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Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

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Development of an Industry-Led Quality Standard for Source-Separated Biodegradable Material Derived Compost

STRIVE

Environmental Protection Agency Programme

2007-2013

Strategy for Science, Technology and Innovation

Comhshaol, Oidhreacht agus Rialtas Áitiúil
Environment, Heritage and Local Government

Environmental Protection Agency

The Environmental Protection Agency (EPA) is a statutory body responsible for protecting the environment in Ireland. We regulate and police activities that might otherwise cause pollution. We ensure there is solid information on environmental trends so that necessary actions are taken. Our priorities are protecting the Irish environment and ensuring that development is sustainable.

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EPA STRIVE Programme 2007–2013

Development of an Industry-Led Quality Standard for Source-Separated Biodegradable Material Derived Compost

(2006-WRM-DS-26)

STRIVE Report

Prepared for the Environmental Protection Agency

by

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The EPA STRIVE Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in relation to environmental protection. These reports are intended as contributions to the necessary debate on the protection of the environment.

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Executive Summary

1 Purpose

The purpose of this project is to offer a quality standard for compost derived from source-separated biodegradable materials in order to promote the development of markets for compost-based products on the island of Ireland as well as to protect human, plant, soil and animal health. Other EU countries with an established composting infrastructure show that successful biowaste treatment must include meeting quality standards in order to control the use and guarantee the environmental safety of compost application within agricultural, horticultural and landscaping industries, by home gardeners and local authorities. The establishment of an industry-based compost standard supports the long-term growth of the industry and ensures product satisfaction to maintain consumer confidence. The market development process will lead to the overall expansion of the composting industry in Ireland by developing other means of revenue generation apart from gate fees. This, in turn, contributes to developing a sustainable compost industry, that can effectively compete on a cost basis with other waste management technologies, and disposal facilities such as mechanical biological treatment (MBT), incineration and/or landfilling.

In 2006, the Department of the Environment, Heritage and Local Government (DoEHLG) published the *National Strategy on Biodegradable Waste* (NSBW), which outlines a plan for reaching Ireland's landfill diversion targets. As a part of this plan, the establishment of a compost quality standard was identified as a necessity to develop and stimulate markets for compost-based products. The following year, the DoEHLG published the Market Development Group 5-year programme to support the development of stable outlets and robust markets for recycled materials and goods manufactured from recovered waste materials, including compost. Recently, at European level, guidance was published by the European Joint Research Centre in its *End of Waste Criteria* report[1], which outlines the criteria to consider in a compost standard. This report provided good direction for the development of the Irish industry standard.

2 Objective

The overall objective of this project was to collate the compost quality databases from Irish compost samples and compare them with databases and standards from other European countries to develop an Irish industry compost standard for source-separated biodegradable materials.

3 Summary of Methodology

The following points outline the methodology used for developing the compost standard:

1. Firstly, the results of laboratory analysis of 256 samples of compost from Irish compost facilities were collated.

2. Statistical analysis using the mean, median and percentile techniques was conducted on the database.

3. Using the 90th percentile analysis method, upper limits standards were determined for heavy metals, pathogens and impurities.

4. Data on stability parameters were examined and compost samples from different compost facilities were tested using a new method for stability to create a stability standard.

5. The criteria for a compost standard outlined in the *End of Waste Criteria* report were examined and the standard amended to take cognisance of missing criteria such as a minimum requirement of organic matter content in compost.

6. A draft standard was presented to representatives from compost facilities and the wider stakeholders in two separate consultative workshops.

1. Anonymous, 2008. *End of Waste Criteria*, Draft Report. European Commission Joint Research Centre, Seville, Spain.

7. Based on comments from the two workshops and feedback from the project's steering committee, a final report was produced for acceptance by the steering committee.

4 Proposed Industry Compost Quality Standard for Ireland

Table 1 presents the proposed industry compost quality standard for Ireland.

Table 1. Proposed industry compost quality standard for Ireland.

Heavy metals (mg/kg dry matter)	
Mercury	0.4
Cadmium	1.3
Nickel	56
Chromium	92
Copper	149
Zinc	397
Lead	149
Pathogens	
***Salmonella* (in 25 g)**	0
***Escherichia coli* (cfu/g fresh mass)**	1,000
Impurities	
Total glass, metal and plastic >2 mm diameter by weight	0.5%
Stability	
Oxygen uptake rate (mmol O_2/kg organic solids/h)	13*
Organic matter	
Organic matter (% dry weight)	20% Minimum

*By 2014 there is an objective of a limit value of 10 mmol O_2/kg organic solids/h.

5 Conclusions and Recommendations

1. The industry standard in this project should eventually be developed into a national standard.

2. The industry standard developed by this project should be considered as a 'preliminary standard' and should be updated as required during the transitional period while source-separated collection schemes and their corresponding treatment facilities are being established, resulting in the gradual improvement of quality management within the composting industry.

3. This standard should not be restricted to compost derived from biodegradable municipal waste (BMW) materials alone (landscape and garden materials, food, clean wood, paper and cardboard), as this does not reflect the wide range of acceptable feedstocks permitted by waste permits and licences of composting facilities in Ireland. It is recommended that the industry standard be widened to include the source-separated 'miscellaneous' category and other source-separated biodegradable materials that are individually assessed to be suitable, such as animal manures, food processing residuals, fish scraps and brewery or distillery residuals.

4. Around this industry standard or national standard, a voluntary compost quality assurance scheme (QAS) should be developed and audited by an independent third party. A QAS system would control the composting process of facilities, including acceptable raw materials, independent sample taking and the analysis of the compost by approved laboratories. In addition, a QAS organisation would evaluate the results independently and award a quality label or certificate to successful facilities.

5. It is recommended that a list of acceptable source-separated biodegradable material and bulking agents, to which the standard applies, be developed in a future QAS project. The list should be easily updatable as circumstances warrant and as agreed upon by industry and regulatory agencies. This list should be cognisant of the criteria outlined in the *End of Waste Criteria* report.

6. In the future QAS, sample frequency, sampling methods and the allowed deviation from the compost quality standard would be determined and standardised throughout Ireland.

7. Research should be conducted with the oxygen uptake rate (OUR) stability test to determine limit values of the OUR test for different end uses of compost.

8. The data collated on the parameters that are mainly related to the beneficial qualities of the compost products (e.g. nutrients) should be used to develop guidelines on the use of compost in different applications.

9. The compost standard developed in this project is for compost manufactured from source-separated biodegradable materials. This standard is not applicable to MBT outputs.

1 Introduction

This project was carried out as part of the Environmental Research Technological Development and Innovation (ERTDI) Programme of the National Development Plan 2000–2006. The project, titled *Development of an Industry-Led Quality Standard for Source-Separated Biodegradable Material Derived Compost* (2006-WRM-DS-26), is primarily a desktop study that was supplemented with additional laboratory analysis.

1.1 Background

A report on compost standards from around the world was produced by the UK government organisation WRAP (Waste & Resources Action Programme) (Hogg *et al.,* 2002). It found that across the world, and in particular in Europe, there has been an increase in the importance of sustainable biodegradable municipal waste (BMW) management. Source separation of BMW for composting is now well established in countries such as Austria, Germany, the Netherlands, Luxembourg, Italy, Belgium and Denmark. Other countries in the EU are only now developing separate collection of BMW as a way of meeting their landfill diversion targets established in the EU Landfill Directive to reduce greenhouse gas emissions from landfills, which in turn helps decrease the impacts of climate change.

In the EU, it is estimated that up to 40 million tonnes of compost can be produced from BMW, which not only diverts huge amounts of BMW away from potentially polluting landfills but also creates compost products that have many positive environmental effects. The use of compost as an organic fertiliser can, to some extent, replace the use of mineral fertilisers. If compost is used to reduce the need for mineral fertilisers, some of the environmental stresses of fertiliser production can be avoided. These include greenhouse gas emissions (N_2O and energy-related emissions) and the impacts of phosphate extraction. The use of compost over longer periods of time and a lower use of mineral fertilisers also reduce nitrate leaching. The nutrient run-off from compost into ground and surface water is usually very low (Anonymous, 2008b).

In the proposed EU Soils Directive, humus from compost will play a key role as a means of replacing depleted organic matter in impoverished soils. Humus also stores some of the biomass carbon contained in compost in soil for longer periods of time. This carbon can be considered to be sequestered (locked up in soils) from the atmosphere, thus countering global warming and climate change. Composting and the production and use of compost can have a major role in helping Ireland implement its National Climate Change Strategy.

Other potential positive environmental effects that have been attributed to compost include:

- Reduced soil erosion
- Good-quality compost may help to control soil-borne plant diseases and thus reduce the need for applying agricultural chemicals
- Improved water retention, thus reducing the need for irrigation and also the risk of flooding
- The improved soil structure reduces the need to work the soil with agricultural machinery, hence reducing fuel usage.

When compost can be used instead of peat in growing media, there is also a lower global warming potential, mainly because peat degrades relatively quickly under the release of 'long-cycle' CO_2 when exposed to oxygen. Replacing peat also plays a part in the protection of the biodiversity and landscape of peatlands (Anonymous, 2008b).

Apart from the industry quality standard developed in this project, there are already a number of legal controls in place which prevent the misuse of compost. They are:

(a) Due to the required compliance with the Nitrates Regulations (SI 378 of 2006), it is most likely that phosphorus will be a limiting factor for soil application rather than the heavy metal content of the compost.

(b) The industry compost standard developed in this project has the same pathogen standards as the Animal By-Product (ABP) Regulations (SI 252 and SI 253 of 2008).

(c) The Environmental Protection Agency (EPA) and local authorities have quality standards specified within their licences and permits for all the composting sites in Ireland. The standards (metals, pathogens and impurities) developed in the industry standard do not have more relaxed limits than current quality standards within waste licences and waste permits for composting sites.

Outside the EU, from North America to New Zealand, source-separation initiatives are being established. For all countries embracing composting as a way to better manage BMW materials, the key behind building a sustainable material recovery infrastructure is stable and well-developed markets for compost-based products. The foundation on which these markets are established rests on developing end-user confidence in the products. This cannot be accomplished without the development of a compost quality standard.

In 2006, as a way to implement the requirements of the EU Landfill Directive, the Government published *The National Strategy on Biodegradable Waste* (NSBW), which outlines a plan for reaching Ireland's landfill diversion targets. As a part of this plan, several initiatives are identified to develop and stimulate markets for compost-based products, including:

- The establishment of a compost quality standard
- The development of a compost quality assurance scheme (QAS)
- The creation of a peat replacement policy (conserve peat by using compost instead), and
- The development of high-value markets for compost.

The following year, the Department of Environment, Heritage and Local Government's (DoEHLG) Market Development Group published a 5-year programme to support the development of stable outlets and robust markets for recycled materials and goods manufactured from recovered waste materials, including compost. This programme provides the co-ordination and resources necessary to implement the compost marketing initiatives outlined in the NSBW. Recently, consultants were appointed to implement this plan.

On 31 July 2008, in the framework of the NSBW, the Minister for the Environment, Heritage and Local Government circulated Circular WPPR 17/08 on the *Implementation of Segregated "Brown Bin" Collection for Biowaste and Home Composting*. In order to meet the challenge of the diversion targets set for 2010 to reduce the amount of biodegradable waste going to landfill, local authorities are requested to take actions that include:

1. Roll-out of 'brown-bin' source-segregated collection schemes for organic materials
2. Segregation of commercial biodegradable materials with a view to foreseen nationwide obligations
3. Promote home composting.

Circular WPPR 17/08 will act as a driver for organic materials to be processed into quality compost products. Following on from Circular WPPR 17/08, the DoEHLG has prepared draft legislation (Waste Management (Food Waste) Regulations 2009) on source separation of commercial organic material from a variety of sources.

Further impetus for conducting this project includes:

- The Joint Research Centre of the European Commission recently published a draft report (*End of Waste Criteria*[1]) (Anonymous, 2008b) on determining the criteria of a compost standard. This defines when compost produced from waste is no longer a waste but a product.
- Previous research sponsored by the EPA in a published document titled *Assessments and*

1. The proposals developed in the report are merely research-based showcases and do not necessarily represent the position of the European Commission.

Evaluation of Outlets of Compost Produced from Municipal Waste (Van der Werf *et al.,* 2002) recommends the development of Irish compost standards.

- The protection of human, plant, soil and animal health to protect Ireland's vibrant agricultural industry.
- The Food Safety Authority of Ireland (FSAI) recently published (Anonymous, 2008a) a report on the land spreading of organic materials in Ireland. In relation to compost, it concluded that adequate treatment of organic materials makes a significant contribution to the safe use of these materials. However, the absence of standards for composting is a matter of concern for the FSAI. One of the key recommendations of the FSAI report is that compost standards should be developed and implemented at a national level.
- The establishment of sustainable high-value compost markets to increase revenue for compost facilities offsets operational costs and can help lower the gate fees charged by compost sites. If a lot of poor-quality compost is 'dumped' on the market, it could lead to a bad reputation for the entire industry and discourage compost use, regardless of its quality, and hamper the development of markets for high-quality compost-based products.
- By stimulating demand for high-quality compost, there is a greater incentive to build new or expand existing composting facilities which in turn helps Ireland meet its EU Landfill Directive targets for BMW.

The composting industry in Ireland has grown rapidly over the last few years. A survey conducted for this project determined that in 2006 within the Republic of Ireland there were 36 operating composting sites that processed source-separated materials (the separate collection of biowaste in such a way as to avoid the different waste fractions or waste components from being mixed, combined or contaminated with other potentially polluting wastes, products or non-biodegradable materials). In 2006, the 36 sites composted approximately 162,606 t of biodegradable materials[2] and from this, produced 79,783 t of finished compost. The main markets (based on the 79,783 t) for this compost were application to agricultural land (33%), use in peat dilution (21%), landscaping (16%) and horticulture (14%), as landfill cover (11%), and for other uses (5%). As the composting industry is projected to grow quickly to meet Ireland's obligation under the EU Landfill Directive, the quantity of compost products is expected to expand significantly. This increased availability of compost warrants a compost quality standard to maintain user confidence in compost-based products, which will result in the further development and expansion of markets for these products.

1.2 Study Purpose and Objective

The purpose of this industry standard research project is to offer a set of quality standards for compost derived from source-separated biodegradable materials in order to promote the development of markets for compost-based products as well as to protect human, plant, soil and animal health. Other EU countries with an established composting infrastructure show that successful biowaste treatment must include the meeting of quality standards in order to control the use and guarantee the environmental safety of compost application within agricultural, horticultural and landscaping industries, by home gardeners and local authorities. The establishment of an industry-based compost standard supports the long-term growth of the industry and ensures product satisfaction to maintain consumer confidence. The market development process will lead to the overall expansion of the composting industry in Ireland by developing other means of revenue generation apart from gate fees. This, in turn, will contribute to developing a sustainable compost industry that can effectively compete on a cost basis with other waste management technologies and disposal facilities such as mechanical biological treatment (MBT), incineration and/or landfilling.

The overall objective of this project was to collate the compost quality databases from Irish compost samples, and compare them with databases and standards from other European countries in order to develop an Irish industry compost standard for source-separated biodegradable materials.

2. This does not include facilities processing non-source-separated materials.

2 Methodology

Compost quality can be assessed in many different ways to meet the needs of various stakeholders within the composting industry, from regulators that oversee compost facility operations to the end-users of compost-based products, such as farmers, landscapers, horticulturalists, greenkeepers, local authorities and hobby gardeners. In addition, compost facility operators can use various compost assessment tools or tests to improve their material-handling procedures and compost-processing techniques in order to increase the quality of their finished products. The testing of certain compost properties is determined by the needs of specific stakeholders. Regulators want to be assured that the compost product is safe to use, and will not spread disease or pollute soil and water resources that may end up in our drinking water or food. Compost facility operators want to know if the compost is ready to be sold as a product, that it is fit for purpose, and whether it is safe to use and not polluting in order to limit their potential liability. Users, on the other hand, need to be assured that there are no health and safety concerns, but their main needs centre around the product's beneficial properties in relation to plant growth, such as its pH, electrical conductivity (EC), stability and available nutrients. The main focus of this study was to determine the appropriate parameters to be included in the compost quality standard. Looking at the overlapping needs of regulators, facility operators and end-users, the common thread for all stakeholders is a standard that protects the health of soil, plants, animals and humans, and one that prevents pollution of soil and water resources.

A review of compost quality standards across Europe illustrates that different countries require the use of different parameters, but the common denominator throughout all of these standards is the testing of compost for four essential parameters:

1. Heavy metals,
2. Pathogens,
3. Impurities, and
4. Stability.

In addition to these another parameter to consider is:

5. The *End of Waste Criteria* report recommended that an 'organic matter' limit be included to prevent compost with heavy metals from being diluted with sand to reduce the metal content.

Heavy metals are analysed to prevent soil and water pollution. Pathogen testing is required to protect soil, plant, animal and human health. Impurity testing helps prevent the laundering of waste, the pollution of soils with non-biodegradable waste and the spread of wind-blown litter. Stability testing helps ensure that compost is fit for purpose and will not pollute soil and water resources. A minimum organic matter content prevents compost with a high metal content from being diluted by mixing inorganic materials such as sand to reduce the metal content. As can be seen, these five parameters serve everyone's need to protect health and prevent pollution. Therefore, these are the parameters that are included in the compost quality standard for Ireland.

Other parameters are mainly related to the beneficial qualities of the compost product and can be considered qualities that can be used to help market the compost and assure its safety to end-users, and include:

- Total nitrogen (N)
- Phosphorous (P) and potassium (K)
- Available nutrients such as N, P and K
- Total carbon
- Carbon to nitrogen ratio
- Ammonium to nitrate ratio
- Electrical conductivity (salts)

- pH or the measure of the product's acidity or alkalinity
- Bulk density
- Moisture
- Particle size
- Organic contaminants, such as polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs).

Different compost facilities produce a variety of compost-based products to meet the specific needs of their customers, and compost quality can vary greatly. Various grades of compost can be used for different purposes. For example, lower-grade compost can be used as landfill cover or to help restore brownfield sites while higher-quality compost can be used to amend agricultural soils or can be an ingredient in topsoils, potting mixes or top dressings for turf. Therefore, it would be counterproductive to set compost quality standards for the 'marketing' parameters listed immediately above.

