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The use and application to land of MBT compost-like output - review of current European practice in relation to environmental protection

Science Report – SC030144/SR3

SCHO0109BPFN-E-P

ea/br/e/sci/v1

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This report is the result of research commissioned and funded by the Environment Agency's Science Programme.

Published by:
Environment Agency, Rio House, Waterside Drive, Aztec West, Almondsbury, Bristol, BS32 4UD
Tel: 01454 624400 Fax: 01454 624409
www.environment-agency.gov.uk

ISBN: 978-1-84432-973-1

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Dissemination Status:
Publicly available

Keywords:
Mechanical, biological treatment, waste, European regulation, land

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Science Project Number:
SC030144

Product Code:
SCHO0109BPFN-E-P

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Steve Killeen

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Head of Science

Executive summary

The main objectives of this review are to describe current EU practice for the production, regulation and use of compost-like outputs from MBT plants, with specific reference to their application to land. A further objective is to assess national differences in approaches across the EU and to attempt to establish why such differences exist. The relevance to the UK situation of uses of MBT outputs on agricultural land in other European countries is also discussed.

"Mechanical-biological treatment" (MBT) refers to systems for the treatment of mixed waste and municipal solid waste feedstocks. MBT is a generic term used for a process stream including mechanical sorting and separation of waste into distinct fractions of biodegradable and non-biodegradable materials.

MBT is often a key element in national strategies for the diversion of biodegradable municipal waste (BMW) from landfill. Unlike incineration, it provides flexibility in the system, which is important in those Member States where the system will have to undergo widespread changes in the amount and quality of residual waste that is dealt with.

Product (compost)-orientated MBT is practised on a larger scale in France, Spain, Portugal, Poland, parts of Italy and Turkey. Several factors are thought to have influenced this development, not least the lower soil organic content in southern Europe's and desertification issues. Although Italy has a long tradition in MBT, the emphasis for MBT outputs is on refuse derived fuel (RDF), with some MBT plants producing compost suitable for restricted applications.

After an initial widespread interest in composting municipal solid waste (MSW), there appears to have been a move away from producing a compost end product due to uncertainties about the economic market for this output. However, whilst the general opinion is that composts from source-segregated materials are likely to make higher quality composts, there still remains interest in composting mechanically segregated MSW feedstocks as part of a MBT process.

There is no uniform system for setting compost standards across the EU. However, almost all EU-15 countries have statutory standards, with just a few relying on voluntary standards (i.e. UK and Sweden). Most countries differentiate between two compost classes, but a few such as Austria and the Netherlands apply three standards. Very few standards consider non-source-segregated MSW outputs.

The standards can differ quite significantly from one country to another. While the seven most common metals are typically covered by the standards, the limit values vary and some countries apply limit values for additional substances. For example, Denmark, Germany and Sweden have limit values for dioxins, Polychlorinated biphenyls (PCBs), Polycyclic aromatic hydrocarbons (PAHs), nonylphenols and Di(2-ethylhexyl)phthalate (DEHP), yet few have a comprehensive or adequate list.

A number of countries have based compost standards on the limit values set

out in the EU Sewage Sludge Directive (86/278/EC). Other policies that have influenced these limit values are the Strategy on Soil Protection (COM(2002)179 final) and the Nitrate Directive (91/676/EEC).

In 2004, waste treated via MBT was sent to landfill in Austria, to incineration in Germany and was used as low grade compost in France, Italy and Spain. Portugal also composts MSW for land-spreading but plans to phase out composting of mixed waste by 2016.

Whilst it is evident that compost from non-source-segregated MSW has been applied to agricultural land in a number of countries it has not been possible to obtain data on the amount that has been applied, nor where and for what specific purpose. Concerns about loading soil with metals and the high salt content of MSW compost have led to many field studies taking place, particularly in southern Europe where application of mixed waste outputs has been highest.

Compost-like outputs (CLO) are treated differently across Member States. For example, Germany uses MBT mostly as a pre-treatment prior to landfill, partially to stabilise biodegradable municipal solid waste, and does not use CLO on land. In France there are 70 plants processing 1.9 million tonnes per annum (tpa) of MSW with CLO used on land. Other countries also have substantial MBT capacities and use some of the CLO output on land, including agricultural land, such as Spain which has treatment capacity of 3 million tpa and Italy which has treatment capacity of 11.7 million tpa. In the UK the current regulatory position precludes the use of CLO from mixed waste sources for any agricultural land.

The development of MBT technologies and the potential recycling of CLO to agricultural land provide a challenge to both regulators and operators to ensure sustainable environmental use. In addition, public perception of risk and heightened awareness of health-related issues from agricultural re-use of wastes requires a robust evidence-based approach if public confidence is to be fostered and markets are to develop.

Acknowledgements

The project team would like thank Tony Chapman of R3 for helpful and constructive comments on this review.

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1 Introduction

1.1 Report structure

The main objectives of this review are to describe current European Union (EU) practice for the production, regulation and use of compost-like outputs from mechanical-biological treatment (MBT) plants, with specific reference to their application to land. A further objective is to assess national differences in approaches, regulation and quality standards across the EU and to establish why such differences exist. The relevance to the UK situation of uses of MBT outputs on agricultural land in other European countries is also discussed.

“Mechanical-biological treatment” (MBT) refers to systems for the treatment of mixed waste and municipal solid waste (MSW) feedstocks. MBT is a generic term used to describe the processing of a waste stream by mechanical sorting and separation of waste into distinct fractions of biodegradable and non-biodegradable materials. The outputs from the mechanical separation generally include recyclables, residues and an organic fraction.

This organic fraction may be treated by several different biological stabilisation processes, depending upon the intended end use for the output, and may include anaerobic digestion or composting. Another option is the conversion of the high calorific fraction of MSW to Solid Recovered Fuel. New techniques for solid fuel recovery (SFR) are currently under trial (i.e. autoclaving, plasma treatment, gasification and pyrolysis) but they are not in use in the UK or other European countries at an operational level. The quality and use of this organic fraction across EU Member States are the focus of this review.

There is limited consistency in terminology used across the EU to describe compost-like outputs from MBT, which can make comparisons of treatment and use difficult. However, throughout this review we have used the term “MBT compost-like outputs (CLO)” broadly to account for all those organic materials produced by the processes described in the paragraph above. Other terms that may be found in the literature include: grey compost, organic matter amendment (OMA), stabilised organic fraction (SOF), and MBT organic outputs.

A large quantity of source-separated waste is already composted and used across Europe. However, source segregation of waste is not consistent across the EU for a number of reasons, both economic and social. In general, however, composting combined with mechanical separation processes is seen to recover lower grade composts and other recyclables.

In this first section (Section 1.2) of the review we provide a historical context for the development of MBT technologies in Europe and the part played by key legislation in the current increased levels of interest in MBT.

The second section (Chapter 2) describes national policies for several EU Member States for the treatment and use of MSW, including compost-like outputs from MBT. The importance of various disposal and recycling options for MSW for individual Member States is also discussed.

Chapter 3 provides a description of how composts and compost-like materials are assessed for physicochemical quality. The variations and differences across Member States are highlighted and the source and provenance of the limit values that are used are discussed, where this information is available.

The final two sections (Chapters 4 and 5) are a summary of the main points of the review and how the findings could be relevant and applicable to policy or practice in the UK situation. These sections include the project's conclusions and recommendations.

Annex I gives a very brief description of how the national use of CLO varies across the EU and provides some of the apparent reasons for these differences.

1.2 European legislation influencing the development of MBT

It has been reported that the large scale composting of municipal wastes originated in Europe in the Netherlands in the early 1930s, when output material was used in reclamation projects (Slater and Frederickson 2001). In the 1970s and 1980s significant development took place across the EU, targeted at treating unsorted MSW by a system of mechanical and biological treatment. However, the quality of the non-source-segregated composts from these plants was relatively poor compared to current source-segregated composts (Partl and Cornander 2006). In particular, large quantities of physical contaminants such as glass and plastics remained in the compost along with significant quantities of metals, producing a compost-like material with a limited market for use, so many of these plants have not survived.

