahmenbedingungen im Abfallmarkt angepasst. Inzwischen haben die MBA-Anlagen einen hohen verfahrenstechnischen Standard erreicht und sich zu einer wichtigen Säule in der Abfallwirtschaft entwickelt.

Im vorliegenden Beitrag werden wesentliche Ansätze zur Optimierung und Nachrüstung von MBA-Anlagen in der Praxis erläutert, die in vielen Fällen bereits umgesetzt sind beziehungsweise derzeit realisiert werden.

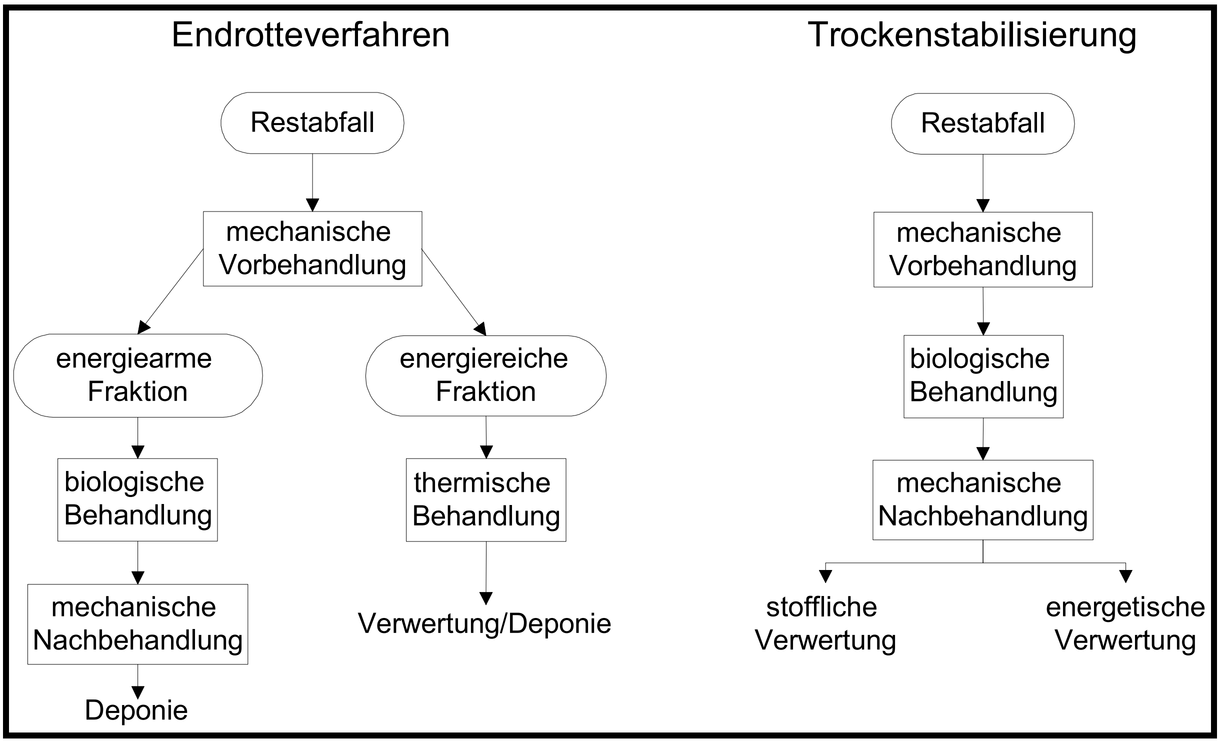


Abbildung 1: Vereinfachte Darstellung grundlegender MBA-Konzepte

Dabei werden die aktuellen Entwicklungen in den Bereichen Anlageninput, mechanische Aufbereitung, biologische Behandlung, Abluftreinigung, Reststoffe sowie die Themen Klimaschutz, Energieeffizienz und Wirtschaftlichkeit angesprochen. Anschließend wird detaillierter auf die energetisch verwertbaren Reststoffe eingegangen, wobei die Möglichkeiten der Aufbereitung und Verwertungsoptionen beschrieben werden und der Stand bei der Qualitätssicherung von Ersatzbrennstoffen erläutert wird. Zum Abschluss des Beitrages wird ein kurzer Ausblick zur Weiterentwicklung der MBA-Technologie in Deutschland aber auch im internationalen Bereich gegeben [4].

2 Optimierung von MBA-Technik, Energieeffizienz, Klimaschutz und Wirtschaftlichkeit

Für die MBA-Anlagen sind teilweise bis zu 70 Abfallschlüsselnummern als **Anlageninput** genehmigt, so dass ein sehr breites Spektrum an Abfällen behandelt werden darf. Dies hat in den ersten Betriebsjahren bei einigen MBA-Anlagen zu Problemen geführt, da teilweise auch Fraktionen in die MBA gelangt sind, die sich (noch) nicht zielführend behandeln ließen. Inzwischen haben die meisten MBA-Anlagen konkrete Annahmelisten entwickelt, so dass die Verpflichtungen eine Region zu entsorgen nicht mehr auf Kosten der Betriebssicherheit der MBA gehen. Auf der anderen Seite wurden umfangreiche Praxiserfahrungen gesammelt, so dass nun auch weitere Abfallschlüsselnummern ohne Gefährdung des Behandlungserfolgs in den Betriebsablauf integriert werden können. Dies ist für viele MBA-Anlagen auch deshalb erforderlich, weil die angelieferten

Abfallmengen, insbesondere aus dem Bereich der Gewerbeabfälle, stark zurückgegangen sind. Vor diesem Hintergrund wird versucht, zusätzliche Abfälle (Straßenkehricht mit hohen org. Anteilen, Rechengut aus der Abwasserbehandlung usw.) am Entsorgungsmarkt zu akquirieren.

Ein großer Vorteil der MBA-Technologie liegt in der hohen Flexibilität auf geänderte Anforderungen des Abfallmarktes reagieren zu können. Basis hierfür sind die **mechanischen Aufbereitungsstufen**, die als Schaltstelle für die jeweils marktangepasste Behandlung und Lenkung der Stoffströme fungieren. Auch in diesem Bereich wurden sehr unterschiedliche Systeme in der Praxis realisiert und inzwischen rund 6 Jahre Erfahrungen gesammelt. Dabei wurden und werden die Aufbereitungsschritte vor und nach der biologischen Behandlung ständig weiter optimiert, um die biologische Abbaubarkeit bzw. Trocknung der nativ-organischen Fraktion zu verbessern und die energetische Verwertung der heizwertreichen Fraktion(en) nach Möglichkeit in industriellen Verbrennungsanlagen mit hohen Gesamtwirkungsgraden zu ermöglichen. So können durch die MBA-Anlagen in Deutschland inzwischen konstant gute Qualitäten von EBS für die unterschiedlichsten Anwendungen (Kohlekraftwerk, Zementwerk oder EBS-Verbrennungsanlage) bereitgestellt werden. Dies ist auch deshalb wichtig, da die hochwertige energetische Verwertung der EBS von entscheidender Bedeutung für die ökologische Gesamtbewertung des jeweiligen MBA-Konzeptes ist. Trotzdem gibt es bei fast allen MBA-Anlagen in Deutschland den Bedarf an einer weiteren Optimierung der mechanischen Aufbereitungsstufen, um die Qualität der Aufbereitungsprodukte weiter zu verbessern und die Wirtschaftlichkeit der Aufbereitung zu erhöhen (Senkung Energieverbrauch, Verschleiß usw.).

In den ersten Betriebsjahren vieler MBA-Anlagen ging es bei der **biologischen Behandlung** insbesondere um die Optimierung, d.h. Verkürzung der Behandlungsdauer, um ein deponiefähiges Material zu erzeugen. Hier konnten die MBA-Anlagen erhebliche Fortschritte erzielen und i.d.R. können die Ablagerungskriterien in weniger als 10 Wochen erreicht werden. Dies schafft zusätzliche Behandlungskapazität, ist ökologisch vorteilhaft und führt zu einer verbesserten Wirtschaftlichkeit der MBA-Anlage. Da eine verkürzte biologische Behandlungsdauer in vielen Fällen zu geringeren Abluftmengen führt ergeben sich auch Vorteile im Bereich der Abluftreinigung. Eine größere Bedeutung werden künftig anaerobe Systeme erlangen, da sich auch aus der zur Ablagerung bestimmten Fraktion Energie „gewinnen“ lässt. Durch die Integration von Vergärungsstufen kann die Energieeffizienz des gesamten MBA-Konzepts positiv beeinflusst werden und damit werden auch die positiven ökologischen Effekte verstärkt. Dass die Nachrüstung einer Anaerobstufe auch bei bestehenden MBA-Anlagen sinnvoll ist zeigt z.B. die MBA Rostock, die um eine Teilstromvergärungsanlage mit 3 thermophil betriebenen Reaktoren ergänzt wurde [1].

Die 30. BImSchV schreibt für MBA in Deutschland die thermische **Abluftreinigung** vor. Aufgrund der nur in der 30. BImSchV auf die behandelte Abfallmenge bezogenen Begrenzung von Frachtwerten für TOC und N_2O wurden die Luftmengen in den neuen MBA drastisch reduziert. Dies wurde durch Mehrfachnutzung, Umluftkühlung, etc. von Ablufttteilströmen erreicht. In vielen MBA haben die RTO-Anlagen die Erwartungen an Verfügbarkeit und technische Reife für den speziellen Anwendungsfall Abluft aus MBA nicht erfüllt (Korrosionserscheinungen, Verblockung der Wärmetauscherfüllkörper mit Siliziumdioxidverbindungen usw.). Trotz der laufenden Bestrebungen zur technischen Optimierung der RTO ist hier anzumerken, dass die Sinnhaftigkeit einer thermischen Abluftreinigung von MBA-Abluft unter ökobilanziellen Gesichtspunkten kritisch zu bewerten ist! Elegant und ökologisch sinnvoll gelöst wurde die Abluftreinigung an der MBA-Anlage Rostock. Hier wird die Abluft inzwischen nicht mehr über die RTO behandelt, sondern als Verbrennungsluft der EBS-Anlage auf dem Nachbargrundstück im Überseehafen zugeführt [1].

Im Rahmen der stofflichen Verwertung der **Reststoffe** ist in der letzten Zeit die Metallabscheidung verstärkt worden, wieder steigende Rohstoffpreise wirken sich hier positiv aus. Besonders Nichteisenmetalle werden zunehmend interessant. Vor 3 Jahren gab es noch Probleme bei der energetischen Verwertung der heizwertreichen Fraktion. Dies lag zum einen daran, weil noch nicht genügend industrielle Verbrennungsanlagen als Abnehmer der produzierten Ersatzbrennstoffe zur Verfügung standen bzw. stehen wollten. Inzwischen sind einige zusätzliche EBS-Verbrennungsanlagen realisiert worden. Kapazitäten von rund 5,8 Mio. Mg/a sind in Betrieb oder im Bau und weitere 1,4 Mio. Mg/a sind genehmigt bzw. in der Genehmigungsphase. Wenn diese Anlagen realisiert werden steht künftig eine Gesamtkapazität von über 7 Mio. Mg/a zur Verfügung [3]. Zum anderen ist die Qualitätssicherung der EBS in den vergangenen Jahren wesentlich verbessert worden, so dass inzwischen konstante und an die jeweilige EBS-Anlage angepasste Brennstoffqualitäten geliefert werden können. Somit hat sich die Situation in der Praxis umgekehrt. Bei Neuverträgen sind die Zuzahlungen durch den MBA-Betreiber für die energetische Verwertung der EBS stark gesunken und inzwischen werden in Einzelfällen bereits Erlöse erzielt. Die Ablagerung einer biologisch stabilisierten oder mechanisch abgetrennten, inerten „Deponiefraktion“ ist Bestandteil aber nicht vorrangiges Ziel von MBA-Konzepten in Deutschland. Der quantitativ und insbesondere vom Energieinhalt höhere Anteil des behandelten Abfalls geht in die stoffliche und energetische Verwertung. Derzeit werden Verwertungskonzepte für die Fein- und Inertfraktion aus den MBA geprüft. Solange die Feinfraktion auf Deponien abgelagert wird, bedarf es einer Entwicklung und Überwachung angepasster Deponiekonzepte. Befürchtungen zur mangelnden Standfestigkeit von MBA-Deponien konnten in der Praxis zwischenzeitlich widerlegt werden.

Die **Energieeffizienz** von Kombinationsverfahren mit MBA und energetischer Verwertung der heizwertreichen Fraktion wird schon heute maßgeblich von der Energieeffizienz der nachgelagerten Verfahren der energetischen Verwertung bestimmt. Der Energiebedarf für die Aufbereitung der Abfälle der MBA ist dagegen nachrangig. Bei weitgehender Abtrennung der heizwertreichen Abfallbestandteilen und deren effektiver Verwertung in Kohlekraft- und Zementwerken lassen sich höhere Nettowirkungsgrade erzielen als mit der Verbrennung der Gesamtabfälle in einer MVA. Dennoch lassen sich die Energieeffizienz des Gesamtverfahrens und damit der Beitrag zum **Klimaschutz** weiter steigern. Zu nennen sind hier u.a. die Integration von Vergärungsstufen, die Optimierung des Energieverbrauchs, die Erhöhung der Ausbeute und Qualität heizwertreicher Abfallbestandteile und die Optimierung der Abtrennung von Fe- und NE-Metallen sowie weiterer Teilfraktionen mit dem Ziel einer stofflichen Verwertung.

Die Optimierung der **Wirtschaftlichkeit** der MBA-Anlagen ist vor dem Hintergrund der aktuellen Rahmenbedingungen am Entsorgungsmarkt mit den inzwischen erheblichen Überkapazitäten im Bereich der thermischen Abfallbehandlung ein zentrales Thema. Die Überkapazitäten haben in den letzten beiden Jahren zu einem erheblichen Preisverfall geführt. Diese Situation wird sich nur langsam entspannen und frühestens in zwei bis drei Jahren sind wieder Abfallannahmepreise von 100 €/Mg zu erzielen. In diesem Spannungsfeld müssen sich auch die MBA-Anlagen behaupten und dies ist nicht einfach. Die spezifischen Behandlungskosten inklusive der Reststoffentsorgung der meisten MBA-Anlagen liegen auch bei voller Auslastung bei etwa 80 bis 120 €/Mg. Die Möglichkeiten zur Beeinflussung der Gesamtbehandlungskosten sind für jede MBA-Anlage anders und hängen von den jeweiligen spezifischen Rahmenbedingungen ab. Der Vorteil einer MBA-Anlage z.B. im Vergleich zu einer MVA liegt in der aktuellen Situation darin, dass die MBA die Stoffströme quantitativ und qualitativ beeinflussen kann, was im Einzelfall auch zu einer verbesserten Wirtschaftlichkeit führt. Darüber hinaus gibt es viele weitere Ansatzpunkte für die Verbesserung der Wirtschaftlichkeit, wozu auch das Nutzen von Synergieeffekten durch integrierte Lösungen über die MBA-Grenzen hinaus gehört. In Lübeck soll z.B. künftig das gering belastete Sickerwasser der angrenzenden stadteigenen Deponie in den Prozesswasserkreislauf der MBA integriert werden und hierdurch entfällt die Notwendigkeit, dass die Deponie eine eigene Sickerwasserbehandlungsanlage betreiben muss [2]. In Rostock wird die Abluft nicht mehr über die RTOs behandelt sondern als Verbrennungsluft der EBS-Anlage auf dem Nachbargrundstück im Überseehafen zugeführt.

3 Aufbereitung, energetische Verwertung und Qualitätssicherung von Ersatzbrennstoffen (EBS)

3.1 Grundlegende Anmerkungen

Die bisherigen Ausführungen zeigen, dass sich die Rahmenbedingungen für die MBA-Technologie in den vergangenen Jahren drastisch geändert haben und der Stellenwert der Herstellung und energetischen Verwertung von Ersatzbrennstoffen aus ökologischen und ökonomischen Gründen massiv gestiegen ist. Die Energieressource Abfall wird durch den derzeitigen und auch künftig zu erwartenden Preisanstieg der Primärenergieträgern Öl, Gas oder Kohle immer begehrter. Die energetische Verwertung von heizwertreichen Fraktionen aus Anlagen mit MBA-Technologie und Gewerbeabfallsortieranlagen bzw. daraus aufbereiteten Ersatzbrennstoffen erfolgt in zunehmendem Maße in EBS-Kraftwerken. Energieintensive Unternehmen haben schon frühzeitig Abfall als Energieressource erkannt und viele EBS-Projekte realisiert. Weiterhin werden hochkalorische Sekundärbrennstoffe mit hoher Energieeffizienz in der Mitverbrennung als qualitätsgesichertes Material in Kohlekraft- oder Zementwerken eingesetzt. Hier lassen sich die ökologischen Ziele Klimaschutz und Ressourcenschonung gut mit den betriebswirtschaftlichen Zielen verbinden. Durch den Einsatz von Ersatzbrennstoffen können Primärenergieträger wie Kohle, Gas oder Öl ersetzt werden. Neben dem Beitrag zur Entsorgungssicherheit wird damit auch ein Beitrag zur Ressourcenschonung geleistet. EBS aus Siedlungsabfällen weisen biogene Anteile von teilweise über 50 % auf, deren Verbrennung CO_2-neutral ist, so dass ein nachhaltiger Beitrag zum Klimaschutz geleistet wird.

Es ist aber anzumerken, dass das verfügbare EBS-Potenzial begrenzt ist und wie bereits dargestellt, sind in Deutschland erhebliche Überkapazitäten mit den entsprechenden Konsequenzen (Preisverfall usw.) geschaffen worden. Außerdem gehen die Hausmüllmengen, bedingt durch den demografischen Wandel stetig und in einigen Regionen deutlich zurück. Geprägt von der wirtschaftlichen Situation in der Wirtschaftskrise gingen bis Mitte 2010 auch die Gewerbeabfallmengen zurück. Außerdem gibt es erhebliche Risiken für den Recyclingmarkt, da durch die niedrigen Verbrennungspreise die stoffliche Verwertung zurück geht und bereits mehrere Aufbereitungsanlagen geschlossen werden mussten.

3.2 Begriffsdefinition sowie Optionen der Aufbereitung und energetischen Verwertung

Die Begriffe „Ersatzbrennstoff“, „Sekundärbrennstoff“ u.a. werden in der Praxis häufig unterschiedlich verwendet, da es bisher keine klare und rechtlich verbindliche Begriffsdefinition gibt. Die Verwendung des Begriffes „Ersatzbrennstoff" in diesem Beitrag orientiert sich an den Festlegungen der Gütegemeinschaft Sekundärbrennstoffe und Recyclingholz (BGS) e.V. Diese unterscheidet **Ersatzbrennstoffe (EBS)** generell in heizwertreiche Fraktionen (hwF) und in Sekundärbrennstoffe [5]. Der BGS e.V. charakterisiert **heizwertreiche Fraktionen** folgendermaßen:

- aus Abfällen abgetrennte Anteile bzw. Fraktionen, die auf Grund ihrer Zusammensetzung und Eigenschaften deutlich höhere Heizwerte aufweisen als das Abfallgemisch
- geringere Aufbereitungstiefe, z.B. gröbere Korngröße
- z.B. heizwertreiche Fraktionen aus Mechanisch-Biologischen Aufbereitungsanlagen oder Gewerbeabfallsortieranlagen

Sekundärbrennstoffe (SBS) definiert der BGS e. V. als endkonfektionierten Brennstoff aus produktionsspezifischen Abfällen oder Siedlungsabfällen nach weitgehender Aufbereitung. Diese erfolgt beispielsweise mittels NIR-Technologie oder zusätzlicher ballistischer Separation. Ziel dieser Aufbereitung ist es, einen Brennstoff mit definierter Qualität herzustellen, der für die Mitverbrennung z. B. in Zement-, Kalk- oder Kraftwerken geeignet ist. SBS weisen i.d.R. Korngrößen < 20 mm auf und der Heizwert liegt zwischen 20 bis 25 MJ/kg bei einem Wassergehalt von 10 bis 15 %. SBS zur Mitverbrennung wird überwiegend in Form von einblasfähigem „Fluff" hergestellt, wodurch die Verbrennung des Materials nach Eintritt in die Brennkammer in der Flugphase ermöglicht wird.