While this study primarily focuses on heavy metal, pathogen, impurity and stability parameters within the Irish database of compost quality parameters to develop an industry compost quality standard for Ireland, the compost quality database also contains testing results for other 'marketing'-based parameters (e.g. nutrients, pH, etc.). These are analysed and discussed as well. This information could be used in the development of fact sheets on compost use for various markets (e.g. landscaping) and the information used to develop a set of compost property guidelines. For example, compost to be used in landscaping should have a pH range of x, an EC range of y, etc.

As well as determining the parameters in a compost quality standard, there are a number of aspects to be considered for determining the rationale for setting suitable limit values. Some aspects are best addressed by very low (i.e. strict) limits; others are reasons for not being too strict. Therefore, a balance is needed that best resolves the different demands in an acceptable way (Anonymous, 2008b).

On the one hand, strict limits are required to meet the following demands:

- There should be no overall adverse human, plant, soil and animal health impact from the use of compost.
- Environmental impacts from the misuse of compost should be within tolerable limits.
- The limits should promote the production of high-quality compost and prevent a relaxation of quality standard.
- The limits should be an effective barrier to diluting more contaminated wastes with compost.

On the other hand:

- The benefits of compost use should not be sacrificed because of disproportionate risk aversion.
- Limits should not be so strict that they disrupt current best practice of compost production from biodegradable materials.
- Composting as a recycling route for biodegradable materials should not be blocked by demanding unrealistic and unnecessarily strict limits (Anonymous, 2008b).

2.1 Collation of the Irish Compost Database

Initially, this project envisaged developing a standard for compost derived from BMW, typically those materials found in household and business waste, including garden and landscape materials, food, wood, paper and cardboard. Source-separated collection systems for organic municipal waste have not been widely established in Ireland and, as a result, there is currently not a sufficient amount of material available for composting facilities. A survey conducted by Cré as part of this study found that Irish compost sites typically process other source-separated biodegradable materials such as animal manures, industrial food processing plant residuals, fish scraps and spent grain from breweries and distilleries in addition to BMW materials. Therefore, a compost quality standard for only BMW would not reflect the diversity of materials processed by the Irish compost industry nor be representative of the acceptable feedstocks listed in waste permits and operating licenses of composting facilities across Ireland. Accordingly, the scope of this project has been widened to include compost derived from source-separated biodegradable materials including BMW. In other words, this study recommends one industry compost standard for a variety of source-separated materials including source-separated green waste (SSGW), source-separated biowaste (SSBW) consisting of green waste, food and non-recyclable paper, and other miscellaneous source-separated biodegradable materials (MISC) including manures, sludges, food processing residuals, spent grain, etc.

This project collated the compost analysis databases from Bord na Móna (BnM) Horticulture Ltd and University College Cork's BioTreat™. The database for this project is based on 256 compost samples from compost facilities in Ireland which were analysed from 2000 to 2006 by BnM and from 2001 to 2003 by BioTreat™. The BioTreat™ data are older than the BnM data. In addition, stability testing of compost from six composting sites was conducted in the spring of 2008. These results are included in this project. Although 92 samples were collated from outputs derived from non-source-separated (NSS) materials and are included in Appendix A for reference only, a standard for NSS materials is not being proposed by this project.

It must be noted that this study does have limitations in relation to the Irish compost database, including:

1. Samples were not taken using a standard sampling method. The way in which samples are taken can affect the test results.

2. There was no way in which the laboratory could verify the source of samples (i.e. source separated or NSS). This potential source of error has to be considered when interpreting the results. When a compost QAS has been developed and is operating in Ireland, there will be significantly more control over sample taking.

3. Another limitation in the database is that not every compost sample was tested for all compost parameters. This was because customers for compost products did not require the testing for the full range of parameters.

The database consolidated for this project was categorised into the following classes based on the feedstock used to produce the compost:

1. **SSGW:** 102 samples from 11 compost facilities

2. **SSBW:** 126 samples from 17 compost facilities

3. **MISC:** 28 samples from 13 facilities.

Each of the headings (SSGW, SSBW and MISC) had some or all of the following parameters collated:

- **Heavy metals** (mercury, chromium, copper, lead, zinc, cadmium, nickel, arsenic and selenium)
- **Pathogens** (total coliforms, *Escherichia coli* and *Salmonella*)
- **Impurities** (plastic, glass and metal)
- **Nutrients** (total carbon, total nitrogen, total potassium, total phosphorus, CAT (calcium chloride DPTA[3] extractant = CAT) nitrogen, CAT potassium, CAT phosphorus, nitrate and ammonium)
- **pH and electrical conductivity**
- **Organic contaminants** (PCBs and PAHs)
- **Physical** (organic matter, particle size, moisture, bulk density, dry bulk density and stones)
- **Stability** (self-heating test, growth trials, cress test and specific oxygen uptake rate (SOUR)).

2.2 Statistical Analysis

John Burrow, a statistician with the Institute of Technology, Sligo, was hired as a consultant on statistical matters related to this project. Statistical analysis of individual parameters in the Irish compost database was conducted using Microsoft Excel. Upon review of the data, it was apparent that there was extremely high variation of test results across all individual compost parameters.

3. DPTA, diethylenetriaminepentaacetic acid.

The use of percentile analysis was recommended to help establish upper limits for compost testing parameters. A percentile is a value on a scale of 1 to 100 that indicates the percentage distribution that is equal to or below a threshold or boundary value. The purpose of this project is to establish an upper limit to serve as a 'not-to-exceed' standard, thus posing the question: where does one set the percentile to achieve this limit? After these analyses, a 90th percentile point was recommended, providing a level where the abnormally high measurements would be discounted or rejected. Furthermore, 90th percentiles are recommended by Amlinger *et al.* (2004) in a study commissioned by the European Commission, the only comprehensive reference on this subject within Europe.

Because the number of samples for metals in each of the three categories (SSGW, SSBW and MISC) varied considerably and the standard is cognisant of the feedstocks in all three, it was decided to take into consideration all the data by calculating a weighted 90th percentile for the three categories. This percentile was calculated as follows: each of the 90th percentile category values was multiplied by the corresponding number of samples and the calculated sum of the three categories was divided by the total sample numbers.

In addition, within this report regression equations and correlation coefficients were used to compare various data sets and analytical methods.

2.3 Comparison of the Irish Database with Other Databases and Standards

The Irish database was compared with other European databases and the compost quality standards adopted by other European countries.

2.3.1 Database

The Irish compost database of heavy metals was compared with:

1. The UK PAS 100 quality assurance database
2. The German quality assurance database managed by the BGK (Bundesgutegemeinschaft Kompost e.V.)
3. Other databases in peer-reviewed publications.

2.3.2 Standards

The Irish compost database was also compared with compost standards adopted by other countries in Europe, the draft European Compost Network QAS, the compost standard proposed in the EU's 2nd draft of the *Technical Working Document for the Biological Treatment of Biowaste*, and the draft *End of Waste Criteria* standard.

2.4 Method for Determining the Irish Industry Standard

2.4.1 Heavy metals

The proposed standard for heavy metals was formulated by using the recommendations of Amlinger *et al.* (2004), which advocate that countries that are starting source-separated collection schemes use the 90th percentile of the country's compost testing database and add a further 50%. The weighted 90th percentile of the three categories (SSGW, SSBW and MISC) was calculated and used[4]. This weighted 90th percentile plus 50% method was used to determine the heavy metal limits.

The calculated figures were then rounded off to the nearest whole number to create the proposed Irish standard for heavy metals. Consideration was also given to the standard proposed in the EU 2nd draft of the *Technical Working Document for the Biological Treatment of Biowaste* and in the *End of Waste Criteria* report (Anonymous, 2008b).

2.4.2 Pathogens

The proposed standard for pathogens in compost was determined by comparing the levels and parameters in the Irish database with those in other standards in Europe and, most importantly, in reference to compliance with the Irish ABP Regulations.

2.4.3 Impurities

The proposed limit value for impurities was determined by comparing the levels in the Irish database with those of other standards in Europe and by considering the standard proposed in the EU 2nd draft of the *Technical Working Document for the Biological*

4. A small number of compost samples results (three from the SSBW copper, two in the SSGW lead and three in the MISC zinc) were excluded from the database as they were extreme outliers and skewed the overall data.

Treatment of Biowaste and in the *End of Waste Criteria* report (Anonymous, 2008b).

2.4.4 Stability

Firstly, stability methods vary widely within Europe with different countries requiring the use of different tests including the self-heating test, the dynamic respiration index (DRI) and the SOUR. Some of these tests are complex, expensive and time consuming. However, a new method of stability testing using the oxygen uptake rate (OUR) is being considered as a standard European-wide test by CEN (Comité Européen de Normalisation – European Committee for Standardisation). On the basis of OUR test results obtained from three countries (Belgium, the Netherlands and Ireland) and a recent analysis of compost samples from Irish composting sites in 2008 correlating with compost processing time and self-heating test results, the OUR stability test was determined to be an accurate and appropriate method for measuring stability. Therefore, this study proposes using an OUR standard to measure compost stability.

2.4.5 Organic matter

The proposed limit for organic matter was determined by comparing the recommended limit value in the *End of Waste Criteria* report with the organic matter limits in the Irish compost quality database.

3 Results

The database of results is large and for the purposes of this report, the entire database is presented in Appendix A. Therefore, this section presents a short written summary of each parameter in the database, starting with the parameters that are of most importance in relation to the proposed industry standard and then finishing with a discussion of parameters that are more important to marketing specific compost-based products.

In this chapter, the tables from the database on heavy metals, pathogens and impurities are shown and a standard is proposed based on these results. Stability results (self-heating, cress and SOUR) in the database are also discussed. However, the stability standard is derived from other sources of data, as described in Section 2.4 and in Chapter 4.

3.1 Heavy Metals

Generally composts made from SSBW, SSGW or MISC materials have similar heavy metal contents when considering the 90th percentile. However, the compost made from SSBW materials gives a slightly higher value for mercury, nickel and chromium, while that made from MISC materials follows the same trend for zinc and copper. The source-separated materials had a much lower concentration of heavy metals (Table 3.1) than in NSS material, which has very high levels of all these heavy metals (see Appendix A). This trend is similar to that found by Amlinger *et al.* (2004) and Genevini *et al.* (1997) where the heavy metal contents are 2–10 times higher in NSS material than in compost made from source-separated materials. The number of samples in each database (Table 3.1) varies considerably. The majority of the samples are from 2004 to 2006.

Table 3.2 shows that the Irish database has similar values to other countries' databases when comparing the median and 90th percentile figures.

In Table 3.3, the mean metal content in the Irish database was compared with published data (Fischer and Jauch, 1991; Genevini *et al.*, 1997; Tomkins, 2006) on compost from source-separated biowaste and green waste.

When comparing data sets with different units or significantly different means, one should use the coefficient of variation[5] for comparison instead of the standard deviation. The coefficient of variation is a useful statistic for comparing the degree of variation from one data series to another, even if the means are drastically different from each other. Table 3.4 shows the percentage coefficient variation of the Irish database of compost made from SSGW as being the same or more homogeneous than the UK PAS[6] (mostly green waste) and the Fischer and Jauch (1991) data from Germany (Genevini *et al.*, 1997), which were also mostly from green-waste-derived composts.

Table 3.5 shows the draft European Compost Network (ECN) QAS for a European Quality Standard (Anonymous, 2006a) which used rounded values from the survey of Amlinger *et al.* (2004). The now defunct draft of the technical working document on biowaste shows the two classes of standards. SI 148 of 1998 is the Irish legislation on the metal content in sewage sludge for use in agriculture. It shows that the concentration of metals in sewage sludge allowed for land application is much higher than adopted compost standards. SI 148 is likely to change in a few years given that the current EU Sewage Sludge Directive is under review. However, it provides a useful benchmark for comparison purposes.

As shown in Table 3.6, in most countries, there is only one class of compost standard, though Austria has three. However, in actuality, over 90% of the compost sector in Austria produces only one class of compost (Class A). There are variations on the limit values for metal content in compost between the standards of different countries.

Table 3.7 shows the industry standard recommended

5. Standard deviation divided by the mean, multiplied by 100.
6. UK PAS 100 is the UK compost quality assurance scheme.

Table 3.1. Heavy metal content in Irish compost quality database. (SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials).

Parameter	SSGW	SSBW	MISC
Cadmium mg/kg dry matter			
Maximum	1.72	1.18	2.61
Minimum	0.26	0.11	0.11
Median	0.52	0.50	0.61
Mean	0.64	0.53	0.79
Standard deviation	0.32	0.21	0.49
Percentile (75th)	0.76	0.67	0.81
Percentile (90th)	0.96	0.77	1.06
Number of samples	40	99	24
Weighted 90th percentile of the three databases		0.86	
Mercury mg/kg dry matter			
Maximum	0.30	0.58	0.20
Minimum	0.05	0.05	0.05
Median	0.10	0.08	0.07
Mean	0.11	0.14	0.08
Standard deviation	0.05	0.13	0.04
Percentile (75th)	0.13	0.18	0.11
Percentile (90th)	0.15	0.30	0.12
Number of samples	42	99	24
Weighted 90th percentile of the three databases		0.24	
Lead mg/kg dry matter			
Maximum	183.00	132.00	126.00
Minimum	12.10	0.37	1.75
Median	73.65	45.1	12.50
Mean	78.94	50.40	27.49
Standard deviation	34.48	33.37	35.29
Percentile (75th)	88.68	71.08	26.10
Percentile (90th)	113.70	100.00	71.50
Number of samples	38*	82	21
Weighted 90th percentile of the three databases		99.65	
Nickel mg/kg dry matter			
Maximum	51.50	105.00	88.15
Minimum	2.70	1.49	0.50
Median	32.30	19.00	11.20
Mean	27.94	21.65	16.97
Standard deviation	11.10	17.17	19.80
Percentile (75th)	35.10	26.68	19.10
Percentile (90th)	37.70	39.05	30.47
Number of samples	41	100	24
Weighted 90th percentile of the three databases		37.47	

Table 3.1 *contd.*

Parameter	SSGW	SSBW	MISC
Zinc mg/kg dry matter			
Maximum	306.00	354.00	334.00
Minimum	3.90	5.20	9.04
Median	182.00	173.00	106.00
Mean	174.61	168.73	135.00
Standard deviation	57.49	77.21	88.88
Percentile (75th)	197.75	210.00	191
Percentile (90th)	253.30	266.00	277
Number of samples	38	87	21*
Weighted 90th percentile of the three databases		264.53	
Copper mg/kg dry matter			
Maximum	119.00	129.00	149.00
Minimum	32.20	2.50	1.68
Median	61.40	64.15	48.60
Mean	62.94	60.96	58.15
Standard deviation	18.92	30.59	42.57
Percentile (75th)	72.70	79.70	85.50
Percentile (90th)	81.73	100.00	105.20
Number of samples	42	86*	23
Weighted 90th percentile of the three databases		99.38	
Chromium mg/kg dry matter			
Maximum	66.90	100.00	200.00
Minimum	11.00	1.95	1.30
Median	39.50	26.50	17.95
Mean	39.40	31.37	32.63
Standard deviation	15.06	24.44	39.94
Percentile (75th)	50.10	45.95	43.93
Percentile (90th)	57.00	64.92	54.36
Number of samples	41	102	24
Weighted 90th percentile of the three databases		61.46	

*Some data were excluded as they were extreme outliers and skewed the overall data. The following numbers of samples were excluded: three from the SSBW copper category, two in the SSGW lead category and three in the MISC zinc category.

in this project regarding the metal content in compost developed in this study. This recommended standard should be a preliminary standard during the transitional period between the implementation of separate collection schemes and the adoption of a QAS. After the stage of improved compost quality and management, the standard should be updated as required with regard to European compost standard developments.

The standards for metals in Table 3.7 were determined by calculating the weighted 90th percentile of the three categories (SSGW, SSBW and MISC) and adding 50% according to the methodology proposed by Amlinger *et*

Table 3.2. Median (Med) and 90th percentile (90%) of heavy metals (mg/kg dry matter) in biowaste compost of national databases (AT, DE, ES, FR, IT, NL and UK)* and statistically weighted figures from Amlinger *et al.* (2004) and the comparison from the Irish, PAS 100 and BGK (mean values).

		AT	DE	ES	FR	IT	NL	UK	Weighted total	Ireland			PAS[2]	BGK[3]
										SSGW	SSBW	MISC		
No. of samples		552–582	17,800	48–56	25–26	22–97	624–627	60	19,280–19,352	38–42[1]	82–102[1]	21–24[1]	285	3000
Cadmium	**Med**	0.38	0.50	1.50	0.86	1.00	0.46	0.51	0.5	0.52	0.50	0.61	0.65	0.45
	90%	0.70	0.87	1.50	1.90	2.00	0.70	1.09	0.87	0.96	0.77	1.06	0.95	
Chromium	**Med**	24.10	23.00	27.00	30.20	41.70	19.00	16.00	23	39.50	26.50	17.95	18.40	22.61
	90%	40.80	40.00	55.00	69.10	120.60	27.00	31.40	39.9	57.00	64.92	54.36	33.44	
Copper	**Med**	47.40	45.00	88.00	89.00	98.50	32.00	50.00	45.1	61.40	64.15	48.60	44.00	49.54
	90%	74.00	74.00	137.80	162.60	159.00	48.00	90.50	73.9	81.73	100.00	105.20	72.24	
Mercury	**Med**	0.16	0.14	0.20	0.50	0.24	0.11	0.20	0.14	0.10	0.08	0.07	0.16	0.13
	90%	0.35	0.30	0.49	1.38	0.97	0.20	0.40	0.3	0.15	0.30	0.12	0.37	
Nickel	**Med**	19.00	14.00	23.00	20.20	31.70	9.30	18.00	14.1	32.30	19.00	11.20	14.75	14.55
	90%	33.00	27.00	56.00	54.60	75.90	12.00	29.20	27	37.70	39.05	30.47	23.00	
Lead	**Med**	37.00	49.00	55.50	93.00	69.70	67.00	102.00	49.6	73.94	45.10	12.50	100.00	41.61
	90%	69.10	87.00	105.50	187.50	150.90	99.50	159.40	87.6	113.70	100.00	71.50	159.50	
Zinc	**Med**	174.00	183.00	202.00	242.00	256.00	169.00	186.00	183	182.00	173.00	106.00	183.00	177.55
	90%	254.00	277.00	306.00	560.00	502.00	201.00	322.00	276	253.30	266.00	277.00	251.00	

*AT, Austria; DE, Germany; ES, Spain; FR, France; IT, Italy, NL, the Netherlands; UK, United Kingdom. SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials.