Modern plants and developing technologies for dealing with the recycling of unsegregated MSW have meant a rebirth of MBT in Europe over the last 15 years. However, while the standards of modern MBT plant are generally far higher than their predecessors, it should be acknowledged that CLO are highly variable in physicochemical quality across different countries (Zmora-Nahum *et al.* 2007), between individual plants within the same country or region (Lasaridi *et al.* 2006, Hargreaves *et al.* 2008) and seasonally (Alminger *et al.* 2004; Nas and Bayrum in press). This is unsurprising in relation to MBT CLO as few plants have identical feedstock or plant technology (Tayibi *et al.* 2007). Indeed, MBT systems can vary greatly in their complexity and functionality; generally speaking, the more complex the setup of the plant, the higher the quality and lower the volume of the organic output. The capacity of facilities ranges from very small plants treating 10,000 tonnes or less per year, to large scale integrated facilities with annual capacities of more than 200,000 tonnes[1]. In Germany and Austria the MBT concept is termed mechanical-biological-pre-treatment because the organic output produced is seen as being a biostabilised material destined for landfill, rather than an onward use.

The management of biodegradable municipal waste (BMW) across the EU is currently guided by the Landfill Directive (1999/31/EC). The Directive sets strict limits on the amount of biodegradable municipal waste that can be disposed of via landfill, and requires landfill operators to collect, treat and utilise landfill gas. In addition, the Directive introduced a requirement for the pre-treatment of all waste prior to landfill. Under the Directive, the amount of biodegradable municipal waste that can be disposed of via landfill must be reduced to:

- 75 per cent of the amount produced in 1995, by 2006;
- 50 per cent of the amount produced in 1995, by 2009;
- 35 per cent of the amount produced in 1995, by 2016.

The UK has been granted a four-year derogation to this timetable, making the deadlines 2010, 2013 and 2020, respectively. The requirement for eligibility to apply for a derogation was that the Member State had to landfill at least 75 per cent of its MSW at the time of the Directive's inception.

An additional regulation that has also affected the amounts of biodegradable material going to landfill in the EU is the Packaging Directive (94/62/EC as amended by 2004/12/EC). This legislation sets minimum recycling targets for glass, paper and board, metals, plastic and wood. In addition to the EU legislation that is in place, Member States are also guided by their own national waste strategies (see Chapter 2).

Further momentum towards change has been the need for Member States to comply with Kyoto commitments on climate change (Marmo 2008). One theory being considered is that organic fertilisation over time promotes a build up of carbon inside the soil which could prove to be a “sink” of sequestered carbon (Chambers *et al.* 2008). Another effect of organic fertilisation is that the supply of nutrients to the soil mitigates the need for chemical fertilisers, saving on the energy and fuel that would otherwise be needed for their manufacture.

In response to these issues the European Commission launched a “Thematic Strategy on Soil Protection”. One of the major concerns raised in the draft soil strategy is the decline of organic matter in soils. Although soil degradation processes vary considerably between Member States, with different threats having different degrees of severity, soil degradation is an issue across the EU. An estimated 45 per cent of European soils have low organic matter content, principally in southern Europe but also in areas of France, the UK and Germany (EC 2006a).

Restoring organic fertility to the soil is seen to have a number of benefits such as:

- prevention of erosion and floods through improved soil structure;
- sequestration of carbon (as mentioned above);
- reduction in the use of mineral fertilisers and pesticides, leading to a reduction in related pollution (also as mentioned above);
- increase in biodiversity.

The EC Communication on the Soil Strategy [COM (2002) 179, of 16 April 2002) focussed on the potential pool of organic matter included in biowaste. The proposed EU Directive on biological treatment of biodegradable waste was merged into the Thematic Strategy on Soil Protection. Source separation of biowaste is a key provision in the working documents and in a ‘Discussion’ document issued in 2003 in the context of the Soil Strategy.

Biodegradable waste is defined in the Landfill Directive as “any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and green waste, and paper and paperboard”. Municipal waste is defined in the Landfill Directive as “waste from households, as well as other waste which, because of its nature or composition, is similar to waste from households”. The precise definition of biodegradable municipal waste (BMW) varies between EU Member States. In general, BMW includes food and green waste, paper and cardboard and other biodegradable waste (such as certain textiles and nappies) from households, but also food waste and paper and cardboard from commerce and industry, as well as garden waste from parks and gardens (COWI 2004). Generally the biodegradable fraction comprises 60-70 per cent of the generated municipal waste in most countries (Skovgaard *et al.* 2007).

It was originally intended that the Biowaste Directive would establish standards and protocols for the use on land of CLO derived from waste processing facilities. The lack of such definitions at the EU level has meant that slightly different standards are being established in those individual Member States where interest in MBT is most active (Germany, Austria, Italy, Spain and the UK; Juniper 2005a). The Biowaste Directive has been withdrawn and it is unclear whether it will be revived in some form at a later date.

A draft discussion document formulated for an ad hoc meeting on “Biowastes and Sludges” held in Brussels (15-16 January 2004), indicated that only “high quality compost generated from source-segregated material should be spread on agricultural land used for growing food crops”. This position was further stressed by Amlinger *et al.* (2004) in a report on behalf of DG Environment on EU waste policy and the biological treatment of biodegradable waste. Specifically, this report provides evidence to support the view that the use of composts from non-source-segregated material should be restricted to landfill cover and biofilters.

At the European level, there are several ‘key’ documents that cover and affect the use of ‘compost-like material’ produced by MBT processes on land. These are:

- the Landfill Directive (1999/31/EC);
- the Animal By-Products Regulations (ABPR) (2002/1774/EC);
- the previously proposed Biowaste Directive;
- the Thematic Soil Strategy;
- the Nitrates Directive (1991/676/EEC) because for any compost product, applications to agricultural land will be controlled by the EC Nitrate Directive, to limit the potential migration of nitrogen to groundwater).

A first draft of the scope of the Thematic Soil Strategy was published in 2002, which was followed by a European Parliament resolution in November 2003; in September 2006 the “Thematic Strategy for Soil Protection” was published (EC 2006a). The Strategy identifies contamination as a key threat to the sustainable use of soils. Also, in September 2006 the EU presented a proposal for a directive “Establishing a Framework for the Protection of Soil” (EC 2006b). However, in December 2007, the Council rejected the Commission's proposal for a Soil Framework Directive. The failure to adopt the directive was largely due to concerns about subsidiarity, with some Member States maintaining that soil was not a matter to be negotiated at the European level. Others felt that the cost of the directive would be too high and that the burden of implementation would be too great (http://eusoils.jrc.ec.europa.eu/library/jrc_soil/policy/).

As it is likely that any future regulations will build on previous discussion documents (e.g. the draft Biowaste Directive), these draft documents provide an indication of the possible future direction of any EU regulations. In Annex III of the 2001 Biowaste Working Document (EC 2001), specific limit values for two grades of ‘compost’ were proposed (Class 1 and 2) and also for ‘stabilised biowaste’ materials, a term used to cover MBT outputs and similar materials (Table 1.1).

Table 1.1 Proposed limit values for compost and stabilised biowaste

Contaminants		**Compost/Digestate***		**Stabilised biowaste***
		Class 1	**Class 2**	
Zn	(mg kg^{-1} dm)	200	400	1500
Cu	(mg kg^{-1} dm)	100	150	600
Cd	(mg kg^{-1} dm)	0.7	1.5	5
Ni	(mg kg^{-1} dm)	50	75	150
Pb	(mg kg^{-1} dm)	100	150	500
Cr	(mg kg^{-1} dm)	100	150	600
Hg	(mg kg^{-1} dm)	0.5	1	5
PCBs	(mg kg^{-1} dm)	not stated	not stated	0.4**
PAHs	(mg kg^{-1} dm)	not stated	not stated	3**
Impurities	> 2mm	< 0.5%	< 0.5%	< 3%
Gravel and stones	> 5mm	< 5%	< 5%	-

* Normalised to an organic matter content of 30%.

** Threshold values for these organic contaminants to be consistent with the Sewage Sludge Directive.

The two classes of compost/digestate from source-separated materials were considered suitable for use on land growing food crops. However, the stabilised biowaste was considered unsuitable for use on pasture or food crops, but suitable for landscape restoration, road construction, golf courses, ski slopes, football pitches etc. Also, it was proposed that stabilised biowaste materials should not be used on the same area within a 10 year period and that applications should not exceed 200 tonnes of dry matter per hectare. There were several other proposed uses for stabilised biowastes, such as daily and final landfill cover, energy crops and forestry, and as a soil improver for contaminated land (Gibbs and Chambers 2007).

There is no EC legislation that directly affects the collection and sorting of waste. Collection methods are the responsibility of individual Member States who can transfer the responsibility to the local authorities. Other EU waste initiatives influence the composition of municipal waste, namely:

- the Waste Electrical and Electronic Equipment (WEEE) Directive [2002/96/EC and 2003/108/EC];
- the Batteries Directive [2006/66/EC];
- the Packaging & Packing Waste Regulations [94/62/EC].

