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

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In Zusammenarbeit mit

Universität Rostock Traditio et Innovatio

Mit Unterstützung der

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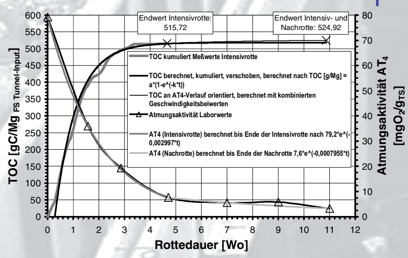

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Hinweis

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.

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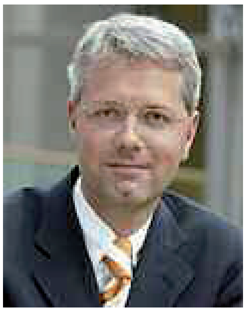

Grußwort von Bundesumweltminister Dr. Norbert Röttgen

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 CO2 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

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

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

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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.

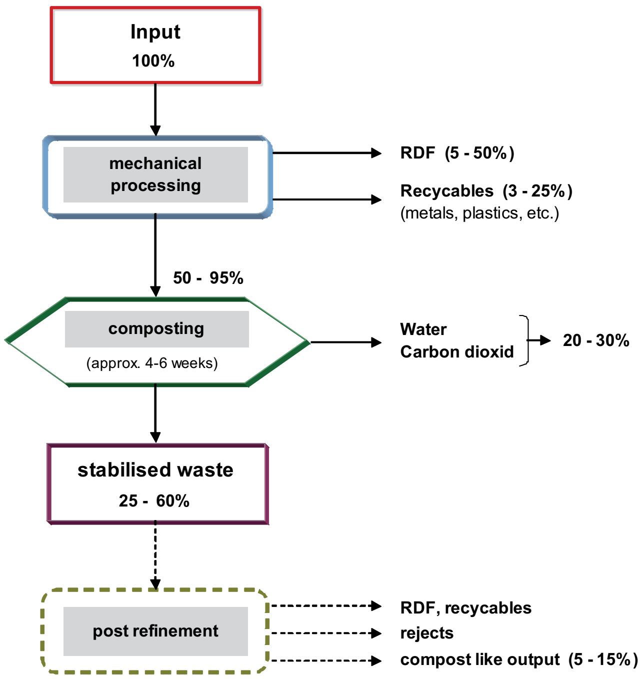

Figure 1: MBT for stabilisation

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.