[1]Irish database for Cd–Zn sample numbers.

[2]PAS database is from Anonymous (2006b). The PAS database is mostly based on green waste compost.

[3]The Bundesgutegemeinschaft Kompost e.V. (BGK) data are the mean values, not the median values.

Table 3.3. Mean metal content (mg/kg dry matter) in Irish compost compared with other peer-reviewed publications.

	Irish database			Tomkins (2006)	Fischer and Jauch (1991)	Genevini *et al.* (1997)	
	SSGW	SSBW	MISC	SSBW	SSGW	SSBW	SSGW
Mercury	0.11	0.14	0.08	no data	0.18	no data	no data
Cadmium	0.64	0.53	0.79	0.51	0.37	1.22	1.12
Nickel	27.94	21.65	16.97	61.0	12.0	17.5	22.6
Chromium	39.40	31.37	32.63	31.0	25.2	34.9	30.3
Copper	62.94	60.96	58.15	42	31.0	72.4	78.9
Zinc	174.6	168.73	135.00	129.7	108.0	326.6	246.1
Lead	78.94	50.40	27.49	69.67	51.0	147.4	70.2
No. of samples	38–42	82–102	21–24	12	52–64	16	20–24

SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials.

Table 3.4. Percentage coefficient of variation between compost databases.

Metals	PAS database	SSGW Ireland	SSBW Ireland	Fischer and Jauch (1991)
Mercury	74	45	93	72
Cadmium	35	50	40	68
Nickel	45	40	79	37
Chromium	97	38	78	83
Copper	54	30	50	46
Zinc	38	33	46	54
Lead	91	44	66	63

SSGW, source-separated green waste; SSBW, source-separated biowaste.

Table 3.5. Heavy metal standards (mg/kg dry matter) from the draft European Compost Network (ECN) Quality Assurance Scheme (QAS), 2nd draft *Technical Working Document Biological Treatment of Biowaste* and SI 148 of 1998 – *Use of Sewage Sludge in Agriculture*.

	ECN QAS	2nd Draft Biowaste		SI 148 of 1998
		Class 1	Class 2	
Mercury	0.45	0.5	1	16
Cadmium	1.3	0.7	1.5	20
Nickel	40	50	75	300
Chromium	60	100	150	no data
Copper	110	100	150	1,000
Zinc	400	200	400	2,500
Lead	130	100	150	750

Table 3.6. Lists of heavy metal limit values of statutory and voluntary standards in EU Member States (Barth *et al.*, 2008).

Country	Regulation	Type of standard	Cadmium	Chromium (total)	Chromium (VI)	Copper	Mercury	Nickel	Lead	Zinc	Arsenic
Austria	Compost Ordinance: Class A+ (organic farming)	Statutory Decree	0.7	70	–	70	0.4	25	45	200	–
	Compost Ordinance: Class A (agriculture, hobby gardening)		1	70	–	150	0,7	60	120	500	–
	Compost Ordinance: Quality Class B limit value (landscaping, reclamation) (guide value)		3	250	–	500 (400)	3	100	200	1,800 (1,200)	–
Belgium	Royal Decree, 7 Jan 1998	Statutory Decree	1.5	70	–	90	1	20	120	300	–
Czech Republic	Use for agricultural land (Group one)	Statutory	2	100	–	100	1	50	100	300	10
Denmark	Statutory Order No. 49; Compost after 1 Jun 2000	Statutory Decree	0.8	–	–	1,000	0.8	30	120/60 for private gardens	4,000	25
Finland	Fertiliser Regulation (12/07)	Statutory Decree	1.5	300	–	600	1	100	150	1,500	25
Germany	Quality Assurance RAL GZ – compost/digestion	Voluntary QAS	1.5	100	–	100	1	50	150	400	–
	Biowaste Ordinance (Class I)	Statutory Decree	1	70	–	70	0.7	35	100	300	–
	Biowaste Ordinance (Class II)		1.5	100	–	100	1	50	150	400	–
Hungary	Statutory Rule 36/2006 (V.18)	Statutory Co: 50; Se: 5	2	100	–	100	1	50	100	–	10
Ireland	Licensing of treatment plants as agreed with EPA, stabilised biowaste	Statutory	5	600	–	600	5	150	500	1500	–
	(Class I compost)	Statutory	0.7	100	–	100	0.5	50	100	200	–
	(Class II compost)	Statutory	1.5	150	–	150	1	75	150	400	–
Italy	Law on fertilisers (L. 748/84, and 03/98 and 217/06) for BWC/GC/SSC	Statutory Decree	1.5	–	0.5	230	1.5	100	140	500	–
Luxembourg	Licensing for plants		1.5	100	–	100	1	50	150	400	–

Table 3.6 ***contd***

Country	Regulation	Type of standard	Cadmium	Chromium (total)	Chromium (VI)	Copper	Mercury	Nickel	Lead	Zinc	Arsenic
Lithuania	Regulation on sewage sludge Category I (LAND 20/2005)	Statutory	1.5	140		75	1	50	140	300	–
Latvia	Regulation on licensing of waste treatment plants (no. 413/23.5.2006) – not a specific compost regulation	Statutory = threshold between waste/product	3			600	2	100	150	1,500	50
The Netherlands	BOOM Compost	Terminated with 31 Dec 2007	1	50	–	60	0.3	20	100	200	15
	BOOM Very clean compost		0.7	50	–	25	0.2	10	65	75	5
	Amended National Fertiliser Act from 2008	Statutory	1	50		90	0.3	20	100	290	15
Poland	Organic fertilisers	Statutory	5	250		400	3	50	250	1,500	–
Spain											
	Class A	Statutory	0.7	70	0	70	0.4	25	45	200	–
	Class B		2	250	0	300	1.5	90	150	500	–
	Class C		3	300	0	400	2.5	100	200	1000	–
Sweden	Guideline values of QAS	Voluntary	1	100	–	100	1	50	100	300	
Slovakia	Industrial Standard STN 46 5735 Class 1	Voluntary (Mo: 5)	2	100		100	1	50	100	300	10
	Class 2	Voluntary (Mo: 20)	20	300		400	1.5	70	300	600	20
UK	UKROFS fertil. organic farming, 'Composted household waste'	Statutory (EC Reg. 2092/91)	0.7	70	0	70	0.4	25	45	200	_
UK	Standard: PAS 100	Voluntary	1.5	100	–	200	1	50	200	400	–

QAS, Quality Assurance Scheme; BWC, biowaste compost; GC, green compost; SSC, source-separated compost; BOOM, The Dutch Fertilizer and Organic Fertilizer Act: "Besluit en gebruik Overige Meststoffen; UKROFS, United Kingdom Register of Organic Food Standards.

Table 3.7. Weighted 90th percentile (mg/kg dry matter) from the Irish database plus 50% and the industry standard for heavy metal content in compost made from source-separated biodegradable materials.

	Weighted 90th percentile of the three categories (SSGW, SSBW and MISC)	Weighted 90th percentile plus 50%	Industry standard
Mercury	0.24	0.35	0.4
Cadmium	0.86	1.29	1.3
Nickel	37.47	56.20	56
Chromium	61.46	92.19	92
Copper	99.38	149.07	149
Zinc	264.53	396.80	397
Lead	99.65	149.47	149

SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials.

al. (2004). The calculated figures were then rounded off to the nearest whole number to produce the proposed Irish industry standard.

3.2 Pathogens

Table 3.8 presents a summary of the pathogen content results in the Irish compost database, while Table 3.9 presents pathogen standards used in other standards and regulations. Table 3.10 presents the industry standard recommended in this project for pathogens (see also Chapter 4).

The total coliform content result (Table 3.8) in the Irish database is not a routine parameter requirement under compost quality analysis. Of the limited number of results (all 12 from one facility), four samples had very high results, which skewed the overall results. Total coliforms are not good pathogen indicator species, as they are ubiquitous in the environment. With regard to being consistent with the ABP regulations, it is therefore proposed that total coliforms as a parameter should not be part of the proposed standard for pathogens.

The proposed standard for pathogens in compost was determined by comparing the levels and parameters in the Irish database with other standards in Europe and with the ABP Regulations. The results (Table 3.8) showed no *Salmonella* in the compost samples from SSGW, SSBW and MISC materials. This study proposes that no *Salmonella* be present in the 25-g sample, as the standard.

The level of *Escherichia coli* in the samples of compost made from SSBW (460 cfu/g) and MISC (7 cfu/g) materials were below the ABP standard of 1,000 cfu/g. There was a 90th percentile value of 1,100 cfu/g of *E. coli* in the SSGW compost, which is slightly higher than in the compost made from SSBW and MISC materials. It is proposed that a limit of 1,000 cfu/g of *E. coli* be adopted as a standard (Table 3.10). This proposed limit is consistent with the ABP Regulations in Ireland. The ABP Regulations give compost operators an option of testing for *E. coli* or *Enterococaceae;* however, because *Enterococaceae* is ubiquitous in the environment, operators test for *E. coli* instead of *Enterococaceae.* Based on this it was decided to use *E. coli* as the parameter in the industry standard.

3.3 Impurities

This section presents the impurities content of the Irish compost database (Table 3.11). Plastic, glass and metals (Table 3.11) are low or non-existent in the Irish database in compost derived from SSGW, SSBW and MISC materials. Tables 3.11 and 3.12 show that there were no impurities in the MISC composts tested and that there was a low impurity content in compost made from source-separated material.

Table 3.8. Pathogen content in Irish compost quality database.

Parameter	SSGW	SSBW	MISC
Total coliforms (cfu/g)			
Maximum	124,000	350,000	No data
Minimum	3	3	No data
Median	1030	3,700	No data
Mean	30,408	32,381	No data
Standard deviation	46,669	80,242	No data
Percentile (75th)	62,750	21,000	No data
Percentile (90th)	93,500	52,800	No data
Number of samples	12	19	No data
***Escherichia coli* (cfu/g fresh mass)**			
Maximum	5,600	1,110	1,100
Minimum	3	3	3
Median	9	3	3
Mean	426	112	72
Standard deviation	1,133	290	274
Percentile (75th)	175	18	3
Percentile (90th)	1,110	460	7
Number of samples	41	87	16
***Salmonella** (in 25 g)**			
Maximum	0	0	0
Minimum	0	0	0
Median	0	0	0
Mean	0	0	0
Standard deviation	0	0	0
Percentile (75th)	0	0	0
Percentile (90th)	0	0	0
Number of samples	35	88	16

*No *Salmonella* has been detected in the compost samples.
SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials.

Table 3.13 presents the impurities standards from other countries. When the Irish database is compared with the other standards, it meets the 0.5% standard (dry weight) of total glass, plastic and metal fragments greater than 2 mm diameter. It is therefore recommended that this limit value be

Table 3.9. Pathogen standards from draft European Compost Network (ECN) Quality Assurance Scheme (QAS), BGK and UK PAS QASs, 2nd draft *Technical Working Document Biological Treatment of Biowaste* and Animal By-Product (ABP) Regulations.

Parameter	PAS 100	BGK	ECN QAS	2nd draft biowaste	ABP Regs Ireland[2]
***Salmonella* (in 25 g)**	0	0	0	0[1]	0
***Escherichia coli* (cfu/g fresh mass)**	1,000	*	*	*	1,000
***Enterococaceae* (cfu/g fresh mass)**	*	*	*	*	1,000
***Clostridium perfringens* (in 1 g)**	*	*	*	0	*

[1]Absent in 50 g.
[2]ABP Regs – Animal By-Product Regulations (SI 252 of 2008).
*Parameter not part of standard.

Table 3.10. Irish industry standard regarding pathogen content in compost made from source-separated biodegradable materials.

Pathogen	Limit value
***Salmonella* (in 25 g)**	0
***Escherichia coli* (cfu/g fresh mass)**	1,000

adopted as the Irish standard regarding the impurities content of compost made from source-separated biodegradable materials on a dry weight basis.

3.4 Stability

The Irish database has many different stability measurement results (e.g. self-heating test, cress test, SOUR) (see Appendix A). These results are discussed briefly in Section 3.7.4. A recent OUR stability method (using the OxiTop® bottle) and standard are being developed by the CEN Technical Committee (TC) 223 (Soil Improvers and Growing Media), based on the work being carried out in Ireland, Belgium and the Netherlands. The OUR method quantifies the carbon dioxide respiration rate of compost by using a pressure sensor that measures a pressure drop (created by soda lime pellets absorbing the carbon dioxide) within a sealed bottle. The OUR method was not used in the analysis of the 256 samples listed in the Irish compost database. Based on comments at the stakeholder workshops in May 2007, the OUR equipment for stability measurement was purchased and stability analysis of compost samples from six different composting sites was conducted by Cré. Analysis was conducted according to Veeken *et al.* (2003). These results were then correlated with compost processing time and results from self-heating tests to establish a corresponding stability standard using the OUR test method.

A detailed explanation of the stability methods (e.g. SOUR and the self-heating test) considered for this project is provided in Section 4.8.

The CEN TC 223 criteria used for choosing a compost stability testing method include:

- Equipment needed
- Simplicity of test or method
- Cost of equipment and the per-unit cost of conducting the stability test
- Ease of use
- Time to conduct the analysis
- Repeatability, reliability and accuracy of the test method.

The OUR methodology (Veeken *et al.,* 2003) (as mentioned above) has been accepted as a CEN method for Europe, subject to the completion of a second ring test to confirm repeatability (CEN TC 223 Working Group 4). Bearing in mind the CEN TC 223 criteria listed above, the project team used the following five points to determine the OUR stability standard to be included in the Irish industry compost standard:

Table 3.11. Impurities content (% dry weight) in Irish compost quality database.

Parameter	SSGW	SSBW	MISC
Plastic			
Maximum	0.18	4.94	0
Minimum	0.00	0.00	0
Median	0.00	0.00	0
Mean	0.01	0.12	0
Standard deviation	0.03	0.54	0
Percentile (75th)	0.00	0.00	0
Percentile (90th)	0.00	0.18	0
Number of samples	42	99	23
Glass			
Maximum	0.31	12.24	0
Minimum	0	0	0
Median	0	0	0
Mean	0.02	0.22	0
Standard deviation	0.07	2.01	0
Percentile (75th)	0.00	0.00	0
Percentile (90th)	0.06	0.12	0
Number of samples	42	95	23
Metals			
Maximum	0	0	0
Minimum	0	0	0
Median	0	0	0
Mean	0	0	0
Standard deviation	0	0	0
Percentile (75th)	0	0	0
Percentile (90th)	0	0	0
Number of samples	42	100	23

NB: ‘0’ results mean that there were no impurities in the samples tested.
SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials.

Table 3.12. The 90th percentile values of plastic, glass and metals added together.

Impurities	SSGW	SSBW	MISC
		90th percentile	
Plastic	0	0.18	0
Glass	0.06	0.12	0
Metals	0	0	0
Total	0.06	0.30	0

SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials.

Table 3.13. Impurities standards from other European Countries, draft European Compost Network (ECN) Quality Assurance Scheme (QAS) and 2nd draft *Technical Working Document Biological Treatment of Biowaste*.

	Impurities	Mesh size	Limit (% dry matter)
Austria	Total	2 mm	<0.5%
Belgium	Total	>2 mm	<0.5%
Germany	Glass, metal and plastic	>2 mm	<0.5%
Spain	Total (glass, metal and plastic)	>2 mm	<3%
The Netherlands	Total	>2 mm	<0.5%
UK PAS	Total	>2 mm	<0.5%
2nd draft biowaste	Impurities	>2 mm	<0.5%
ECN QAS	Total (glass, metal and plastic)	>2 mm	<0.5%

1. Relation between OUR and duration of the composting process (Figs 3.1–3.3)

2. Relationship with an established method (Fig. 3.4)

3. Derivation of standards from established method (e.g. self-heating) (Fig. 3.4)

4. Formulation from standards in other European countries (the Netherlands and Belgium) (Tables 3.14 and 3.15)

5. Analysis of compost from six different Irish composting sites (Fig. 3.5).

3.4.1 Relation between OUR and the duration of the composting process

The methodology used to determine the degree of the relationship between a particular test and compost processing time is widely used to determine the robustness of a stability test, as demonstrated by:

- AT4 test (van Becker, 1998) (see Appendix C)
- RA7 test (Binner, 2006) (see Appendix C)
- Solvita® test (Changa *et al.,* 2003)
- SOUR (Chica *et al.,* 2003)

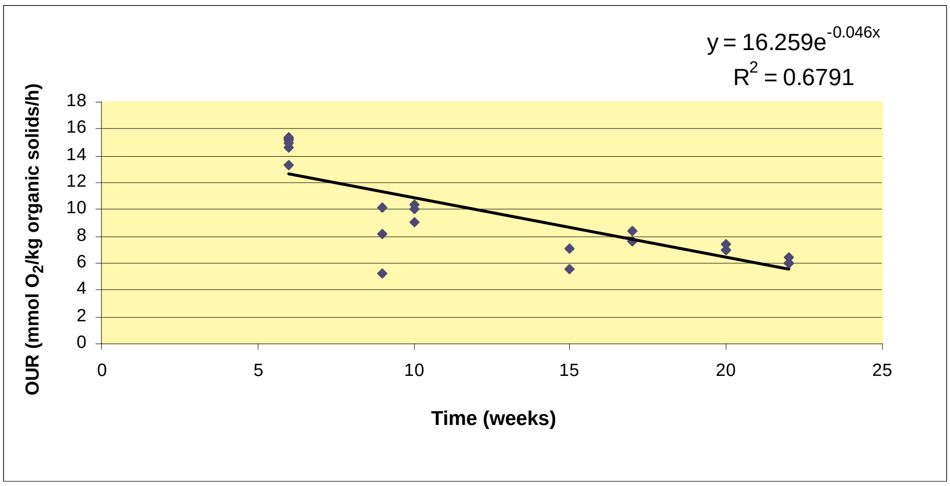

Figure 3.1. Relationship between the oxygen update rate (OUR) and pile age for piles above 5 weeks for evaluation of stability in composting piles consisting of green materials and brewery waste (N = 18) (Ní Chualain and Prasad, 2008).