To prevent or reduce the negative effects on the environment from the landfilling of waste, the EU Landfill Directive (1999/31/EC) was agreed on 16 July 1999. The Directive aims to improve standards of landfilling across Europe through setting specific requirements for the design, operation and aftercare of landfills, and for the types of waste that can be accepted in landfills.

2 National drivers for MBT CLO management in Europe

MBT is often a key element in national strategies for the diversion of BMW. Unlike incineration, it provides flexibility in the system, which is important in those Member States where the system will have to undergo widespread changes in the amount and quality of residual waste that is dealt with. Product (compost)–orientated MBT is practiced on a larger scale in France, Spain, Portugal, Poland, parts of Italy and Turkey. Several factors are thought to have influenced this development, not least Southern Europe’s lower soil organic content and desertification issues. It should be noted that although Italy has a long tradition in MBT, the emphasis for MBT outputs is on Refuse Derived Fuel (RDF), with some plants producing compost suitable for restricted applications (Partl and Cornander 2006).

Figure 2.1 provides a pictorial comparison of how other EU Member States and Turkey handle their waste, based on data from Eurostat (2002). Table 2.1gives more up to date tonnages with data from the OECD. Whilst there may have been further reductions in volumes going to landfill as countries continue to meet the obligations of the Landfill Directive, the trends in waste management options for each country have remained broadly the same. Turkey has been included in this discussion as they wish to accede to full membership of the European Union and have been using EU directives to guide their waste strategy (Külcü and Yaldiz 2003, Taşeli 2007). Eurostat does not produce data on MBT and it is likely that this capacity is included within recycling and composting totals.

Further detail for individual countries is provided below in country-specific subsections.

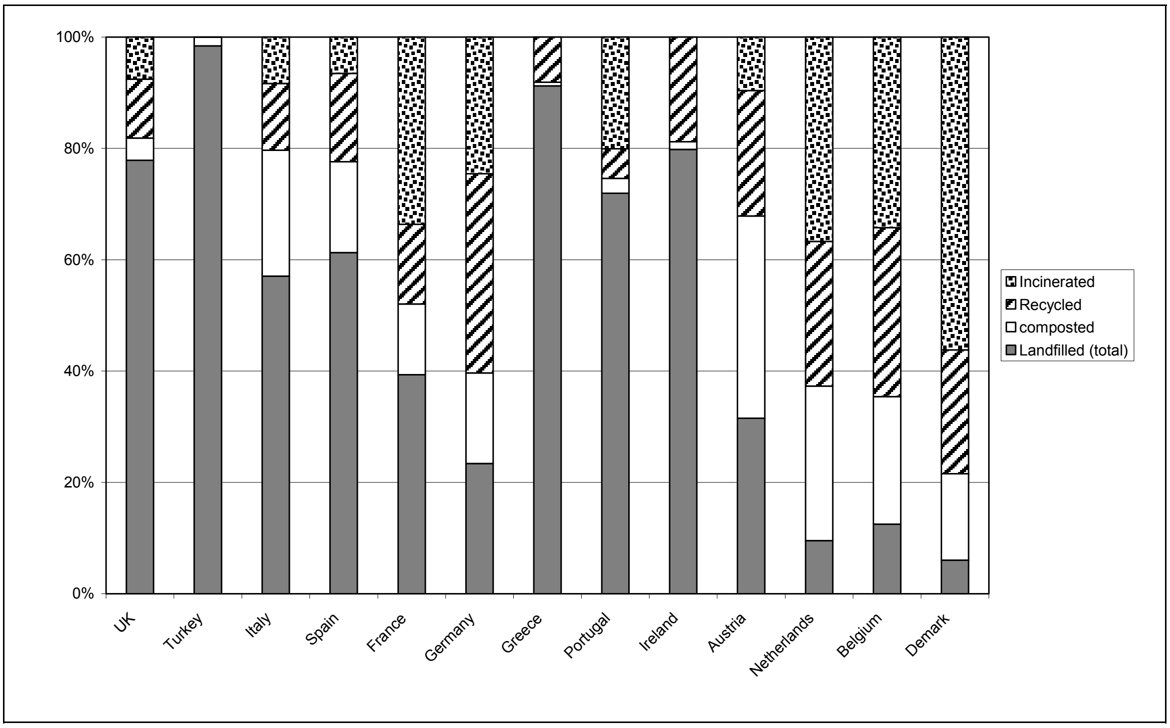

Figure 2.1 Percentage of municipal waste going to various treatments in different EU Member States and Turkey (Eurostat 2002)

Table 2.1 Disposal of Municipal Waste for the latest year available (data in 000s of tonnes)

Country	Year	Recycled	Composted	Incinerated with energy recovery	Incinerated without energy recovery	Landfilled (total)	Other
Austria	2004	1218	2052*	969		310	
Belgium	2003	1433	1049	1453	128	533	
Bulgaria						3188	
Czech Republic	2004	36	92	396	1	2267	
Demark	2003	925	553	1955		184	
Germany	2004	16052	8305	-	11892	8578	
Estonia	2002	13	2	0	0	419	
Ireland	2005	964				1883	
Greece	2002	375	32			4233	1853#
Spain	2004	2036	7433	1505	10	11752	
France	2005	5380	4870	10805	670	12238	
Italy	2005	-	10546*	3781	43	17225	
Latvia	2002	35	24	55	0	657	
Hungary	2003	117	47	245		3968	
Netherlands	2004	2581	2387	3281		175	1737**
Poland	2005	368	318		44	8623	
Portugal	2005	430	314	1057		3210	
Slovenia	2002	87	11	5	0	699	
Slovakia	2005	17	21	2	181	1144	
Sweden	2005	1474	454	2182		210	
UK	2005	6100	3262	2933	6	22559	
Turkey	2004		349		0	23714	174***

*includes amounts treated in MBT facilities
** MBT
*** disposal to lake/sea/river or open area burning
# disposed to uncontrolled landfill
(Eurostat 2002/OECD 2003-2005)

2.1 Austria

Austria fulfilled in 2001 the target set for 2016 in the Landfill Directive to reduce the amount of BMW to 35 per cent of the total amount produced in 1995 (EU 2005). The main management strategies used by Austria are separate collection of biowaste and packaging, including paper, and general obligations for pre-treatment of residual waste before landfilling. Separate collection and reuse or recovery of packaging waste has been required under the Austrian Packaging Ordinance since 1993. A general obligation for separate collection of biodegradable waste from household and commercial activities has been required under the Austrian Ordinance on separate collection of biodegradable waste (food and garden) since 1995. Under the Austrian Ordinance on landfill, only waste with a maximum TOC (total organic carbon) content of 5 per cent may be landfilled; waste that undergoes BMT and is below a certain respirometric index and a certain calorific value is excluded from this obligation. The Ordinance on Composting (2001) includes a set of quality standards for MBT outputs so they can be used in landfill remediation projects or biofilters (SLR 2005).

2.2 Denmark

With effect from January 1997 all Danish municipalities were required to send all waste that is suitable for incineration to incineration. Increases in volumes of waste and delays in the conversion to co-generation (combined power and heating generation) led to a capacity shortfall and this target was not met until 2001. Local authorities are under an obligation to collect paper and packaging-glass separately for recycling from households in areas with more than 1,000 inhabitants. Biowaste collection is mainly limited to separate collection of garden waste (ETCRWM 2006a). Ninety-nine per cent of garden waste and approximately four per cent of organic kitchen waste is recovered in anaerobic digestion (AD) plants to produce biogas for energy generation. Whilst the Environment Ministry's Waste Strategy for 2005-8 stated that it would develop a decision-making tool for municipalities to compare the benefits of composting, incineration and AD of the biodegradable fraction of MSW, it made clear that MBT was not considered an economically viable approach (SLR 2005).

2.3 France

In France a large percentage of MSW is diverted to incineration, and MBT is not well developed (Lornage *et al.* 2007). In 1992, France set a target of only "final waste" (i.e. waste that cannot be treated anymore under present technical and economic conditions) going to landfill by July 2002. Consequently, France has already achieved its second (2009) Landfill Directive target. In 2004 there were four MBT plants (two with anaerobic digestion) with an average throughput capacity of 75 kTpa. A further 1 MTpa of mixed MSW was sorted and composted in 62 small-scale facilities. Composting/AD of MSW was also carried out at a further 286 plants with an average capacity of 10 kTpa (SLR 2005).