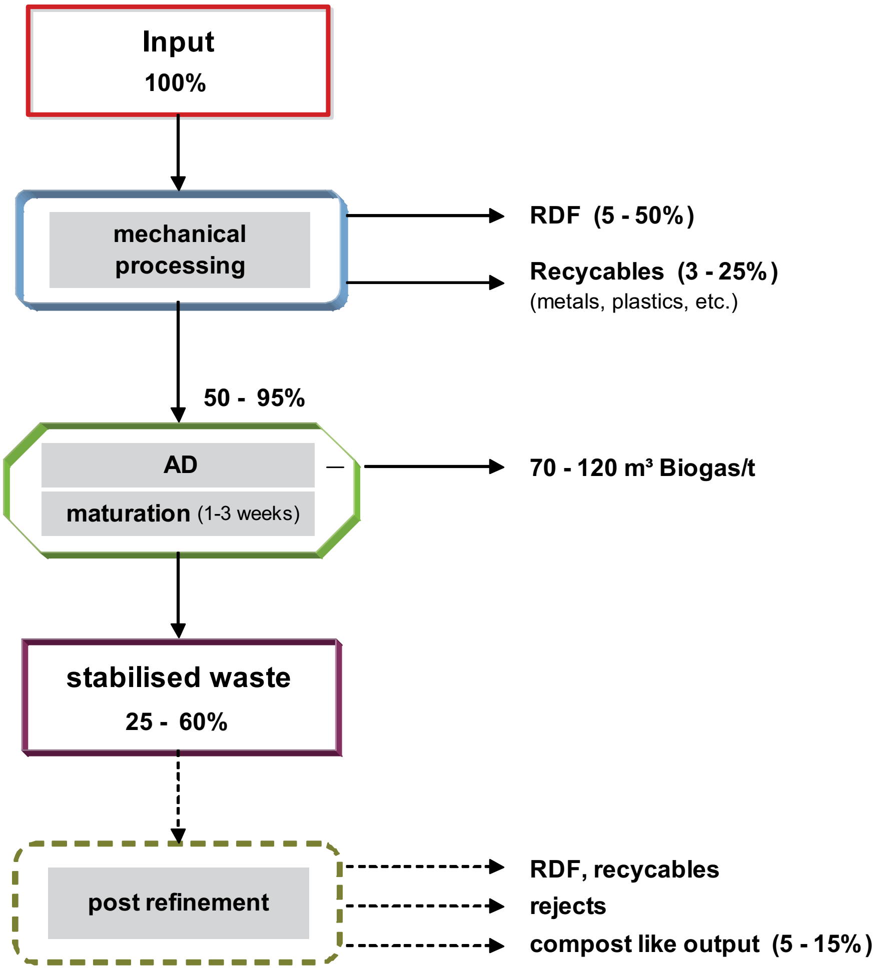

Figure 2: MBT with Anaerobic Digestion

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.

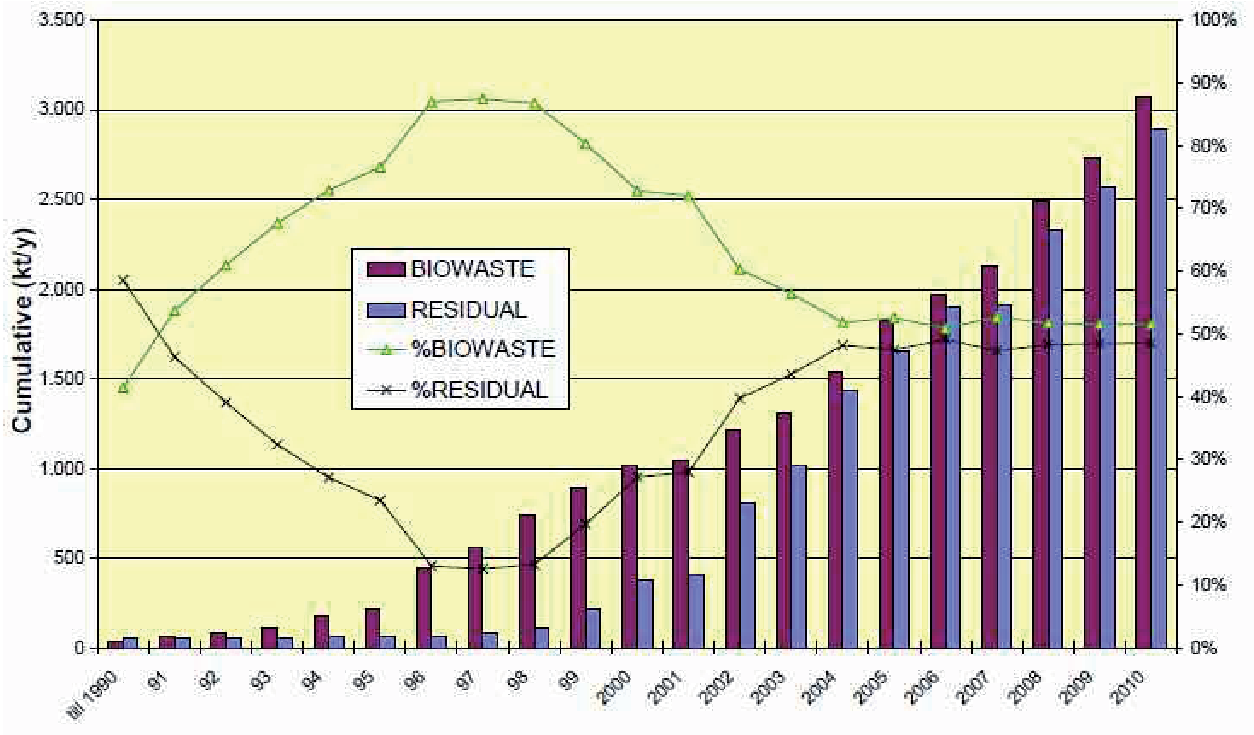

Figure 3: Development of MBT plants in Europe (Mattheeuws, 2010)

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.