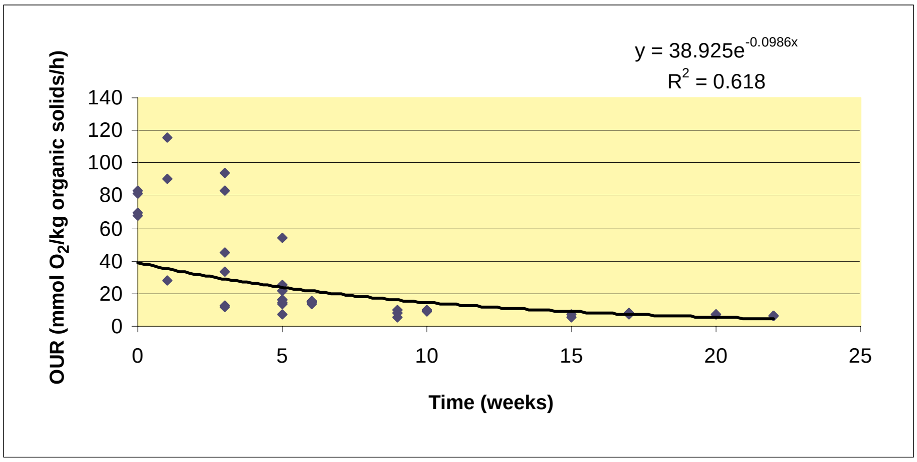

Figure 3.2. Relationship between the oxygen update rate (OUR) and pile age for evaluation of stability in composting piles consisting of green materials and brewery waste (N = 48) (Ní Chualain and Prasad, 2008).

- Self-heating and Solvita® tests (Brewer and Sullivan, 2003)
- Carbon dioxide evolution (PAS test) (Llewelyn, 2005).

Hence, the relationship between the age of compost and the test is a most significant factor in testing the efficiency of a stability test. However, it has certain shortcomings in the sense that the processing time can vary depending on the technology used, feedstock inputs and processing efficiency, e.g. the degree of oxygenation during the composting process.

Variation was observed in the OUR and self-heating methods in the initial sampling (piles <5 weeks old); however, much less variation was evident in later samplings. This is probably due to the heterogeneous nature of the feedstock. This heterogeneity becomes less obvious as turning and composting proceed and piles become more uniform. Hence, the R^2 values improve if the results from samples taken in the first 5 weeks are excluded (compare Figs 3.1 and 3.2). From the data presented in Fig. 3.1, 11 weeks of composting show an OUR test result of 10 mmol O_2/kg organic solids/h.

Figure 3.2 shows a good relationship between OUR and duration of the composting process. The data show a declining respiration rate (measured by OUR) over the duration of the composting process from composting garden and landscape materials in open windrows. Bord na Móna is licensed to produce 96,000 t of garden and landscape materials and/or spent grains from brewery operations at its Kilberry windrow composting facility in Kildare. From this experience, it has been demonstrated that 10–12 weeks of composting produce a stable compost that can be used as a component in growing media.

Figure 3.3 from VLACO in Belgium also shows a good relationship between days of compost processing and OUR respiration method measurement (this graph was presented at the CEN meeting in January 2007). These data follow a similar trend to the BnM data presented in Fig. 3.1. When comparing the data in Fig. 3.1 (BnM) with those from Fig. 3.3 (VLACO), it should be considered that the time for the BnM compost to reach a stability measurement of 10 mmol O_2/kg organic solids/h is less because the BnM windrow piles were turned more frequently (5 times a week) than the VLACO piles (once every fortnight). More frequent turning of the compost pile results in better oxygenation, which results in a faster composting process.

3.4.2 Relationship with an established method

Figure 3.4 shows the relationship between OUR and the self-heating test. VLACO also found in its work a good relationship (r = 0.8364) between the self-heating test and the OUR method. The self-heating test has been used by a number of countries (see Table 4.6). The good relationship between OUR and the self-

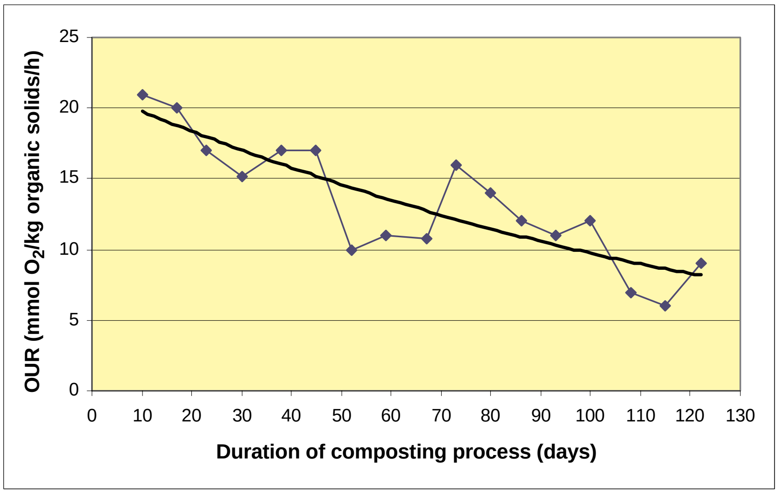

Figure 3.3. Relationship of oxygen update rate (OUR) and the duration of composting process for VLACO green waste composting in Belgium. (NB: Compost was turned on Days 18, 25, 37, 47, 67, 87 and 100. Water was added to the process on Days 25, 47 and 66.)

heating test confirms the robustness of the OUR stability test. In the development of the carbon dioxide method (PAS method), carbon dioxide evolution was related to the self-heating test (Llewelyn, 2005).

3.4.3 Derivation of a standard from an established method

Because there is a good relationship between OUR and the self-heating test (BnM data from Fig. 3.4 and the VLACO data), the self-heating test stability limit can be used to determine the OUR limit by extrapolating data from the graph in Fig. 3.4. The self-heating test limit of 30°C is described as 'finished compost' (Kehres and Thelen-Jungling, 2006) and corresponds to approximately 14 mmol O_2/kg organic solids/h shown in Fig. 3.4. 'Finished' is a German translation to English. It means 'ready-to-use compost'. Although the self-heating test has deficiencies, it is widely used in Central Europe and a number of researchers have compared their methods with the self-heating test. Hence, it is a good idea to see how the stability values for the OUR test method compare with those from the self-heating test.

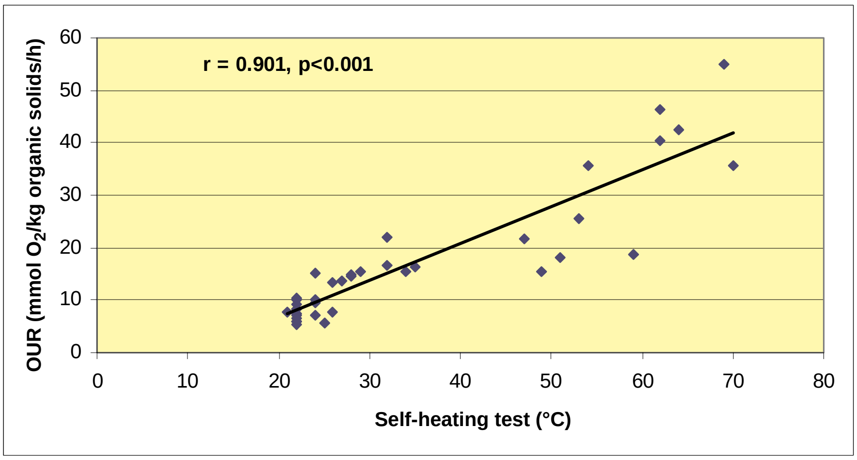

Figure 3.4. Relationship between oxygen update rate (OUR) and self-heating test (Ní Chualain and Prasad, 2008).

3.4.4 Standards from other European countries

The limits presented in Table 3.14 were developed by the Nutrient Management Institute and Wageningen University (Veeken *et al.,* 2003) for composts produced in the Netherlands. The limits presented in Table 3.15 were developed by VLACO in Belgium. VLACO is a large semi-state company that operates a top-class composting facility, which is believed to be one of the best in Europe (J. Barth, personal communication, 2006). Both of these tables were used as a guide for determining the Irish industry standard for compost stability. Studies from both the Netherlands and VLACO in Belgium indicate that the OUR method is very reliable and consistent. Preliminary results in Ireland have shown good repeatability, which would further confirm their findings.

In Belgium, the OUR method has been officially approved by a government agency (Public Waste Agency) as a criterion for compost product quality. It has also been approved at the federal level by the Department of Environment, Food Safety and Public Health (Wim Vanden Auweele, personal communication, 2008). The OUR limit value is 15 mmol O_2/kg organic solids/h with the objective of a future limit value of 10 mmol O_2/kg organic solids/h for garden/landscape material compost and vegetable, fruit and garden (VFG) compost (E. Schokker, personal communication, 2008).

Table 3.14. Oxygen update rate limits for compost stability in the Netherlands (Veeken *et al.,* 2003).

Level of stability	mmol O_2/kg organic solids/h
Very stable	<5
Stable	5–15
Unstable	16–30
Very unstable	<30

Table 3.15. Oxygen update rate limits for compost stability in Belgium (CEN, 2006).

Level of stability	mmol O_2/kg organic solids/h
Completely stable	<5
Stable	5–10
Moderately stable	11–15
Unstable	16–25
Very unstable	>26

In the Netherlands, there is no stability limit value for the overall compost industry. However, the Regeling Handlespotgronden (RHP, the regulatory body for growing media and soil improvers) has overseen over 1,000 samples analysed by the OUR method over the last 4 years. The RHP determines that for compost to be used in peat replacement there is a limit value of 15 mmol O_2/kg organic solids/h (E. Schokker, personal communication, 2008), with the objective of a future limit value of 10 mmol O_2/kg organic solids/h (H. Verhagen, personal communication, 2008).

3.4.4.1 European Committee for Standardisation (CEN)

The OUR testing method has been widely used in Belgium, the Netherlands and in Ireland, with promising results. This has led to this method being proposed by CEN as a standard method throughout Europe. The self-heating test is the other test being considered. In June 2008, the CEN TC 223 made a decision that the OUR test and the self-heating test will be the standard methods for monitoring stability. An EU-wide ring test under the auspices of CEN TC 223 using the two methods has been carried out and the results are being assessed. It is likely that another ring test will be performed later this year to confirm the results of the first ring test.

Table 3.16 gives some perspective on the OUR values for a range of organic materials normally applied to land.

3.4.5 Testing of Irish composting sites

In response to the comments at the stakeholder workshops, Cré purchased the OUR equipment for stability analysis. The Institute of Technology Sligo kindly provided the use of its research laboratories to conduct the analysis of compost from six different composting sites across Ireland. These sites used different technologies and feedstocks to make compost (Table 3.17). Compost sites were asked to provide compost samples at the stage in the composting process when the facility operators knew

Table 3.16. Comparison of oxygen update rate values for various organic materials normally applied on land (Anonymous, 2007a).

Organic material	mmol O_2/kg organic solids/h
Pig slurry	35.25
Cattle manure	33.10
Mushroom compost	15.68
Chicken manure	96.4
Anaerobic digestion residue	27.3
Industrial sludge	60.1
Partially composted biowaste with manure	49.9

Table 3.17. Details on compost sites where compost was tested by oxygen update rate.

Compost site ID	Technology	Feedstock
Site A	In-vessel	Brown bin
Site B	Aerated static piles	Garden/Landscape materials
Site C	Windrow	Garden/Landscape materials
Site D	Windrow	Garden/Landscape materials
Site E	In-vessel	Brown bin
Site F	Windrow	Garden/Landscape materials

that the compost was stable and at the point when the compost is sold to end-users.

The OUR stability results (Fig. 3.5) from the different compost sites ranged from 8.8 to 15.5 mmol O_2/kg organic solids/h. Another site was sampled, but the results are not presented here because the compost became anaerobic as it was not cured/stored properly. The results showed that stability is not only associated with the duration of composting, but also with how the compost operator managed the composting process. For example, two different sites (C and F) achieved a similar result but at different durations, 12 and 20 weeks, respectively.

3.4.6 Summary of the determination of the stability compost standard

- The industry standard for stability was determined using the criteria stated at the start of this section.
- The OUR method using the OxiTop® bottle is proposed for conducting compost stability measurement in the Irish standard.
- The self-heating stability limit of 30°C corresponds to an OUR reading of 14 mmol O_2/kg organic solids/h (Fig. 3.4).
- Tables 3.14 and 3.15 can also be used to derive an OUR standard for Ireland. An OUR upper limit reading of 15 mmol O_2/kg organic solids/h in the Netherlands (Table 3.14) would be considered 'stable' or considered moderately stable in Belgium (Table 3.15).
- In Tables 3.14 and 3.15, from the Netherlands and Belgium, an OUR reading above 15 mmol O_2/kg organic solids/h is considered unstable.

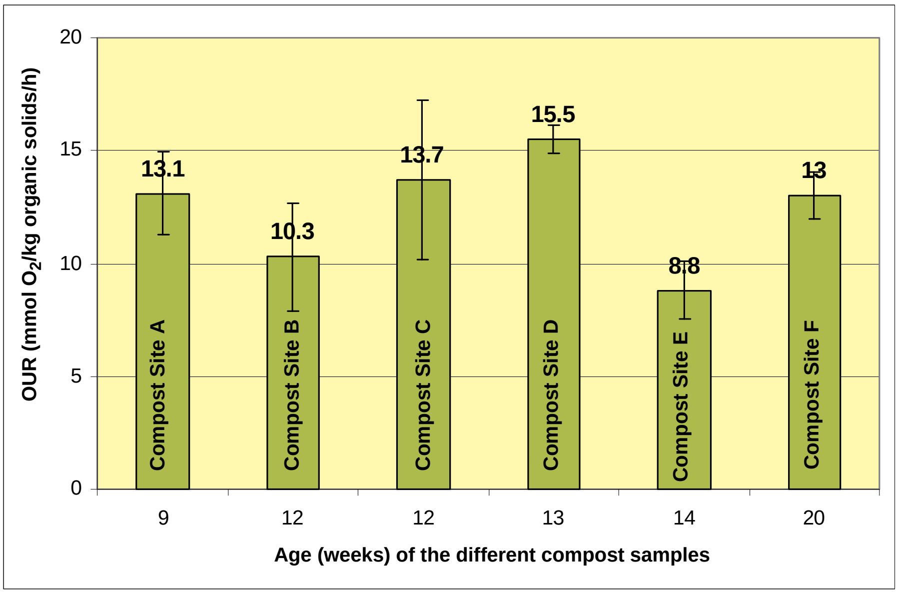

Figure 3.5. Results of oxygen uptake rate value of compost from six different Irish composting sites. Error bars denote standard deviation from four samples.

- In Belgium, an upper limit value of 15 mmol O_2/kg organic solids/h is the standard for garden/ landscape compost and VFG compost. In the future, there is an objective of a limit value of 10 mmol O_2/kg organic solids/h.

- For the use of compost in peat replacement, the RHP in the Netherlands uses an upper limit value of 15 mmol O_2/kg organic solids/h with the objective in the future of a limit value of 10 mmol O_2/kg organic solids/h.

- Results from testing six different managed composting sites in Ireland showed that 13 mmol O_2/kg organic solids/h can be achievable if the composting process is managed properly.

- Based on the information provided, an OUR stability limit standard for compost made from source-separated biodegradable materials of 13 mmol O_2/kg organic solids/h with the objective by 2014 of a limit value of 10 mmol O_2/kg organic solids/h is proposed. The stricter limit in the future is in line with the *End of Waste Criteria* philosophy of improving standards as the industry develops (Anonymous, 2008b).

3.5 Organic Matter

Organic matter content is the measure of all the carbon-based material in compost and is expressed as a percentage of the weight of dried compost. Although most soils have less than 5% organic matter, it plays a vital role in improving soil structure, nutrient availability and water-holding capacity, which, in turn, affect crop productivity.

The *End of Waste Criteria* report recommends a lower limit of 20% organic matter in a quality standard. Primarily this is to prevent the dilution of compost with inorganic materials (e.g. sand) to reduce the apparent heavy metal content.

The organic matter content of compost in the Irish database is presented in Fig. 3.6, which shows that the majority of the compost sample has an organic matter content above 20%. Organic matter tends to be highest in compost made from MISC materials and SSBW and lowest in compost made from SSGW. Only 0.5% of the total samples had an organic matter content below 20%. The organic matter results in the Irish database showed that a standard limit of 20% minimum organic matter would be acceptable. Therefore it is proposed that the Irish standard regarding organic matter content in compost made

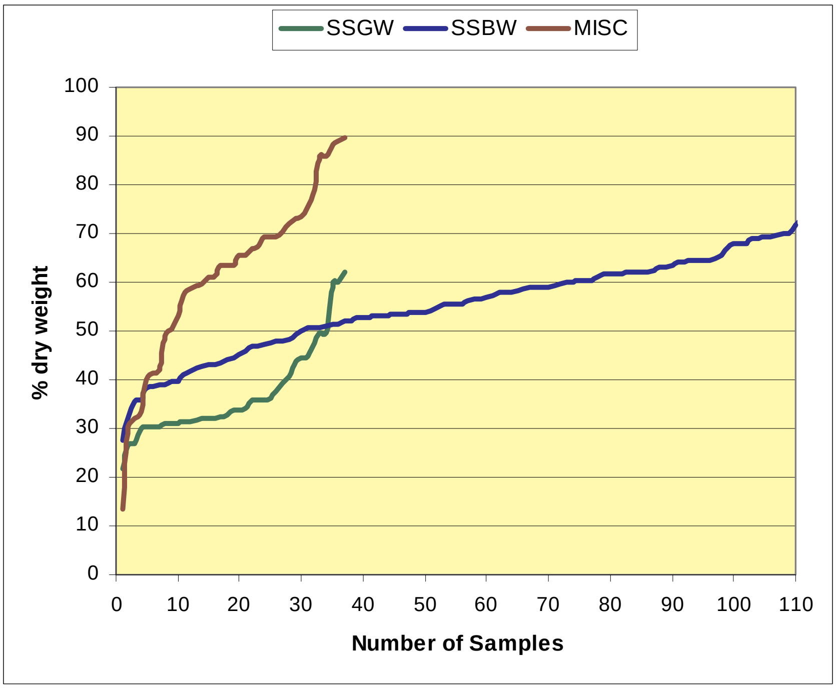

Figure 3.6. Results of organic matter content of compost in the Irish compost quality database. SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials.

from source-separated biodegradable materials should include a 20% minimum organic matter (% dry weight) requirement.