Nach aktuellen Angaben der BGS e.V. wurden in Deutschland zwischen 1,8 und 2,5 Milliarden Euro in die Aufbereitungstechnologie von über 140 Anlagen investiert. In diesen Anlagen, in denen mehrere Tausend Arbeitsplätze geschaffen wurden, werden jährlich etwa 7 Mio. Mg Ersatzbrennstoffe hergestellt.

Die **Herstellung von Ersatzbrennstoffen** wird maßgeblich vom jeweiligen Einsatzort und –zweck beeinflusst. Unabhängig hiervon werden allgemein definierte Vorgaben für physikalische und chemische Parameter wie z. B. Korngröße, Schüttdichte, Wassergehalt, Heizwert, Chlor- und Schwermetallgehalt etc. gemacht. Für Industriefeuerungsanlagen ist maßgeblich, dass der jeweils zu verwertende Ersatzbrennstoff in gleichbleibender Menge und Qualität zur Verfügung steht. Um die von einem Verwerter geforderten Anforderungen an den EBS einzuhalten, sollte bei den Brennstoffherstellern eine entsprechend angepasste Aufbereitung erfolgen.

Heizwertreiche Fraktionen können in entsprechend geeigneten Monoverbrennungsanlagen (EBS-Kraftwerke) energetisch verwertet werden. Sie dienen aber auch als Ausgangsmaterial zur weiteren Aufbereitung von Sekundärbrennstoffen. In Anlagen mit

MBA-Technologie werden Siedlungsabfälle auf Basis einer stoffspezifischen Abfallbehandlung aufbereitet. Dies bedeutet, dass bei der Auswahl und Festlegung von Behandlungsschritten für Siedlungsabfälle deren - größtenteils sehr unterschiedliche – stoffliche Eigenschaften maßgebend sind. Dieser Ansatz spiegelt sich in drei verfahrenstechnischen Konzepten wieder:

_ **M**echanisch-**B**iologische **A**bfallbehandlung (MBA-Verfahren, aerob/anaerob)

_ **M**echanisch-**B**iologische **S**tabilisierung (MBS-Verfahren)

_ **M**echanisch-**P**hysikalische **S**tabilisierung (MPS-Verfahren)

Das am häufigsten verwendete Verfahren zur stoffspezifischen Abfallbehandlung ist die Mechanisch-Biologische Abfallbehandlung (MBA). Hier werden die Stoffströme zur weiteren biologischen Behandlung sowie diejenigen zur Wiederverwertung oder zur energetischen Verwertung ausgeschleust. Die biologische Behandlung erfolgt in Rottestufen (Tunnel, Zeilen oder Mieten) oder in Vergärungsstufen (Trocken- oder Nassvergärung). Als Endprodukt wird am Ende ein ablagerungsfähiges Material (Deponat) erzeugt. Bei der Mechanisch-Biologischen Stabilisierung erfolgt die biologische Trocknung des gesamten Abfallinputs zur Gewinnung heizwertreicher Abfälle bei Minimierung des abzulagernden Stoffstroms. Bei der Mechanisch-Physikalischen Stabilisierung werden heizwertreiche Abfallbestandteile aus Siedlungsabfällen nur über mechanische und physikalische Verfahren selektiert und im Rahmen eines mehrstufigen Behandlungsprozesses zu einem Ersatzbrennstoff aufbereitet. Dieser Aufbereitungsprozess umfasst z. B. eine Abtrennung der heizwertarmen Bestandteile und der Fe- und NE-Metalle sowie eine mehrstufige Zerkleinerung. Bei Bedarf werden schadstoffreiche Teilfraktionen abgetrennt und die heizwertreiche Fraktion getrocknet.

Wenn auch der Ausbau stoffstromspezifischer Aufbereitungsanlagen in der Bundesrepublik abgeschlossen scheint, führt eine Stärkung dieser Aufbereitungstechnologie zur besseren Ausnutzung der Abfalleigenschaften und liefert entsprechende Vorprodukte für weitere Verfahrensschritte. Unerheblich ist an dieser Stelle die Frage, welche Menge nach biologischer Behandlung noch deponiert werden muss, denn das Ziel all dieser Vorschaltanlagen – vor allem MA, MBS oder MPS aber auch MBA - ist, heizwertreiche Abfallbestandteile einer **energetischen Verwertung** zuzuführen. Mittlerweile sind in der Bundesrepublik 46 stoffstromspezifische Anlagen (MBA/MBS/MPS) mit einer Brennstoffproduktion von 2 bis 3 Mio. Mg/a in Betrieb. Diese Anlagen werden zwar nach den unterschiedlichsten Verfahrenskonzepten betrieben, aber alle stellen am Ende der Aufbereitung einen nennenswerten Massenstrom (je nach Abfalleigenschaft und Konzept bis zu 70 %) heizwertreicher Abfallströme für eine energetische Verwertung bereit. Daneben existieren noch 91 Anlagen zur SBS/hwF-Produktion mit einer Brennstoffproduktion von ca. 4,7 Millionen Mg/a.

Bei den meisten Anlagen mit MBA-Technologie handelt es sich bei den erzeugten Ersatzbrennstoffen um mittelkalorische heizwertreiche Fraktionen. Diese werden u. a. in energieeffizienten EBS-Kraftwerken zur Strom- und Dampferzeugung eingesetzt. Exemplarisch wird dies am Beispiel Neumünster dargestellt. Die MBA Neumünster weist eine Behandlungskapazität von 200.000 Mg/a auf. Die Anlage ist ausgelegt auf die Aufbereitung von jährlich 150.000 Mg Hausmüll sowie 50.000 Mg Gewerbeabfall. Der Abfall wird nach Vorbehandlung biologisch getrocknet. Jährlich werden so etwa 160.000 Mg heizwertreiche Fraktionen gewonnen. Diese werden in der Thermischen Ersatzbrennstoffverwertungsanlage (TEV) der Stadtwerke Neumünster GmbH energetisch verwertet. Die TEV Neumünster hat eine Jahreskapazität von 190.000 Mg (bei einem Heizwert von 12 MJ/kg). Neben heizwertreichen Fraktionen aus der MBA Neumünster werden weitere aus der MBA Lüneburg eingesetzt. Die Anlage weist eine Feuerungslinie mit zirkulierender Wirbelschicht auf. Die Kesselleistung beträgt 75 MWelektrisch. Im Jahr 2009 hat die TEV Neumünster über 1,1 Mio. Mg Dampf erzeugt. Die Stromerzeugung lag bei 183 Mio. kWh.

In den letzten Jahren hat sich die Herstellung von **Sekundärbrennstoffen** zur Mitverbrennung beispielsweise in Industriefeuerungsanlagen (z.B. Zementwerke) wie auch Großkraftwerken etabliert. Die Gesamtmenge der mitverbrannten Sekundärbrennstoffe beläuft sich aktuell auf ca. 2 Mio. Mg/a und davon werden ca. 15 % der Gütesicherung nach RAL-GZ 724 unterzogen (siehe auch Kapitel 3.3).

Angesichts der weltweiten Wirtschaftslage ist der Einsatz von Sekundärbrennstoffen für einige Branchen von entscheidender Bedeutung. Für die deutsche Zementindustrie ist der SBS-Einsatz alternativlos. Die Zementherstellung ist ein äußerst energieintensiver Prozess. Um Kosten zu senken und somit auf dem Weltmarkt weiterhin handlungsfähig zu sein, ersetzen deutsche Zementwerke ihre Primärbrennstoffe in immer größerem Umfang durch Sekundärbrennstoffe (teilweise bis zu 100 % der Feuerungswärmeleistung).

3.3 Qualitätssicherung

Mit der zunehmenden Inbetriebnahme von EBS-Kraftwerken in den vergangenen Jahren steigt die Relevanz anwendbarer Qualitätssicherungskonzepte für heizwertreiche Fraktionen. Das Hauptmotiv für den Betrieb von EBS-Kraftwerken ist die Nutzenergiegewinnung. Die Kraftwerksprojekte werden daher vorrangig in Kooperation mit energieintensiven Unternehmen realisiert. Diesen Unternehmen liefert das EBS-Kraftwerk Prozessenergie für die Produktion. Die technische Verfügbarkeit der Produktion ist gerade für die produzierenden Unternehmen eine elementare Grundlage ihrer Geschäftstätigkeit. Aus diesem Grund ist die Verfügbarkeit der EBS-Kraftwerke von hoher Bedeutung.

Um ein EBS-Kraftwerk störungsfrei zu betreiben ist eine permanente Verfügbarkeit der Energiequelle entscheidend. Diese ist nur mit einem auf die Verbrennungstechnik abgestimmten Brennstoff von konstanter Qualität zu realisieren. So werden an den Ersatzbrennstoff definierte Anforderungen an die physikalische bzw. chemische Beschaffenheit aber auch an eine Begrenzung von Störstoffen gestellt. Brennstoffverträge zwischen Verwertungsanlagen und Brennstoffproduzenten enthalten aus diesem Beweggrund in der Regel Pönalen für prozessrelevante Qualitätsparameter. Exemplarisch kann hier der Parameter Chlor genannt werden, welcher in hohen Konzentrationen zur so genannten Hochtemperatur-Chlorkorrosion führen kann. Des Weiteren sind genehmigungsrechtliche Randbedingungen hinsichtlich der Brennstoffqualität von Kraftwerksbetreibern zu erfüllen.

Um sicherzustellen, dass die Vertragspartner die Bestimmung der Qualitätsparameter eindeutig und analog zueinander definieren ist es unerlässlich, ein einheitliches Vorgehen bei der Probenahme sowie Analytik und auch Auswertung, z. B. die Arbeitshilfe der Gütegemeinschaft Sekundärbrennstoffe und Recyclingholz e.V., zu nutzen [6]. Unabhängig davon, ob die Brennstoffe einer Mit- oder Monoverbrennung zugeführt werden sollen, sind u.a. folgende Randbedingungen einzuhalten:

- ➔ definierter Heizwert - geringer Chlorgehalt
- ➔ definierte Korngröße sowie Schüttdichte
- ➔ geringe Störstoffanteile
- ➔ geringe Schwermetallgehalte (bei der Mitverbrennung)
- ➔ in ausreichender Menge und gleich bleibender Qualität verfügbar.

Um eine gleich bleibende Qualität bei der Produktion eines Ersatzbrennstoffs sicherzustellen, ist eine kontinuierliche Qualitätssicherung durchzuführen. Dazu ist es zudem unerlässlich, ein einheitliches Vorgehen bei der Probenahme sowie Analytik und auch Auswertung zu nutzen. Bei der Qualitätssicherung von Ersatzbrennstoffen ist eine repräsentative Probenahme elementar. In vielen Fällen wird die Probenahme bei der Anlagenplanung nicht berücksichtigt. Eine detaillierte Planung und Durchführung der Probenahme ist jedoch die Grundvoraussetzung für belastbare Analysenergebnisse. Das Personal vor Ort sollte geschult und hinsichtlich der Thematik „Qualitätssicherung“ sensibilisiert werden.

Für die Heizwertreichen Fraktionen sind die Regelungen nach RAL-GZ 724 aufgrund der verschiedenen Verwertungswege sowie der deutlich größeren Stückgröße nicht anwendbar. Die Qualitätsparameter werden neben den in der Genehmigung festgelegten Parametern in diesen Fällen zwischen Verwerter und Hersteller bilateral verhandelt. Aber auch hier ist es notwendig, dass das Vorgehen bei der Bestimmung sowie die zugehörigen Verfahren und auch die Bewertung festgelegt sind. Der „Arbeitshilfe – Qualitätssicherung von heizwertreichen Fraktionen“ [5] der Gütegemeinschaft Sekundärbrennstoffe und Recyclingholz e.V. sind entsprechende Vorgaben zu entnehmen.

Da die Beprobung der Heizwertreichen Fraktion sowie die weitere Aufbereitung zur Laborprobe aufgrund der Korngröße ein sehr aufwändiges Prozedere darstellt, soll dieses Vorgehen durch Möglichkeiten u.a. der automatische Probenahme sowie entsprechender weiterer Aufbereitung optimiert werden. Dazu wurde von der Fachhochschule Münster ein Forschungsantrag gestellt, in dem verschiedene derzeit schon umgesetzte Verfahren miteinander verglichen und optimiert werden sollen. Vertreter einiger EBS-Kraftwerke sowie Hersteller von automatischen Probenahmesystemen haben sich an der erfolgreichen Antragstellung beteiligt und das 3-jährige Forschungsvorhaben läuft seit Anfang 2011.

4 Perspektiven der MBA-Konzepte und der energetischen Verwertung von Ersatzbrennstoffen aus nationaler und internationaler Sicht

Die Abfallwirtschaft muss sich zunehmend an den Vorgaben nachhaltiger Ressourcen- und Klimaschutzziele ausrichten. Nach aktuellen Studien kann die Abfallwirtschaft dazu auch weiterhin einen wesentlichen Beitrag durch eine stoffliche und energetische Verwertung von Abfällen bei energieeffizienter Optimierung der Behandlungsanlagen leisten. In Europa wird die konkrete Umsetzung der AbfRRL in den Staaten der EU zu einer zurzeit nur schwer abschätzbaren Veränderung des Abfallaufkommens hinsichtlich Menge und Qualität sowie dessen Verbleib führen. Die MBA muss und wird sich diesem Wettbewerb um Mengenströme und Qualitäten stellen. Die technischen Voraussetzungen und Entwicklungspotenziale sind dafür vorhanden. Die stoffspezifische Abfallbehandlung mit einer MBA als Schaltstelle einer Stoffstromtrennung mit energieeffizienter Behandlung und Verwertung der Teilströme bietet dafür nicht nur in Europa eine gute Ausgangsposition. Die technische Ausführung der MBA lässt sich dabei flexibel an die jeweiligen Anforderungen und Rahmenbedingungen anpassen.

Die MBA hat in Deutschland innerhalb weniger Jahre einen hohen Entwicklungsstand erreicht und diese Erfahrungen gilt es in den nächsten Jahren in angepasster Form im

Ausland zu etablieren. Hier lassen sich bei vereinfachter Betrachtung zwei Ländergruppen unterscheiden.

Zum einen sind dies die Länder, die bereits über eine gut funktionierende Abfallwirtschaft verfügen. Dies sind insbesondere die Länder der Europäischen Union, die teilweise bereits ähnliche MBA-Standards in der Abfallbehandlung (z.B. Österreich) umgesetzt haben aber auch die „neuen“ und teilweise „alten“ EU-Länder, deren Abfallwirtschaft noch im Aufbau ist. Hier können stoffstromspezifisch optimierte Abfallwirtschaftskonzepte mit integrierten MBA-Lösungen einen wesentlichen Beitrag zur nachhaltigen Entwicklung leisten und dabei steht immer mehr die die Herstellung von Ersatzbrennstoffen und deren umweltverträglich energetische Verwertung im Fokus.

Zum anderen sind hier die Entwicklungs- und Schwellenländer zu nennen, deren in den meisten Fällen nur rudimentär vorhandene Abfallwirtschaft häufig für etwa 10 bis 15 % der klimarelevanten Emissionen verantwortlich ist, während in Deutschland inzwischen aufgrund der hohen Entsorgungsstandards eine Nettoentlastung realisiert ist. Mehr als 5 Mrd. Menschen auf der Welt leiden unter den gesundheitlichen Folgen einer nicht vorhandenen bzw. völlig rückständigen Abfallwirtschaft. Hier lässt sich gerade mit (einfachen) angepassten MBA-Lösungen sehr viel, u.a. für den Klimaschutz bewegen und der Export von Technik und Wissen in diesem Bereich ist auch wirtschaftlich für alle Akteure interessant. Besonderen Stellenwert hat dabei die Herstellung und energetische Verwertung von Ersatzbrennstoffen.

Die aktuelle Situation bei der Herstellung und energetischen Verwertung von Ersatzbrennstoffen ist in Deutschland stark durch die bereits angesprochenen Überkapazitäten im Bereich der thermischen Abfallbehandlung geprägt. Derzeit ist eine hochwertige Aufbereitung von qualitätsgesicherten Sekundärbrennstoffen derzeit ökonomisch kaum noch darstellbar. Auf hierdurch bewirkte vorübergehende Stilllegungen von Aufbereitungsanlagen wurde hingewiesen. Ziel aller am Markt Beteiligten sollte aber eine nachhaltige Abfallwirtschaft sein und vor diesem Hintergrund wäre ein Preis für Ersatzbrennstoffe sinnvoll, der sich an deren Energiewert orientiert. Nach diesem Ansatz müsste der Einkaufspreis von Sekundärbrennstoff nach Berechnungen der Autoren je nach Heizwert zwischen 30 und 90 Euro/Mg liegen müsste. Hiervon sind Zusatzkosten abzuziehen, die einem Verwerter beim Einsatz von SBS entstehen (z. B. Lagerung, Qualitätssicherung etc.). Diese Kosten werden mit 15 Euro/Mg abgeschätzt. Für den „reellen“ Preis ergibt sich somit eine Spanne von 15 bis 75 Euro/Mg. Mögliche Gutschriften für CO_2-Minderungen, die seitens des Verwerters geltend gemacht werden können, wurden hierbei noch nicht berücksichtigt.

Neben den ökonomischen Betrachtungen sollte auch der Klima- und Ressourcenschutz mehr in die Betrachtungen einfließen. Im Bereich der energetischen Verwertung sollte die energieeffizienteste Form das zu erreichende Ziel darstellen. Hierbei spielt der Wirkungsgrad der Verbrennungsanlage eine wesentliche Rolle, da bei einem höheren Wirkungsgrad die im Abfall enthaltene Energie entsprechend effizienter genutzt wird. Der Wirkungsgrad von Industriefeuerungsanlage bzw. Großkraftwerken ist i.d.R. höher als bei Müllverbrennungsanlagen. Deshalb sollte die Mitverbrennung von Sekundärbrennstoffen weiter ausgebaut werden. Dies wird auch durch die vorliegenden Ökobilanz-Studien bestätigt, die letztlich zu dem Ergebnis kommen, dass die CO_2-Einsparung umso höher ausfällt, je effizienter eingesetzte Energie genutzt wird.

Es bleibt abschließend festzustellen, dass die Monoverbrennung im Zuge von „Kombinationsverfahren“ (heizwertreiche Fraktionen aus Anlagen mit MBA-Technologie plus energetische Verwertung in energieeffizienten EBS-Kraftwerken) und die Mitverbrennung von gütegesicherten Sekundärbrennstoffen eine der effizientesten Verwertungsformen für energiereiche Abfälle darstellen und somit einen wichtigen Beitrag zum Klima- und Ressourcenschutz leisten. Eine moderne und vor allem nachhaltige Kreislaufwirtschaft kann auf die Herstellung und energetische Verwertung von Ersatzbrennstoffen auch zukünftig nicht verzichten. Dies gilt nicht nur für Deutschland sondern auch für den internationalen Bereich. Deutschland wird in vielen Ländern (z.B. arabischer Raum, China, Indien) als abfallwirtschaftliches Vorbild gesehen und unsere abfallwirtschaftlichen Konzepte und die realisierte Anlagentechnik genießen hohes Ansehen. Dies gilt es zu nutzen und die globale Entwicklung der Abfallwirtschaft als Zukunftsaufgabe zu begreifen.