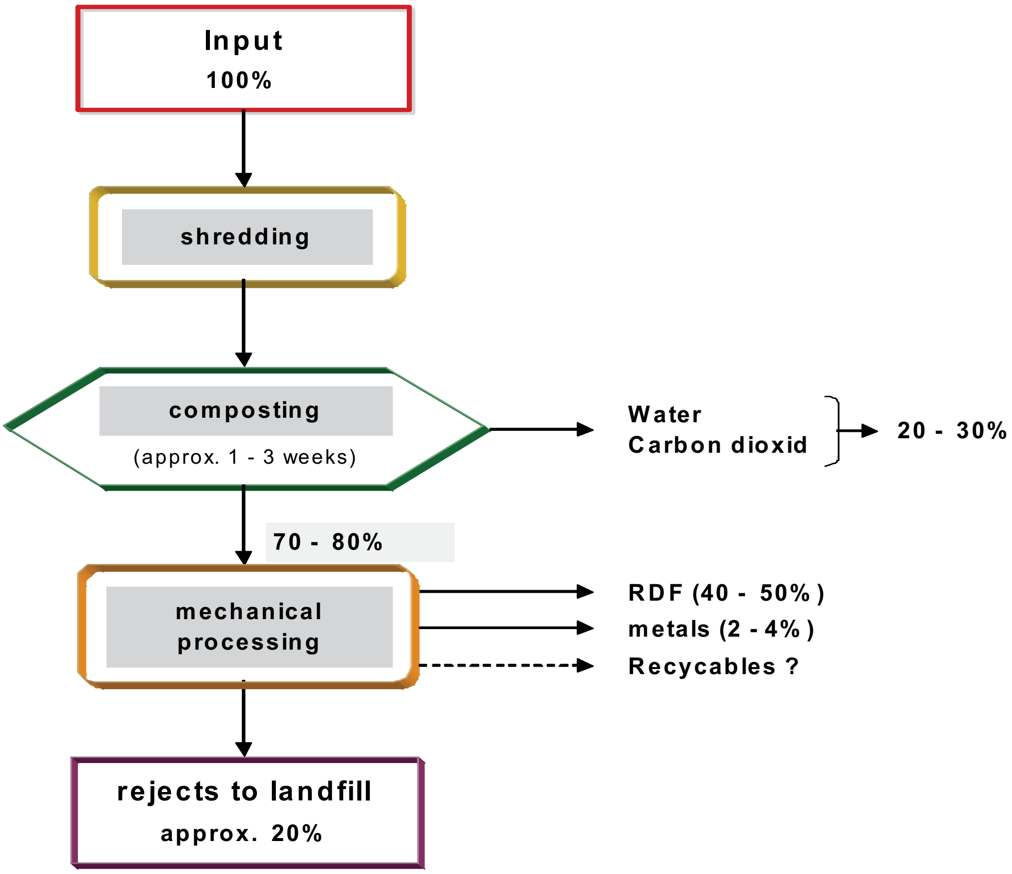

Figure 4: MBT – biological drying

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.

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A Comparison of two Biological Treatment Processes for Residual Waste Management

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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 CO2 (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

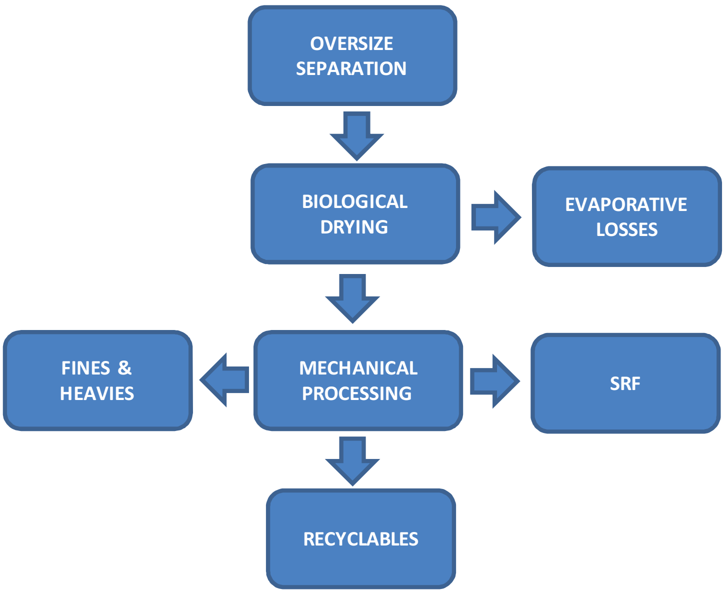

Figure 1: MBT- Biodrying Concept

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.