3.6 Summary of Industry Standard

Table 3.18 presents a summary of the overall recommended limits for metals, pathogens, impurities and stability in the industry standard for compost derived from source-separated biodegradable material.

3.7 Results for Other Testing Parameters

3.7.1 pH and electrical conductivity (Appendix A)

pH is the measure of alkalinity or acidity, with a pH reading of 7.0 being neutral on a scale of 1–14. It must be noted that the pH scale works exponentially, meaning that a pH of 6.0 is 10 times more acidic than pH 7.0 and that a pH of 5.0 is 100 times more acidic than pH 7.0; likewise a pH of 12 is 1,000 times more alkaline than a pH of 9.

The pH values of composts are high in relation to peat. There are limited differences in pH between composts made from various feedstocks, although the pH is slightly lower in compost made from SSGW than in compost made from SSBW or MISC materials.

Electrical conductivity is a measure of a material's ability to conduct an electric current. In terms of compost it is a measure of salts within a compost sample and can affect seed germination and plant growth when the compost is applied to soils. In general, EC is lowest in compost derived from SSGW and highest in SSBW compost, with the MISC compost in-between the two. The high EC of compost made from SSBW is a limiting factor in container growing where peat is predominantly used. In this application, the roots are restricted to a small volume of growing media within a container and thus can be exposed to this higher salt content. However, high EC levels are of a lesser concern for plants growing in a field, as the roots are not restricted by a container and the rates of compost application are much lower on a volume basis and natural rainfall can wash away the salts.

3.7.2 Extractable plant nutrients (CAT method – Alt, 2001) (Appendix A)

Nutrients such as N (in the form of nitrate), K and P are essential for plant growth. SSGW composts had the

Table 3.18. Summary of proposed Irish industry standard for compost made from source-separated biodegradable materials.

Metals (mg/kg dry matter)	
Mercury	0.4
Cadmium	1.3
Nickel	56
Chromium	92
Copper	149
Zinc	397
Lead	149
Pathogens	
***Salmonella* (in 25 g)**	0
***Escherichia coli* (cfu/g fresh mass)**	1,000
Impurities	
Total glass, metal and plastic >2 mm diameter (dry weight)	0.5%
Stability	
Oxygen uptake rate (mmol O_2/kg organic solids/h)	13*
Organic matter	
Organic matter (% dry weight)	20% minimum

*By 2014 there is an objective of a limit value of 10 mmol O_2/kg organic solids/h.

lowest value of extractable total nitrogen compared with composts made from SSBW and MISC materials which have higher corresponding values. This probably reflects the high total nitrogen content in these feedstocks. Ammonium N levels are much higher in composts made from SSBW and MISC materials and this limits its use in peat dilution (high levels of ammonium are toxic to plants grown in peat-based media) but not as a soil amendment for agricultural or landscaping purposes. Nitrate N levels follow a similar trend. Extractable phosphate P levels are of similar magnitude in all composts. Extractable K levels are lowest in composts made from MISC and SSGW materials, but are higher in SSBW-derived compost.

The very appearance of significant amounts of nitrates in compost can be a sign of stability if no source of fertiliser was added to help the composting process. No particular level of nitrate, or its ratio to ammonium, can be relied upon alone as confirmation of compost stability so other stability tests are required. When calcium ammonium nitrate is added as an N source at the start of the composting phase to stimulate composting activity nitrate may persist through to the end of the composting process.

3.7.3 Total plant nutrients (Appendix A)

Total nitrogen levels are highest in composts made from SSBW and MISC materials and lowest in SSGW. Total phosphorus levels are also highest in compost made from MISC feedstock materials and follow the order MISC > SSBW > SSGW. Total potassium values are highest in compost made from SSGW and SSBW and lowest in compost made from MISC materials. Carbon to nitrogen (C:N) ratios are low in composts made from SSBW, MISC and SSGW materials and indicate that they have been composted. The carbon to phosphorus (C:P) ratio is of a similar order of magnitude and at these levels, according to Iyamuremye and Dick (1996), would indicate release of phosphorus and thus be available for plants. There was a significant positive correlation between total nitrogen and total phosphorus ($r = 0.62$, $p < 0.001$) and total nitrogen and total potassium ($r = 0.57$, $p < 0.001$).

These results indicate that compost with a high N content is also likely to have a high P and K content.

3.7.4 Stability tests (Appendix A)

Stability tests determine the compost's readiness to be used as a soil amendment or as an ingredient in topsoils, top dressings or potting mixes. Unstable composts contain organic acids or ammonia, both of which inhibit seed germination and plant growth. Composts made from SSGW and MISC materials are very stable, with compost made from SSBW being almost stable using the self-heating test. The SOUR test shows that compost made from SSGW tends to be very well stabilised and follows the order SSGW > MISC > SSBW in order of stability.

There was a significant correlation between SOUR and the self-heating test ($r = 0.782$, $p < 0.001$). The self-heating and SOUR tests were not significantly correlated with the C:N ratio, indicating that the C:N ratio is not a good indication of stability, at least from these data.

The self-heating and SOUR results were negatively related to extractable nitrate-N ($r = –0.363$, $p \leq 0.001$ and $r = –0.19$ $p \leq 0.10$). This is expected, as nitrifying bacteria that are responsible for nitrification from ammonium N to nitrate require lower temperatures of ±3°C. Both the parameters were positively related to EC ($r = 0.42$, $p \leq 0.001$ and $r = 0.39$, $p \leq 0.001$). An explanation for this is not obvious.

3.7.5 Cress test (Appendix A)

The cress test is a very sensitive seed germination test that determines the maturity of compost. An immature compost contains phytotoxic compounds such as organic acids or ammonia, both of which inhibit seed germination. There is a weak relationship between the cress test and the two stability measurements (self-heating and SOUR).

The cress test also tends to give an indication of stability and indicates that for good germination to occur the compost has to be diluted with peat by 75%. The need for dilution is primarily due to the high EC value of the compost.

The relationship between the cress test and the self-heating test showed that there was a trend with lower temperature (higher stability) being related to better germination. The relationships between the self-heating and cress tests at 0%, 50% and 75% dilution with peat were $r = 0.38$ ($n = 20$), $r = 0.18$ ($n = 43$) and $r = 0.19$ ($n = 35$), respectively. This relationship was more obvious where compost was not diluted with peat or was less diluted.

A similar trend was found between SOUR and the cress test and was more obvious when the compost was not diluted. The relationships between SOUR and the cress test at 0%, 50% and 75% dilution with peat were $r = 0.53$ ($n = 13$), $r = 0.18$ ($n = 35$), $r = 0.21$ ($n = 31$), respectively. These results which show relatively poor relationships are in complete agreement with the findings of Brewer and Sullivan (2003) and of Warman (1999), who concluded that compost seed germination tests are often not sensitive enough to detect differences between mature (stable) and immature (unstable) compost.

3.7.6 Growth test (Appendix A)

The growing trials give a good indication of phytotoxicity or something that inhibits plant growth, and show that compost made from SSBW at 10% volume in the growing media stimulates good growth. With compost made from SSGW, test results showed up to 30% improved growth when used as an ingredient in growing media. Due to the limited and incomplete data, it is not possible to make a good comparison between composts made from different feedstocks.

3.7.7 Moisture levels (Appendix A)

The end-point moisture levels are of the same order of magnitude for all the composts. During the composting process, a moisture content of 40–60% is required, starting at the high end of the range and ending up at the lower end of the range when the compost process is complete. At the end of the composting phase, operators prefer to have the moisture content as low as feasible to facilitate blending with other ingredients, to keep transport costs down, and to facilitate application. Moisture is primarily a product handling and transportation issue. Composts possessing a moisture content greater than 50% can become difficult to handle and somewhat 'clumpy'. Since water is heavier than compost, excess moisture has a significant impact on the product's bulk density.

3.7.8 Bulk density (Appendix A)

Bulk density is the weight per unit volume of compost. It is used to determine the volume of compost that may be transported in a vehicle. The lower the bulk density, the more volume of compost can be transported. The bulk density of compost made from SSGW is lower than that of composts made from SSBW and MISC materials. Dry bulk density results also follow a similar trend.

3.7.9 Particle size (Appendix A)

Although the particle size of compost may affect the porosity of the soil/media to which it is added, particle size typically determines the product's usability in specific applications (e.g. finer compost in top dressing, coarser compost in mulching). Compost made from SSGW material tends to have the largest fraction of particle size of less than 1 mm. The 1- to 5-mm fraction is of a similar percentage in all composts. The 5- to 10-mm and 10- to 20-mm fractions are relatively small while the 5- to 10-mm fraction is higher in compost made from SSBW material. The >20-mm fraction is negligible in all composts due to the fact that most compost product is screened at the end of the process to remove oversized materials.

3.7.10 Organic contaminants (Appendix A)

The level of organic contaminants (PCBs and PAHs) in compost made from SSBW material is based on a small number of samples (five to six). All of the PCB results were less than 120 µg/kg and the PAH content ranged from 2 to 20.8 mg/kg. There are no data from composts made from SSGW and MISC materials. The PAH results are based on only six samples and therefore should be disregarded. One sample (20.8 mg/kg) has skewed the overall percentile results for compost made from SSBW material and the likelihood is that the high value resulted from the composting of construction and demolition waste timber containing preservatives.

4 Discussion

This study collated two compost quality databases of Irish compost samples and then compared the Irish data with other databases and standards within Europe. From this, one industry standard is being recommended (with one class) for compost derived from source-separated biodegradable materials. The proposed industry standard has been developed having regard to:

1. The draft *End of Waste Criteria* report by the European Commission Joint Research Centre
2. Levels of metal, pathogens, stability and impurities found in Irish compost made from source-separated green waste and biowaste as well as from miscellaneous source-separated materials
3. Levels found in compost from other countries, especially Germany and the UK
4. Compost quality standards already adopted by a number of other European countries
5. A comprehensive report on heavy metals and organic compounds from waste used as organic fertiliser that was prepared for the European Commission by Amlinger *et al.* (2004)
6. Recent development in stability measurements, and its relationship to existing stability tests
7. The 2nd draft of the *Technical Working Document for the Biological Treatment of Biowaste*
8. Ireland’s National Strategy on Biodegradable Waste, and
9. The Department of the Environment, Heritage and Local Government’s Market Development Group Plan.

Ireland is starting the source-separated collection of biodegradable materials (domestic and commercial kerbside brown bin collection, as well as drop-off collection for garden and landscape materials), leading to the development of a large-scale composting sector and the subsequent production of high-quality compost. Those European countries with an advanced composting infrastructure used a period of around 5–10 years to optimise their treatment and collection systems in order to obtain the experience and practice necessary to consistently produce high-quality composts. This period of development and optimisation has not taken place in Ireland. Therefore, it is proposed that the standard developed in this project be a preliminary standard during this transitional period of development and optimisation in Ireland. When a QAS is established, it will lead to improved composting practices and increased compost quality. By monitoring the quality of Irish compost on an annual basis through the QAS, the industry standard can be updated as required. This also allows Ireland the flexibility to monitor European developments such as a European compost standard and incorporate aspects of these developments into the Irish standard as appropriate. This approach of adopting a transitional period for standard development during the optimisation of collection schemes is also recommended by Amlinger *et al.* (2004).

It is proposed that this industry standard eventually be developed into a national standard and a voluntary QAS should be built around it. If the national standard is used in legislation (e.g. EPA waste licence), it then becomes statutory and mandatory. If the national standard is not made statutory by legislation, it would be voluntary and may or may not be adopted by the industry.

In the introduction phase of composting and compost markets in Ireland, a quality standard and a QAS, which can be easily updated, are required in order to respond to customer needs and market developments. A distinction should be drawn between a compost quality standard and a voluntary QAS. The compost quality standard should be limited to the parameters of heavy metals, pathogens, stability, organic matter and impurities which seek to ensure protection of the human, plant, soil and animal health, while the voluntary QAS should focus on the product properties of compost which would expand compost use and open the market for successful new applications of compost-based products.

The main focus of the industry standard is to develop compost markets and protect human, plant, soil and animal health. The standard should be achievable using good composting practice and using suitable input material. The industry standard can be certified by a voluntary QAS which includes an independent third-party inspection element as is common in most quality management systems. This independent inspection element includes the necessary proof and documentation for the relevant authorities that composting plants and indeed the composting industry comply with this interim compost quality industry standard in the short run and eventually with a national compost standard that would be adopted at some point in the future.

4.1 *End of Waste Criteria* Report

4.1.1 Overview

There is currently no harmonised way in the EU for determining whether a compost material is a waste or a 'normal' product. European countries deal with the question rather differently. The lack of harmonisation and of alternative European legislation on biowaste management create legal uncertainty for waste management decisions and for the different actors dealing with the material, including the producers and users of compost or haulage contractors. The uncertainty arises especially when trading compost between different countries. The thematic strategy on the prevention and recycling of waste, adopted by the European Commission on 21 December 2005, proposed the revision of the Revised Framework Directive, including clarification of certain conditions under which, at EU level, waste could cease to be waste, and could be regarded as a non-waste material to be freely traded on the open market. A review of the Waste Framework Directive (Directive 75/442 EEC on Waste) was recently approved by the European Parliament and included an article on 'end of waste'. The European Commission is considering the adoption of compost quality standards under the proposed 'end-of-waste characteristic'. In this context, on request from the European Commission, the Institute for Prospective Technological Studies (IPTS) has prepared a draft report. This has developed a general methodology analysing the principles according to which the criteria should be set up and then has attempted to derive suitable 'end-of-waste' criteria for compost. This report gives good guidance on the parameters and limits in a compost quality standard.

The *End of Waste Criteria* report (Anonymous, 2008b) showed the likely effect that the end of waste criteria for hazardous substances would have on EU countries. It concluded that "*in most countries the end of waste criteria would introduce new quality standards for compost production that are stricter than the current compost standards. This is expected to lead to a reduced average concentration of hazardous substances, in particular heavy metals in composts*".

The establishment of a quality standard for compost offers environmental and economic benefits as this improves certainty of when a waste becomes a product, promotes the production of high quality compost and facilitates its use by avoiding unnecessary regulatory burden (Anonymous, 2008b).

The *End of Waste Criteria* report (Anonymous, 2008b) states that regulators are faced with the challenge of maximising the benefits of recycling organic matter by way of compost and of avoiding unnecessary barriers, while at the same time the human, plant, soil and animal health impacts and risks need to be managed so as to ensure adequate levels of safety and environmental protection.

4.1.2 Report recommendations

The *End of Waste Criteria* report states that there should be minimum compost product quality requirements for ensuring the usefulness of compost and for achieving the desired levels of human, plant, soil and animal health protection. The report (Anonymous, 2008b) recommends that the typical minimum product quality requirements for compost should:

1. Have a minimum organic matter content (to ensure basic usefulness and to prevent dilution with inorganic materials)

2. Have a minimum stability (to avoid methane emissions during uncontrolled anaerobic conditions after sales, e.g. during storage)

3. Have an absence of pathogen indicator organisms that pose health risks

4. Have a limitation on heavy metals

5. Contain only a limited amount of macroscopic impurities (as a basic requirement for usefulness and to limit the risks of injuries).

The report recommends that the parameters and limit values of minimum product quality requirements for compost should be as outlined in Table 4.1.

4.1.3 *The end of waste criteria and the industry standard for compost*

Table 4.1 compares the proposed Irish industry compost quality standard with the recommended minimum quality standard in the *End of Waste Criteria* report. It shows that the standards developed in this research project are similar to most of the *End of Waste Criteria* report parameters and limit values. The main difference that the *End of Waste Criteria* report has made to the development of the industry standard is the inclusion of a minimum requirement of organic matter as a parameter. Another difference is that the *End of Waste Criteria* report does not include *Escherichia coli* as a parameter. The *End of Waste Criteria* report proposed a requirement for stability and the industry standard proposes a stability limit with the

Table 4.1. Comparison of the proposed compost quality standard in this project with the recommended minimum quality standard in the *End of Waste Criteria* report.

	Irish industry standard	*End of Waste Criteria* report
Heavy metals (mg/kg dry matter)		
Mercury	0.4	1
Cadmium	1.3	1.5
Nickel	56	50
Chromium	92	100
Copper	149	100
Zinc	397	400
Lead	149	120
Pathogens		
***Salmonella* (in 25 g)**	0	0
***Escherichia coli* (cfu/g fresh mass)**	1,000	Not mentioned
Impurities		
Total glass, metal and plastic >2 mm diameter by weight	0.5%	0.5%
Stability		
Oxygen uptake rate (mmol O_2/kg organic solids/h)	13[1]	Proposed requirement[2]
Organic matter		
% dry weight	20% Minimum	20% Minimum

[1]By 2014 there is an objective of a limit value of 10 mmol O_2/kg organic solids/h.
[2]No specific test is mentioned, but a minimum stability requirement is proposed.

objective to become stricter within the next 5 years. Mercury, cadmium, chromium and zinc have stricter limit values in the standards proposed in this project. However, the nickel limit in the *End of Waste Criteria* report is slightly stricter.

The limits for copper and lead are stricter in the *End of Waste Criteria* report. However, compost applied to land at the limits proposed in this report and in accordance with best practice will not cause a threat to soils. Obviously the metal limits proposed in this report will be reviewed as part of the ongoing review process outlined in the roadmap in Section 4.11 to take account of progress being made in recycling of organics and relevant development at national and EU levels.

Some of the metals standards (e.g. copper and zinc) developed in this project are not as strict as those in other more advanced countries (as shown in Table 3.6), such as Germany, which have had time to improve the overall management and quality of collection schemes and treatment systems. It should be noted that this finding for Ireland has been correlated with recent work by Barth *et al.* (2008). From the evaluation of data sets from national investigations from other EU countries, copper, lead and zinc limits, as typical anthropogenic elements, seem to be elevated in less advanced countries with respect to biowaste management and composting (Barth *et al.,* 2008).