5 Literaturangaben

[1] Nelles, M.; Westphal, J.; Morscheck, G.: „Erweiterung von MBAs um eine anaerobe Stufe am Beispile Rostock“ Beitrag im Tagungsband, Seite 215 bis 227 zur 3. Internationalen Tagung MBA und Sortieranlagen vom 12. bis 15. Mai 2009 in Hannover, ISBN 978-3-86727-953-6, deutsch und ISBN 978-3-86727-236-0, englisch (5/2009)

[2] Nelles, M.; Nassour, A.: „Technische und wirtschaftliche Prüfung und Beurteilung des Entwicklungskonzeptes für die MBA Lübeck“, Gutachten im Auftrag der Entsorgungsbetriebe Lübeck, Rostock, unveröffentlicht (9/2009)

[3] Arbeitsgemeinschaft Stoffspezifische Abfallbehandlung (ASA): „MBA-Steckbriefe 2010/2011“; ASA GmbH, Enningerloh (2/2010)

[4] Nelles, M.; Morscheck, G; Nassour, A; Schüch, A.: „Optimierung und Nachrüstung von MBA-Anlagen in der Praxis“ Beitrag in: Witzenhausen Institut – Neues aus Forschung und Praxis, Bio- und Sekundärrohstoffverwertung V, S. 598-610, ISBN 3-928673-56-4 (4/2010)

[5] Flamme, S.: „Ersatzbrennstoffe – Aufbereitung, Spezifika, Anforderungen, aktuelle Absatzmärkte“, Beitrag im Tagungsband zu den Internationalen 7. ASA Abfalltagen, S. 149 – 160, ISBN 3-935974-14-0

[6] BGS (2008): Gütegemeinschaft Sekundärbrennstoffe und Recyclingholz e.V., Probenahme-, Probenaufbereitungs- und Analysenvorschrift für Sekundärbrennstoffe im Rahmen des RAL-GZ 724, Stand Oktober 2008, Münster, Germany

6 Angaben zu den Verfassern

Prof. Dr. Michael Nelles und M.Sc. Jennifer Grünes
Universität Rostock
Agrar- und Umweltwissenschaftliche Fakultät
Lehrstuhl Abfall- und Stoffstromwirtschaft
Justus-von-Liebig-Weg 6
D-18059 Rostock
Tel.: +49 (0) 381/498-34-00
Fax: +49 (0) 381/498-34-02
Email: michael.nelles@uni-rostock.de

Dipl.-Ing. Michael Balhar
Arbeitsgemeinschaft Stoffspezifische Abfallbehandlung (ASA) e. V.
im Hause der Abfallwirtschaftsgesellschaft des Kreises Warendorf mbH
Westring 10
D-59320 Ennigerloh
Tel.: +49 (0) 2524 9307-18
Fax: +49 (0) 2524 9307-12
Email: michael.balhar@asa-ev.de

Prof. Dr.-Ing. Sabine Flamme
Fachhochschule Münster
Fachbereich Bauingenieurwesen
Lehr- und Forschungsgebiet Kreislauf- und Abfallwirtschaft, Infrastruktur, Ressouren- und Stoffstrommanagement
Corrensstraße 25
D-48149 Münster
Tel.: +49 (0) 251 83-65253
Fax: +49 (0) 251 83-65260
Email: flamme@fh-muenster

Herstellung und Einsatz von Ersatzbrennstoffen (EBS) in Österreich

Karl E. Lorber, Renato Sarc[1], Roland Pomberger[2]

1) Montanuniversität Leoben (IAE), Leoben, 2) Saubermacher Dienstleistungs AG, Graz, Austria

"Production and Application of Refuse Derived Fuels in Austria"

Abstract

The Austrian experiences in processing, quality control and industrial application of Refuse Derived Fuels (RFD) in co-incineration facilities are reported as well as potential problems like fire risks and plant corrosion. Beginning with legal regulations and definitions, the recovery process and quality management of RDF is described together with conditioning steps for different RDF - specifications and finally a classification scheme for RDF - qualities is elaborated. On the basis of two case studies, the processing and confectioning of middle caloric (e.g. HOTDISC - RDF) and high caloric (e.g. ASB) RDF for the cement industry are described. Furthermore, it is shown, that the well known method of "material flow analysis" can be successfully used as a helpful tool to generate necessary data on waste separation and processing needed for the design of splitting plants, where specified RDF - qualities are recovered from municipal solid waste and commercial refuse.

Inhaltsangabe

Es wird über die österreichischen Erfahrungen bei der Aufbereitung, Qualitätssicherung und dem Einsatz von Ersatzbrennstoffen (EBS) in Mitverbrennungsanlagen berichtet und es werden darüberhinaus potentielle Probleme wie z.B. Brandrisiko und Anlagenkorrosion angesprochen. Mit den gesetzlichen Regelungen beginnend, wird die Qualitätssicherung von EBS behandelt, Aufbereitungsmöglichkeiten für verschiedene EBS - Spezifikationen beschrieben und eine Klassifizierung von Ersatzbrennstoff - Qualitäten vorgenommen. Anhand von zwei Fallbeispielen wird die Aufbereitung und Konfektionierung von mittelkalorischem (HOTDISC - EBS) und hochkalorischem EBS (z.B. ASB) für die Zementindustrie dargestellt. Dabei wird gezeigt, wie durch die bekannte Methode der Stoffflussanalyse ganz gezielt Basisdaten zur Auslegung von EBS - Produktionsanlagen abgeleitet werden können, um damit aus gemischten Siedlungsabfällen und Gewerbemüll unterschiedliche EBS - Spezifikationen erzeugen zu können.

Keywords

Ersatzbrennstoffe, EBS - Aufbereitung, Klassifizierung, Spezifikationen, HOTDISC-EBS, Refuse Derived Fuels, RDF - Processing, Classification, Specification, High caloric RDF.

1 Einleitung

Die Deponieverordnung 2004 (Dep VO 2004) stellt einen Wendepunkt in der österreichischen Abfallwirtschaft dar, da mit 1. 1. 2004 die Deponierung von Abfällen, deren TOC - Wert mehr als 5M% beträgt, nicht mehr zulässig ist. Damit ist es erforderlich geworden, den nach der getrennten Sammlung und Sortierung der Altstoffe übrig bleibenden „Restabfall“ vor seiner kontrollierten Ablagerung auf Deponien vorzubehandeln. Im Prinzip gibt es dazu zwei Verfahren: die thermische Behandlung (Mono-Verbrennung) in Müllverbrennungsanlagen (MVA) und die mechanisch-biologische Behandlung in MBA, siehe Abb. 1.

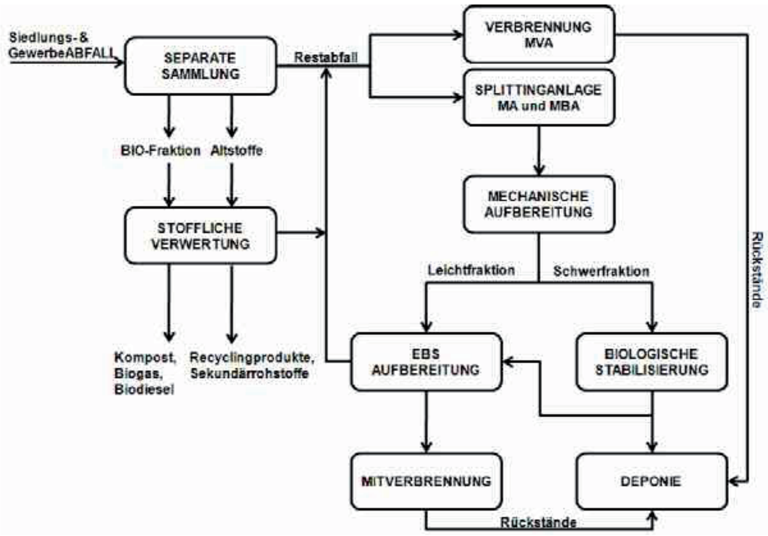


Abbildung 1 Das Österreichische „Restmüll-Splitting“ Konzept

Obwohl durch die mechanisch-biologische Restmüllvorbehandlung der nach der Deponieverordnung 2004 (bzw. der neuen Novelle Deponieverordnung 2008) geforderte TOC < 5M% für das im Rottetunnel stabilisierte „MBA-Material“ nicht erreicht werden kann, ist durch eine Ausnahme-Klausel die Ablagerung auf (einem gesonderten Kompartiment) einer Massenabfalldeponie zulässig, sofern der Brennwert (Ho) 6.600 kJ/kg TM nicht überschreitet. Durch diese Regelung muss also der höher kalorische Anteil bei der mechanischen Aufbereitung und der Siebung nach der Rotte abgetrennt und einer thermischen Behandlung/Verwertung zugeführt werden. Dazu kommt die Monoverbrennung in der MVA (z.B. Wirbelschichtverbrennungsanlagen) aber auch die Mitverbrennung als Ersatzbrennstoff (EBS) in Frage, wobei dieser durch Aufbereitung und Konfektionierung der Leichtfraktion hergestellt wird. In Österreich ist die verfügbare Kapazität von (Restmüll)Verbrennungsanlagen (MVA) zurzeit noch nicht ganz ausreichend, um die jährlich anfallende Gesamtmenge von 1.665.000 t nicht verwertbarer Siedlungs- und Gewerbeabfälle (Stand 2009) vor der Deponierung thermisch behandeln zu können. Daher kommt der mechanisch-biologischen Restmüllvorbehandlung (MBA) und damit einhergehend der Aufbereitung von EBS zur Mitverbrennung in industriellen Feuerungsanlagen nach wie vor Bedeutung zu, um die Deponieverordnung 2004 (bzw. 2008) überhaupt implementieren zu können.

1.1 Anfallende Abfallmengen und Anlagen

Laut Bundesabfallwirtschaftsplan (Statusbericht 2009) waren in Österreich im Jahr 2009 insgesamt 1.665.000 t/a Abfälle in thermischen Anlagen zu behandeln, und zwar:

- 1,270.000 t/a: Restmüll und Sperrmüll,
- 225.000 t/a: heizwertreiche Fraktion aus Sortierung bzw. Restmüll-Splitting,
- 170.000 t/a: energetisch verwertbare Rückstände aus Sortierung getrennt erfasster Abfälle;

Dem stehen insgesamt 24 Aufbereitungsanlagen (MA) zur „vorwiegend mechanischen Behandlung“ von gemischten Siedlungs- und Gewerbeabfällen mit einer maximalen Verarbeitungskapazität von 1.224.000 t/a gegenüber. In 14 im Detail untersuchten Mechanischen Aufbereitungs-(MA)-Anlagen werden vor allem heizwertreiche Fraktionen oder Ersatzbrennstoffe (EBS) zur weiteren externen thermischen Behandlung oder externen stofflichen Verwertung mit einer Gesamtkapazität von max. 765.500 t/a aufbereitet (ANMERKUNG: Der Einsatz von EBS in Zementwerken gilt sowohl als thermische Behandlung als auch stoffliche Verwertung, da die bei der Verbrennung anfallende Asche in den Klinker eingebunden wird. Die hier berichteten Anlagenkapazitäten dürfen nicht mit den tatsächlich in den Anlagen behandelten Abfallmengen, die von der Marktsituation abhängen, verwechselt werden.).

2 Begriffsbestimmung und gesetzliche Grundlage

In der Novelle zur Abfallverbrennungsverordnung (AVV-Novelle 2009) wird für Ersatzbrennstoffe (EBS) in § 3 Punkt 18 folgende Definition gegeben:

Ersatzbrennstoffe: Abfälle, die zur Gänze oder in einem relevanten Ausmaß zum Zweck der Energiegewinnung eingesetzt werden und die die Vorgaben gemäß Anlage 8 zu dieser Verordnung erfüllen. Ein relevantes Ausmaß zum Zweck der Energiegewinnung liegt vor, wenn eine selbstgängige Verbrennung ohne Zusatzfeuerung möglich ist. Klärschlämme und Papierfaserreststoffe, die verbrannt werden und die die Vorgaben gemäß Anlage 8 zu dieser Verordnung erfüllen, gelten im Sinne dieser Verordnung als feste Ersatzbrennstoffe.

Anlage 8 enthält u.a. Vorgaben für Abfälle, die für Verbrennung in Mitverbrennungsanlagen vorgesehen sind, wobei hier in drei Anlagentypen unterschieden wird, und zwar:

- Anlagen zur Zementerzeugung,

- Kraftwerksanlagen,
- Sonstige Mitverbrennungsanlagen.

Bemerkenswert ist, dass der Anteil der Brennstoffwärmeleistung aus der Verbrennung von Abfällen (bzw. EBS) in Steinkohle- oder Braunkohlekesseln mit max. 15M% begrenzt ist und zudem die Grenzwerte vom mitverbrannten Anteil des Ersatzbrennstoffes (d.h. ≤ 10% bzw. ≤ 15%) abhängen, siehe Tab. 1.

Tabelle 1 Grenzwerte [mg/MJ] für Abfälle bei der Verbrennung in Mitverbrennungsanlagen

Parameter	ZEMENTWERK [mg/MJ]		KRAFTWERK ≤ 15% [mg/MJ]				SONSTIGE MIT-VERBRENNUNGS-ANLAGE [mg/MJ]	
	Median	80er Perzentil	Median		80er Perzentil		Median	80er Perzentil
			≤ 10%		≤ 15%			
As	2	3	2	3	2	3	1	1,5
Pb	20	36	23	41	15	27	15	27
Cd	0,23	0,46	0,27	0,54	0,17	0,34	0,17	0,34
Cr	25	37	31	46	19	28	19	28
Co	1,5	2,7	1,4	2,5	0,9	1,6	0,9	1,6
Ni	10	18	11	19	7	12	7	12
Hg	0,175	0,15	0,075	0,15	0,075	0,15	0,075	0,15
Sb	7	10	7	10	7	10	7	10

Umrechnungsformel: $[mg / MJ] = \frac{Schadstoffgehalt\ [mg / kg\ TM]}{Heizwert\ [MJ / kg\ TM]}$

Festzuhalten ist auch, dass Ersatzbrennstoffe (EBS) im Sinne der Abfallverbrennungsverordnung (AVV-Novelle 2009) nach wie vor Abfälle und keine Produkte sind und dass die Grenzwerte - wie in Tabelle 1 dargestellt - auf den Heizwert (Dimension: [mg/MJ]) bezogen sind. Desweiteren enthält Anlage 8 noch detaillierte Angaben zur Qualitätssicherung von EBS mit statistisch unterlegter Probenahmeplanung und Probenahmevorschriften. Ergänzt wird die AVV-Novelle 2009 noch durch die Richtlinie für Ersatzbrennstoffe (BMLFUW 2008), die - abgesehen vom Parameter Sb - dieselben Grenzwerte zur Regelung der Qualitäten von Ersatzbrennstoffen enthält und neben den „Begriffsbestimmungen" sehr ins Detail gehende statistische Vorgaben zu Qualitätssicherung von EBS enthält.

Trotz oder möglicherweise gerade wegen der Definition „Ersatzbrennstoff" in der Abfallverbrennungsverordnung und der EBS-Richtlinie gibt es für Ersatzbrennstoff vielfältige Bezeichnungen, die manchmal zu Verwirrung führen können, z.B.:

- **BraM**: Brennstoff aus Müll, in den 80iger Jahren eingeführt, hat sich nicht durchgesetzt,
- **ABS**: Alternativbrennstoff,
- **SBS**: Substitutbrennstoff aus Siedlungsabfällen,
- **BGB**: Brennstoff aus produktionsspezifischen Gewerbeabfällen,

- **ASB**: Aufbereiteter Substitut Brennstoff,
- **RDF**: Refuse Derived Fuels,
- **SRF**: Solid Recovered Fuels,
- **EBS**: Ersatzbrennstoff (Allgemeine Definition: EBS ist ein Brennstoff, der in der Regel aus heizwertreichen Abfällen gewonnen wird. Die ursprünglichen Abfälle können dabei aus Haushalt, Industrie und Gewerbe stammen).

Im deutschen Kreislaufwirtschaft- und Abfallgesetz (KrW/AbfG 2007) wird dazu im §4 Absatz 4 festgestellt: „Die energetische Verwertung beinhaltet den Einsatz von Abfällen als Ersatzbrennstoff, vom Vorrang der energetischen Verwertung unberührt bleibt die thermische Behandlung von Abfällen zur Beseitigung, insbesondere von Hausmüll. In Deutschland wird zudem durch die Bundesgütegemeinschaft Sekundärbrennstoffe (BGS), die Qualität von EBS gesichert (z.B. durch die Güte- und Prüfbestimmung der RAL-GZ 724). Zusammenfassend festgestellt, können (im weitesten Sinne) folgende Abfälle aus Haushalt, Industrie und Gewerbe ohne oder nach einem Aufbereitungsverfahren als Ersatzbrennstoff in Verbrennungs- und Mitverbrennungsanlagen eingesetzt werden: Klärschlamm, Altholz, heizwertreiche Fraktionen aus MA- und MBA-Anlagen, Kunststoffabfälle aus Haushalte & Gewerbe, Schredderleichfraktionen (z.B. aus Altfahrzeugen, Elektro- und Elektronikaltgeräten), tierische Nebenprodukte (z.B. Tierfett, Tiermehl), Altreifen, Altöl, etc.

Neben den gesetzlichen Vorgaben, die die Behörde den Anlagenbetreibern vorschreibt, geben auch Mitverbrenner von Abfällen den Produzenten von Ersatzbrennstoffen bestimmte Qualitätskriterien (d.h. Spezifikationen) vor. Dabei kommt der Konfektionierung große Bedeutung zu. Es wird eine heizwertreiche Brennstofffraktion nach Entfrachtung der Störstoffe durch z.B. Trocknung und Pelletierung weiter „veredelt“. Mithilfe der Trocknung (z.B. 10% H_2O - Gehalt für harte Pellets) werden weitere biologische Zersetzungsprozesse unterbunden und der EBS lagerfähig gemacht. Durch die damit verbundene Verminderung des Wassergehaltes erhöht sich der Heizwert des EBS. Generell gilt, dass erst bei einer Überschreitung von **11 MJ/kg** TM der Abfall zum Ersatzbrennstoff geworden ist (ANMERKUNG: Der Heizwertbereich für mitteleuropäischen Restabfall liegt zwischen 9 - 13 MJ/kg TM).

3 Aufbereitung und Klassifizierung von EBS

Als EBS im engeren Sinn werden nur Brennstoffe bezeichnet, die aus sortenreinen oder gemischten Abfällen (Siedlungsabfälle, Gewerbeabfälle, Produktionsabfälle mit Schlüsselnummer 91101 (Hausmüll und hausmüllähnliche Gewerbeabfälle) nach ÖNORM S2100 bzw. EAK 200301 (gemischte Siedlungsabfälle) hergestellt werden und direkt ohne nennenswerte weitere Aufbereitung in industriellen Mitverbrennungsanlagen eingesetzt werden können. Siebüberläufe aus der mechanisch-biologischen Abfallbehandlung (MBA), die lediglich durch Vorzerkleinerungen und Absiebung eine in Korngröße und Störstoffgehalt nicht näher definierte Fraktion (ca. 35 - 45M% des Inputs) darstellen, stellen nur ein Zwischenprodukt bzw. einen Sekundärabfall für die nachfolgende EBS-Produktion dar. Durch zusätzliche Verfahrensschritte (Zerkleinerung, Windsichtung, Fe- und NE-Metallabscheidung) entsteht in der Regel ein mittelkalorischer EBS für Wirbelschichtanlagen, wobei der EBS - Anteil zwischen 30 - 40% des Inputs betragen kann.