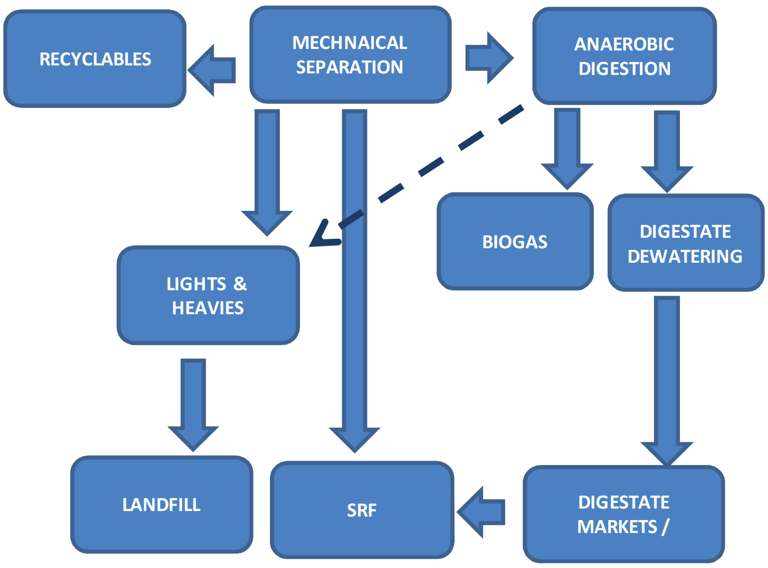

Figure 2 MBT-AD Concept

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

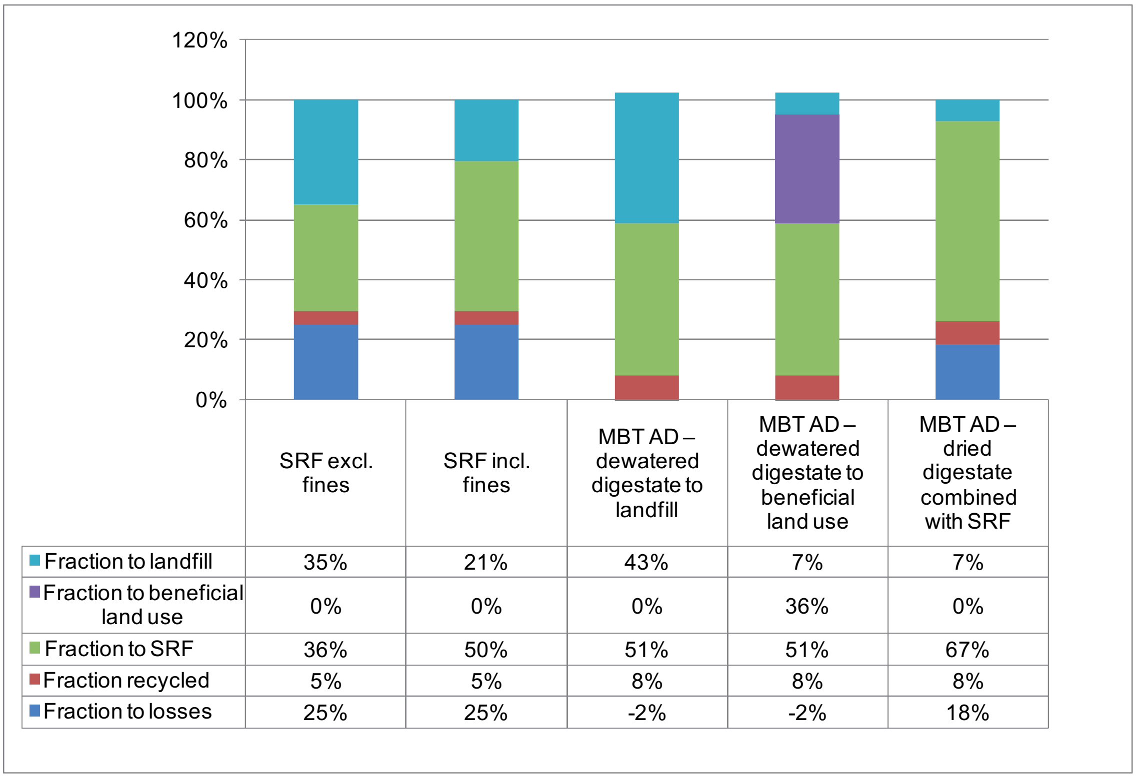

Figure 3 Scenario Mass Balance Performance

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

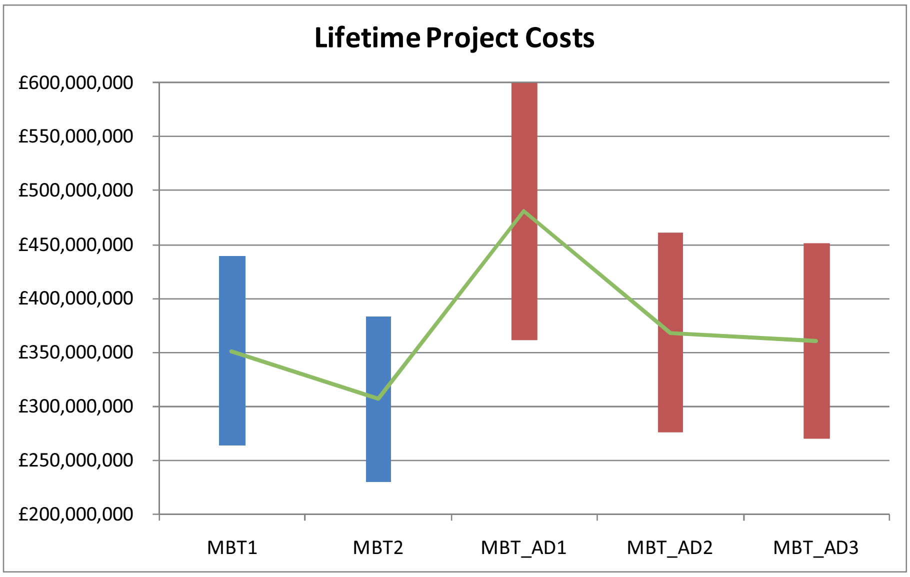

Figure 4 Predicted Lifetime Project Costs