The Irish industry standard developed in this project will not lead to a relaxation of quality standards in current EPA waste licences/local authority waste permits for manufacturing compost products. This is because the standard limits for hazardous substances (e.g. heavy metals and pathogens) are not lower than those standards in current EPA waste licences/local authority waste permits.

Hypothetically, if lower-quality composts were allowed to be manufactured, then overall adverse environmental impacts can only be avoided by using less compost. This would then work against the central aim of this project, which is to promote the development of markets for quality compost (Anonymous, 2008b).

4.2 Tolerated Deviation of Limit Values

Limits are fixed at two different sets of levels in EU countries. There are cut-off limits, such as in this project's standard where a given limit must not be exceeded, and there is a type of limit of 'allowed tolerated deviation'. This is where regular sampling frequencies for compost allow a deviation from the cut-off limits in a standard. These allowed tolerated deviations should apply to all quality parameters.

In relation to heavy metals, other European countries have adopted two different philosophies in determining these deviation limits:

1. Have a very low and strict level for heavy metals and allow a considerable deviation (e.g. Austria +50%, Denmark +50% and the Netherlands +1.43 times the standard), or

2. Establish a moderate limit for heavy metals and a relatively small allowed deviation (e.g. Germany allows a deviation of 25%).

The European Commission's 2nd draft of the *Technical Working Document for the Biological Treatment of Biowaste* allowed a deviation of 20% from the statutory limit in any sample.

In the future QAS project, sample frequency, sampling methods and the allowed deviation from the standard should be determined. Cognisance should be taken of criteria outlined in the *End of Waste Criteria* report for analytical methods. Consideration in the development of a QAS will have to be given to the method of sample taking, as this can affect the testing analysis. In some QASs, trained sample takers from laboratories could be charged with visiting compost sites to take independent samples, thus standardising sample collection and guaranteeing uniformity in sampling protocol across the composting industry.

4.3 List of Acceptable Source-Separated Materials

A list of acceptable non-hazardous raw/source-separated biodegradable material feedstocks and suitable bulking agents to which the compost quality standard applies was not in the initial scope of this project, as the types of materials suitable for composting could be controlled in a future QAS. Therefore, it is proposed that acceptable materials should be developed and defined in consultation with all the stakeholders in a future QAS project. This list should be developed in line with the criteria for acceptable feedstocks in the *End of Waste Criteria* report (Anonymous, 2008b). This standard should not apply to compost made from pharmaceutical sludges and other materials not suitable for the production of high-quality compost. Acceptable feedstocks processed in composting sites are controlled under EPA licences and local authority waste permits. An 'acceptable feedstocks list' should not be part of a national standard which could be used in legislation, because if mistakes are made by not including suitable feedstocks, then these can be difficult and time consuming to rectify because of the need to revise legislation. This list should not be part of a future national standard but rather of the voluntary QAS to enable it to be changed easily and reasonably.

4.4 Heavy Metals

Testing for heavy metals is necessary to evaluate and monitor the potential for soil and water pollution and reduce user concerns related to risks associated with compost application. Testing may also be relevant for end-use management, especially in agriculture, as several heavy metals are also trace elements needed by plants.

Some countries have used a rule-of-thumb method to determine limit values in a compost standard. This method uses the category (based on feedstock) in a compost database with the highest median values and doubles these values to determine a standard (personal communication with J. Barth, ECN, 2006, and B. Kehres, BGK, 2006). However, as it is not science based, it was decided in this project to use the method recommended by Amlinger *et al.* (2004). The heavy metal parameters outlined in the *End of Waste Criteria* report were taken into account in developing the standard.

The proposed Irish industry standard was determined using the recommendation of the study by Amlinger *et al.* (2004). This study recommends that countries that are starting source-separated collection schemes use the 90th percentile of the country's compost testing database and add a further 50% for deviation purposes. The figures thus determined were then rounded off to the next whole number. Table 4.2 presents the determined limits for heavy metals in the proposed Irish industry standard. On the basis of existing experiences in countries with established QASs, the ECN is developing a European QAS (ECN-QAS) for compost. This ECN-QAS also uses the methodology proposed by Amlinger *et al.* (2004).

Table 4.2. Summary of heavy metal limits in the proposed Irish industry standard for compost made from source-separated biodegradable materials.

Metals	(mg/kg dry matter)
Mercury	0.4
Cadmium	1.3
Nickel	56
Chromium	92
Copper	149
Zinc	397
Lead	149

The study carried out by Amlinger *et al.* (2004) is a comprehensive report which describes well a methodology for establishing national standards for heavy metals in compost. It includes a recommendation for limit values based on a survey of compost quality in European countries. The recent *End of Waste Criteria* report stated that there are knowledge gaps regarding heavy metals in compost interacting with soil and many uncertainties in the toxicological and ecotoxicological assessments (Anonymous, 2008b). The Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE) concluded that the study *Heavy Metals and Organic Compounds from Wastes Used as Organic Fertilizers* (Amlinger *et al.*, 2004) did not provide sufficient scientific bases for the Commission to be able to propose the appropriate threshold levels for pollutants in compost. To date there appear to be no other studies or research results that could easily provide a strictly scientific basis at a European level (Anonymous, 2008b).

Table 4.3. Possible approach for compost limit values for heavy metals derived from the accumulation scenarios for soils (mg/kg dry matter) (Amlinger *et al.,* 2004). (The recommended Levels 1 and 2 are highlighted.)

		Cadmium	Chromium	Copper	Mercury	Nickel	Lead	Zinc
90th percentile EU all		0.89	37.4	79.5	0.35	29.7	105.2	284.2
90th percentile UK and Spain		1.27	42.8	113.1	0.43	42.1	133.4	314.0
Difference [(UK and Spain) – EU] / EU (%)		+47	+7	+53	+43	+56	+52	+14
90th percentile EU + 50% (Level 1)		1.3	60	110	0.45	40	130	400
90th percentile UK and Spain + 50% (Level 2)		1.9	64	170	0.65	63	200	470
Averaged limit values of EU countries		1.4	93	143	1.0	47	121	416
Working Document 2nd Draft[1]	**Class 1**	0.7	100	100	0.5	50	100	200
	Class 2	1.5	150	150	1	75	150	400

[1]EU Commission, DG Environment. 2nd draft *Technical Working Document for the Biological Treatment of Biowaste.*

Amlinger *et al.* (2004) collated the databases on the quality of compost from different European countries. The 90th percentile for all EU countries was determined and for countries that are starting source separation (e.g. the UK and Spain). The study recommended that there should be two levels for heavy metal limits in a compost quality standard: Level 1 for advanced separate collection, and Level 2 a transitional standard for countries that are just starting separate collection. Level 2, as shown in Table 4.3, should only be used during a transitional period of optimising a country's collection and treatment schemes with the aim that the country should be improving the quality of collection and treatment, and changing to the Level 1 limit over time. It is important to note that the proposed Irish industry standard developed in this project suggests standards for heavy metals similar to Level 1 for cadmium, mercury, lead and zinc and similar to Level 2 for copper, nickel and chromium. To support this two-tiered compost standard for heavy metals, Amlinger *et al.* (2004) found that:

1. Countries in the early stages of implementing separate collection schemes showed 10–50% higher metal concentrations in compost[7] made from biowaste and green waste than those in more established schemes.

7. This did not include miscellaneous source-separated materials.

These findings need to be considered in the light of two factors:

(i) A very limited set of data, and

(ii) In some cases, the difficulty of distinguishing between facilities producing compost from only biowaste and green waste and those that are also including sludge (Amlinger *et al.,* 2004).

2. A study was conducted involving 34 laboratories in Europe, including BnM, to determine the amount of variability in the analysis of the same compost samples. The testing results showed that there was a large deviation of 16–43% in results from laboratories across Europe. This variation differs for various metals due to different sample taking and preparation methods as well as the use of different laboratory methods (Kehres and Schachtner, 2003). Amlinger *et al.* (2004) determined that the deviation in results of all the metal elements is around ±30% among the various laboratories.

4.4.1 Heavy metal limit values and the environment

The contents of heavy metals in composts are generally well studied and controlled in compost applications. They are determined by controlling the type of feedstocks entering the composting process. The fate of the heavy metals in soil is very site specific and depends on a number of factors such as the nature of the crop and the type and the pH of the soil (Anonymous, 2008b).

The limit values suggested for heavy metals in the proposed Irish industry standard (Table 3.18) do not pose a problem in relation to environmental pollution or a danger to plant, animal or human health as a result of compost application for the following five reasons:

1. Source-separated biowaste compost has concentrations of heavy metals that are two to ten times lower than those found in compost made from NSS material (Genevini *et al*., 1997; Amlinger *et al*., 2004).

2. Results from agricultural crop trials in Germany using source-separated compost show that the annual compost application rate does not result in any significant increase in soil heavy metal levels. The long-term effect of the application of SSGW-derived compost onto agricultural land (six different locations in Germany) was studied over 8 years. The trials looked at the effect of three rates of compost application (5, 10 and 20 t/ha dry weight) on heavy metal levels of soil growing four crops: silage maize, maize, winter wheat and winter barley (Timmermann *et al*., 2003). The compost is part of the German BGK compost QAS (heavy metal standard in Table 3.6). Some of the heavy metal content of the compost used in the research is lower when compared with the values in the Irish database for lead, chromium and nickel. The research is relevant due to the fact that the compost was made from source-separated materials and that the study was a long-term trial. After an 8-year experimental period of annual compost application at a rate of around 5 t/ha (on a dry matter basis), the concentration of total heavy metals in the soils showed no significant increases. In fact, even at a higher annual compost application rate of 20 t/ha, lead, cadmium, chromium, nickel and mercury did not show any accumulation within the soil when compared with the control treatment of no compost application. Only copper and zinc at a higher annual application of compost, showed a slight increase (1–2 mg/kg). At a moderate application rate of 5–10 t of compost/ha/year (dry matter), there was no increase or accumulation for these two metals (Timmermann *et al*., 2003).

   This study showed that, even with increased application of compost, there was a reduction in the extractable cadmium, nickel and zinc. This was due to the 'liming' effect of compost application on soil by raising the soil's pH (Timmermann *et al*., 2003).

   Thus, in overall terms, the study showed that compost application does not result in any significant increase in soil heavy metal levels and predicts that even a recognisable change in levels, due to a build-up, would not be detected for many years. Based on the trial results (as shown in Fig. 4.1), the current laboratory equipment and the methods used to detect metals, and predictions[8] on the time taken to detect an increase in heavy metal concentrations in soils as a result of compost application of 5 or 10 t/ha/year, it takes 5 years for zinc at the higher rate of compost application (10 t/ha dry matter) compared with 82 years for mercury at the lower rate of application (5 t/ha) to begin showing any signs of accumulation (Timmermann *et al*., 2003)

3. Uptake of heavy metals by plants and its effect on the heavy metal content in produce is negligible when source-separated compost is applied to the soil in moderate amounts.

   Many years of compost application on crops (maize and corn) had little or no influence on the metal concentration (particularly of lead, chromium and mercury) in these crops (Timmermann *et al*., 2003).

   In a few experiments (Timmermann *et al*., 2003), the cadmium, nickel and zinc content in the produce actually decreased in relation to the control treatment (no compost). This corresponds with the result described above which showed a decrease in extractable heavy metals in soil as a result of compost application. In some experiments (Timmermann *et al*., 2003), the

8. These predictions may change in the future when analytical methods and equipment develop.

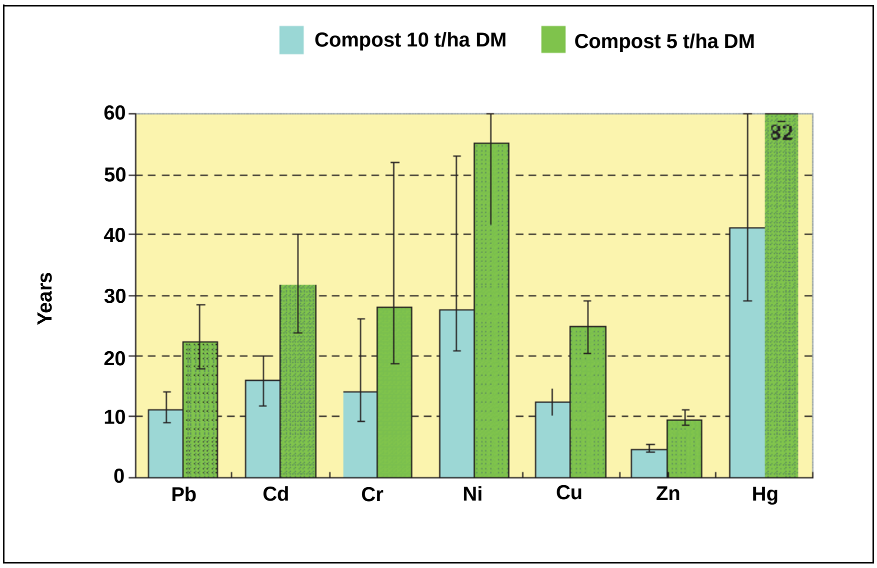

Figure 4.1. Predicted time for increases in analytical measurable soil metal concentration due to the application of compost (10 or 5 t/ha, dry matter (DM)) (Timmermann *et al.,* 2003). Error bars denote minimum/maximum values of the four different field trial locations.

copper content of the produce (summer maize) showed a tendency to increase in concentration. This also correlated with a slight increase in extractable copper within the soil due to compost application. However, these results are not statistically significant but appear to show a trend. The uptake patterns of the heavy metals in the plants were as follows: lead < chromium < nickel < cadmium < copper < mercury < zinc. The study concluded that the heavy metal content of the harvested produce was not influenced by compost application (Timmermann *et al.*, 2003).

In different experiments, any increase in the heavy metal content of produce was predominantly due to the soil parent materials and its plant availability (Steffens *et al.*, 1996; Traulsen *et al.*, 1997; Buchgraber, 2002). Only in exceptional cases was a slight increase due to compost application.

4. The *National Soil Database* (Fay *et al.,* 2007) found that, in the case of mercury, copper, lead and zinc, some elevated levels exist and are attributed to a varying combination of natural geology and anthropogenic effects, including mining, industrial production, land use and urban activities. It should be noted that zinc, nickel and copper are essential plant nutrients as long as their quantity is not too high (Anonymous, 2008b) and they are generally regarded as not very toxic in contrast to other heavy metals, such as mercury, cadmium and lead. The publication of the *National Soil Database* in 2007 (Fay *et al.,* 2007) is timely against the background of the adoption in September 2006 of the *Thematic Strategy on Soil Protection* by the European Commission. This strategy requires Member States to acquire a more comprehensive knowledge of their soils and soil quality and lays the groundwork for a Soil Framework Directive.

5. Due to required compliance with the Nitrate Regulations (SI 378 of 2006), it is most likely that phosphorus will be a limiting factor for soil application rather than the heavy metal content of the compost. This is because composts can have a high level of readily available phosphorus which can limit application rates of compost to land. This can result in lower levels of metals being applied onto land from compost which, if we are to consider the conclusions of the studies highlighted above, will have no effect on heavy metal accumulation in soils or plants. Only in situations where phosphorus is very low (e.g. 0.05–0.1%) and heavy metal contents are very

high, may phosphorus not be the limiting factor.

The nitrogen and phosphorus levels in compost are being determined by Cré in two desktop literature appraisal studies that are due for completion soon. Thus, a more definitive conclusion regarding nitrogen and phosphorus application rates and dynamics from composted material will be available very shortly.

The application of compost to land at allowable application rates will not cause adverse environmental impact. It should also be noted that soils with metal concentrations above Irish median concentrations have to be monitored every year prior to compost application and soils below the median value once every 3 years. Further guidance on this will be available in the EPA land spreading of organic materials manual (EPA, 2009).

4.5 Pathogens

Pathogens are living micro-organisms, such as bacteria, viruses or fungi, that can cause plant, animal or human disease, e.g. *E. coli* and *Salmonella* spp. Pathogen monitoring is necessary to evaluate and monitor the health and safety risks of compost usage and to reduce user concerns related to the spread of disease. The pathogen content of compost is primarily determined after the stabilisation phase and before distribution. However, composting temperatures are monitored during the composting process in order to ensure that adequate temperatures are being generated and sustained to eliminate pathogens. A key measure for controlling the contamination of compost with pathogens is to sort out especially risky material, such as nappies, from the compost feedstock (Anonymous, 2008b).

The proposed standard for pathogens in compost was determined by comparing the levels and parameters in the Irish database with other standards in Europe as well as by setting a standard that would comply with the EU ABP regulations and the recently adopted Irish regulations (SI 252 of 2008, SI 253 of 2008).

"*The EU has adopted Regulation No. (EC) 1774/2002 and associated legislation laying down health rules concerning animal by-products not intended for human consumption. As a country with a large dependence on agriculture, Ireland, with its important livestock industry, must always be conscious of the need for caution when dealing with activities that have a potential to impact adversely on animal health and food safety. Ireland has therefore adopted particularly stringent national legislation on the management and use of animal by-products. In pursuing the twin objectives of developing the necessary biological treatment capacity in Ireland and the need to maintain animal health and food safety standards, due care and consideration must be given to ensuring adherence to the appropriate national criteria*" (Anonymous, 2006c).

The EU ABP Regulation 1774/2002 mentions that additional microbial analysis is required if manures are used as a feedstock in the production of compost. It states that the compost must be tested for toxins and spore-forming bacteria.

Total coliform analysis of compost is not a routine parameter in the compost standards examined and the Irish database contained only one compost facility that conducted tests for total coliforms. Coliforms are not a good pathogen indicator species as they are ubiquitous in the environment. It is therefore proposed that total coliforms should not be included as a part of this project's analysis or be a parameter to be included in the Irish industry compost standard.

The results showed no *Salmonella* in the compost samples made from SSGW, SSBW and MISC materials (Table 3.8). Therefore, the standard proposed by this study is that no *Salmonella* be present in a 25-g sample of compost (Table 3.10). This recommendation is in line with the Irish ABP regulations.