2.4 Germany

The landfilling of untreated biodegradable matter and of MSW containing organics ceased on 1 June 2005. Germany expected to fulfil the 2016 Land Directive target in 2006 not only for biodegradable municipal waste but for all biodegradable waste (EC 2005). The German national strategy for the reduction of BMW going to landfill is separate collection of biodegradable waste and packaging, composting or anaerobic digestion of biodegradable waste, and stipulating criteria for the landfilling of waste with a limitation on organic content. For municipal waste this is 3 per cent TOC, unless it is MBT for which a maximum level of 18 per cent TOC is set, with concurrent compliance in tests determining respirometry and methane production potential. Biodegradable wastes from households, gardens and parks are mostly collected separately and recovered. Waste is collected from households via "bio-bins". The biowaste is mostly processed into compost using anaerobic digestion processes. These strict standards have led to intensive MBT with high-efficiency mechanical and biological processes, able to comply with the regulations.

2.5 Greece

Joint Ministerial Decision 50910/2727/2003 (OJG 1909/2003) provides measures and terms for solid waste management at national and regional level in compliance with the EU Waste Framework Directive 91/156/EEC. Greece took advantage of the four-year extension to meet the Landfill Directive reduction targets. Various regional waste management plans foresee the construction of MBT plants as the main tool to meet these targets. In 2006 three MBT plants were in operation. At that time there were no facilities processing source-separated organic waste, although in some areas green waste was being collected separately (ETCRWM 2006b).

2.6 Italy

In 2001 Italy reached the first target set for 2006 under the Landfill Directive. This was achieved by increasing the amount of separate collection and composting, installation of MBT plants, and partial incineration of MSW. Italy is divided into 20 regions that can be aggregated in three macro-geographical areas: North, Centre and South. MSW in 2004 was 31.1 million tonnes, with source-separated collection of recyclables and compostables making up 22.7 per cent of the total. The Italian regions that separate the largest quantity of recyclable and compostable materials are Veneto (43.9 per cent) and Lombardia (40.9 per cent) in the North, with the smallest quantity occurring in Southern regions, e.g. Molise (3.6 per cent) (Rigamonti 2006). At the regional level financial incentives are given to farmers to use mixed-waste derived compost on land (SLR 2005).

2.7 Netherlands

The Netherlands complied with the 2016 Landfill Directive target in 2005. The Waste Substances Decree prohibits materials to be landfilled when they can be recycled or incinerated. Separate collection of Vegetable-Garden-Fruit (VGF) is mandatory by law for municipalities on a weekly basis with a target of around 55 per cent set for the amount of VGF produced that must be separately collected (EU 2005).

2.8 Portugal

In 2005 there were six composting plants with a total capacity of 391,400 tonnes in Portugal. These composting plants mostly treated unsorted MSW. The yield from these plants was low and a high proportion of the output material was rejected and sent to landfill. Three new biological treatment plants (two composting and one anaerobic digester) are planned. These new plants are expected to treat biodegradable waste separately collected from commercial outlets only, with separate collection from domestic households phased in at a later stage. Low-end category 'waste compost' will be permitted for use in agriculture only until 2008; after that date it may only be used for recultivation purposes. This marks the transition from a recovery-based concept (composting) to MBT as a treatment method (Steiner 2005).

2.9 Spain

Moves to divert biodegradable waste from landfill in Spain have led to the development of composting schemes for MSW in sparsely populated regions, such as Estamadura, where the benefits of applying organic matter to agricultural land, to prevent desertification, have had widespread political support. Desertification is a key driver for compost-based solutions in many parts of Spain, such that the government has adopted a national Action Plan under the UN Convention to Combat Desertification (UN-CCD). As a result, the use of material derived from mixed, i.e. non-source-separated, wastes on agricultural land receives far greater acceptance than in other Member States (SLR 2005). Spanish regions have a significant degree of autonomy from central government and as a consequence separate collection of biowaste in Spain varies from region to region. Catalunya is one region where separate collection has been promoted since 1996. In Catalunya there are 20 plants for biological treatment (composting or anaerobic digestion) in operation, with an overall capacity for biological treatment of about 375,000 tonnes biowaste per year. The introduction of separated biowaste collection resulted in the production of compost with significantly higher quality than compost coming from mixed MSW. The proportion of impurities (glass, plastic, etc) has been reduced dramatically and metal concentrations are also significantly reduced, fulfilling Spanish compost legislation. In 2005, a total of 30,000 tonnes of compost, generated in Catalunya, was marketed for agriculture, gardening and the recovery of landfills (Giró 2006).

A draft for a new National Plan for Waste is currently being developed. Under consideration for this new plan is a source separation scheme for biowaste and green waste in cities. Until now, source separation of biodegradable waste has only been implemented in some towns and regions like Catalunya. This plan will also include a national strategy for reduction of biodegradable waste in landfills, to comply with European legislation. This will have to ensure that no more than 5.8 million tonnes biowaste are landfilled in 2009 (ECN 2006a).

2.10 Turkey

MSWs have been one of the major environmental problems in Turkey where MSW is generally disposed of in open dumps. Legislation relating to solid waste management is continuously updated but there has been no proper application. A 'Solid Waste Control Regulation' was published in the official gazette of Turkey on 14 March 1991 and encompasses the full range of solid waste management concerns (Akdemir *et al.* 2007). One MBT plant is located in Istanbul and has a capacity of 150,000 Tpa. The output from this plant is reportedly used as a soil improver (Juniper 2005). Composting of source-separated MSW is being implemented in new MSW management systems but this development is partly constrained by the current limited market for the outputs. An education programme for farmers informing them of the advantages of using compost is considered necessary (Ağdağ in press).

2.11 Summary

The following is a summary of the main points:

i. Separate collection schemes for biodegradable packaging (i.e. paper and cardboard) are generally applied.

ii. Separate collection of food waste and garden waste is already well established in Central Europe and is rapidly growing in Italy and Spain.

iii. Some Member States are already able to achieve the reduction targets of BMW from landfilling for 2016 defined in Article 5 of the Landfill Directive; in most cases they apply a combined set of measures and instruments (i.e. separate collection, obligations for pre-treatment, etc).

iv. Most countries, especially those that are in the starting/developing phase of a BMW management strategy, are planning to develop a large treatment capacity for biowaste (both composting, MBT, anerobic digestion (Holiwast 2006).

v. The ban on landfilling of high caloric fractions and the obligation for the pre-treatment of MSW before landfilling contribute significantly towards reaching the targets to reduce BMW under the Landfill Directive; both incineration (i.e. mineralization of BMW) and MBT are applied to residual waste as treatment before landfilling. Only in a few selected cases are there criteria and specifications for the acceptance of treated waste going to landfill (Austria, Germany).

3 Assessment of compost quality and national regulations

The development of MBT technology has been driven through legislative change and environmental quality standards; quality criteria have increased stringency (Slater and Frederickson 2001). Indeed, it is a widely held view that CLO from MBT will always be of inferior quality compared to those derived from source-segregated materials (Steiner 2005). These views are based on the outputs of plants operating in the late 1990s and early 2000s. Modern plants have been, or are being, developed that claim to provide a better quality product (Annex I). While source-segregated material is likely to be of higher quality – and this quality will be more reliable over a longer period – it is possible for good quality CLO to be comparable with the lower end of the source-segregated market (Chapman *et al.* 2008). However, compost quality is a contentious subject area for which the definition will often depend upon professional background, national legislation and marketing potential (Lasaridi *et al.* 2006).

Only a few countries make up most of the EU compost production from MSW. Germany is the biggest producer (>3 million tonnes), followed by Italy and the Netherlands. On a per capita basis, compost production is highest in the Netherlands, followed by Austria, Germany, Luxembourg and Belgium. These countries rely almost exclusively on source-separated putrescible fractions of MSW for compost production (compost that is not landfilled). In Denmark, compost is only produced from green wastes. In France and Spain, compost is also produced in considerable amounts from mixed MSW. A working document published by the EU Joint Research Centre in March 2007 (JRC 2007) gives the following yearly production totals for compost produced in France:

- 500,000 tonnes from non-source-separated household waste;
- 170,000 tonnes from separately collected 'biowastes' mixed with green wastes;
- 920,000 tonnes from pure green wastes.

Most of the compost produced from MSW is said to be used in agriculture although the exact figure is not reported.