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.

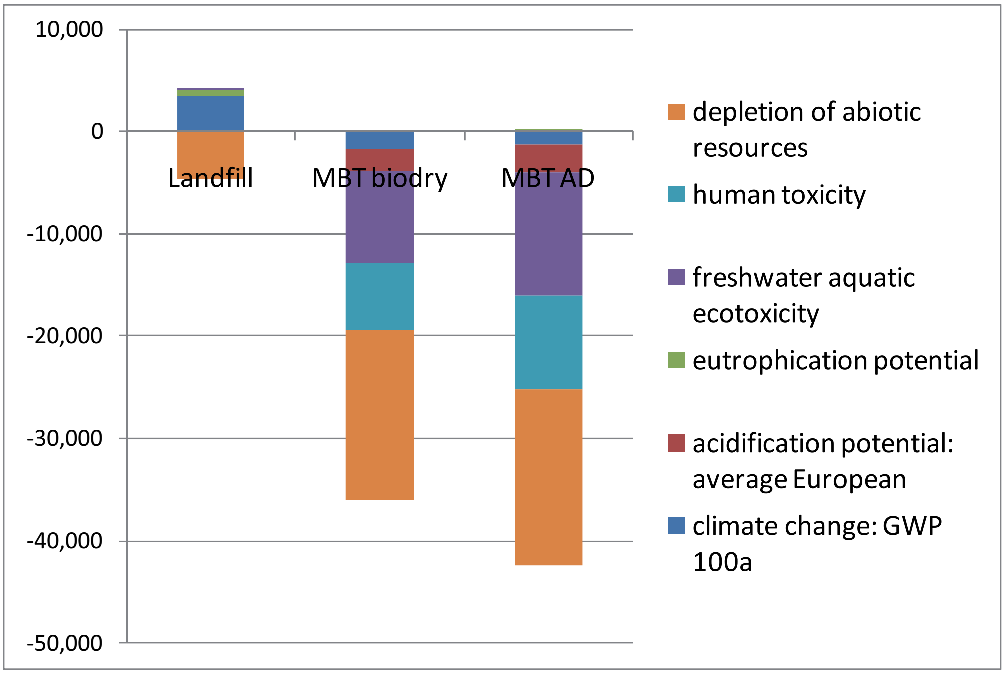

Figure 5 Lifecycle Environmental Impacts

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

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

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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.