The levels of *E. coli* in the samples of compost made from SSBW (460 cfu/g) and MISC (7 cfu/g) materials were below the ABP standard of 1,000 cfu/g. However, there was a 90th percentile value of 1,100 cfu/g of *E. coli* in the compost made from SSGW material. In light of these results and the limits required in the ABP regulations, it is proposed that a limit of 1,000 cfu of *E. coli* be adopted as the Irish industry standard (Table 3.10).

In most countries, a combination of specified temperature–time regimes and end-product tests (*Salmonella*, *E. coli* or *Enterococaceae*) are used to guarantee pathogen reduction to safe levels. The limit values are used universally. Regulation No. (EC) 1774/2002 reflects a high European safety standard which considers risk assessment. The scientific committee of the Food Standards Agency (FSA) concluded, after extensive consultation with European microbiologists, environmental biologists and veterinarians, that the standards for pathogens in this regulation are safe.

The proposed pathogen standards in the Irish industry compost standard are consistent with the ABP Regulations in Ireland.

4.6 Impurities

Impurities mainly consist of man-made materials that may be part of the feedstock. Man-made impurities include glass, plastic film, and metal fragments. When introduced into the composting process, these materials do not decompose.

Although there may be some health/safety and environmental implications of using compost that is physically contaminated, such as product handling (e.g. glass) and litter generation from wind-blown plastic film, aesthetic issues are a greater long-term concern. When compost is used as a component in growing media, direct health and safety aspects are of special importance because of the often quite intense contact workers have with the material. Macroscopic glass fragments, for example, must not be present. Composts containing physical contaminants possess a reduced market value. These materials can decrease the value of the finished compost products because they offer no benefit to the compost and, in many cases, are aesthetically offensive. A common way of controlling impurities is to prevent them from contaminating feedstocks in the first place (Anonymous, 2008b). When included in the composting process, machinery, such as screens and wind sifters, can remove impurities from the finished compost product.

The test results from the Irish database showed that there were low levels of impurities within compost derived from source-separated material: for composts made from SSGW the impurity level was 0.06%, for composts made from SSBW the impurity level was 0.30%, and for composts made from MISC materials there were no impurities (Table 3.11). Conversely, the compost made from NSS materials (as illustrated in Appendix A) had a much higher level of impurities (10.07%).

It is proposed that an industry standard regarding the impurities content (total glass, plastic and metal fragments >2 mm diameter) in compost made from source-separated biodegradable materials should not make up more than 0.5% of the total compost by dry weight.

4.7 Organic Matter

The *End of Waste Criteria* report recommends a minimum requirement of 20% organic matter in a quality standard (i) to prevent dilution of compost with inorganic materials (e.g. sand) to reduce the heavy metal content and (ii) to ensure basic usefulness of compost used as a soil amendment. The organic matter content of compost in the Irish database (Fig. 3.6 and Appendix A) was examined and only 0.5% of the total samples had a value below 20%. The organic matter results in the Irish database showed that a standard limit of 20% minimum organic matter would be acceptable. Therefore, it is proposed that the Irish standard should include a 20% minimum organic matter requirement.

4.8 Stability

Compost stability is defined in terms of the potential bioavailability of organic matter, which relates to the rate of decomposition. There are several methods available to determine compost stability/maturity (Mathur *et al.,* 1993), including:

- Self-heating
- Specific oxygen uptake rate (SOUR)
- Dynamic Respiration Index
- Carbon dioxide evolution (PAS method)
- Oxygen uptake rate (OUR by OxiTop®)
- Carbon to nitrogen ratio (C:N ratio).

Scientists generally have the greatest confidence in those methods that assess microbial respiration as evidenced by oxygen depletion or carbon dioxide evolution. Generally, a good correlation has been found between different methods (Adani *et al.,* 2003; Changa *et al.,* 2003; Ní Chualain and Prasad, 2008). Interpretation and application require some knowledge of the composting process, feedstock and science involved in the test (Rynk, 2003) as results are often not consistent among different materials tested.

Stability is an important characteristic of compost. Immature or unstable compost can cause problems if added to growing media or existing soils and may have negative effects on seed germination and plant growth due to reduced oxygen in the soil root zone, reduced availability of nitrogen, or the presence of phytotoxic compounds, such as organic acids or ammonia (Brinton and Evans, 2001). If dry immature compost is land spread during wet weather conditions, it can cause pollution of surface water and groundwater. It can have an adverse effect when these materials are packaged or bagged. Here, the substrate can become anaerobic and then it becomes toxic to plants. A minimum stability limit is needed to avoid methane emission during uncontrolled anaerobic conditions after sales (e.g. storage) (Anonymous, 2008b).

It is known that different uses of compost (e.g. as mulch, as a soil conditioner in agriculture, and as a component in growing media) need different levels of compost stability. In general, when compost is used as a component in growing media it will have to be more stable than compost used as mulch or compost used as a soil conditioner in agriculture. For example, in Germany, compost used on agricultural land is called 'fresh compost' which is half-matured compost with a relatively high biological activity but still would have reached a high temperature phase to kill pathogens (Timmermann *et al*., 2003; Anonymous, 2008b). Mulch compost used in landscaping has fewer demands regarding maturity (Anonymous, 2008b). For compost to be used successfully in growing media, there are more stringent performance criteria, which include stability and other parameters such as plant response, salt content, nutrient availability and particle size (Anonymous, 2008b).

At the moment there is not enough research conducted using the OUR test to link different stability limits for different end uses of compost. This would be a good research project to conduct. The *End of Waste Criteria* report suggested that there should be a minimum stability limit and this is proposed in this project with the aim of achieving a higher level of stability in the future. It is hoped that future research would provide data in which specific stability limits linked with different end uses could be determined.

There is a need for a baseline stability standard for the composting industry in Ireland to avoid material that has been processed for only a few weeks and then labelled as 'compost' when in fact it is not. If unstable compost is used, it could have a negative impact on plant growth and also on the environment by causing foul odours. This could give the overall composting industry a bad reputation and make it more difficult to sell high-quality compost that is both stable and mature.

4.8.1 Compost stability methods

Until recently, across European countries, there has not been agreement on a standard stability measurement for compost and, as such, different countries recommend different stability tests as shown in Table 4.4.

Table 4.4. Stability tests used in other European countries (Hogg *et al.,* 2002).

Country	Test for stability
Austria[1]	Cress test
Belgium[1] – Flanders	Self-heating test
Denmark	AT4
Germany	Self-heating test
Luxembourg	Self-heating test
The Netherlands	Self-heating test
Sweden	Self-heating test
UK[2]	Carbon dioxide evolution

[1]Recently Belgium has started to use the OUR test and Austria a humic substance method using FTIR (Fourier transform infrared).
[2]PAS 100:2005.

To make stability measurements (which are based on assessing microbial respiration) practical at composting sites, several tests have been developed. One such test, known as the self-heating (Rottegrad) test, is widely used in a number of European countries as shown in Table 4.4, although in recent times Belgium and the Netherlands have been moving to the OUR method. The self-heating test integrates a number of factors and provides a holistic evaluation of compost. The disadvantage of this method is that it mostly distinguishes between very stable and very unstable compost and is not as good at measuring stability between these two extremes. Nonetheless, it is still widely used in Europe.

The SOUR method utilises an oxygen probe to measure the dissolved oxygen concentration of an aqueous suspension under conditions ensuring optimum microbial activity. The test measures the maximum oxygen consumption rate over a 12-h period of a 2- to 5-g sample of compost in a 1-l aqueous suspension (Lasaridi and Stentiford, 1998).

There are uncertainties regarding the limit values for compost stability measured by SOUR:

- Chica *et al.* (2003) studied the relationship between SOUR and compost processing time. They found that the peak activity was at Day 21, with a reading of 73 mg O_2/g volatile solids/h, and 12–9 mg O_2/g volatile solids/h at Days 41 and 51, respectively. The resulting product was still unstable and its SOUR value continued to decrease to 1 mg O_2/g volatile solids/h at Day 130, where it indicated complete stability. A reading of 3 or 4 mg O_2/g volatile solids/h was recorded at 11–12 weeks of the composting process.

- Gazi *et al.* (2006) found that SOUR reached a value of 4 mg O_2/g volatile solids/h at the end of the active composting phase (after 21 days) and then declined gradually to below 1 mg O_2/g volatile solids/h. This value is indicative of stable compost after 12 weeks of composting, and this parameter correlated fairly well with compost age ($r = 0.85$, $p < 0.02$).

- Adani *et al.* (2003) compared the well-established DRI method with the SOUR method on 14 samples. A DRI reading of 1,000 mg O_2/kg volatile solids/h is considered stable. SOUR gave a mean reading of 7.038 mg O_2/g volatile solids/h, which corresponded to the DRI reading of 1,000 mg O_2/kg volatile solids/h. However, with that mean, there was a wide range of values from 0.93 to 15.06 mg O_2/kg volatile solids/h. This was despite a fairly good correlation between the two methods ($r = 0.70$, $p < 0.05$).

Therefore, it was decided not to consider this method for the Irish compost stability standard in view of the discrepancy between the stability values from the three aforementioned publications and other considerations, such as the small quantity of compost tested, the short testing time, and the view of the method's developer (Prof. Stentiford) that it is more suitable for monitoring the composting process than for measuring the final product (personal communication, E. Stentiford, 2007).

A DRI test was included as a method in the second draft of the EU Biowaste Directive because it is reliable. However, it is very expensive and not suitable for routine testing of compost.

The UK PAS 100:2005 method for stability uses a carbon dioxide test. This method is long, tedious, and expensive to conduct due to high labour input and is not being considered for Ireland.

The OUR method measures the respiration rate of compost by measuring the carbon dioxide evolution. This can be done using Draeger tubes (limited research done using this method) (Anonymous, 1999; Brewer and Sullivan, 2003) or by using an OxiTop® pressure sensor (Veeken *et al.,* 2003) (most of the research is done using this device). The OUR test using the OxiTop® pressure sensor is a modified method commonly used in the waste-water industry for measuring the biological oxygen demand of waste waters.

A study carried out by Sadaka *et al.* (2006) has shown that the two methods, carbon dioxide evolution (PAS Method) and the OxiTop® (pressure sensor method), gave similar results. The advantages of the OUR (OxiTop®) method are that it is reliable, easy to conduct, and relatively inexpensive (approx. €30–50 per sample).

Fricke (2004) conducted a ring test that compared AT4 measured by Sapromat, by OxiTop® and using a respirometer. *Inter alia*, Fricke measured 16 samples using OxiTop®, 36 samples using Sapromat (reference method) and four samples using the respirometer (Sensomat). From the results obtained, an analysis of variance was carried out and it was concluded that the OxiTop® and the more expensive Sapromat gave statistically similar results.

The C:N ratio is generally used in the compost industry to formulate feedstock recipes and to evaluate the final compost product (Rynk *et al.,* 1992; Epstein, 1997). The quality of carbon is very important, i.e. the proportion of lignin to cellulose to soluble C, but the total carbon determination does not take this into account. Hence, a C:N ratio may at times be a good indicator where the composition of carbon is similar. For instance, when a nitrogen-rich fertiliser or a nitrogen-rich waste is added to the compost mixture, then even an immature compost will give a low C:N ratio. Thus, as a standard test, it can be easily subverted by the addition of urea, ammonium or nitrate fertiliser. Hence, the C:N ratio is usually not a reliable indicator of stability. It does give an indication of the mineralisation of nitrogen when compost is added to soil, though with the above reservation in mind. One can get a low C:N ratio if the processor has added nitrogen to fresh or semi-fresh material. Hence, a respirometric test for stability is essential when a C:N ratio is being used.

Table 4.5 summarises the advantages and disadvantages of the different stability methods. Where one particular compost pile is being monitored using the C:N ratio, a good correlation is found between days of composting process and the C:N ratio (Prasad and Maher, 2000). However, where a mixture of feedstocks or multiple piles are being used, the relationship is not good. This is confirmed by recent data from BnM (unpublished) which showed no relationship between the C:N ratio and the compost processing time.

4.8.2 Summary of the determination of the stability compost standard

The OUR method is relatively cheap and is used by at least three EU countries. An initial ring test has already been carried out and has found it to be promising. Currently (March 2009) another ring test is being carried out in 20–25 laboratories across Europe. Based on these developments and other technical considerations, this project is proposing the OUR test as the stability method of measurement for the Irish industry compost standard.

A value of 13 mmol O_2/kg organic solids/h for the Irish compost standard is proposed with an objective of a stricter limit value of 10 mmol O_2/kg organic solids/h by

Table 4.5. Summary of the advantages and disadvantages of stability methods not proposed for the Irish compost standard.

Stability test	Advantages	Disadvantages
Self-heating	Duration of test is short and can be performed on a compost site	Distinguishes between very stable and very unstable compost and is not as good at measuring stability between these two extremes
SOUR	Cheap test. Very short term to conduct test of 12 h	Discrepancies of stability values between publications. Unreliable for testing the stability of the end compost product, small sample size tested
DRI	Very suitable as a reference method	Very expensive and complicated to conduct
Carbon dioxide (PAS method)	Variations of CO_2 measurements are widely used	Long, tedious and expensive (~€100 per sample)
C:N ratio	Relatively inexpensive test	Not a good relationship with compost processing time and can be easily subverted by adding urea, ammonium or nitrate fertiliser

SOUR, specific oxygen uptake rate; DRI, Dynamic Respiration Index.

2014. The standard will be reviewed at a minimum before 2011 to take into account changes in policy/ legislation and nationwide waste management practices. The stricter limit in the future is in line with the *End of Waste Criteria* philosophy of improving standards as the industry develops (Anonymous, 2008b).

The specific determinations to the proposed limit of 13 mmol O_2/kg organic solids/h are:

- The industry standard for stability was determined using the criteria stated in Section 3.4.
- The self-heating stability limit of 30°C (used in Germany to indicate a compost ready for use) corresponds to an OUR reading of 14 mmol O_2/kg organic solids/h.
- In Belgium, an upper limit value of 15 mmol O_2/kg organic solids/h is the standard for garden/ landscape compost and VFG waste compost. In the future, there is an objective of a limit value of 10 mmol O_2/kg organic solids/h.
- For the use of compost in peat replacement, the RHP in the Netherlands uses an upper limit value of 15 mmol O_2/kg organic solids/h, with the objective in the future of a limit value of 10 mmol O_2/kg organic solids/h.
- Results from testing six different well-managed Irish composting sites showed that 13 mmol O_2/kg organic solids/h can be achievable if the composting process is managed properly.
- Tables on OUR from the Netherlands and Belgium can also be used to derive an OUR standard for Ireland. An OUR reading of 15 mmol O_2/kg organic solids/h would be considered stable in the Netherlands or moderately stable in Belgium. The OUR tables from the Netherlands and Belgium state that an OUR reading above 15 mmol O_2/kg organic solids/h is considered unstable.

4.9 Organic Contaminants

Amlinger *et al.* (2004) found that the concentrations of organic contaminants (PCBs, polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) (PCDD/F) and PAHs) in source-separated compost from biowaste and green waste were similar to concentrations in soil. This led to the conclusion that routine measurements of PCBs, PCDD/F and PAHs and the inclusion of limit values in standards are not required for compost derived from source-separated biodegradable materials. Compost standards that include organic pollutants only exist in a region in Germany (Baden–Wuttemerg) and in Denmark. In the early nineties, there was much controversy about organic contaminants (Anonymous, 2008b), which was followed up by a lot of research which detected low levels in compost derived from source-separated material. Amlinger *et al.* (2004) concluded that there are much higher concentrations of organic contaminants in compost derived from mixed municipal waste. In circumstances where mixed waste compost is used as a soil amendment, organic contaminants should be measured. There are no statutory requirements to measure PCBs and PAHs in compost derived from source-separated waste in PAS 100, BGK QAS, the Austrian and Italian standards, and the 2nd draft of the *Technical Working Document for the Biological Treatment of Biowaste*. Based on this information and in consultation with the BGK (German Compost QAS), it is proposed that the draft industry standard should not include a requirement to measure organic contaminants in compost made from source-separated materials.

4.10 Mechanical Biological Treatment Outputs

The compost standard developed in this project is for compost manufactured from source-separated biodegradable (SSGW, SSBW and MISC) materials. This standard, however, is not applicable to MBT outputs.

4.11 Roadmap on the Use of Industry Compost Standard

The roadmap in Table 4.6 gives an overview of the use of the industry compost standard developed in this project. The ongoing review process takes account of progress being made in recycling of organics and relevant development at national and EU levels.

Table 4.6. Roadmap on the use of the industry-led quality standard for compost derived from source-separated biodegradable materials.

Initiative	Oct 2008	Feb 2009–Aug 2009	Sept 2009–Nov 2009	Dec 2009–Mar 2010	April 2010–April 2013	Jan 2011	Jan 2014
Launch/publication of Industry-led quality standard for compost derived from source-separated biodegradable materials		Report launched in March 2009					
Appointment of MDG consultant	Appointed Oct 2008						
Implementation of MDG programme – Organic Programme (C001–C011)	Programme started in January 2009 and will continue until January 2014						
Development of national standard for compost and QAS (C001 – MDG Programme)		**Stage 1:** Develop NSAI national standard	**Stage 2:** Apply and trial national standard in a pilot scheme	**Stage 3:** Develop and promote QAS leading to implementation	**Stage 4:** Support QAS over 3 years, after which it becomes self-funding		
Review of quality standard		Ongoing review of the quality standard to take account of progress being made in the compost industry and relevant development at national and EU levels				Formal review of standard	Review and update of quality standard

MDG, Market Development Group; QAS, Quality Assurance Scheme; NSAI, National Standards Authority of Ireland.

5 Conclusions

1. This study collated a compost quality database from 256 Irish compost samples, and then compared the Irish database with databases and standards from other European countries (obtained from an extensive literature search and in consultation with other European compost organisations). From this collation and comparison process, an industry compost standard for Ireland is proposed.

2. Ireland's compost manufacturing industry is in the early stages of development and, as a result, the size of the database of compost samples is relatively limited when compared with those of other European countries.

3. One standard was developed for one class of compost derived from source-separated biodegradable material.

4. The proposed industry standard should be used during a transitional period of development and optimisation of source-separated collection schemes and corresponding treatment facilities. As more data are collected, the standard should be updated regularly being cognisant of EU developments.