Um Ersatzbrennstoffe mit definierten Qualitäten und garantierten Spezifikationen zu erzeugen, ist eine mehrstufige Aufbereitung nötig, die im wesentlichen folgende Aufbereitungsschritte enthält, siehe Abb.2

a) Vorzerkleinerung,
b) Störstoffabscheidung (z.B. durch Windsichter, ballistischen Separator),
c) Nachzerkleinerung,
d) Konfektionierung (z.B. durch Sternsieb);

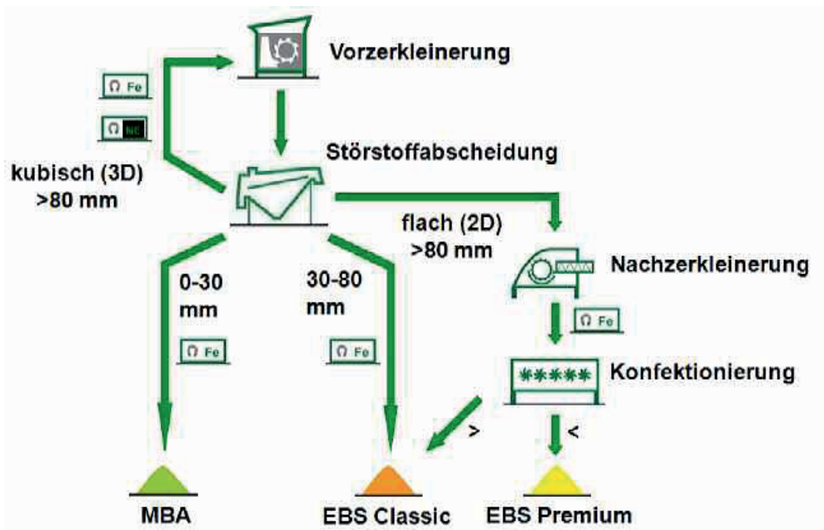


Abbildung 2 Schema einer Ersatzbrennstoff-Aufbereitungsanlage aus kunststoffhaltigen Abfällen (Restmüll und Gewerbemüll) nach Kunter & Wellacher (2010)

Nach Pomberger (2007) können die EBS-Produktionsanlagen grundsätzlich in 3 Typen unterteil werden, und zwar:

a) EBS-Produktionsanlagen für sortenreine Produktionsabfälle mit: Vorzerkleinerung, Nachzerkleinerung und Fe- und NE-Abtrennung,

b) EBS-Produktionsanlagen für Siedlungs- & Gewerbeabfall (bzw. MBA mit Nachaufbereitung des Siebüberlaufs) mit: Vorzerkleinerung, Siebung, Fe- und NE-Abtrennung, Windsichtung, Störstoffentfachung und Nachzerkleinerung,

c) EBS-Produktionsanlagen für Leichtfraktionen aus Vorbehandlungsanlagen (z.B. MA- und MBA-Anlagen), Produktions- & Verpackungsabfälle mit: Vorzerkleinerung, Windsichtung, FE & NE-Abscheidung, sowie Nachzerkleinerung (Inertstoffabscheidung).

Für Anlagentyp a) und c), deren Hauptzweck die Störstoffentfrachtung und Konfektionierung ist, kann die EBS - Ausbringung zwischen 60 und 90M% liegen. Für Anlagentyp b) (d.h. MBA mit Nachaufbereitung des Siebüberlaufs) liegt der Hauptzweck auf der Abfallvorbehandlung vor der Deponierung. Die EBS - Ausbringung erreicht dabei 30 bis max. 45M%.

3.1 Klassifizierung EBS

Verschiedene industrielle Mitverbrennungsverfahren und Anlagen haben unterschiedliche Anforderungen an die EBS Qualität. Wesentliche Parameter sind daher neben dem Chlor-Gehalt der Heizwert (Hu [MJ/kg]) und die Korngröße (d_{90} [mm]). In Abb.3 ist der Zusammenhang zwischen Heizwert und Körngröße verschiedener Ersatzbrennstoffe zusammen mit dem Einsatzort dargestellt.

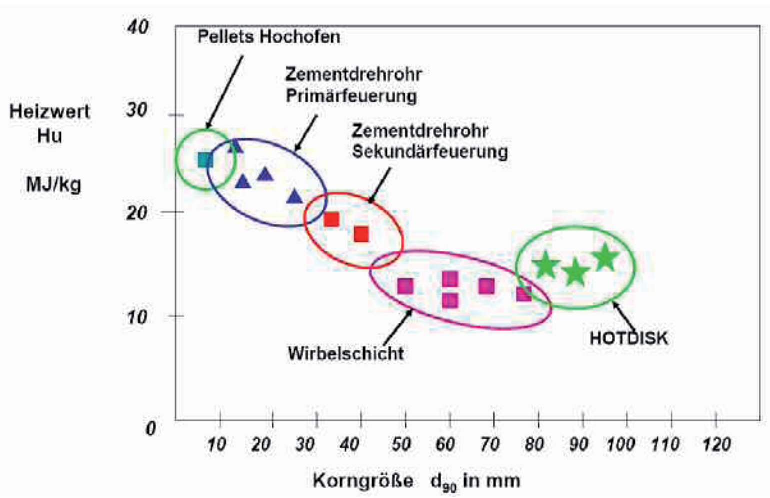


Abbildung 3 Einsatzgebiete unterschiedlicher EBS Sorten in Abhängigkeit von Heizwert und Korngröße, Pomberger (2007)

Eine weitergehende Klassifizierung von Ersatzbrennstoffen in Abhängigkeit von relevanten, brennstoffspezifischen Kriterien wird von Kunter & Wellacher (2010) vorgeschlagen, siehe Tab. 2.

Tabelle 2 Klassifizierung von Ersatzbrennstoffen, Kunter & Wellacher (2010)

Kriterium	Ersatzbrennstoffqualitäten					
	Kohlekraft-werk EBS	„EBS-Low" (Rostfeuerung)	„EBS-Classic" (Wirbelschicht)	Kalzinator-feuerung EBS	„EBS-Premium" (Primärfeuerung)	Hochofen EBS
Heizwert	11-15 MJ/kg	12-16 MJ/kg	12-16 MJ/kg	11-18 MJ/kg	22-25 MJ/kg	> 25 MJ/kg
Korngröße	< 50 mm pelletiert	< 300 mm	< 20-100 mm	< 50-80 mm	< 10-30 mm	< 10 mm pelletiert
Übergröße	0%	< 3%	< 2%	< 1%	< 1%	0%
Störstoffgehalt	< 1%	< 3%	< 1%	0	< 1%	0%
Chlorgehalt	< 1,5%	< 1%	< 0,8%	< 0,8%	< 0,8%	< 2%
Aschegehalt	< 35%	–	< 20%	–	< 10%	< 10%

Ein interessantes Einsatzgebiet von EBS ist die Stahlindustrie. Dabei werden EBS Kunststoffpellets (Dimension: L < 9 mm, ∅ < 6 mm), die zu 50% aus gesichteten Gewerbemüll, zu 30% aus aufbereiteten MBA-Material und zu 20% aus gemischten Kunststoffverpackungen (aus dem „gelben Sack" bzw. der „gelben Tonne" stammen) in den Hochofen eingeblasen, wobei hier EBS anstelle von Koks oder Heizöl - schwer als Reduktionsmittel dient:

$$Fe_2O_3 + 2CO + H_2 \leftrightarrows 2Fe + 2CO_2 + H_2O$$

Ein Versuchsbetrieb mit 30.000 t EBS - Pellets wurde 2005 bei der Fa. Voestalpine Linz erfolgreich durchgeführt, Projektziel ist der Einsatz von bis zu 220.000 t/a EBS - Pellets (nach Fleischhacker (2009)).

4 Qualitätssicherung und Ergebnisse

Es müssen 3 grundsätzliche Voraussetzungen vorhanden sein, damit sich ein Anlagenbetreiber für die Mitverbrennung von EBS (die ja mit nicht unerheblichen Investitionen, wie z.B. Lagerung, Anlagenmodifizierung etc. belastet ist) entscheidet, und zwar:

- Rechtssicherheit,
- Versorgungssicherheit und
- Qualitätssicherheit.

Nach den Vorgaben der Richtlinie für Ersatzbrennstoffen 2008 ist für jeden EBS getrennt nach Herkunft und Abfallart gemäß **ÖNORM CEN/TS 15442** von 2007 ein Probenahmeplan zu erarbeiten. Auch Anzahl und Masse der Stichproben bzw. die Mindestprobenmenge für die qualifizierte Stichprobe ist entsprechend ÖNORM CEN/TS 15442 zu berechnen. Für die erforderliche repräsentative Probemenge wird parallel dazu auch **CEN/TS 3443N88** „solid recovered fuels - sampling methods" eingesetzt.

Kurz zusammengefasst, müssen zur Qualitätssicherung von Analysenergebnissen folgende Punkte beachtet werden:

- Um den zufälligen Fehler zu minimieren, sind ausreichend große Probemengen, Zwischenzerkleinerung und Probenteilung erforderlich.
- Entmischungen und falsche Probenvorbereitung können zu hohen systematischen Fehlern führen.
- Einzelmessungen der Qualitätssicherung sind nicht aussagekräftig und ein ungeeignetes Mittel zur Qualitätsbeurteilung von Einzelchargen.
- Aussagekräftig sind lediglich Durchschnittswerte über lange Zeiträume. Diese Werte unterliegen nicht der Normverteilung, weshalb der Median bzw. der 80er Perzentilwert und nicht der Mittelwert und die Standardabweichung bessere Aussagekraft hat.

Der Zusammenhang zwischen Probemenge [kg], Probenanzahl [n], Korngröße [d_{90}] und Kornform (2 - dimensional (2D) und 3 - dimensional (3D)) wird in der Berechnungsmethode der CEN TC 343 berücksichtigt. Wie in Tabelle 3 dargestellt, ergeben sich für die Anwendungen dieser Methode auf die angeführten EBS - Spezifikationen folgende repräsentative Probenahmeparameter, Pomberger (2005).

Tabelle 3 Repräsentative Probenahmeparameter für EBS - Produkte gem. CEN TC 343 und CEN 292

EBS	Korngröße d_{90} [mm]	Inkremente		Masse Probe
		[n]	[kg]	[kg]
ASB Thermoteam	30	100	0,7	70
Wirbelschicht	60	166	1,5	250
Wirbelschicht	80	150	4,0	600

5 Potentielle Probleme mit EBS

EBS ist kein Regelbrennstoff sondern Abfall bzw. aus Abfall hergestellt. Es wäre daher wohl zu viel erwartet, wenn sein Einsatz gänzlich problemlos wäre.

5.1 Brandrisiko bei Lagerung

Um eine Mengendifferenz zwischen Anlieferung (INPUT) und Abnahme (OUTPUT) auszugleichen, ist eine Zwischenlagerung bzw. Lagerung von EBS oder seinen Zwischenprodukten erforderlich. Dazu werden meist folgende Lager betrieben:

- Ballenlager für heizwertreiche Leichtfraktion,
- Folierte Rundballen - Lager für EBS (Wirbelschicht),
- Schüttgutlager für EBS (Wirbelschicht),
- Produktlager (bzw. Silo) für EBS (Zementindustrie).

Als sinnvolle Lagerkapazität für ein Entsorgungsunternehmen ist aufgrund von Erfahrungswerten ein Jahreszwölftel des Inputs anzusetzen. Probleme bereiten dabei Geruchsemissionen und das Selbstentzündungsrisiko (die Zündtemperatur des ASB - Ersatzbrennstoffes z.B. liegt zwischen 319°C und 460°C, Pomberger (2005)). Gelagertes EBS - Material hat ein erhöhtes Selbstentzündungspotential. Während der Lagerung kommt es zu einer deutlichen Erwärmung des Materials, hervorgerufen durch mikrobiologischen Abbauvorgänge von organischen Anhaftungen und chemische Oxidationsreaktionen des Kunststoffes. Dieses Selbstentzündungspotential hängt sowohl von den Materialeigenschaften (z.B. Reaktivität, Oberflächenbeschaffenheit, Feuchtegehalt und Wärmekapazität) aber auch von der Art und der Geometrie des Lagers ab, welche Wärmeabfuhr und Sauerstofftransport beeinflussen. Durchgeführte Modellierungen, die durch Vor - Ort - Messungen verifiziert wurden (Raupenstrauch & Walkner, (2004)) zeigten, dass die höchsten Temperaturen (T > 80°C) im Bereich von Böschungen auftreten, siehe Abb. 8.

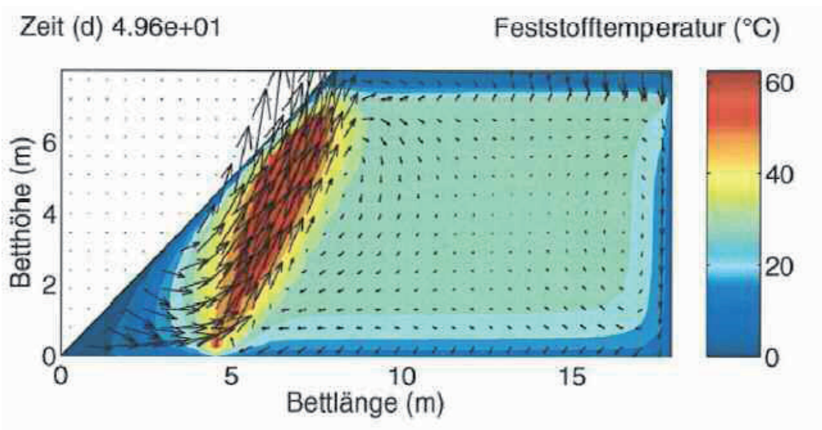


Abbildung 4 Temperaturverteilung im Querschnitt des ASB Produktlagers (Simulation) nach Raupenstrauch & Walkner (2004)

Hohe Verdichtung und breite Korngrößenverteilung des Lagergutes bewirken eine schlechte Permeabilität und wirken damit der Selbsterwärmung durch mikrobiologischen Abbau und chemischer Oxidation entgegen. Durch brandschutztechnische und bauliche Maßnahmen sowie Brandmeldeanlagen lässt sich das Risiko von Bränden bei Herstellung und Lagerung von EBS in den Griff bekommen (Pomberger (2005)). In letzter Zeit wird auch der sog. Real Dynamic Respiration Index (RDRI) zur Bestimmung des Selbsterhitzungsverhaltens von Ersatzbrennstoffen herangezogen (CEN/TC 343 / WG3 N320 (2010)).

5.2 Anlagenkorrosion bei EBS - Einsatz

Abfall ist durch relativ hohe Chlor - (Cl) und relativ niedrige Schwefel - (S) Gehalte gekennzeichnet, wodurch die Verbrennung von Abfall (und aus Abfall hergestellten Produkten) generell mit einem höheren Korrosionsrisiko für die Verbrennungsanlagen verbunden ist. Um eine möglichst gute Energieeffizienz zu erreichen, ist es zudem das Bestreben des Anlagenbetreibers, die Anlage mit möglichst hohen Dampfparametern (z.B. bei MVA sind 400°C und 40 bar üblich) zu betreiben, wodurch das Korrosionsrisiko weiter steigt. Der Chlor - Gehalt im Brennstoff spielt dabei nicht nur bei der Korrosion in Kesselanlagen eine notorisch üble Rolle, sondern trägt auch durch Bildung von flüchtigen Metallchloriden zur Schwermetallanreicherung im Abgas von Verbrennungsanlagen bei. Ein guter Teil des im Brennstoff unerwünschten inneren Chlor wird durch PVC (Polyvinylchlorid) in der Plastikfraktion, die höhere Heizwerte hat, eingetragen. Auch im Zementprozess sind höhere Chlorgehalte (> 1,0M%) ein verfahrenstechnisches Problem, da es durch Verflüchtigung von Chloriden in den heißen Zonen und Kondensation in den kälteren Zonen zu unerwünschten Chlor - Kreisläufen kommt, die zu Verklebungen und Anbackungen führen können. Diesem Problem ist durch die strikte Begrenzung des Chlorgehaltes im Ersatzbrennstoff (d.h. ein Durchschnittswert von 0,8M% Cl ist einhaltbar) und durch Chlorbypassanlagen in Zementwerken beizukommen. In letzter Zeit werden Versuche durchgeführt, PVC mittels Nahinfrarotsensoren (NIR - Technologie) im EBS - Produktionsstrom bei der Sortierung zu erkennen und aus dem Produktionsprozess durch die am Band installierten Druckluftdüsen auszuschließen, um damit eine weitere Cl - Entfrachtung von EBS zu erreichen (Kreindl (2010)). Abschließende Ergebnisse sind noch nicht bekannt.

6 Fallbeispiele und Ergebnisse

6.1 Hochkalorischer Ersatzbrennstoff ASB

Als ein Beispiel für die Herstellung von Ersatzbrennstoffen wird hier kurz über die Produktion von ASB, einem qualitätsgesicherten, blasfähigen, hochkalorischen, ofenfertigen EBS zum Einsatz in der Primärfeuerung von Zementwerken berichtet (Pomberger (2005, 2008)).

Einsatzmaterial für die ASB - Anlage ist die Leichtfraktion, die durch mechanische Vorbehandlung aus gemischten Gewerbemüll und Siedlungsabfall durch Windsichtung gewonnen wird. Dabei fällt bei dieser Vorbehandlung (MA - Splittinganlage) auch niedrig bis mittelkalorischer EBS für die Wirbelschicht - Verbrennung an. Daneben können auch sortenreine Produktionsabfälle direkt eingesetzt werden. Nach der Vorzerkleinerung wurde der Massenstrom in einem Windsichter in eine Leichtfraktion mit hohem Anteil an 2 - dimensionalen Körnern („2D Fraktion") und in eine Schwerfraktion mit hohem Anteil an dickwandigen Materialien und Störstoffen („3D Fraktion") getrennt. Die Leichtfraktion umfasst ca. 90% des Volumsstroms und kann direkt der Nachzerkleinerung auf kleiner 30 mm zugeführt werden. Die 3D Fraktion (ca. 25M% aber nur ca. 10Vol%) lässt sich auf Grund des geringen Volumsstroms gut von den Störstoffen (Eisen, Nichteisen, Inertstoffe) trennen. Die Abtrennung der metallischen Störstoffe erfolgt durch 2 Magnetabscheider (Überband, Trommel) sowie einen Wirbelstromscheider. Die Nachzerkleinerung in der 3D Linie erfolgt auf kleiner 10 mm. Die getrennte Behandlung der 2D und 3D Fraktion ist deswegen erforderlich, da diese beiden Kornformen unterschiedliches Verbrennungsverhalten zeigen und ihr Anteil in den Spezifikationen genau festgelegt ist. Die Schüttdichte von ASB (lose verladen im walking floor LKW) erreicht 200 - 250 kg/m^3.

1.1 Mittelkalorischer Ersatzbrennstoff für HOTDISC - Verfahren

Bei der Produktion von EBS aus gemischten Siedlungsabfällen und Gewerbemüll fallen vor allem mittelkalorische Ersatzbrennstoffe mit gröberer Körnung an. Sie werden vorwiegend in Wirbelschichtanlagen eingesetzt und sind für Zementdrehrohröfen in der Primärfeuerung ungeeignet und mit Korngrößen bis 100 mm und Heizwerten zwischen 10 - 15 MJ/kg auch am Calzinator (Sekundärfeuerung) nicht einsetzbar. Durch das neuentwickelte HOTDISC - Verfahren, dass großtechnisch erstmals im Zementwerk Rohožnik (Slowakei) bei der Holcim Ltd. umgesetzt wurde, ist es nun möglich, mittelkalorischen EBS gröberer Korngröße in der Klinkerproduktion einzusetzen (Pomberger (2008), Pomberger & Abl (2008)). Die HOTDISC ist eine Vorbrennkammer im Bereich des Zyklon-Wärmetauschers eines Zementdrehrohrofens. Der Ausbrand des über ein Klappensystem eingebrachten EBS erfolgt auf einem feuerfest ausgemauerten Drehteller, der von einem Teilstrom der Ofenabgase durchströmt wird, wobei das Brennkammerabgas der Vorwärmung und Vorcalzinierung des Rohmehls dient, siehe Abb. 5.