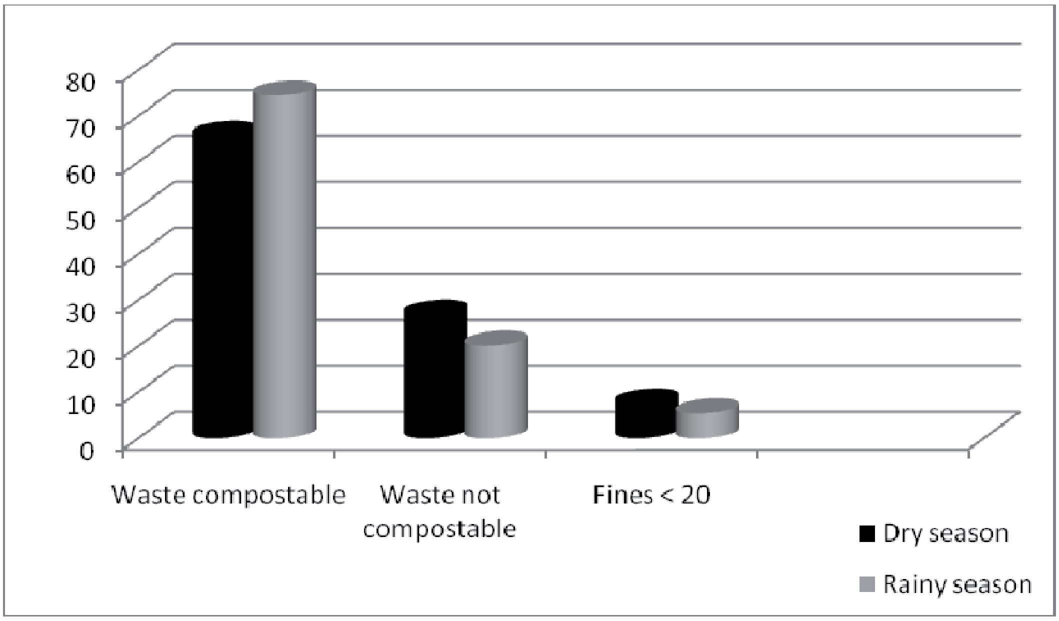

Figure 1a: Composition Of Waste After Collection Directly In Households

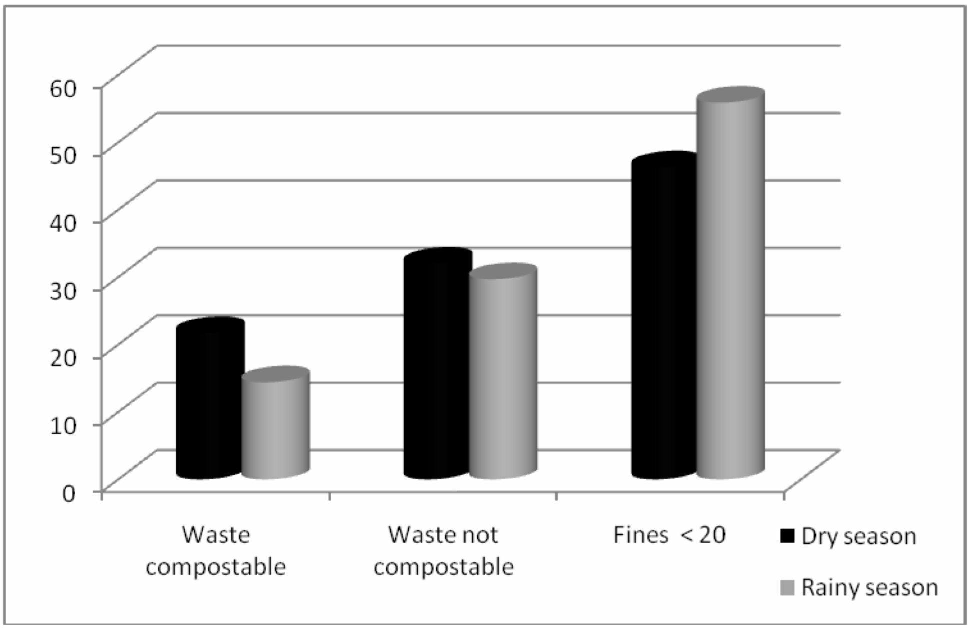

Figure 1b: Waste Composition in Final Discharge

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**).