MBT CLO have several properties which may be of potential benefit for soil improvement, such as plant nutrients and stabilised organic matter. Conversely, there are a number of potential environmental and health risks associated with compost that is spread on soil. However, there is considerable uncertainty about their exact nature and magnitude. The reasons for this uncertainty include the variability of the input materials used to produce the compost. It is important to remember that source segregation does not eliminate risk, it merely reduces it. Table 3.1 summarise the main qualitative hazards associated with different potential composting feedstocks, with a specific focus upon plastics.

Table 3.1 Summary of main hazards associated with different potential composting feedstocks (Entec 2004)

Feedstock	Feedstock	Animal/human pathogens	Plant pathogens	Metals	Toxic organic chemicals	Weeds	Phytotox
Food waste	Vegetable processing	L	M	L	L	L	L
	Food factory	M	L	L	L	L	L
	Catering	H	L	L	L	L	L
Animal wastes	Slurries & manure	H	L	M	L	L	L
	Blood	H	L	M	L	L	L
	Gut contents	H	L	M	L	L	L
Municipal wastes	Green waste	L	M	L	M	M	M
	Mixed domestic	M	L	H	H	L	L
	Source-separated	M	L	M	M	L	L
Industrial	Paper mill	L	L	M	M	L	L
	Pharmaceutical	L	L	L	M	L	M
	Forestry	L	M	L	L	M	M
	Wood processing	L	L	L	M	L	M
	Packaging	L	L	L	M	L	M
Construction & (wood waste)	Demolition	L	L	M	M	L	M
Sewage	Septic tank and cesspit	H	L	H	M	L	M
	Sewage sludge	H	L	M	M	L	M

Higher levels of contamination contained in MBT output (relative to other types of compost produced from separately collected green waste) limits the end use for MBT outputs. A study carried out for DG Environment in 2004 showed that the levels of metals from material derived from MBT plants can be two to 10 times greater than those present in compost derived from source-separated green waste (Amlinger *et al.* 2004).

There is no uniform system for setting compost standards across the EU. However, almost all EU-15 countries have statutory standards, with just a few relying on voluntary standards (e.g. UK and Sweden). Most countries differentiate between two compost classes, but a few such as Austria and Netherlands apply three standards.

Very few include consideration of non-source-segregated MSW outputs. The standards can differ quite significantly from one country to another. While the seven most common metals are typically covered by the standards, the limit values vary and some countries apply limit values for additional substances. For example, Denmark, Germany and Sweden have limit values for dioxins, PCBs, PAHs, nonylphenols and DEHP. In 2004, waste treated via MBT was sent to landfill in Austria, to incineration in Germany and used as low grade compost in France, Italy and Spain. Portugal also composts MSW for land-spreading but plans to phase out composting of mixed waste by 2016 (COWI 2004).

Quite a few countries have based compost standards on the limit values set out in the EU Sewage Sludge Directive (86/278/EC). Other policies that have influenced these limit values are the Strategy on Soil Protection (COM(2002)179 final) and the Nitrate Directive (91/676/EEC).

All national compost standards include compost sanitisation criteria for human pathogens and occasionally for plant pathogens. These criteria may refer to the product (e.g. absence of *Salmonella*, absence or low levels of faecal coliforms, etc.), the process (i.e. setting a minimum period for which the compost should maintain a temperature higher than a designated level) or both.

The EC has proposed to adopt compost quality criteria under the end-of-waste provision put forward for the Waste Framework Directive.

3.1 Austria

Waste management in Austria is heavily influenced by the Landfill Ordinance of 2004 which sets high quality standards for landfilled residues. Altogether there are 17 plants for the MBT of household waste in operation throughout Austria, with capacity to treat 686,350 tonnes per year (www.umweltbundesamt.at, accessed 5 June 2008). In Austria, since the Ordinance on the Separate Collection of Organic Waste ('Separate Collection Ordinance') came into force in 1995, there has been an established culture of production of source-separated compost. This has since been complemented by the Ordinance on Quality Requirements of Composts from Wastes 2001 ('Compost Ordinance'), which defines quality standards for three classes of compost.

Compost ceases to be waste and is suitable for use in accordance with the Austrian regulations when it is documented in the producer's records that a certain batch belongs to: a) one of the compost quality classes and, b) that it is suitable for at least one of the use areas as specified by the Ordinance. The compost classes are defined by different metal threshold values and by the input materials that may be used for them. The highest standard is A+; the middle class, A, is typically achievable by using source-separated biowaste as feedstock, and it can be used for agriculture. MBT residues fall under Class B and are deemed suitable for land reclamation and landfill cover or, in some cases, for the manufacture of biofilters. Additional limit values for organic pollutants are set for compost from mixed MSW. The producer or importer of Class B compost must declare the potential users and receivers to the authorities as well as the amounts of compost actually delivered. It is important to note that compost from mixed MSW cannot be marketed freely, but instead must be transferred from the producer to the user (Juniper 2005c, JRC 2007). Composts from sewage sludge and bark have their own legal designations (JRC 2007).

As well as the restrictions applied through the class designation, other criteria may also be applied for certain use areas. For example, compost not meeting the Compost Ordinance criteria may still be used in agriculture, but this requires a specific permit according to waste law. In Austria, soil protection is regulated at Länder (state) level. The Länder may directly use the provisions of the Austrian Federal Compost Ordinance; they may further specify them or introduce deviating provisions, e.g. amounts of a certain class of compost that can be applied to land; or they may specify their own compost classes.

In addition to soil protection law, the use of compost on land must also comply with the water protection legislation. If the amount of nitrogen applied exceeds certain limits, a specific permit is required for spreading compost, whether it is considered a product (i.e. compliant with the Compost Ordinance) or a waste.

3.2 Belgium

The marketing of fertilisers, soil improvers and growing media is regulated for the whole of Belgium by a royal decree of the Federal Ministry of Agriculture. It does not consider compost, which requires derogations (temporary permits) to be issued by the Ministry. In practice these derogations are given for one year if the compost to be used fulfils the standards established by the Ministry.

In addition, the use of compost in Flanders requires approval by the Public Waste Agency of Flanders (OVAM). OVAM has specified maximum metal loadings (g ha^{-1} yr^{-1}) and also requires quality control of the compost by VLACO (Flemish compost organisation). VLACO is a co-operation between OVAM, communities, private compost producers, some cities and compost distributors and producers of growing media and soil conditioning products.

Compost in Belgium is either produced from separately collected green waste (organic waste generated by gardening and maintenance in public and private gardens, in parks and along roadsides) or from biowaste or 'vegetable, fruit and garden waste'. There is only one statutory compost class in Belgium which is defined by product quality criteria. The metal concentration limit values are all stricter than the Austrian Class B values , but do not show a comparable pattern to any of the other Austrian compost classes. Generally, only green compost can be used in growing media.

3.3 France

Regulations in France do not differentiate between materials manufactured from source-separated biowaste and those from MSW. If residues meet the statutory 'NF U44-051' standard for urban compost, they can be marketed as compost with no restrictions. The standard includes thresholds for concentrations of metals and some organic compounds as well as microbiological and agronomic parameters. Except for sewage sludge, which has a separate standard, no input materials are excluded. Composts that comply with the requirements of the standard are considered products and not wastes.

There are also quality assurance agreements between individual compost producers and the agricultural associations of the users, although these are not well developed (Coppin 2006). The metals threshold values of NF U44-051 are, in most cases, less strict than the standards applied to compost for general use in countries that rely substantially on separate collection of putrescible wastes. They are, however, stricter than the Class B Austrian compost quality. A new generation of MSW compost treatment plants is being introduced in France with the aim of achieving compliance with NF U44-051 for compost from MSW without source separation of putrescible wastes (JRC 2007).

3.4 Germany

In Germany a combination of statutory (Biowaste Ordinance) and voluntary (BGK Quality Assurance) standards enables the marketing and use of higher quality, source-separated composts. However, material derived from MSW is not considered under either of these instruments. There are no limit values for organic pollutants, based on the rationale that the restriction on input materials limits their presence. Farmers who produce compost for use on their own land are not bound by the Biowaste Ordinance. There are two classes of compost distinguished by the limit values set for metal concentrations. The volumes of compost that may be applied on land are different for these two compost classes, being either 20 or 30 tonnes per hectare in three years. The use of compost is prohibited where background levels of metals already exceed certain concentration thresholds. The Biowaste Ordinance requires traceability of the compost and the organic wastes used. The compost producer has to give a ‘delivery note’ to the user and at the same time must send copies to the competent authority as well as to the agricultural authority responsible for the receiving plot of land.