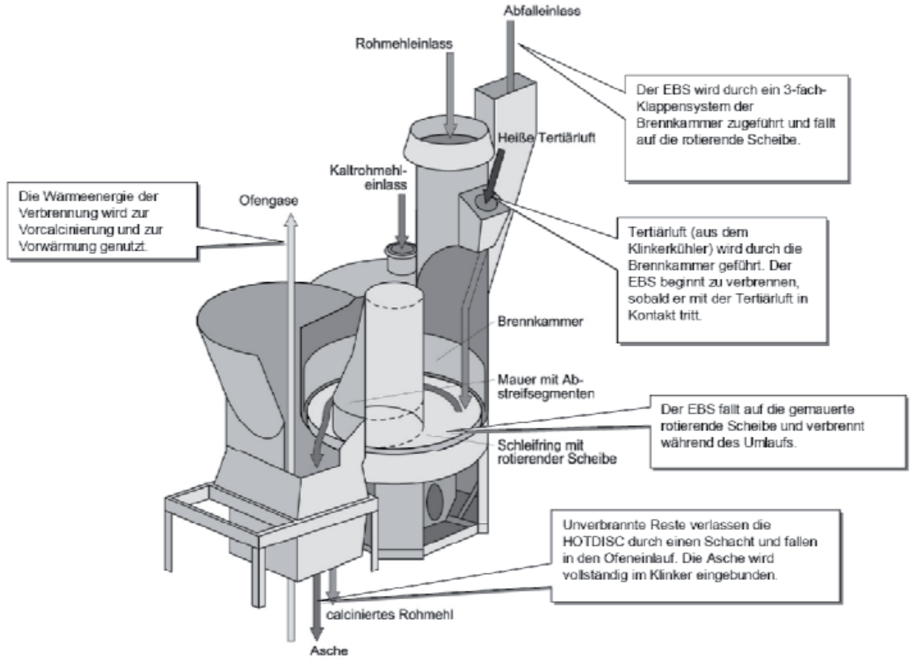


Abbildung 5 Funktionsprinzip des HOTDISC - Verfahrens (Pomberger (2008))

Für das neue HOTDISC - Verfahren musste nun auch ein geeigneter Ersatzbrennstoff gefunden und bereitgestellt werden. Dazu wurde die von der Saubermacher Dienstleistungs AG in Wien betriebene Splittinganlage (MA) für gemischte Siedlungsabfälle und Gewerbemüll, die EBS für Wirbelschicht und die hochkalorische Leichtfraktion zur Produktion von ASB bei ThermoTeam hergestellt, modifiziert und umgebaut. Dies wurde im Rahmen eines wissenschaftlichen Forschungsprojektes (Pomberger (2008)) durchgeführt, wobei ausgehend von einer repräsentativen Sortieranalyse von Abfallfraktionen die Transferkoeffizienten der Inhaltsstoffe bestimmt wurden und durch eine nachfolgende Stoffflussanalyse die Auswirkungen der Prozessänderung (bzw. des Anlagenumbaus) auf Qualität und Massenströme der neuen Anlage simuliert und prognostiziert wurden (Pomberger (2008), ÖWAV (2003)). Dadurch war es möglich, eine Optimierung der Anlage in Bezug auf Störstoff- und Schadstoff- (insbesondere Chlor und Schwermetalle) -entfrachtung für vorgegebene Heizwerte (Hu) und Ausbringungsmengen zu erreichen.

Wesentliche Anlagenänderungen wurden durchgeführt, indem der Stoffstrom über einen weiteren Magnetabscheider, einen Wirbelstromabscheider für NE - Metalle und über einen speziellen Windsichter zur Störstoffabscheidung geführt wird. Durch besondere Luftführung und Bürsten können dabei gezielt schwere 3D - Körner abgetrennt werden. Der dadurch gewonnene HOTDISC - EBS hat u. a. folgende Qualität:

Korngröße [d_{90}]: ≤120 mm

Heizwert (H_u): 14 - 16 MJ/kg

Chlorgehalt:	0,6 - 0,8M%
Biogener Kohlenstoff (C_{biogen})	50,6 - 51,9M%
Aschegehalt:	19,9 - 30M%
Wassergehalt:	15%

2. SCHLUSSFOLGERUNGEN

Wie vorausgehend dargestellt worden ist, gehen Erzeugung und Einsatz von Ersatzbrennstoffen (EBS) in Österreich auf das in der Deponieverordnung 2004 verankerte Verbot der Ablagerung von Restmüll ohne Vorbehandlung zurück. Da die Kapazität an (Rest) - Abfallverbrennungsanlagen auch z.Z. noch nicht ganz ausreichend ist, muss ein Teil des stofflich nicht verwertbaren Abfalls in MBA mechanisch - biologisch für die nachfolgende Deponierung vorbehandelt werden, wobei zwangsweise eine höher - kalorische Leichtfraktion als „Siebüberlauf" anfällt, die als Sekundärabfall zur EBS - Produktion eingesetzt wird. Die EBS - Produktion umfasst allgemein die Schritte: Vorzerkleinerung, Störstoffabscheidung, Nachzerkleinerung und Konfektionierung, wobei je nach Bedarf des Abnehmers bzw. je nach Anforderungen der Mitverbrennungsanlagen – abgesehen von den gesetzlichen Regelungen zur Schadstoffbegrenzung – bestimmte Spezifikationen eingehalten werden müssen. So umfasst z.B. der Heizwert unterschiedlicher EBS - Sorten eine Bandbreite von 11 MJ/kg bis 25 MJ/kg. Eine wesentliche Grundvoraussetzung für den Einsatz von EBS in Mitverbrennungsanlagen ist eine sehr rigorose Qualitätssicherung, die nur durch ein relativ aufwendiges Probenahme- und Analyseprogramm zu erzielen ist. In Österreich werden hauptsächlich Ersatzbrennstoffe für Wirbelschichtanlagen und für Zementwerke (Primär- & Sekundärfeuerung) erzeugt. Der Einsatz von EBS in Kraftwerken (z.B. Kraftwerk Dürnrohr) ist dazu in Vergleich zu Deutschland eher gering, da beim Einsatz von EBS gesetzliche Probleme bei der Verwertung/Entsorgung von anfallenden Kraftwerksschlacken & -Aschen bestehen (Baumgartner (2004)). Wie die dargestellten Beispiele, d. h. Aufbereitung von gemischten Siedlungsabfällen und Gewerbemüll zu Wirbelschicht EBS, hochkalorischen ASB und mittelkalorischen HOTDISC - EBS zeigen, können durch Anlagenmodifikationen ganz gezielt bestimmte Qualitäten von Ersatzbrennstoffen hergestellt werden. Dabei ist die Stoffflussanalyse eine unschätzbare Hilfe, da sich mit ihr aus den abfall- und anlagenspezifischen Transferfaktoren (die aus der Sortieranalyse bestimmt werden) die Qualitäten der Stoffströme in der Anlage simulieren und prognostizieren lassen. Damit hat man dann die Basisdaten in der Hand, um eine bestehende Anlage in Hinblick auf die Produktpalette der gewünschten EBS - Ausbringung auslegen, modifizieren und umbauen zu können.

7 Literatur

Baumgartner, A.	2004	Stoffliche Verwertung von Reststoffen aus der Mitverbrennung von Alternativbrennstoffen in Kraftwerken. Dissertationsarbeit (PhD-Thesis) am IAE-Institut der Montanuniversität Leoben.
Beckmann, M.	2008	Zusammenhang zwischen Biogenem Anteil von EBS und seinem Heizwert. Persönliche Mitteilung, TU Dresden.
BMFLUW	2004	BGBl. II Nr. 389/2002 zuletzt geändert durch BGBl. II Nr. 296/2007: Verordnung des Bundesministers für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft und des Bundesministers für Wirtschaft und Arbeit über die Verbrennung von Abfällen (Abfallverbrennungsverordnung - AVV).
BMFLUW	2004	BGBl. II Nr. 39/2008: Verordnung des Bundesministers für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft über Deponien (Deponieverordnung 2008).
Bundesminister für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (BMLFUW) und Bundesminister für Wirtschaft, Familie und Jugend	2009	Verordnung mit der die Abfallverbrennungsverordnung geändert wird (AVV-Novelle 2009).
Bundesministerium der Justiz	2007	KrW-/AbfG - Kreislaufwirtschafts- und Abfallgesetz.
Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (BMLFUW)	2006	Bundesabfallwirtschaftsplan 2006; Die Bestandsaufnahme der Abfallwirtschaft in Österreich (Statusbericht 2009).
Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (BMLFUW)	2008	Richtlinie für Ersatzbrennstoffe. März 2008
European Committee for Standardization (CEN/TC 343 / WG3)	2010	pr EN 15590 "Solid recovered fuels - Determination of potential rate of microbial self heating using the real dynamic respiration index, 2010
Kreindl, G.	2010	Herausforderungen der NIR - Sortierung von gemischten Abfällen aus Industrie und Gewerbe. In: K. E. Lorber et al. (Hrsg.): DepoTech 2010 Tagungsband, S. 249-256., ISBN: 978-3-200-02018-4.
Kunter, A & Wellacher, M.	2010	Neue Entwicklungen bei der Ersatzbrennstoffaufbereitung. In: K. E. Lorber et al. (Hrsg.): DepoTech 2010 Tagungsband, S. 653-656., ISBN: 978-3-200-02018-4.
Lorber, K.E., Kneissl, P.J. & Staber, W.	2008	Bestimmung des biogenen/fossilen Brennstoffanteils durch ^{14}C im Rauchgas. In: K. E. Lorber et al. (Hrsg.): DepoTech 2008 Tagungsband, S. 251-256., ISBN: 978-3-86797-028-0.

Lorber, K. E., Staber, W. & Kneissl, P.	2008	Neue Abfallverbrennungsanlagen in Österreich. In: K. J. Thomé – Kozmiensky & Beckmann, M. (Hrsg.): Energie aus Abfall Tagungsband 4, 2008, S. 553-570., ISBN: 978-3-935317-32-0.
ÖNORM CEN/TS 15442	2007	Feste Sekundärbrennstoffe - Verfahren zur Probenahme, 2007/01/01.
ÖWAV	2003	Regelblatt 514 - Die Anwendung der Stoffflussanalyse in der Abfallwirtschaft Wien. Österreichischer Wasser- und Abfallwirtschaftsverband.
Pomberger, R.	2007	Ersatzbrennstoffe aus Siedlungsabfällen - Anforderungen, Möglichkeiten, Betriebserfahrungen. Vortragsmanuskript zur ÖWAV / UBA - Tagung in Wien, 2007.
Pomberger, R.	2008	Entwicklung von Ersatzbrennstoff für das HOTDISC - Verfahren und Analyse der abfallwirtschaftlichen Relevanz. Dissertationsarbeit (PhD-Thesis) am IAE-Institut der Montanuniversität Leoben.
Pomberger, R. & Abl, C.	2008	Mittelkalorischer Ersatzbrennstoff für das HOTDISC - Verfahren. In K. E. Lorber et al. (Hrsg.): DepoTech 2008 Tagungsband, S. 275-280., ISBN: 978-3-86797-028-0.
Raupenstrauch, H. & Walkner, R.	2004	Untersuchung des Selbsterwärmungsverhaltens eines Lagers für aufbereiteten Substitut Brennstoff (ASB). Untersuchungsbericht des Instituts für Apparatebau, Mechanische Verfahrenstechnik und Feuerungstechnik, TU Graz.
Romano, S.	2010	Municipal Solid Waste Management Policies and Problems in Naples. In: K. E. Lorber et al. (Hrsg.): DepoTech 2010 Tagungsband, S. 135-140., ISBN: 978-3-200-02018-4.
Schelch, M.	2007	Qualitätssicherung bei der thermischen Verwertung von Ersatzbrennstoffen. Dissertationsarbeit (PhD-Thesis) am IAE-Institut der Montanuniversität Leoben.

Anschrift der Verfasser(innen):

O.Univ.Prof.Dipl.-Ing.Dr.techn. Karl E. Lorber. Dipl.-Ing. Renato Sarc

Institut für Nachhaltige Abfallwirtschaft und Entsorgungstechnik, MUL
Franz-Josef-Straße 18
A-8700 Leoben

Telefon: +43 3842 402 5101 +43 3842 402 5105
Email: iae@unileoben.ac.at renato.sarc@unileoben.ac.at
Website: http://iae.unileoben.ac.at

Dipl.-Ing. Dr. Roland Pomberger
Saubermacher Dienstleistungs AG
Hans-Roth-Straße 1
A-8073 Feldkirchen bei Graz
Email: R.Pomberger@saubermacher.at
Website: http://saubermacher.at

Decoding interdependencies between primary and secondary raw material markets by means of the Capacity Model

Hannes Klampfl-Pernold, Roland Pomberger, Gerald Schmidt

Saubermacher Dienstleistungs AG, Feldkirchen bei Graz

Abstract

On the basis of the well-known life-cycle-concept the Capacity Model presents an explanation approach for the interdependencies between primary and secondary raw material markets alongside the life-cycle of different waste materials. Depending on site capacity and waste amount the price for a certain waste material is either determined by the disposal market or the energy and raw material market. Consequently the price is either based on the disposal and/or treatment costs or on the price of the substituted primary raw material price. In matters of interdependencies to markets that underlie substantial variations, interlinking waste industry into the raw material industry makes it vulnerable to prevalent changes that have their origin within the latter. The necessity arises for an adequate description and explanatory model like the Capacity Model. Following an abductive approach the model offers the basis for discovering hypotheses in regard of the interdependencies between the primary and secondary raw material markets. Considering the position of different secondary raw materials within the Capacity Model there are different strategic implications for regulating the product and service programme on an individual firm’s level. Companies within the waste management industry are able to seize their chances for enlargement of their business segment as well as for the possibility to prolong their own value chain in a more efficient way.

Keywords

Raw material market; waste market; waste; resources; interdependencies between markets.

1 Introduction

Secondary raw materials obtain their economic relevance by substituting primary resources and thus cutting costs. Regarding the latter not only the European economies and industries are especially interested in. This yields to a demand for comparatively inexpensive raw materials. It is the waste industry that needs to deliver such raw materials from wastes in different quantities and qualities. To be able to do this waste management companies need an appropriate model that depicts the development of individual secondary raw materials from waste and allows statements concerning their future development from the waste to the resource market. Such a basis enables companies to assess and plan the required capacities to produce the secondary raw materials in need.

Following an abductive approach the Capacity Model establishes the basis for the discovery of hypotheses with regard to the correlations and interdependencies between the primary and secondary raw material markets. Insights from fundamental and within the scientific community widely approved models like S-Curve- and Life-Cycle-Models are picked up and transferred to the object of study. According to the position of individual secondary raw materials along the S-Curve of the Capacity Model different strategic implications and considerations arise concerning the regulation of a company's product and service programme. Therefore the model provides an understanding of the whole life cycle of individual secondary raw materials and substitute fuels produced from waste materials. Such an appreciation is of central importance to the responsible company units that have to be able to manage the products development from waste to resource.

2 Waste vs. Resource

Waste and waste management within a society is perceived as a problem with varying intensity over time. The waste problem itself can be seen as an elementary deficit of industrialized societies, having its origin in an imbalance between supply and disposal infrastructure (SACHVERSTÄNDIGENRAT 1991). Thompson defined waste from a philosophical viewpoint as „substance in the wrong place" (THOMPSON 1989). Therefore it is a purely subjective relationship of every living being towards a particular matter. When we think of these matters as products from different metabolic processes, waste describes that part of the output of a certain metabolic process that is subjectively undesired. Moreover not only can this output change its position within the value system over time but it can even be seen as waste from one subject whereas at the same time for another subject it is a valuable raw material (LIESEGANG, STERR 2003).

While in nature waste exists only within a limited period of time because nature operates in complete cycles, it is the human's intervention in natural cycles that leads to an imbalance (PRISCHING 2010). Following this argument it can be stated that matter represents waste only within a certain space and time and only for the part that is not demanded by the economic agents sufficiently according to its production rate. It is therefore a capacity problem within which the matter loses its waste characteristic as soon as it is demanded as an input from an economic agent. In such a way the negative waste price is transferred into a positive raw material or energy price. In this reasoning waste is the matter's demand deficit that is accumulated in the form of anthropogenic stocks. Especially in advance there cannot be assigned a positive or negative value to a certain matter. It is rather a result from a subjective value system that underlies the evaluation (GELBMANN 2001).

For coping with matter defined as waste within a market it is essential that at least one economic agent recognizes its value. In this sense the waste gets a positive value and a corresponding demand is induced. In redefining waste into resource, which is again inserted into the material flow of the economic system in other areas and thus saving primary resources as well as energy it cannot be seen as worthless anymore (GELBMANN 2001). On the other hand from such a redefinition result various interdependencies with other industries and sectors.

Regarding the interdependencies to submarkets that underlie considerable changes, developing the sector from classical waste management to resource management and therefore taking part in the raw material sector makes it vulnerable for up- and downturns that have their origin within the latter. There is a strong need for an appropriate explanatory model like the Capacity Model, giving companies the opportunity to take advantage from their chances to expand their business field and their value chain at the best.

3 Theories and Methods

To achieve the objective of the underlying task we chose an abductive approach like it has been introduced by Charles Sander Peirce. In contrast to other commonly used syllogisms, like deduction and induction, abduction is the act of establishing an explanatory hypothesis. The difference lies not so much within the research method itself but in the character of reasoning (REICHERTZ 2003). Therefore we are applying a three-step process of cognition starting with the abduction, that is to say the finding of hypotheses. Within the second step predictions by means of deduction are constructed and derived from hypotheses. This leads to the third and last step where data research allows for inductive reasoning as to whether hypotheses get rejected or approved for now.

The Capacity Model is the basis for finding hypotheses regarding the interdependencies between primary and secondary raw material markets aggregating insights from S-Curve and Life-Cycle-Models within the area of research. As to the strong support to these models their relevancy is briefly discussed within the underlying context.

In course of a life cycle products, services as well as technologies are passing through different stages according to the particular level of acceptance and demand on the side of consumers (CORSTEN, 2000; MUSSNIG ET AL, 2007). In that sense Brockhoff understands a product's life cycle as the past ascertained and/or the expected trend of the product's sale during the whole period the product is on the market (BROCKHOFF, 1999). In regard to the different stages over a life cycle, the differentiated value to the market ideally takes the form of an S-shape and can be divided into the categories: introduction, growth, maturity and decline (BELL, 2005). This differentiation is based on four assumptions (GERPOTT, 2005; CORSTEN ET AL, 2006):

- Each product and service but even each technology carries a solution principle that approximates to its performance limit over time.
- Starting with little performance growth because of start-up problems on the side of the problem solution itself, the performance growth increasingly takes up pace after reaching a certain critical knowledge base.
- Approaching the performance boundary the rate of progress declines.
- At the same time there is an increasing chance for the appearance of new problem solutions (products, services and technologies) and existing ones get increasingly displaced.

Such a concept is of great use in the sense of a thinking model that enables an appreciation for the relevance of particular products, services and technologies across the different stages in association with markets and competition (SCHNEIDER, 2002). Still, there should be kept in mind that this is a description of an ideal sequence. Such basic models do not provide a content-related explanatory statement for the representation in form of an S-shaped curve nor do they implicitly allow for the future prediction. However such models are of great value in terms of awareness raising as to possible further development of technologies, the necessity for considering technology changes at an early stage as well as expectable performance improvements by research and development activities and the possibilities and constraints for reaching strategic competitive advantages through research and development within the company (GERPOTT, 2005).

4 Capacity Model

In support of the life-cycle-concept the Capacity Model establishes an explanatory approach for the interdependencies between primary and secondary raw material markets alongside the life cycle of different waste fractions (cf. Figure 1). Depending on plant capacity and waste amount the price for waste is either determined by the disposal market or the energy and raw material market. Consequently the price is geared towards the disposal and treatment costs or towards the substituted primary raw material's price.

In the introduction phase of the life cycle there are the barriers for market entry to overcome in the first place. In case of wastes and recovered raw materials and products technologies are playing an important role for the establishment of a business segment. Especially in the beginning of a market's life cycle the existence as well as the characteristics of the new products respectively secondary raw materials from waste are widely unknown (ERLEI, 1998). Markets have to be established which requires an intensive collaboration between secondary raw material producers and possible customers from industry and trade. Moreover the input of secondary raw materials regularly requires adequate market innovations that lead to changes of existing production systems on side of the industrial customers for being able to use such materials as an input (GELBMANN, 2001). For attaining the growth phase within the life cycle there is a need for restructuring the consumer behaviour in favour of new secondary raw materials (ERLEI, 1998). So far the focus lies within the disposal service. However in the growth phase recovery capacities are increasingly available and appropriate markets are established that compete with primary raw material markets. Experience and learning curve effects can be gained as to the increasing amounts of secondary raw materials produced from waste. The combination of increasing sales volume and declining investment needs improves the profitability regarding the production of secondary raw materials from waste (MUSSNIG ET AL, 2007). Following this argumentation the diffusion research constitutes an adequate explanatory framework in building the theoretical background for the dissemination of technologies within a social system in terms of a country or a region (HAUSCHILDT, 2004).