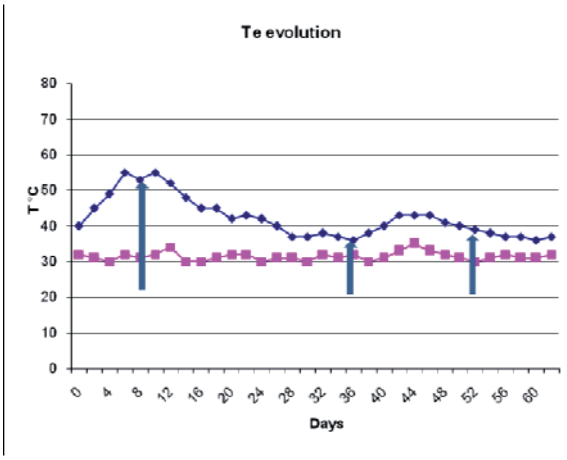

Fig 2a Compost A

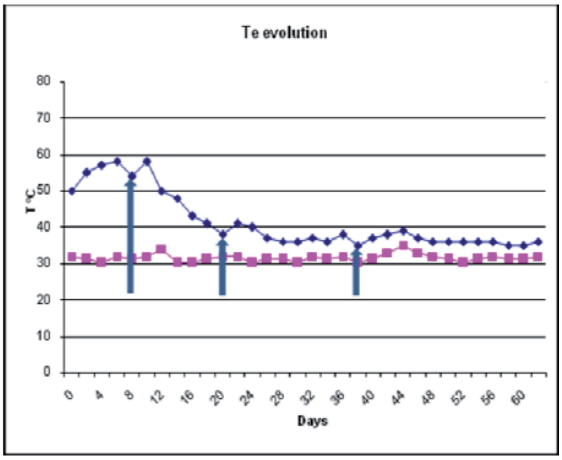

Fig 2b Compost B

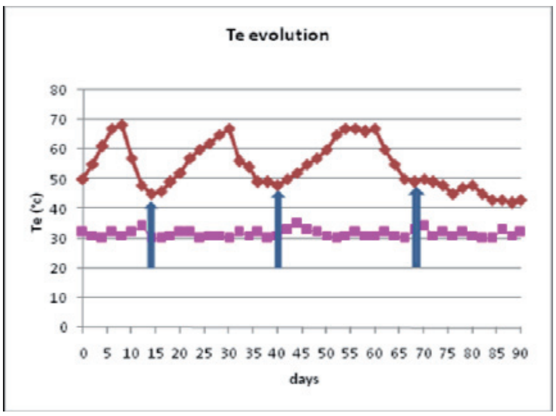

Fig 2c Compost C

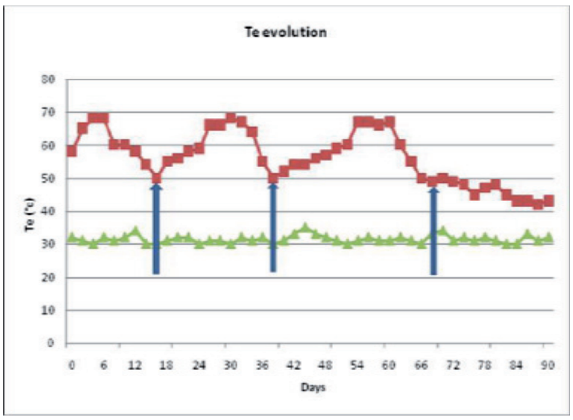

Fig 2d Compost D

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