The German Compost Quality Assurance Organisation (BGK) has established general quality standards and a nationwide system for external monitoring of composting and compost. The success of this scheme has allowed competent authorities to introduce a number of exemptions under the Biowaste Ordinance for members of the scheme, such as reduced requirements for laboratory testing and external controls.

3.5 Italy

In Italy, the National Law on Fertilizers (Law 748/84) was updated via Decree 27/3/98, which classifies compost as a ‘product’, provided that it is derived from source-separated organic materials. However, the Draft Decree on Bio-stabilised Materials (2000) determines two classes of ‘biostabilizzato’ or ‘stabilised organic fraction’ (SOF). Both may come from MSW. However, first class SOF must meet stricter limit values for metals, plastics and inerts which may be present in the material, with permitting decisions made at regional level. It is not clear if limits for organic micropollutants are available. The metal concentration thresholds are less strict than in the corresponding standards for source-separated wastes in Belgium, Germany, the Netherlands and Austria. However, they are stricter than the French standards defining product quality. First class SOF is regarded as suitable for daily landfill cover or land reclamation applications, while second class SOF is deemed only suitable for landfill and must conform to biodegradability restrictions (Juniper 2005c).

3.6 Netherlands

There are two classes of compost, standard and high quality, defined by limit values for the concentrations of metals and their minimum content of organic matter. The limit values for standard compost are amongst the strictest in Europe, but the high quality requirements are hardly ever reached in practice (JRC 2007). Compost can be produced from ‘green waste’ or ‘vegetable, fruit and green waste’. Limitations on loads for use on land are specified in tonnes as dry matter as well as kg of phosphorus per hectare per year. For green waste and high quality composts, only the phosphate limitation applies. There is also a voluntary quality assurance and certification scheme.

3.7 Spain

In Spain the 1998 Ordinance on Fertilising and Related Products offers some general characteristics on compost quality, but does not exclude composts derived from MSW. Furthermore, like Italy, Spain has adopted a national Action Plan under UN-CCD to combat the threat of desertification. The resulting significant requirement for organic matter means that there is pressure to continue to allow mixed waste compost to be used as a soil improver. However, the Spanish Ministry of Agriculture has prepared new draft regulations on biological treatment of waste which are designed to bring standards into line with the now defunct Biowaste Directive, and the Junta de Residuos in Catalunya has also prepared a bill on compost standards (Draft of Decree on Compost Quality).

Spain established in 2000 a National Plan for Waste, “Plan Nacional de Residuos (2000-2006)”. Spain, following the EU directives, has developed national and territorial plans that confront the problems of MSW and notes compost production as the main alternative to disposal of organics to landfill.

Outlined in the section dedicated to the National Plan for Composting, the main goals for composting are:

- the development of an agricultural quality standard for compost;
- the foundation of a National Centre for Compost;
- the creation of incentives for research programmes and promotion of compost;
- the promotion of voluntary agreements to increase the demand for, and use of, compost.

Compost quality is briefly discussed in the law on fertilisers (Real Decreto 824/2005, sobre Productos Fertilizantes) where, for the first time, different kinds of compost are established according to their quality in terms of metals concentrations (Class A, B and C). The thresholds for Class A correspond to the requirements for composts from household waste that may be used in organic agriculture. Classes B and C have lower limit values which are less strict than in corresponding standards for source-separated wastes in Belgium, Germany, the Netherlands and Austria. There are no limit values for organic pollutants, but there are limit values for the presence of *Salmonella* and *Escherichia coli*.

The amount that may be applied on land is limited for Class C products to five tonnes of dry mass per hectare per year. Compost is also regulated in the Spanish Law 10/1998 21 April, on Waste (Ley 10/1998 21 Abril, de Residuos) and in the Royal Decree 1310/1990 29 October 1990, regarding the use of sludge from waste water treatment plants in the agrarian sector (RD 1310/1990 29 Octubre).

3.8 Greece

The standards on compost quality refer to mixed MSW CLO, but there is currently no market for CLO. Greek legislation imposes compost specifications with agricultural end use in mind and these are based on EU Directive 86/278/EEC concerning the use of sewage sludge in agriculture. In addition any CLO meeting these standards would be subject to a limitation on the number of applications on fields over a period of years in order to avoid bioaccumulation of metals. Farmers are reluctant to use CLO and prefer to use the commercial products they have always applied (Lasaridi *et al.* 2006, Skoulaxinou *et al.* 2004).

3.9 UK

In the UK there is no specific regulation for compost. There is a publicly available product specification for composted materials (BSI PAS 100) and a certification scheme by the Composting Association. MBT derived composts do not qualify for certification under PAS 100 (which requires that compost products must be derived solely from source-separated material to be certified). The general metal limits of BSI PAS 100 are stricter than the French NF U44-051 limits but less strict than the standards for source-separated wastes in Belgium, Germany, the Netherlands and Austria. The provenance of the PAS 100 standards is not clear and like other Member

States (Lasaridi *et al.* 2006), reversion to the sewage sludge limits (DoE 1986) for receiving soils is the 'default' position.

A formalised quality control procedure for the production and use of quality compost from source-segregated biodegradable waste, based on BSI PAS 100, was launched last year (WRAP 2007). The only contaminants for which limit values are available are metals.

3.10 Summary

There are two main parameters used to define compost types:

- the waste fractions used to produce the compost;
- threshold values for contaminant (exclusively just metal) concentrations.

There are basically three types of compost produced from MSW and used in considerable amounts in several Member States. They can be characterised as follows:

i. Compost from separately collected green waste with or without strict metal limits.
Some countries regard limits as unnecessary given the nature of the source material. This is considered a product if complying with the corresponding national standards and quality assurance in Austria, Italy, the Netherlands, Belgium and France (with lower metal limits), and is not regulated in Denmark. In Germany it is still regarded as a waste product, although with reduced waste-related obligations and restrictions if quality certified. The UK also regards these outputs as waste. The main uses for this type of compost are as a soil improver in agriculture and as a component of growing media.

ii. Compost from separately collected biological waste (including green waste and kitchen waste) with strict metal limits.
This is considered a product if complying with the corresponding national standards and quality assurance in Austria, Italy (the biological MSW fraction may be mixed with up to 35 per cent sewage sludge), the Netherlands and Belgium. It is considered a waste in Germany (with reduced waste-related obligations and restrictions if quality certified). The main uses for this type of compost are as a soil improver or organic fertiliser in agriculture (although it typically has higher salinity and nutrient contents than compost from green waste).

iii. Compost from mixed MSW (no source separation) with lower metal limits.
This is considered a product if complying with the corresponding national standards in Spain and Austria. However, in Austria there are tight restrictions on use (e.g. it cannot be used on soil for feed or feed production). In a number of countries, including Italy and France, this type of compost may be used on soil as waste requiring special permits.

Table 3.2 provides a summary of the metal concentration limits set by various countries for different classes of compost outputs and Table 3.3 provides the current limits as set out in the Sewage Sludge Directive.

Table 3.2 Metal concentration limits for compost classes in EU countries.

	Metal concentration limits (mg kg^{-1} dry matter)								
	Cd	**Cr (total)**	**Cr(VI)**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**	**As**
Austria (Class A)	1	70	-	150	0.7	60	120	500	-
Austria (Class B)	3	250	-	500	3	100	200	1800	-
Belgium	1.5	70	-	90	1	20	120	300	-
Denmark+	0.4	-	-	1000	0.8	30	120	4000	25
France (NF U44-051)	3	120	-	300	2	60	180	600	18
Germany (Class II)	1.5	70	-	100	1	50	150	400	-
Greece				500		200	500	2000	
Italy (Class I)	1.5	-	0.5	150	1.5	50	140	500	-
Italy (Class II)	10	500	10	600	10	200	500	2500	10
Netherlands	1	50	-	60	0.3	20	100	200	15
Spain (Class A)	0.7	70		70	0.4	25	45	200	
Spain (Class B)	22	250		300	1.5	90	150	500	
Spain (Class C)	3	300	-	400	2.5	100	200	1000	-
UK (PAS 100)	1.5	100	-	200	1	50	200	400	-
Organic farming+	0.7	70	-	70	0.4	60	120	500	-

+ Metal limits not regulated for green waste

Table 3.3 Metal limits for biosolids according to the Sewage Sludge Directive (86/278/EEC).