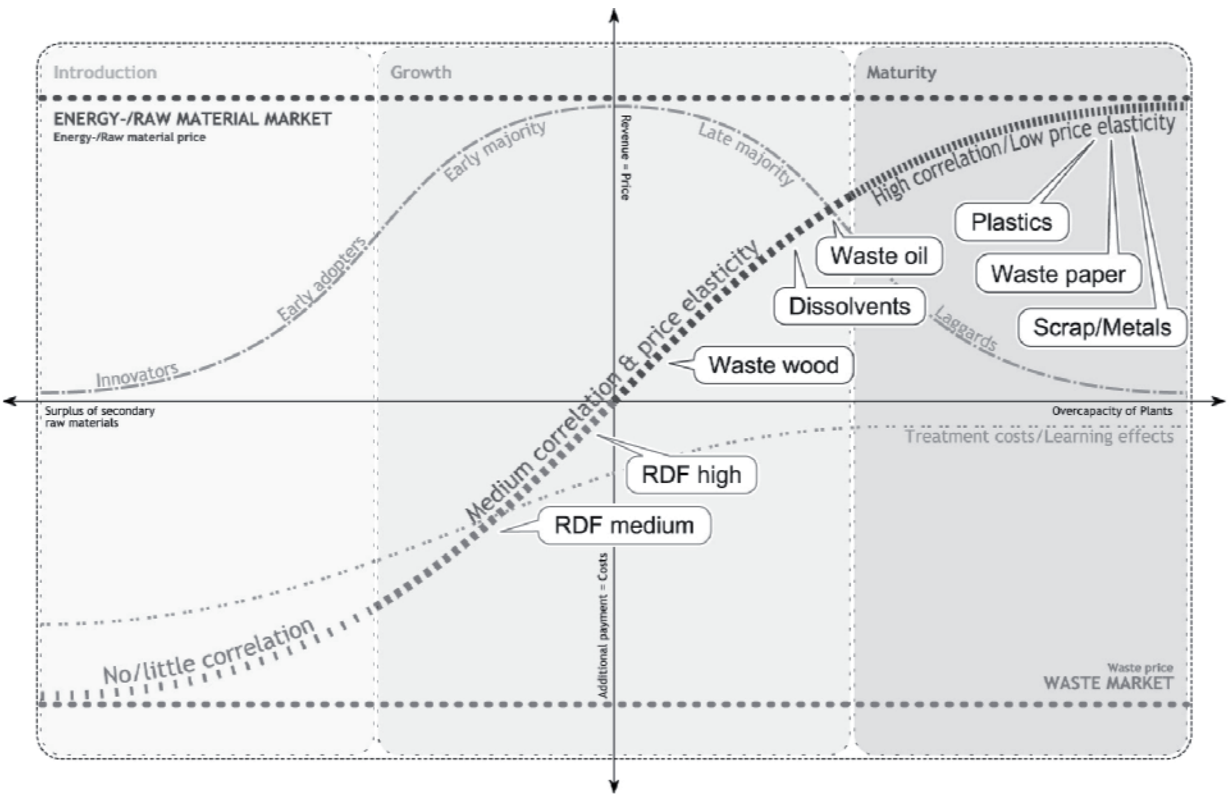


Figure 1: Capacity Model (Situation Austria 2007)

Entering the maturity phase it is reasonable to expand this phase as long as possible because of the increased profitability (MUSSNIG ET AL, 2007). The challenge lies in the upcoming of other substitutes, which is an ongoing threat even for already established secondary raw materials within the market. Generally emerging substitutes will be accepted under the following conditions: In addition to fulfil the same functions as the products already existing in the market, substitutes have to be superior in at least one component. Hence, they have to fulfil functions in a more efficient way, be easier available or just cheaper (GELBMANN, 2001). The last two arguments mentioned apply especially for the waste sectors secondary raw material products.

In course of the life cycle of products from waste with advancing marketability additional plant capacities as well as adequate recovery possibilities are available and the price approximates to the particular substituted raw material's price in the long run. The higher the development of different secondary raw materials from waste, the higher is the correlation to the primary raw material market. Therefore with increasing recovery capacities the price elasticity in reference to the substituted primary raw material decreases. Following this basic statement, several secondary raw materials from waste do have different maturity levels alongside their life cycle:

- Wastes, that are traded as secondary raw materials on an international level and that have a broad buyer's market show a high correlation to primary raw material markets. Such wastes are in particular metals/scrap metals, waste paper and plastics (for material recycling). Thus, they are mainly waste types that have been used as a substitute for primary resources for a long time.
- On the contrary hazardous wastes and relatively new products (e.g. refuse derived fuels = RDF) or wastes with trade restrictions (e.g. notification requirements) combined with rather underdeveloped markets (e.g. due to new technologies, regional significance, etc.) show merely an average correlation to primary raw material markets. Raw materials do have a positive influence on pricing but benefits are only passed to secondary raw material suppliers to some extent. Hence, there is still a potential for positive price developments and there is a certain tolerance for price fluctuations within the primary raw material markets.
- For wastes being treated within the disposal operations of a waste management system correlations to raw material markets are low or non-existent.

5 Decoding interdependencies by means of the Capacity Model

The Capacity Model is applicable to explain and depict price developments of secondary raw materials without making a statement about the development of primary raw material markets. With the economic crises even secondary raw materials have been effected to different extents. Secondary raw materials with a high correlation to the respective substituted primary raw materials alongside a corresponding low price elasticity have been effected particularly negative by the crisis development. In contrast secondary raw materials produced from waste with an average or even low correlation and respective sufficient price elasticity have been largely spared from these developments and were even able to make further positive progress (cf. Figure 2).

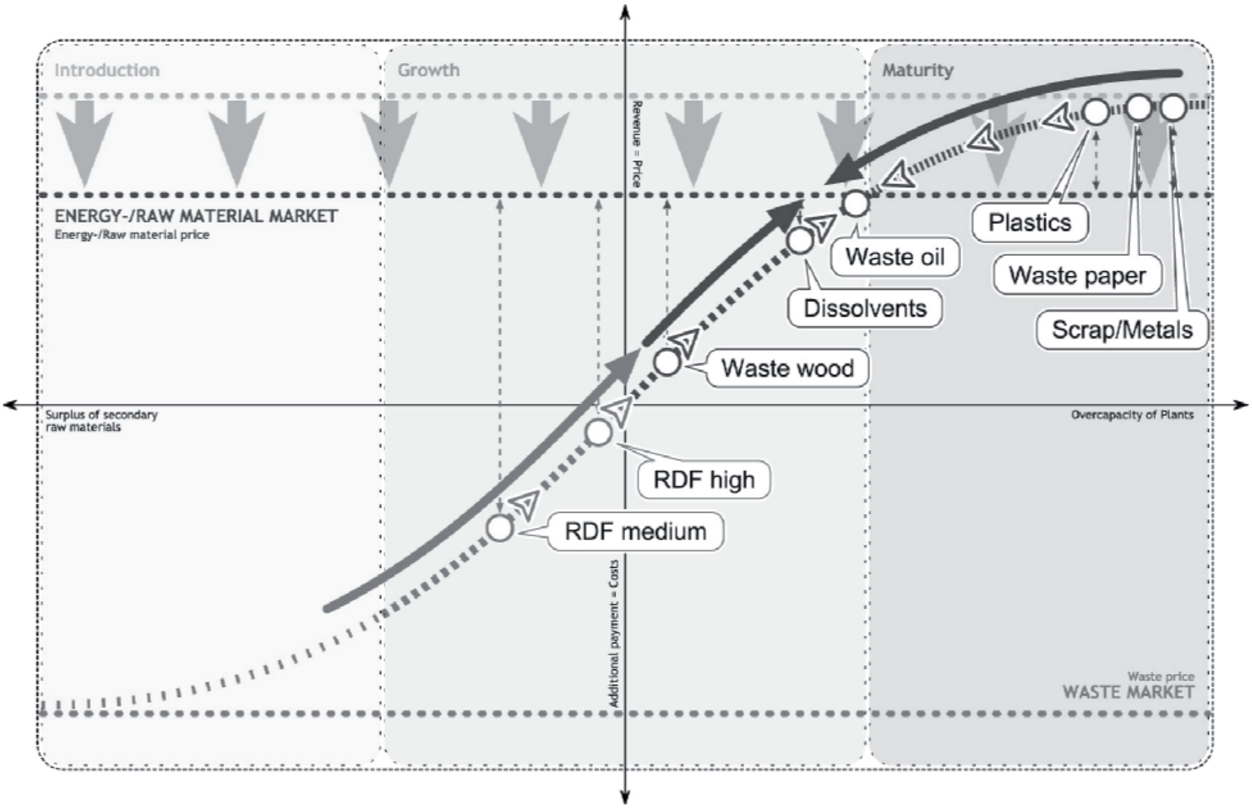


Figure 2: Capacity Model (Situation Austria 2008-2009)

The high correlation of scrap prices towards metal prices inevitably lead to an adjustment of the scrap price to the lower primary raw material price with a simultaneous capacity crunch. The same situation can be described within the area of plastics. According to the high correlation paired with a low price elasticity declining prices have been the result. The waste paper market represents a special case that can be as well illustrated by using the Capacity Model. In contrast to the other raw material markets the waste paper market did not break down because of the crisis developments within the primary raw material market but because of massive limitations of production within the paper industry. Therefore the plant capacity dropped at very short notice followed by considerable price reductions.

In the area of RDF (e.g. waste oil, dissolvents, high and medium caloric RDF) there has been the paradox case of further improved conditions despite strongly declining energy prices. Due to a medium correlation there has been sufficient price elasticity by which positive price developments could be gained. Although the substitution turned less attractive, secondary raw materials are applied as long as economic advantages towards primary raw materials exist.

6 Discussion

According to the above described developments the dependency on primary raw material markets is especially given in case of high developed countries concerning the waste management sector (Klampfl-Pernold, Gelbmann 2006). Waste management is increasingly becoming a sector that covers the rising demand for raw materials (Faulstich 2008). With these developments from waste to resource we are already part of the raw material sector in large areas and the question arises about what connections do exist between our "products" and those from other sectors. However, with increasing maturity of our secondary raw material products we are subject to positive and negative price fluctuations in the area of primary raw material markets. Waste management systems abroad continue to develop and internationally operating companies have to cope with an increasing dependency on primary raw material markets.

On the basis of the waste management's Phase Model (Klampfl-Pernold, Gelbmann 2006) we can therefore define a 6^{th} phase named "Raw material sourcing". Within such a phase waste management companies are more and more transformed into production and supply companies and a partner for the industry being able to control and manage quantities as well as qualities. In matters of interdependencies to markets that underlie substantial variations, interlinking waste industry into the raw material industry makes it vulnerable to prevalent changes that have their origin within the latter. The necessity arises for an adequate description and explanatory model like the Capacity Model. It offers an explanatory approach for the interdependencies between primary and secondary raw material markets alongside the life cycle of different wastes. With an advancing maturity of the respective product from waste additional plant capacities with appropriate recycling options evolve and the its price approximates inevitably to the raw material price of the substituted primary raw material in the long run. The more developed the product from waste the higher gets the correlation to the primary raw material markets and the price elasticity towards the substituted primary raw material decreases with rising plant and recycling capacity. In this course the model depicts the development of individual secondary raw materials from waste and allows for statements concerning their future development from the waste to the resource market. Especially companies in high developed countries in regard to waste management are already heavily affected by the primary raw material market in case of certain secondary raw materials. Nevertheless the Capacity Model shows that there is still room for positive improvements even in the case of negative price developments within the primary raw material market. Such a basis provided by the Capacity Model enables companies to assess and plan the required capacities to produce the secondary raw materials in need.

The model has gone through a first validation by means of price comparisons of different primary and secondary raw materials. The results achieved so far are very promising whereas further research will show to what degree the model allows for future-oriented statements.

7 Literature

Bell, P.	2005	Modeling the Diffusion of System-Effect Technologies. Deutscher Universitäts-Verlag, Wiesbaden, ISBN 3-8350-0348-8.
Brockhoff, K.	1999	Produktpolitik. UTB, Stuttgart, ISBN: 3-8252-1079-0.
Corsten, H.	2000	Produktionswirtschaft - Einführung in das industrielle Produktionsmanagement. Oldenbourg, München, ISBN: 3-4862-5076-0.
Corsten, H.; Gössinger, R.; Schneider, H.	2006	Grundlagen des Innovationsmanagements. Vahlen, München, ISBN: 3-8006-3327-2.
Erlei, M.	1998	Institutionen, Märkte und Marktphasen. Allgemeine Transaktionskostentheorie unter spezieller Berücksichtigung der Entwicklungsphasen von Märkten. Mohr Siebeck, Tübingen, ISBN: 3-1614-7034-6.
Faulstich, M.	2008	Abfallwirtschaft im Sinne des Wortes. In: *Müll und Abfall* 11/2008, S. 545.
Gelbmann, U.	2001	Externe Abfallbewältigung im Business-to-Business-Bereich - Entwicklung eines marketingorientierten Ansatzes und Instrumentariums. Deutscher Universitäts-Verlag, Wiesbaden, ISBN: 3-8244-0571-7.
Gerpott, T. J.	2005	Strategisches Technologie- und Innovationsmanagement - Eine konzentrierte Einführung. Schäffer-Poeschel, Stuttgart, ISBN: 3-7910-9245-6.
Hauschildt, J.	2004	Innovationsmanagement. Vahlen, München, ISBN: 3-8006-3075-3.
Klampfl-Pernold, H.; Gelbmann, U.	2006	Quantensprünge in der Abfallwirtschaft - Entwicklung eines innovationsorientierten Phasenmodells der europäischen Abfallwirtschaft. Shaker Verlag, Aachen, ISBN: 3-8322-5599-0.
Liesegang, D.;Sterr, T.	2003	Industrielle Stoffkreislaufwirtschaft im regionalen Kontext - Betriebswirtschaftlich-ökologische und

		geographische Betrachtungen in Theorie und Praxis. Springer-Verlag, Heidelberg, ISBN: 3-5404-3939-0.
Mussnig, W.; Mödritscher, G.; Oberchristl, W.	2007	Werkzeuge des Strategischen Managements. In: Mussnig, W. (Hrsg.) Strategien entwickeln und umsetzen. Linde Verlag, Wien, ISBN: 3-7143-0102-X. S. 456-568.
Prisching, M.	2010	Trash economy - Abfallmaximierung als Wirtschaftsprinzip. In: Wagner, A. (Hrsg.): Abfallmoderne - Zu den Schmutzrändern der Kultur. Lit Verlag, Wien, ISBN: 3-6435-0117-X. S. 29-43.
Reichertz, J.	2003	Die Abduktion in der qualitativen Sozialforschung. Leske + Budrich, Opladen, ISBN: 3-8100-3595-5.
Sachverständigenrat	1991	Abfallwirtschaft: Sondergutachten September 1990. Metzler-Poeschel, Stuttgart, ISBN: 3-8246-0073-0.
Schneider, D.J.G.	2002	Einführung in das Technologie-Marketing. Oldenbourg Wissenschaftsverlag, München, ISBN: 3-486-27247-0.
Thompson, M.	1989	Die Theorie des Abfalls - Über die Schaffung und Vernichtung von Werten. Verlagsgemeinschaft Klett-Cotta, Stuttgart, ISBN: 3-1293-7920-7.

Author’s addresses

Mag. Hannes Klampfl-Pernold, DI Dr. Roland Pomberger, Ing. Mag. Gerald Schmidt
Saubermacher Dienstleistungs AG
Hans-Roth-Straße 1
A-8073 Feldkirchen bei Graz
Telephone +43 (0)59 800-5006
Email h.klampfl@saubermacher.at
Website: www.saubermacher.at

KOMPOFERM® - Modular Waste Transforming Systems for MBT Technology: Case Study MBT Varna (BG)

Iris Steinberg

Eggersmann Anlagenbau GmbH & Co. KG, Bad Oeynhausen, Germany

Abstract

Bulgaria, like other new EU Member States, has a shortage of waste treatment capacity. This paper presents the MBT Varna, the first MBT meeting European standards in Bulgaria. The MBT consists of a mechanical and biological process and an aerobic tunnel rotting process. The mass balance for the plant is presented. A case study investigates the integration of a KOMPOFERM® dry digestion process with regard to its impacts on the mass and energy balances. The paper shows that a modular system provides access to modern waste treatment systems, with the flexibility to integrate further processes.

Keywords

Bulgaria, MSW, MBT, modular waste treatment systems, rotting, digestion, mass balance, energy balance

1 Introduction

1.1 The Company

Eggersmann Anlagenbau, a member of Eggersmann Group, successfully provides turnkey waste treatment plants, including engineering, manufacturing and construction aspects as well as the required infrastructure. The company Eggersman Kompotec combines experience gained from a range of different waste treatment plants, aiming to contiuously integrate this experience in the development of new plants. This provides sophisticated process design as well as operational safety in line with pratical needs. This concept focuses on a high level of modularity, providing all relevant interfaces.

1.2 Legal background and situation of waste treatment in Bulgaria

Bulgaria, as a member state of the EU, is obliged to reduce the amount of biodegradable municipal waste landfilled, according to the requirements of the COUNCIL DIRECTIVE 1999/31/EC on the landfill of waste (NN, 1999).

The following targets, according to Article 5, 1999/31/EC, have to be achieved:
Reduction of the total amount of biodegradable municipal waste going to landfill

- to 75 % of the total amount generated in 1995 by 2006 (2010)
- to 50 % of 1995 levels by 2009 (2013)
- to 35 % of 1995 levels by 2016 (2020)

Bulgaria belongs to the Member States who landfilled more than 80 % of their municipal waste in 1995 and therefore has been granted an extension of the time limits not exceeding four years (cf. figures in brackets).

The following figure shows the types of waste treatment practiced in the EU Member States. It can be clearly seen that Bulgaria disposes, or rather landfills, nearly the total amount of waste. Therefore Bulgaria needs facilities for the treatment of waste in order to meet the requirements of the Landfill Directive and to divert waste from landfills, especially the biodegradable waste fraction.

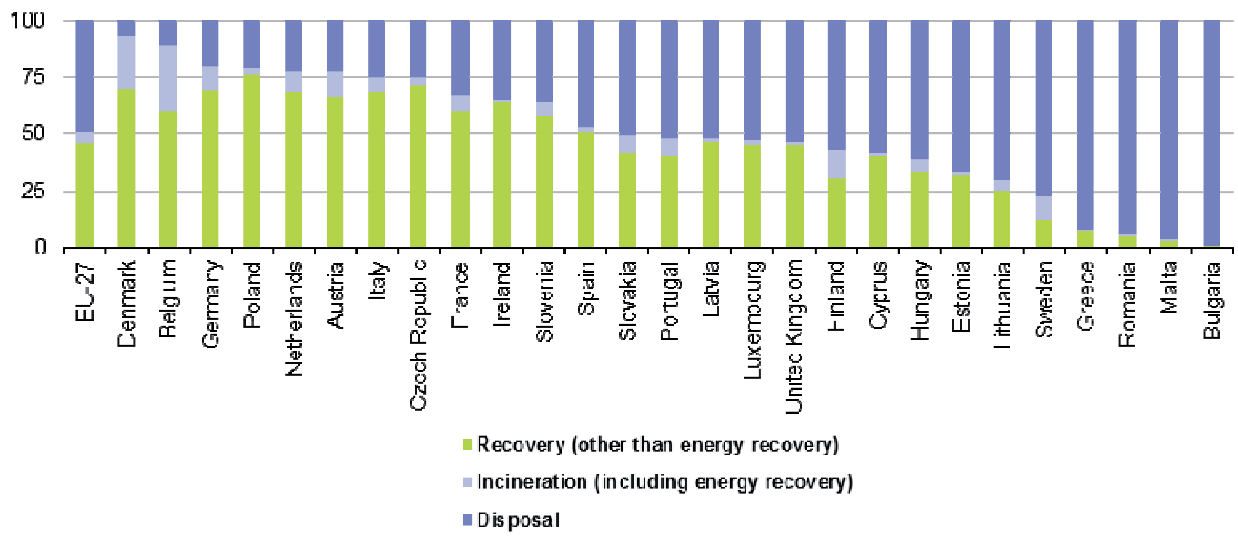


Figure 1 Types of waste treatment (2008), EUROSTAT

2 The MBT Varna

Eggersmann Anlagenbau is the contractor responsible for the delivery and assembly of the machinery and process equipment of the MBT Varna. The following figure presents the key facts of the plant.

Table 1 Key Facts and Design Parameters of the MBT Varna

Client	Ecoinvest Assets JSC
Contractor (Machinery and Process Equipment)	Eggersmann Anlagenbau
Technology	Mechanical-Biological Treatment (MBT)
Input (total)	140,000 to/a MSW
Throughput (total)	50 to/h
Input (Biological Treatment)	75,000 to/a organic fraction
Biological Treatment	10 Rotting Tunnels
Start of construction	January 2011
Start of operation	Summer 2011

The next figure presents the mass balance of the MBT Varna. During mechanical treatment the waste will be treated by means of shredding, separation and sorting. Recyclables like Fe- and Ne-Metals and plastic fractions like PET will be separated using a combination of automatic and manual processes. Nearly half the total waste input to the plant consists of organic matter, which will be separated and directed towards biological treatment process. Organic matter with a grain size of 0 – 60 mm will be biologically degraded in rotting tunnels by means of a fully-controlled aerobic process. The tunnels will be filled automatically using a tunnel loading device (TEG). Within the tunnels the intensive rotting process will be run under optimal conditions regarding temperature, water content and oxygen supply. After a process retention time of approximately 3 weeks, one third of the input material will be discharged from the intensive rotting process.

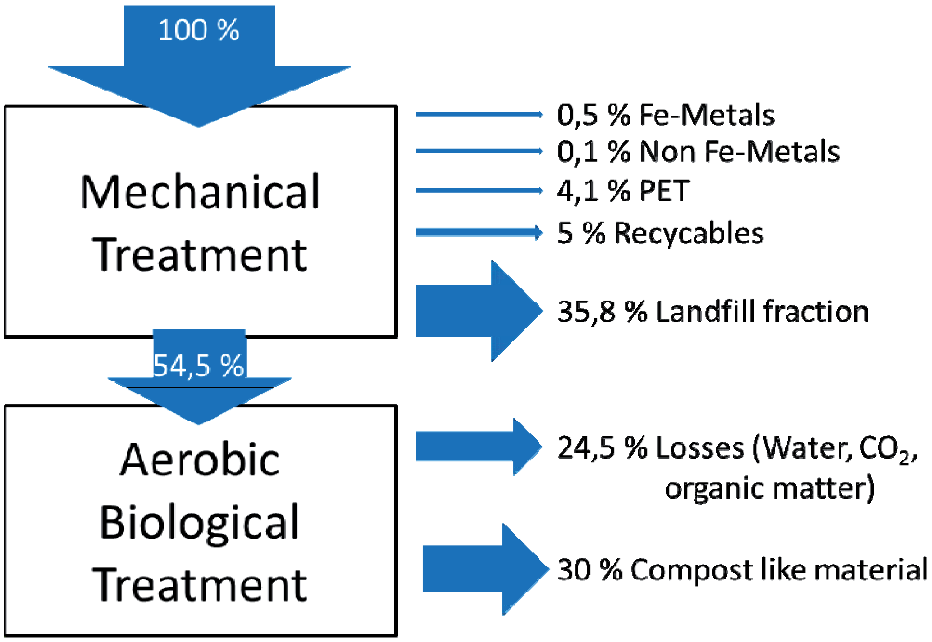


Figure 2 Mass Balance MBT Varna

The MBT Plant Varna is equipped with a sophisticated air management system, which allows the reduction in the amount of ambient air consumed, as well as a reduction in air emissions. To this end the air is re-circulated internally and re-used. The plant is a closed system and waste air is purified by means of biofilters before being emitted to the atmosphere.

3 Case Study: Integration of a KOMPOFERM® dry digestion process

The MBT Varna as-built provides interfaces to integrate further treatment processes. One option is the integration of an anaerobic process to directly recover the energy contained in the organic waste fraction. Generating energy from waste contributes to the reduction of fossil fuel consumption and therefore reduces greenhouse gas emissions. In this chapter, the impacts of the integration of a KOMPOFERM® dry digestion process on the mass and energy balance will be investigated. An appropriate and tested input fraction for the dry digestion process is the fraction 20 – 60 mm, which can be separated by means of an additional sieving process. The fraction 0 – 20 mm is bypassed to avoid blockages caused by inert fractions and due to the comparatively low gas formation rate. During the digestion process, organic matter is decomposed anaerobically and biogas, consisting mainly of methane and carbon dioxide, will be produced. This biogas can be used for the production of electrical and thermal energy in a combined heat and power plant directly on-site. After three weeks, the digestion process will be completed. The digestate will be mixed with the fine fraction 0 – 20 mm and further treated in the rotting tunnels. During rotting, the organic compounds, which are not suitable for biodegradation under anaerobic but under aerobic conditions, will be decomposed and the material further stabilised. In the following figure the adjusted mass balance for the MBT Varna with the integration of a KOMPOFERM® digestion process is shown.

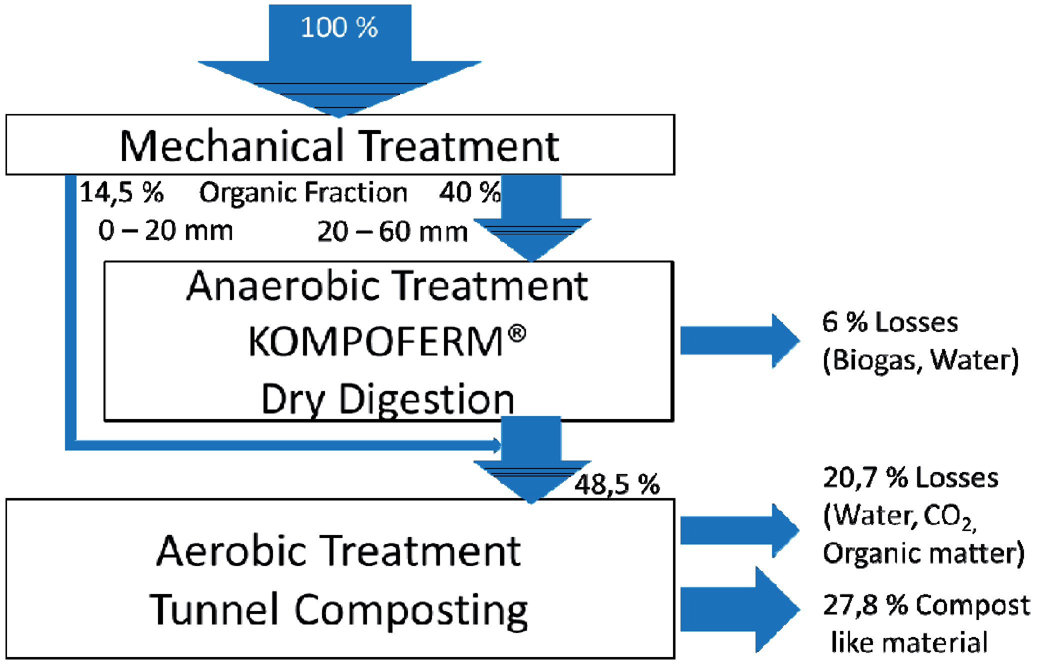


Figure 3 Case Study: Estimated Mass Balance MBT Varna after integration of a KOMPOFERM® digestion process

The main reason for the integration of a digestion process is the possibility to produce energy, especially electrical energy. In the next figure, the consumption and production of electrical energy are given for the MBT Varna. Approximately 30 % of the total required electrical energy will be needed for the operation of the mechanical treatment; the remaining 70 % will be used for the operation of the biological processes as well as the air treatment. In relation to the consumed electrical energy, the electrical energy[1] produced will be 1.75 higher. Therefore, it might possible to operate the plant self-sufficient and furthermore gain additional revenues if the surplus energy may be sold.

[1] Assumption: 95 Nm³ biogas / to of digestion input

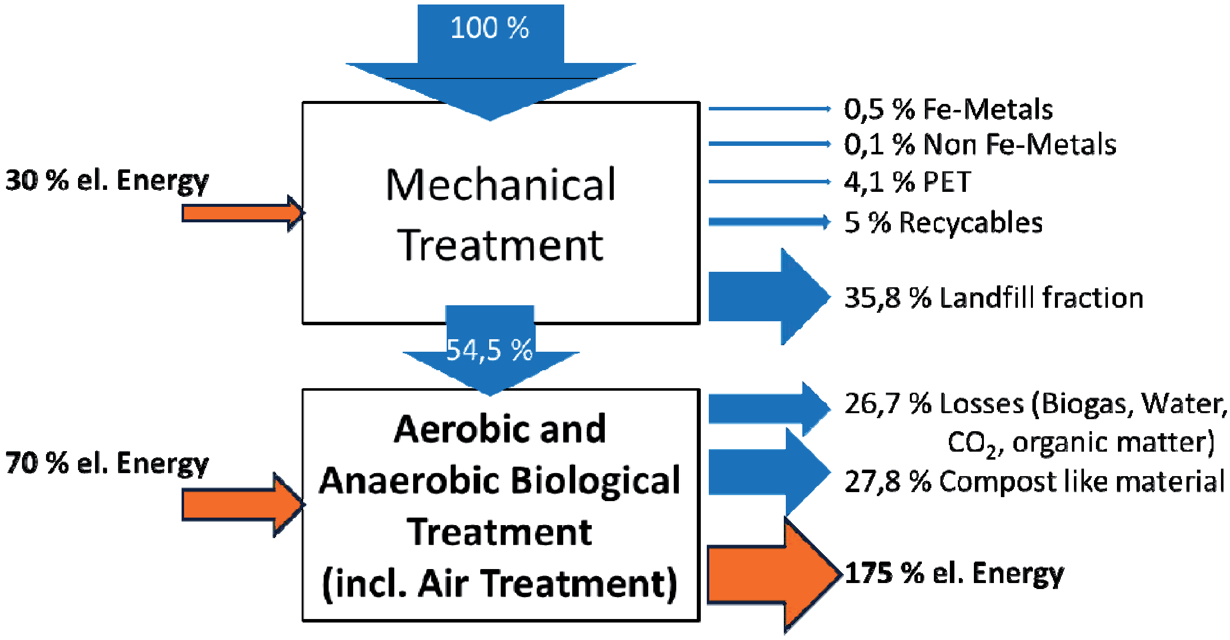


Figure 4 Case Study: Mass and Energy Balance MBT Varna with integration of a KOMPOFERM® digestion process

If the electrical energy consumption of the MBT Varna as-built is taken as base-line scenario (100 %), then the electrical energy demand of whole plant after integration of the digestion step may increase slightly up to 118 %, amounting to approx. one-fifth more. However, the amount of energy generated using the KOMPOFERM® process amounts to 205% of the base-line scenario, i.e. more than double the initial energy requirement is produced. This means that the process can run self-sufficiently from an energy point, and surplus electrical may be sold.

4 Summary

The MBT Varna contributes to the implementation of a waste management system meeting European Standards and Legislation. The plant can be characterised as having high adaptability and interfaces for the integration of further treatment processes. The case study of the integration of a KOMPOFERM® dry digestion process shows that further benefits from the treatment of waste can be generated: By means of the digestion, electrical energy will be produced which enables the self-sufficient operation of the plant as well as the option of selling the surplus energy.

5 Literature

NN	1999	COUNCIL DIRECTIVE 1999/31/EC on the landfill of waste; http://eur-lex.europa.eu/LexUriServ/ LexUriS-erv.do?uri=CELEX:31999L0031:EN:HTML
Eurostat	2008	Types of waste treatment http://epp.eurostat.ec.europa.eu/statistics_explained/ index.php/Waste_statistics#Treatment_of_municipal_waste

Author's address

Dr.-Ing. Iris Steinberg
Eggersmann Anlagenbau GmbH & Co. KG
Carl-Zeiss-Straße 8
32549 Bad Oeynhausen
Email: i.steinberg@f-e.de
Website: www.f-e.de

Emissions, leakages and measures for emission control in biogas plants and MBT

Carsten Cuhls

gewitra Ltd Hannover

Keywords:

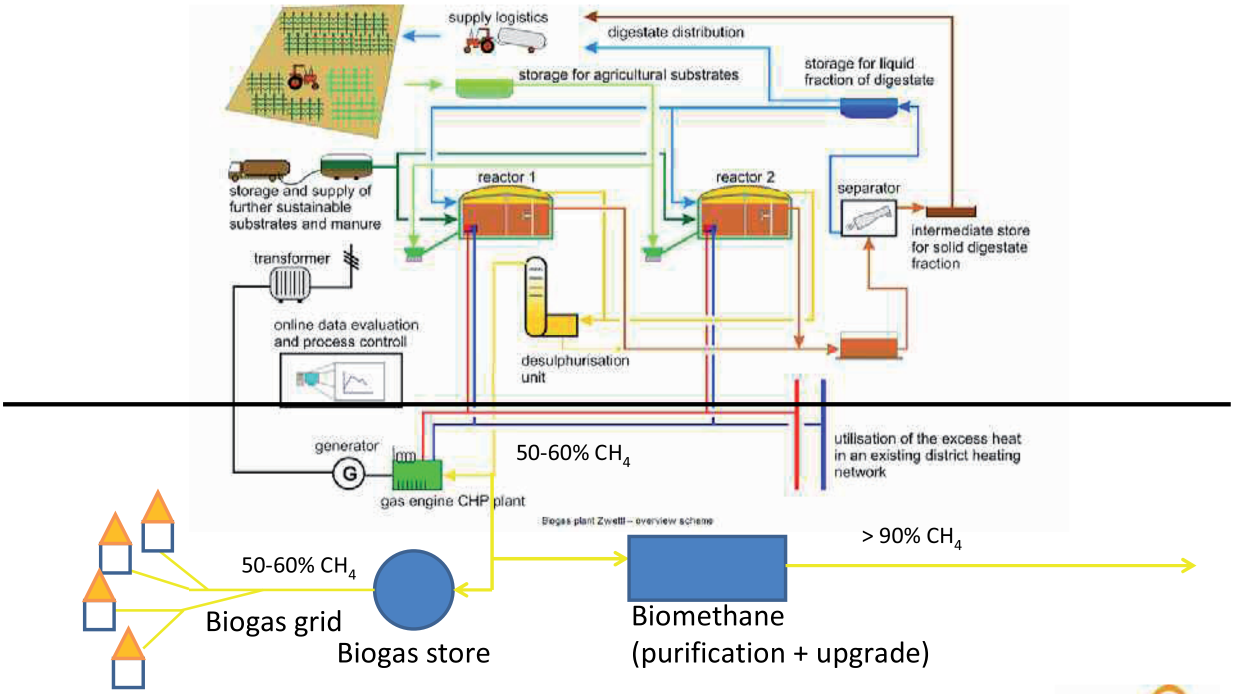
Biogas, Methane, GHG, Emission, Emission Control, Mitigation, Leakage, MBT, Biogas Plant, Anaerobic Digestion (AD), Combined Heat and Power Unit (CHPU), Biogas Purification, Pressure Swing Adsorption (PSA)

Why are Emissions interesting?

- ECOLOGY
  Methane is a greenhouse gas and ist 25 times more powerful as Compared to CO_2
  1kg CH_4 = 25 kg CO_2 1kg N_2O = 298 kg CO_2
- ECONOMY
  Methane emissions reduce the benefit of the biogas plant.
- SAFETY
  Methane emissions may generate an explosive atmosphere and may lead to explosion.

gewitra

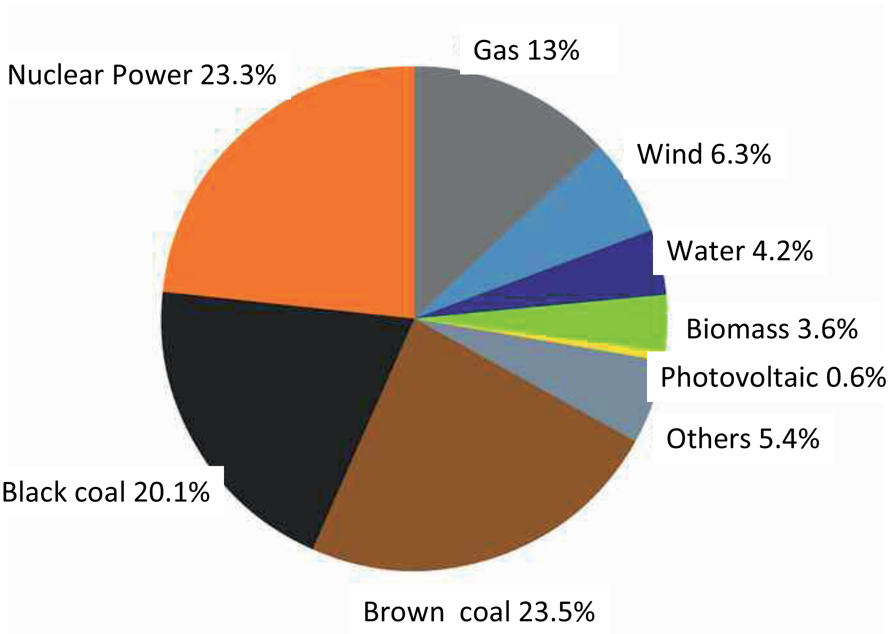
Scheme of a Biogas Plant



Modified: http://www.bios-bioenergy.at/

gewitra

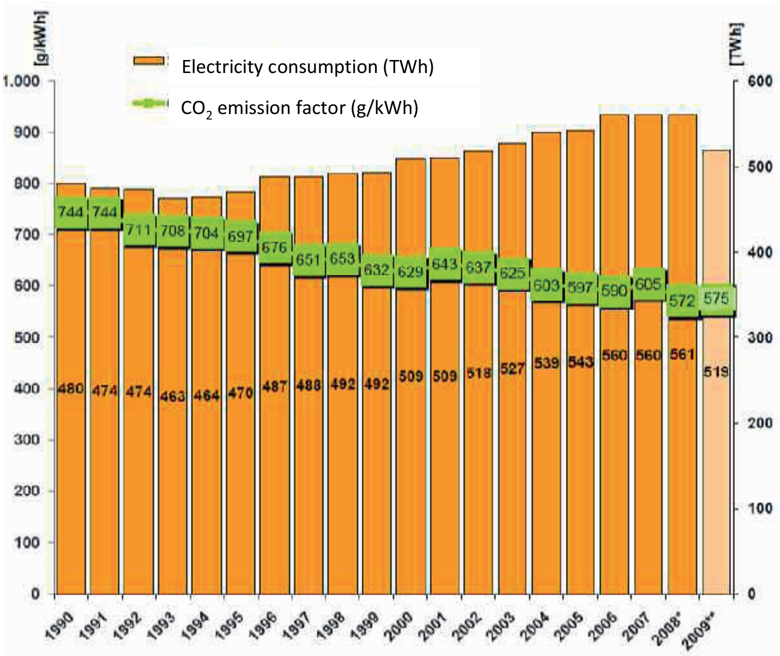
Electricity Mix in Germany 2008



http://de.wikipedia.org/wiki/Datei:Strommix-D-2008.png

gewitra

Germany: Electricity Consumption and related CO_2 Emissions

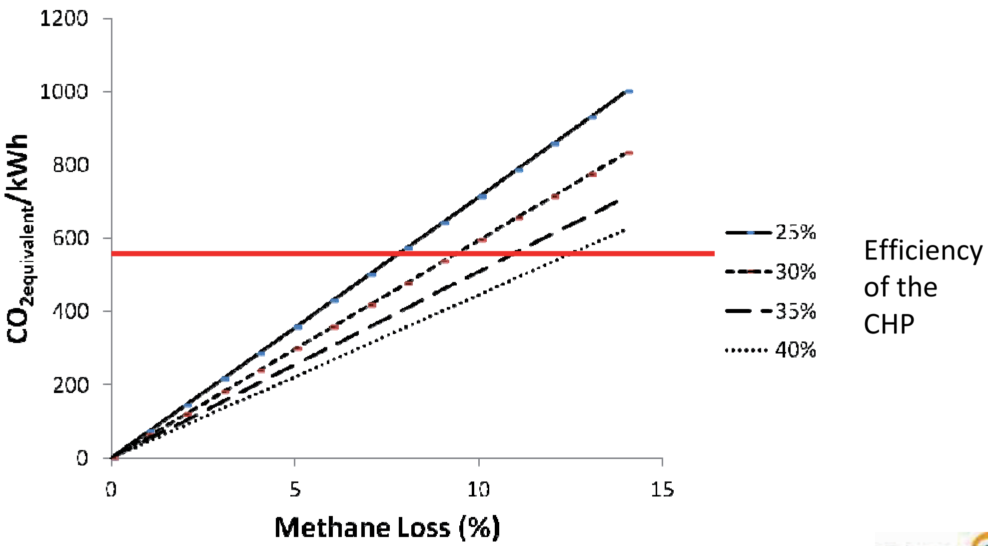


Umweltbundesamt 2009

gewitra

Ecology: Why are emissions to be considered ?