Metal	**Limit values for concentrations of metals in soil (mg kg^{-1})**	**Limit values for metals concentrations in biosolids for use in agriculture (mg kg^{-1})**	**Limit values of metals which may be added annually to agricultural land, based on a 10 year average (kg ha^{-1} yr^{-1})**
Cadmium	1 - 3	20 -40	0.15
Copper	50 - 140	1000 -1750	12
Nickel	30 - 75	300 - 400	3
Lead	50 – 300	750 – 1200	15
Zinc	150 – 300	2500 – 4000	30
Mercury	1 – 1.5	16 - 25	0.1

4 Summary

MBT is a generic term covering a range of waste treatment options for mixed and municipal waste feedstocks across the EU. The relatively recent revival of MBT technologies has been driven almost exclusively through EU-wide legislative initiatives aimed at reducing the amount of biodegradable material going to landfill and increasing re-use of this material in a sustainable way. However, end uses for MBT outputs vary greatly across the EU, with only the southern EU Member States routinely applying CLO to agricultural land.

There are significant differences in how countries are treating municipal waste. Netherlands, Denmark, Sweden and Belgium have achieved low landfilling rates. These countries have a substantial level of incineration together with a high level of material recovery. Incineration is also widely used in Luxembourg and France. Austria, the Netherlands, Belgium, Sweden, Denmark and Germany have already met the Landfill Directive's BMW reduction target for 2016. France has reached its target for 2009, and Italy and Finland have reached the target for 2006. Greece and the UK and the EU-10 have until 2010 to meet the first reduction target. In Germany the main material recovery operation is recycling, whereas Austria has the highest composting rates in Europe at around 40 per cent.

CLO are treated differently across Member States. For example, Germany uses MBT mostly as a pre-treatment prior to landfill (partially to stabilise biodegradable MSW) and does not use CLO on land. In France there are 70 plants processing 1.9 million tonnes per annum of MSW with CLO outputs used on land. Other countries also have substantial MBT capacities and use some of the CLO output on land, including agricultural land, such as Spain which has a treatment capacity of 3 million tonnes per annum (tpa) and Italy which has a treatment capacity of 11.7 million tpa (Bardos 2007).

There are currently no EU-wide standards for the assessment of CLO. National regulatory frameworks for CLO use and associated product standards, whether voluntary or statutory, are highly variable. Some of these standards are taken directly from existing regimes, especially for sewage sludge, while others have been derived for use with general composts; some (but very few) have been derived specifically for CLO. Generally the standards always include limits for physical contaminants, microbial pathogens and metals.

Few, if any, national limits or standards for composts contain values for many organic micropollutants. This situation is especially relevant for CLO, as with sewages sludges, in that recent evidence suggests that too little effort has been invested in assessing risks from xenobiotic organic compounds, such as pharmaceuticals, fragrances, surfactants, and ingredients in household cleaning products, likely to be found in waste streams destined for land (Eriksson *et al.* 2008).

5 Conclusions

After initial interest in composting MSW, there appears to have been a move away from producing a compost end product, due to uncertainties about the economic market for this output. However, whilst it is generally thought that composts from source-segregated materials are likely to make higher quality composts, there still remains interest in composting mechanically segregated MSW feedstocks as part of an MBT process.

The physical, chemical and biological characteristics of mechanically segregated MSW are variable from plant to plant, with residual inerts and metal content remaining in the refined compost to differing degrees. There is evidence that the best quality composts made from mechanically segregated MSW are similar in trace element content to the lower quality composts produced from source-segregated materials.

The benefit of composts arises from their organic matter and plant nutrient content. Concerns about the level of trace elements and inerts have limited the use of composts made from mechanically segregated fractions of MSW. An emerging concern is the possible elevated levels of toxic organic compounds for which there is currently limited data on both household waste source material and the final CLO product (Amlinger *et al.* 2004).

For MBT CLO to gain acceptance there needs to be clear quality criteria, sampling regimes and guidance on the most suitable MBT processes (separation technologies).

The marketability of compost is affected by the concentration of contaminants. Some facilities in Europe are processing mixed waste (composting and anaerobic digestion) with the intent of recovering a product suitable for landscaping and for use by the agricultural sector. The ad hoc and piecemeal standards for applying compost to farmlands make the use of MBT CLO difficult for this purpose. There remains significant uncertainty about potential environmental and human health risks associated with the use of these products on agricultural land. This uncertainty is due in part to the paucity of temporal, physical and chemical product data and also the absence of a robust evaluation of potential human health and environmental effects for numerous potentially hazardous xenobiotic organic compounds.

The development of MBT technologies and the potential recycling of CLO to agricultural land provide a challenge to both regulators and operators to ensure sustainable environmental use. Public perception of risk and heightened awareness of health-related issues from agricultural re-use of wastes requires a robust evidence-based approach if public confidence is to be fostered and markets are to develop.

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Annex I: Use and application of MBT Outputs

Whilst it is evident that compost from non-source-segregated MSW has been applied to agricultural land in a number of countries, it has not been possible to obtain data on the amount that has been applied, or where and for what specific purpose. Concerns about loading soil with metals and the high salt content of MSW compost has led to many field studies taking place, particularly in southern Europe where application of mixed waste outputs has been highest.

A primary benefit of MSW compost is the high organic matter content and low bulk density. A survey of MSW compost reported that on average, 20 per cent of the total carbon (C) in MSW compost was organic C, eight per cent carbonate C and 71 per cent residual C which may have included organic C components (He *et al.* 1995). The quality of MSW compost will depend on many factors including:

- composting facility design;
- feedstock source and proportions used;
- composting procedure;
- length of maturation.

Furthermore, when MSW compost is applied to different types of field soils, differences are seen in plant response. Hargreaves *et al.* (2008) carried out a literature review of field studies using MSW compost and their findings can be summarised as follows:

- composting of MSW has the potential to be a beneficial recycling tool;
- its safe use in agriculture depends on the production of good quality compost – specifically, compost that is mature and sufficiently low in metals and salt content;
- the best method of reducing metal content and improving quality of MSW compost is early source separation, preferably before or at curbside collection;
- sewage sludge should not be added to the compost at any point since it will raise the metal content of the final product;
- bioavailability should be addressed in the guideline limits, however, more research is required before this could be done with sufficient accuracy;
- the physical and chemical makeup of MSW compost tends to shift with time and source and thus careful yearly monitoring of MSW compost quality would be required.

Below is a brief summary of the MBT facilities and other compost outputs for several EU countries.However, it has not been possible to establish a complete picture of any of the countries for which information has been collated.

Austria

Sixteen plants were in operation in 2006 for the MBT of municipal waste and other waste with an authorised total capacity of approximately 873,000 tonnes (including other lines of treatment, e.g. composting). For the year 2005 the total waste delivered to the MBT plants consisted of approximately 482,000 t of municipal household waste and commercial waste similar to household waste (residual waste), 51,000 t of commercial waste, 34,000 t of sewage sludge, 30,000 t of bulky waste and 12,500 t of other waste (Lebensministerium 2006). A large proportion of the output from these facilities was sent to landfill. Inputs of source-separated biowaste at MBT composting facilities go to agricultural markets for use as compost (SLR 2005). An example of this is the Linz MBT facility which has a total capacity of 84 kTpa of which 14kTpa is source-separated biowaste.

France

Estimated compost production in France is 3.5 - 4 million tonnes, with approximately 2.2 million tonnes coming from industrial and municipal waste. These composts have been mainly used in agriculture, where those derived from MSW have been given away rather than sold. The higher grade composts are sold in the main for vegetable crops and organic farming. The farmland area in France is 28 million hectares and composts are spread on less than one per cent annually.

Coppin (2006) estimated the distribution of compost use across different sectors as follows:

- Landscaping, 15 per cent;
- Hobby gardening, 5 per cent;
- Agriculture,
    - Organic farming, 6 per cent;
    - Vegetable crops, 4 per cent;
    - Vineyards, 12 per cent;
    - Other crops, 58 per cent.

After an initial increase in the production of MSW composts in the 1980s and 1990s the number of plants decreased due to the poor compost quality, i.e. high concentrations of impurities and metals. A new generation of MSW composting plants aimed at producing compost meeting the NF U44-051 compulsory standard are now being built. One such plant that has achieved this objective is located in Launay Lantic, Brittany, which started its new process in 2004; its compost is used for vegetable crops in the surrounding area.