- A biogas plant is as good as our German electrical average if ist CH_4 emissions are between 8-12%!



gewitra

Emissions from a Biogas Plant

- Substrate storage and input
- Fermenter leakage
- Pipelines

For these components, the emissions are between 0 - 3.9% of the produced CH_4 (under normal operation)

gewitra

Different Biogas Use

- Micro gas grid
- Electricity and heat production
- Biogas purification

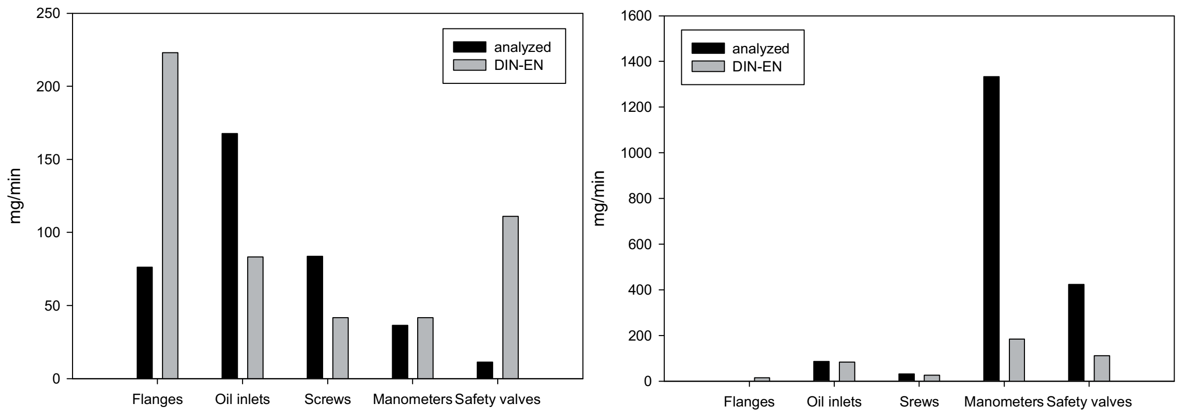
gewitra

Micro Gas Grid

- Tanks
- Gas is used for heating and cooking

gewitra

Analysed and estimated Emissions from a Biogas Storage Unit from a Biogas Grid in China



CH_4 emissions from different technical equipment; own flux measurements and estimation using DIN EN 15446

XuPan et al. 2009

gewitra

Analysed and estimated Emissions from a Biogas Storage Unit from a Biogas Grid in China

Plant 1

- 245 sampling point
- 13 leakages
- > 0.6 % of the CH_4 produced was emitted
- 9 of the 13 leakages could be repaired immediately
- Then emissions were 0.34% of the produced CH4

Plant 2

- 296 sampling points
- 10 leakages
- > 3% of the CH_4 produced were emitted
- No immediate repair possible according to the operator

XuPan et al. 2009

gewitra

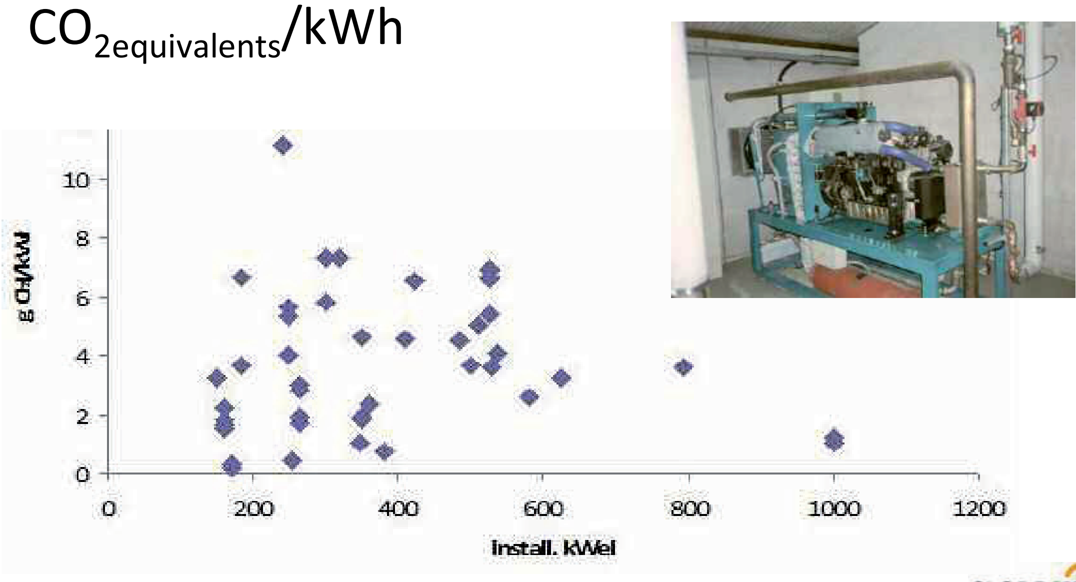
Mitigation options

- Regular control and repair
  - pipelines
  - vents
  - flanges

gewitra

Emissions from CHPs

- Emissions between <1 to more than 275 g $CO_{2equivalents}$/kWh



gewitra

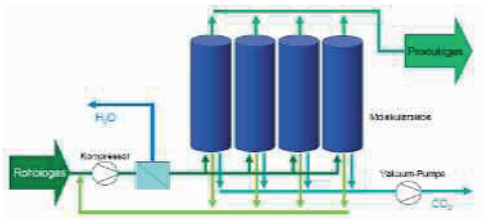
Mitigation options

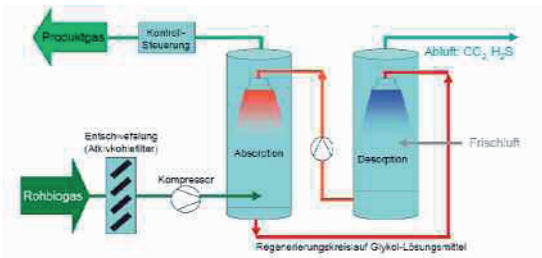
- Regular control of CHP unit
- Combustion of the exhaust air by regenerative thermal oxidation (RTO) (not yet state of the art).

gewitra

Emissions from Biogas Purification units

- Gas can be fed into normal gas grids after purification (different standards in different countries)
- Physical and chemical processes





Baum 2007

Regulation

- Germany:
  - CH_4 leakage < 0.5% (purification and feeding into the grid), from 31.May 2012: only 0.2%
  - H_2S < 2.9 mg/m³

2010:Verordnung über den Zugang zu Gasversorgungsnetzen (Gasnetzzugangsverordnung - GasNZV)

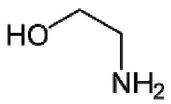
- Switzerland:
  - CH_4 leakage < 5% (purification and feeding into the grid

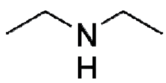
SVGW (2008): Regelwerk G13. Richtlinie für das Einspeisen von Biogas ins Erdgasnetz.

CH_4-Emissions from different technologies (according to the manufacturer)

	PSA	WS	Genosorb, Seloxol	MEA	DEA
Leakagê (%)	2 – 5 (up to 10 using short cycles)	< 1	2-4	<0.1	<0.1

PSA: Pressure swing Absorbtion
WS: Water scrubber
Genborsorb, Seloxol: Polyethylene gycol Dimethylether
MEA: Monoethanol amine
DEA: Diethyamine





Umsicht 2008

gewitra

Emissions according to analysis

- In German a research project concluded that all purification plants are above the new German treshold of 0.5% Methane loss (DVGW). However, there was no amine scrubber included.

http://www.dvgw.de/fileadmin/dvgw/angebote/forschung/report/pdf/TR12/tr1_10.pdf

gewitra

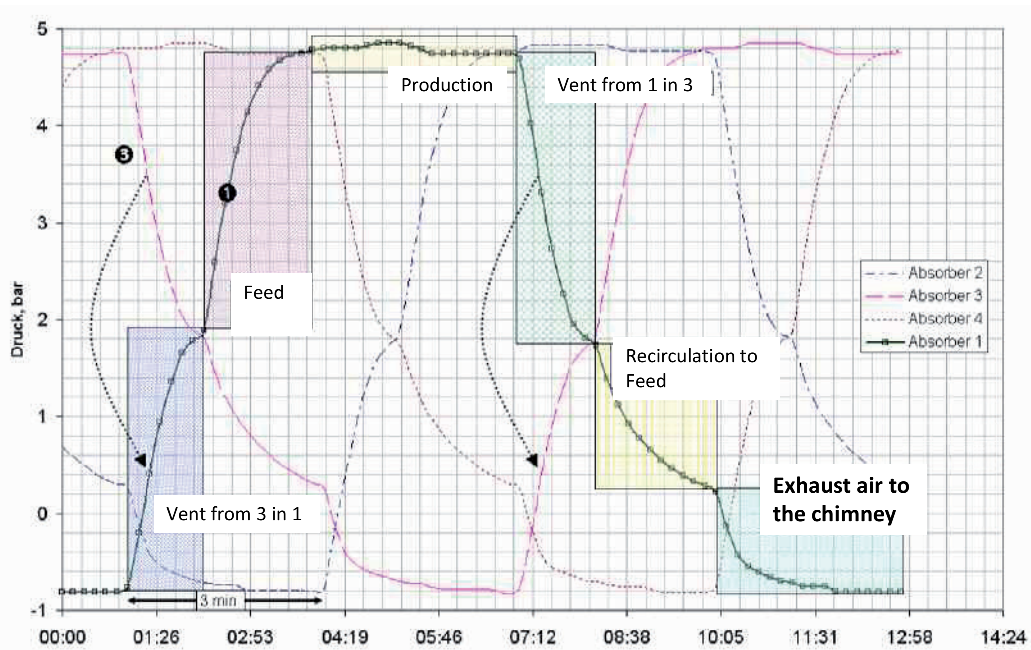
Case Study in Switzerland

- Pressure Swing Adsorption technology
- 90 m³N/h purified gas
- Analysis over 200 cycles
- Additional analysis of the start up and shut down of the PSA

Baum & Baier 2008

gewitra

Case Study: PSA: Typical Pressure Curve of one Absorber and Source of CH_4 Emission

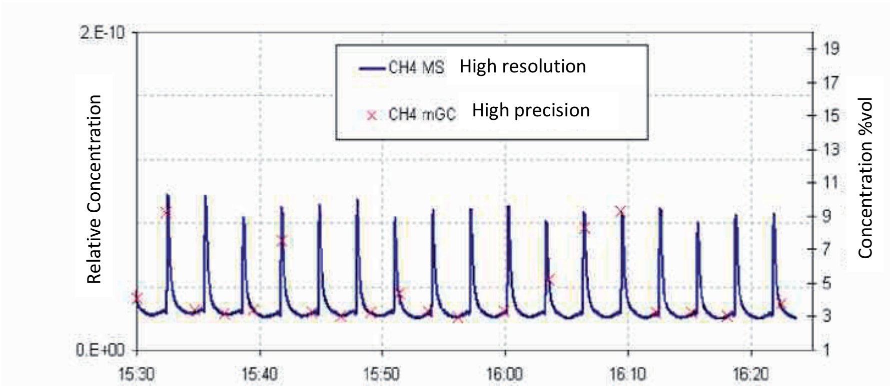


Baum & Baier 2008

gewitra

Case Study: PSA: CH_4 in the exhaust gas

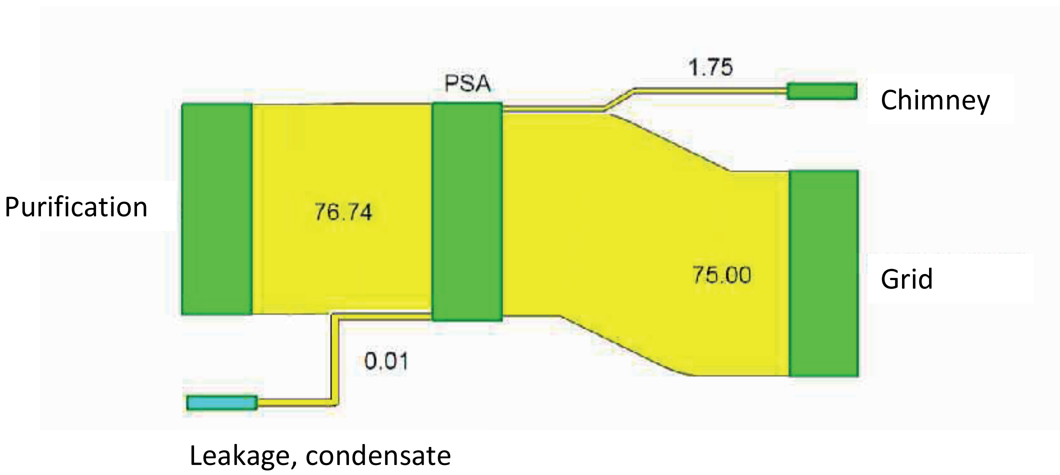
- CH_4 peaks at the end of one cycle



Baum & Baier 2008

gewitra

Case Study: PSA: CH_4 Emissions during operation (m^3N/h)



Baum & Baier 2008

gewitra

Case Study: PSA: Summary

- Overall emission: 2.6% of produced CH4
- About 88% of the CH4 emission during normal operation
- About 2% during start up
- About 10% during shut down

Baum & Baier 2008

gewitra

How to reduce CH_4 emissions

- For PSA: longer cycles, more absorbers
- Burn exhaust gas:
  - RTO (regenarative thermal oxidation): this is consuming additional gas if the CH_4 content is low!
  - Thermal combustion: oxidizes CH_4 without energy input down to 4%

gewitra

RTO with acid scrubber

gewitra

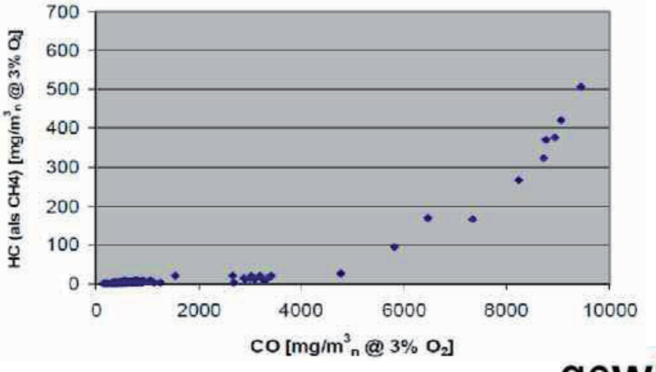
How to reduce CH_4 emissions

- PSA: exhaust gas may be oxidized thermally without additional energy input (CH_4 concentration in the exhaust air may be high enough)
- Water scrubber, amine scrubbers and Genorsorb: CH_4 concentration is low, RTO is needed (with additional energy input, CH_4 concentration in the exhaust air is too low for thermal oxidation)

gewitra

Flox Flare: Thermal oxidation at CH_4 content of 5-7% and >90% CO_2

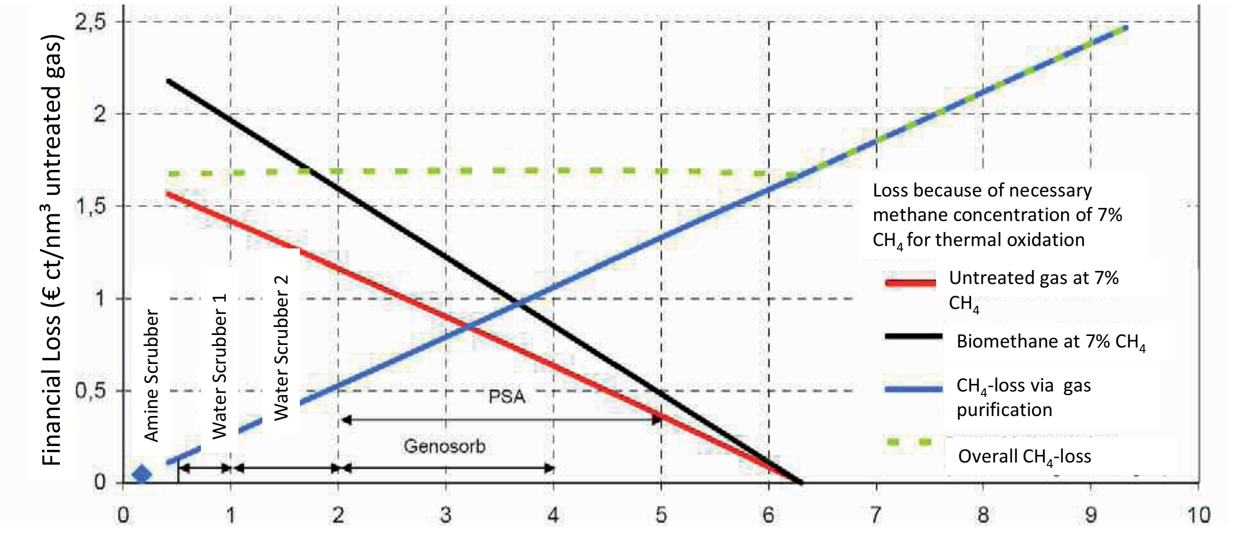
- Heat can be generated.
- at CO concentration >1000 mg/m³$_n$ CH_4 < 10 mg/m³$_n$
- Worst CO concentration during normal operation: 4000 mg CO/m³$_n$



Schmid, 2009

gewitra

Financial Loss because of Exhaust Air Treatment



Assumption: thermal oxidation at 6.3%, production costs for untreated biogas 5 €ct/kWh, for biomethane 7 € ct/kWh)

Umsicht, 2009

gewitra

Summary

	CH_4 losses	mitigation
Biomethane	Up to 4%	RTO Thermal oxidation maintenance
CHP	up to 2%	RTO maintenance
Gas grid	up to 3% (own analysis)	maintenance
Biogas production	Without covered digestate store, mean: **3,9%** (of 20 biogas plant analysis) With covered digestate store, mean: **1.7%** (of 20 biogas plant analysis)	Cover digestate store maintenance

Summary

- Every use of biogas goes along with CH_4 emissions
- The CH_4 leakage has to be minimized because of ist environmental impact as green house gas.
- It is important to maintain the biogas usage devices (chech, repair, check-philosophy)
- For unavoidable emissions, a posttreatment is required if CH_4 emissions are too high.
- Here, there is still a big demand for research

Author’s address:

Dr.-Ing. Carsten Cuhls

gewitra - Ingenieurgesellschaft für Wissenstransfer mbH

Im Moore 45, D-30167 Hannover

Telephone: +49 (0)511 9 99 08 74

Fax: +49 (0)511 70 10 60 8

Mobile: +49 (0)179 5 04 45 24

Email: cuhls@gewitra.de

Website: www.gewitra.de