Italy

In 2004 MBT facilities managed about nine million tonnes of MSW with 20 per cent of these processes dedicated to the production of compost, while the other 80 per cent produced a large variety of materials such as bio-stabilized, dry fraction and RDF (Rigamonti 2006). The amount of quality compost produced in Italy is estimated at 850,000-900,000 tonnes per year. About 50 per cent of this high end compost is utilized on agricultural fields to improve soil organic carbon content. This practice has replaced the use of manure, which as a traditional agricultural practice has almost completely disappeared in Italy (Tittarelli and Centemero, undated).

Portugal

In 2002 MSW entering the composting plants came from mixed collection systems and represented 8 per cent of MSW generated, i.e. 400,412 tonnes. From these, 49,114 tonnes of compost was produced. The metal content in the compost produced by the organic wastes recovery plant at Setubal was above the limit values proposed for Portuguese Standard Class III and the European Directive proposal for Class II and is shown in Table A.1 (Magrinho *et al.* 2006). This plant is considered to be one of the better facilities and it is likely that the compost generated at this plant has been applied to agricultural land.

Table A.1 Metal concentrations (mg kg^{-1}) in the compost produced in the Setubal organic waste recovery plant (Magrinho *et al.* 2006)

Metal	Compost at Setubal Plant (measured)	Portuguese Standard proposal for Class III	EU Directive proposal for Class II
Cadmium	1-4	5	1.5
Lead	165-654	400	150
Copper	134-539	500	150
Chromium	20-172	300	150
Mercury	0.2-1.5	5	1
Nickel	24-113	200	75
Zinc	210-721	1500	400

Spain

Two large MBT facilities (capacity 300 and 265 kTpa) were operating in the City of Barcelona in 2004, with a third under construction. Following anaerobic digestion, there is a composting stage which produces three grades of compost, two of which are largely used in agriculture, with the third lower quality material used in landfill remediation (SLR 2005).

The main regions producing compost in 2006 were La Rioja, Murcia, Baleares and Valencia. Compost produced at MSW plants goes mainly to agriculture (95 per cent) with the balance going to horticulture (2 per cent) and landscaping (3 per cent). Source-separated compost has a greater market in horticulture (15 per cent) and landscaping (5 per cent) with the balance going to agriculture (ATEGRUS 2007).

Spain has added composted urban waste to agricultural land for a number of years (García-Gil *et al.* 2000). The composted organic fraction of an MSW produced from domestic waste was assessed as a soil amendment material for restoring the canopy cover of a degraded soil in an area in central Spain (Walter *et al.* 2006). A single application at four rates (0, 40, 80 and 120 t ha^{-1} dry weight) of MSW was surface-applied to the calcareous soil and the effects on soil properties and the native plant community were monitored for five years. Soil N, P and K levels increased significantly after application. SOC increased with the highest MSW rate applied (120 t ha^{-1}) and remained higher for the entire study period. In the other MSW-treated plots, differences were small and inconsistent. Although metal concentrations (Zn, Pb, Ni and Cu) increased in the MSW-treated soils compared to controls, the levels remained below the maximum allowed by Spanish legislation. The changes in metal content over the study period are shown in the Table A.2 below. Total aerial plant biomass yields and canopy cover increased with MSW amendment compared to the control treatment and plant production increased three-fold in the amended plots in the first years, but declined subsequently, although no consistent trends were observed. Native plant species richness decreased slightly with increasing MSW rates and plant communities showed a reduction in perennial species and an increase in annual species after five years. Plant tissue N, P, K, Zn and Cu levels generally increased with the MSW rate. The authors suggested 80 Mg ha^{-1} as an application rate.

Table A.2 Effect of MSW rate on soil metal content (Walter et al 2006)

	Treatment Mg ha-1	Zn	Pb	Cd	Ni	Cr	Cu
MSW as applied		334	193	1.48	21.6	32.9	203
1998	0	22.7	34.3	0.52	6.4	14.3	5.38
	40	23.1	37.1	0.53	6.85	14.6	8.13
	80	33.5	46.4	0.56	7.13	18.6	12.5
	120	33.4	44.0	0.57	6.88	18.2	15.7
1999	0	22.7	39.7	0.46	7.55	10.5	6.59
	40	35.6	46.9	0.48	8.46	11.5	15.2
	80	42.8	48.6	0.54	8.55	12.8	19.9
	120	49.3	55.3	0.53	9.75	14.3	23.0
2000	0	24.5	34.8	0.40	5.99	9.81	6.02
	40	32.0	39.3	0.42	6.16	10.0	11.6
	80	39.8	42.9	0.43	6.68	10.1	13.5
	120	42.9	44.8	0.45	9.19	12.3	17.6
2001	0	26.2	38.8	0.44	7.2	10.5	6.41
	40	37.2	43.2	0.47	7.85	11.2	15.0
	80	48.2	50.1	0.58	9.26	12.3	19.4
	120	58.4	52.3	0.57	10.7	15.3	26.3
2002	0	23.3	39.6	0.5	7.44	10.7	6.46
	40	50.6	51.2	0.53	9.54	10.9	16.1
	80	50.9	56.0	0.57	10.9	13.2	19.5
	120	52.7	58.8	0.63	12.1	13.6	24.6

Recent evidence from a glasshouse horticulture trial in southern Spain showed that following three years of using non-source-separated MSW compost at an annual application rate of 21t ha^{-1}, metal levels in the soil had risen significantly compared to an untreated control (Madrid *et al.* 2007). Further, by the third year of the trial and the third application of compost Diethylene triamine pentaacetic acid (DTPA) extractable metals had also risen significantly, suggesting that metals added with compost were more available than native metals in soils. The metal content in the MSW compost applied was below the legal limits for compost that could be applied to agricultural soils at that time and the metal contents in the soil at the end of the trial were not high enough to classify the soil as polluted (see Table A.3 below). No effects were seen on the crops. Despite these results, the authors suggest that lower compost limits are required to protect intensive horticultural production systems that utilize composts from municipal sources.

Table A.3 Metal content of MSW compost (Madrid *et al.* 2007)

Metal	Compost 1 Mean (± SD) mg kg-1	Compost 2 Mean ± SD) mg kg-1	Compost 3 Mean ± SD) mg kg-1	Maximum Limit of metals in compost (mg kg^{-1})
Cu	128 (21)	312 (58)	244 (10)	450
Zn	261 (30)	494 (78)	512 (16)	1100
Ni	23 (5)	54 (8)	39 (5)	120
Pb	98 (18)	172 (43)	203 (19)	300

Turkey

A year long study, between spring 2004 and winter 2005, characterized the solid waste stream in the Municipality of Gümüşhane, Turkey (Nas and Bayrum in press). The

MSW collection method in Gümüşhane is kerbside collection and generally consists of wastes generated from residential and commercial areas, parks and streets, and is not source-separated. In this study the following were determined and evaluated: percentage of components and specific weight of the MWS, the composting parameters (moisture content, TOC, total N and pH), organic matter content (OMC), calorific value and metal concentrations of the compostable wastes sorted from the mixed MSW. Approximately 30 per cent of the MSW generated was compostable wastes, which is lower than the 50 per cent average for Turkey. In Gümüşhane, people utilize the organic fraction, especially food remains and grass clippings, as feed for their animals. The yearly mean moisture content, OMC, C/N ration and pH were 78 per cent, 92.1 per cent, 21.6/1 and 4.73, respectively. Approximately 24 per cent of the MSW consisted of recyclable materials. The metal content is given in the Table A.4 below. Chromium, copper, nickel, lead, iron and manganese concentrations reached highest levels in spring. Overall, metal content was not considered to be high since few industrial and hazardous solid wastes are generated in Gümüşhane.

Table A.4 Seasonal metal content levels in MSW, Gümüşhane, Turkey

Metal	Spring		Summer	Autumn	Winter
Mg kg^{-1} dm	Range	Average	Average	Average	Average
Cd	<0.5-0.87	<0.5	<0.5	0.84	0.51
Cr	5.1-338.7	50.96	14.7	10.72	11.08
Cu	4.89-87.83	15.47	6.57	11.57	6.12
Ni	0.65-10.36	6.11	2.5	4.51	5.28
Pb	1.3-23.4	9.02	3.71	6.08	7.83
Zn	16.7-135.7	49.88	26.75	43.3	31.7
Fe	708-11818	3095	999	1190	1646
Mn	35.0-480.4	139.6	40	38.87	57.38
Co	<0.6	<0.6	<0.6	<0.6	<0.6

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