5. This industry standard has been designed so that it is mutually supportive in both helping to develop markets for compost products and also protecting human, plant, soil and animal health.

6. A list of acceptable source-separated biodegradable materials and suitable bulking agents should be developed as a part of a future QAS for composting facilities.

7. This industry compost standard will support the long-term growth of the industry by developing high-value markets for compost which will provide compost producers with means of generating revenue for composting facilities other than gate fees and allow them to effectively compete with other disposal options and recovery facilities in the waste management industry.

8. Ultimately, this standard will ensure product satisfaction and provide consumer confidence in compost-based products.

9. This standard is a cornerstone in leading to robust compost market development and expansion.

10. The compost standard developed in this project is for compost manufactured from source-separated biodegradable materials. This standard is not applicable to MBT outputs.

6 Study Recommendations

Based on the findings of this study, a number of recommendations can be made and these are summarised below:

1. The industry standard in this project should eventually be developed into a national standard.

2. The industry standard developed in this project should be considered as a preliminary standard and should be updated as required during the transitional period while source-separated collection schemes and their corresponding treatment facilities are established, resulting in the gradual improvement of quality management within the composting industry.

3. This standard should not be restricted to compost derived from BMW materials alone (landscape and garden materials, food, clean wood, paper and cardboard), as this does not reflect the wide range of acceptable feedstocks listed in waste permits and licences of composting facilities in Ireland. It is recommended that the industry standard be expanded to include the source-separated miscellaneous category and other source-separated biodegradable materials that are individually assessed to be suitable, such as animal manures, food processing residuals, fish scraps and brewery or distillery residuals.

4. Around this industry standard or national standard, a voluntary compost QAS should be developed and audited by an independent third party. A QAS would control the composting process in facilities, including acceptable raw materials, independent sample taking, and the analysis of the compost by approved laboratories. In addition, a QAS organisation would evaluate the results independently and award a quality label or certificate to successful facilities.

5. It is recommended that a list of acceptable source-separated biodegradable materials and suitable bulking agents to which the standard applies be developed in a future QAS project which would allow the list to be updated easily as circumstances warrant and as agreed upon by industry and regulatory agencies. The list developed should be cognisant of the criteria outlined in the *End of Waste Criteria* report.

6. In the future QAS, sample frequency, sampling methods and the allowed deviation from the compost quality standard would be determined and standardised throughout Ireland.

7. Research should be conducted with the OUR stability test to determine limit values of the OUR test for different end uses of compost.

8. The information collated in this project of the parameters that are mainly related to the beneficial qualities of compost products (e.g. nutrients) should be used to develop guidelines on the use of compost in different applications.

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8 Glossary of Terms

Ammonium to Nitrate Ratio

At the start of composting, there is more ammonium than nitrate (provided that nitrate fertiliser is not added). During composting, nitrification takes place (conversion of ammonium to nitrate). At the end of a well-managed composting process, there should be more nitrate than ammonium.

Bulk Density

Bulk density is defined as the weight per unit volume of material and is expressed on a dry weight basis or as received. This test is important to determine the weight of compost that can be placed into bags, which is a concern for transportation.

Biowaste (Biodegradable Material)

Biowaste is source-segregated biodegradable waste of an organic or putrescible character.

Biodegradable Municipal Waste

Biodegradable municipal waste is waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard.

Carbon to Nitrogen Ratio

The carbon to nitrogen ratio is an indication of stability. If the ratio is low there could be possible release and leaching of nutrients. If it is high there could be nitrogen immobilisation.

Cress Test

The cress test is a short germination test in which cress seeds are placed into compost in a petri dish. If a low number of seeds germinate this indicates that the compost is not mature enough.

Compost

Compost is the stable, sanitised and humus-like material, rich in organic matter and free from offensive odours, resulting from the composting process of separately collected biowaste.

Correlation coefficient

The correlation coefficient indicates the strength and direction of a linear relationship between two random variables. If there is a perfect linear relationship with a positive slope between the two variables, the correlation coefficient is 1. A correlation coefficient of 0 means that there is no linear relationship between the variables.

Carbon Dioxide Test

The carbon dioxide test is the UK PAS 100:2005 method for stability. As organic material decomposes, carbon dioxide is liberated, which is absorbed in an alkaline solution. The alkaline solution has to be titrated to determine the carbon dioxide absorption.

Dynamic Respiration Index (DRI)

The DRI is a stability test that determines the difference in the oxygen concentration between the inlet and outlet air passing through a sample of compost.

Electrical Conductivity (EC)

The EC is a measure of the salt content in compost. Sources of salt content can be sodium, chloride, nitrates and potassium. If the EC content is high, this can have a negative effect on plant growth. High EC can also be an indication of high levels of available nutrients in the compost. Excessive levels of nutrients in compost result in high EC and in poor plant growth.

Growth Test

The growth test is carried out over 3–4 weeks. Pre-germinated tomato seeds are grown in the compost. If the growth of the tomatoes is as good as in the control, this indicates that there are no phytotoxic substances in the compost that will have a negative effect on plant growth.

Green Waste (Garden and Landscape Material)

Green waste is vegetation waste from gardens and parks, including tree cuttings, branches, grass, leaves, prunings, old plants and flowers.

Heavy Metals

Heavy metals are individual metals that negatively affect human health. Some toxic, semi-metallic elements, including arsenic and selenium, are sometimes included in this group. In very small amounts, many of these metals are necessary to support life. However, in larger amounts, they become toxic. They may build up in biological systems and become a significant health hazard.

Impurities
Impurities mean the presence of fragments of plastic, glass, metals or similar non-biodegradable materials with a size greater than 2 mm.

Industry Standard
An industry standard is a technical specification that defines quality parameters for a product or service that is accepted by industry on a voluntary basis. It is non-statutory. The procedure for the development of an industry standard for a product or service involves consultation with industry and other interested parties. Conformity to the standard involves auditing by an independent third party.

Landfill Directive
The Landfill Directive aims, by means of stringent operational and technical requirements on the landfilling of waste, to implement measures, procedures and guidance to prevent or reduce as far as possible negative effects on the environment, in particular the pollution of surface water, groundwater, soil and air, and on the global environment, including the greenhouse effect, as well as any resulting risk to human health, during the whole life cycle of the landfill.

Municipal Waste
Municipal waste is waste from households, as well as commercial and other waste, which, because of its nature or composition, is similar to household waste.

Moisture Content
Moisture content is the measure of the amount of water in a compost product, expressed as a percentage of the total weight. Moisture is primarily a product handling and transportation issue. Often, composts possessing a moisture content over 50% start to become difficult to handle and somewhat clumpy. Since water is heavier than compost, excess moisture has a significant impact on the product's bulk density.

Median
The median is the middle value in a set of numbers arranged in increasing order.

Mean
The mean is the mathematical average of a set of numbers.

Nutrients
Testing the nutrient content of compost is necessary for end-use management. Each plant species possesses a specific nutrient requirement. These nutrients can be supplied through fertilisation, innate nutrients found within the soil/media, or compost. Since the nutrients in compost can supply some of a plant's nutrient requirement, the addition of compost will affect subsequent fertiliser requirements. It should be understood that not all compost nutrients are readily or quickly available and this is often viewed as advantageous.

- Total nitrogen (N), phosphorus (P), potassium (K) is the total of these nutrients present. Nitrogen, phosphorus and potassium are the three nutrients (macronutrients) used by plants in the greatest quantities.

- Available (extractable) nitrogen, phosphorus and potassium are the forms of the total nutrients that are available for plant uptake.

National Standard
A national standard is a specification for a product, process or service which, with the consent of the Minister of Enterprise, Trade and Employment, is published by the National Standards Authority of Ireland (NSAI) as an Irish standard.

Organic Contaminants
The term organic contaminants refers to chemicals such as dioxins, polychlorinated biphenyls (PCBs) and absorbable organic halogens (AOX).

Oxygen Uptake Rate (OUR)
If compost is biologically active, it will consume oxygen and respire carbon dioxide. The OUR method measures the respiration rate of compost by indirectly measuring (using a pressure sensor) the carbon dioxide evolution as a pressure drop in a bottle. The

pressure drop is created by soda lime pellets absorbing the carbon dioxide.

Organic Matter

The organic matter content is the measure of carbon-based materials in compost, typically expressed as a percentage of dry weight.

Pathogens

Pathogens are living micro-organisms, such as bacteria or fungi, that can cause plant, animal or human disease, e.g. *Escherichia coli* and *Salmonella* spp.

pH

pH is the numerical measure of the acidity (or alkalinity) or hydrogen ion activity of the media.

Phytotoxicity

Phytotoxicity refers to substances that are toxic to plants and for seed germination.

Particle Size Distribution

Although the particle size of a compost may affect the porosity of the soil/media to which it is added, particle size typically determines the product's usability in specific applications (e.g. finer compost in top dressing, coarser compost in mulching). Particle size distribution measures the percentage product passing through a series of screens of different size.

Percentiles

Percentiles are standard descriptive statistics that are used to divide a set of data points into equally sized subsets.

90th Percentile

The 90th percentile is that position in a data set that has 90% of data points below it, and 10% above it.

75th Percentile

The 75th percentile is that position in the data set that has 75% of values below it and 25% above it.

Regression Equations

Regression equations attempt to model the relationship between two variables by fitting a linear equation to observed data.

Specific Oxygen Uptake Rate (SOUR)

The SOUR test measures the microbial activity of compost. If compost is microbially active, it will use up oxygen and this indicates that the compost is not stable enough.

Self-Heating Test

The self-heating test measures stability/maturity. It measures the self-heating potential (due to microbial respiration) of a compost sample in an insulated flask until the maximum temperature is attained. If the temperature increases significantly, this indicates that the compost is not stable.

Stability/Maturity

Stability is the potential level of biological activity in compost. Unstable compost consumes nitrogen and oxygen in significant quantities to support biological activity and generates heat, water vapour and carbon dioxide. Stable compost consumes little nitrogen and oxygen and generates little heat and carbon dioxide. If stored improperly or unaerated, unstable compost can become anaerobic giving rise to methane, nitrous oxides and ammonia that create an odour nuisance. Continued decomposition when these unstable composts are added to soil or growth media may have negative impacts on plant growth due to reduced oxygen in the soil root zone, reduced available nitrogen, or the presence of phytotoxic compounds. Maturity can be defined as the point at which the end product is stable and the process of rapid degradation is finished, or, when a biodegraded product can be used in horticultural situations without any adverse effects. Maturity is a measure of the compost's readiness for use.

Stabilised Biowaste

Stabilised biowaste is waste resulting from the mechanical/biological treatment of unsorted waste or residual municipal waste, including treated biowaste which does not comply with the specified minimum standards of environmental quality set out in EPA Waste Licenses and Local Authority Waste Permits.

Separate Collection

Separate collection is the collection of certain categories of biodegradable municipal waste, such as paper/cardboard and organic waste, in such a way as to avoid the different waste fractions or waste components from being mixed, combined or contaminated with other potentially polluting wastes, products or materials.

Quality Assurance Schemes (QASs)

Quality assurance schemes are usually non-statutory in nature, and are designed to ensure that producers maintain a large degree of control over process management and produce a compost product of high quality, which is easily marketed and profitable in nature.

Vegetables, Fruit and Garden (VFG) Waste Compost

Vegetables, fruit and garden compost has special significance in regions in the Netherlands where brown bin collection is restricted to pure non-meat sources of source-separated organic waste.

9 Acronyms Used for EU Member States

AT	Austria
BE	Belgium
DE	Germany
DK	Denmark
ES	Spain
FI	Finland
FR	France
GR	Greece
IE	Ireland
IT	Italy
LU	Luxembourg
NL	Netherlands
NO	Norway
PT	Portugal
SE	Sweden
UK	United Kingdom

Appendix A Statistical Tables of the Irish Compost Database and Non-Source-Separated Outputs

Table A.1. Non-source-separated metals (mg/kg).

Parameter	Cadmium	Mercury	Lead	Nickel	Zinc	Copper	Chromium	Arsenic	Selenium
Maximum	36.50	18.80	1098.00	140.00	2688.00	1743.00	129.00	12.50	2.10
Minimum	0.01	0.05	0.23	4.86	9.66	21.70	0.33	0.48	0.12
Median	0.74	0.14	199.00	36.95	396.50	170.00	41.80	7.33	0.66
Mean	1.81	0.67	315.35	43.94	549.31	246.80	43.38	6.80	0.70
Standard deviation	4.68	2.41	299.42	29.42	534.30	292.51	27.25	2.90	0.48
Percentile (75th)	1.27	0.36	471.5	49.85	636	286.00	58.7	8.58	0.80
Percentile (90th)	2.27	0.55	769	79.55	1010.8	537.80	76.48	10.26	1.47
Number of samples	72	71	75	76	72	77	73	34	36

Table A.2. Non-source-separated pathogens.

Parameter	Total coliforms (cfu)	*Escherichia coli* (cfu/g fresh mass)	*Salmonella* (in 25 g)
Maximum	No data	24,600	0
Minimum	No data	3	0
Median	No data	3	0
Mean	No data	870	0
Standard deviation	No data	4,230	0
Percentile (75th)	No data	3	0
Percentile (90th)	No data	1,169	0
Number of samples	No data	34	32

Table A.3. Non-source-separated impurities (% dry weight).

Parameter	Plastic	Glass	Metals
Maximum	14.81	26.1	0
Minimum	0.00	0	0
Median	0.00	0	0
Mean	0.80	2.72	0
Standard deviation	2.35	5.40	0
Percentile (75th)	0.00	0.93	0
Percentile (90th)	2.29	7.78	0
Number of samples	57	61	56

Table A.4. Source-separated metals (mg/kg).

Parameter	SSGW	SSBW	MISC
Arsenic (As) mg/kg dry matter			
Maximum	11.20	8.28	91.50
Minimum	4.38	0.48	1.30
Median	6.66	4.70	7.63
Mean	7.08	4.83	19.95
Standard deviation	2.34	1.57	25.75
Percentile (75th)	7.63	6.14	25.40
Percentile (90th)	9.52	6.56	44.30
Number of samples	6	35	13
Selenium (Se) mg/kg dry matter			
Maximum	0.98	1.04	1.99
Minimum	0.28	0.02	0.01
Median	0.40	0.55	0.76
Mean	0.56	0.79	0.92
Standard deviation	0.33	0.25	0.61
Percentile (75th)	0.84	0.62	1.25
Percentile (90th)	0.92	0.87	1.86
Number of samples	5	33	13

SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials.

Table A.5. Organic contaminants (polychlorinated biphenyl (PCB) (µg/kg as received) and polycyclic aromatic hydrocarbons (PAH) (mg/kg as received) content).

	SSBW	NSS	SSBW	NSS
Parameter	PCB*	PCB*	PAH	PAH
Maximum	<120	<120	20.8	6.1
Minimum	<120	<120	2	1.6
Median			3.2	2.5
Mean			6.2	3.2
Standard deviation			7.3	1.8
Percentile (75th)			4.98	3.5
Percentile (90th)			13.1	5.06
Number of samples	6	5	6	5

SSBW, source-separated biowaste; NSS, non-source-separated materials.
*The PCB results were presented by the laboratory as less than 120 µg/kg, so even if a sample had a result of 30 or 90, it is presented as a result of <120 µg/kg (You cannot get averages, etc., of results presented as ‘less than’). The PAH results are based on only six samples and really should not be taken seriously due to the limited number of samples. One sample (20.8) has skewed the overall percentile results for SSBW. The compost site where this sample originated was asked about the possible source of PAH. It was suggested that it was possibly from preserved timber from construction and demolition waste which was composted.

Table A.6. Stones (% dry weight).

Parameter	SSGW	SSBW	MISC	NSS
Maximum	11.00	47.79	6.60	48.65
Minimum	0.00	0.00	0.00	0.00
Median	0.00	0.12	0.00	0.00
Mean	1.36	4.00	1.42	4.28
Standard deviation	2.73	7.83	2.41	10.85
Percentile (75th)	0.91	4.25	1.73	1.88
Percentile (90th)	6.17	11.82	5.50	12.76
Number of samples	42.00	100.00	15.00	57.00

SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials; NSS, non-source-separated materials.

Table A.7. Particle size.

Parameter	SSGW	SSBW	MISC	NSS
<1 mm				
Maximum	76.57	63.70	79.81	67.67
Minimum	0.00	0.00	2.33	0.85
Median	45.41	26.69	31.05	20.56
Mean	44.91	26.94	32.14	24.51
Standard deviation	18.15	15.84	20.75	18.09
Percentile (75th)	61.11	38.72	38.42	40.22
Percentile (90th)	68.06	46.99	57.99	48.95
Number of samples	37	76	20	46
1–5 mm				
Maximum	59.38	76.41	64.38	86.00
Minimum	12.00	24.77	9.25	6.39
Median	43.00	44.70	40.78	39.85
Mean	40.58	45.62	40.79	41.59
Standard deviation	11.71	10.67	13.31	14.62
Percentile (75th)	49.00	53.18	50.06	50.04
Percentile (90th)	53.47	58.77	53.38	57.06
Number of samples	37	76	20	46
5–10 mm				
Maximum	36.00	40.59	24.95	49.07
Minimum	0.00	0.87	0.33	0.83
Median	6.31	16.14	14.02	15.67
Mean	9.10	17.89	14.56	17.62
Standard deviation	9.90	9.41	7.30	11.68
Percentile (75th)	14.80	24.33	19.54	23.38
Percentile (90th)	20.57	30.70	22.64	37.00
Number of samples	37	76	20	46

Table A.7 *contd*

Parameter	SSGW	SSBW	MISC	NSS
10–20 mm				
Maximum	29.8	27.0	74.7	46.6
Minimum	0.0	0.0	0.0	0.0
Median	0.2	4.6	8.0	7.3
Mean	3.9	7.0	11.9	13.7
Standard deviation	7.0	7.1	18.3	14.3
Percentile (75th)	3.99	10.78	11.00	24.59
Percentile (90th)	13.20	17.60	19.29	33.49
Number of samples	33	76	20	44
>20 mm				
Maximum	32.00	25.87	4.44	53.71
Minimum	0.02	0.00	0.00	0.09
Median	0.00	0.01	0.00	0.49
Mean	2.27	2.62	0.66	4.19
Standard deviation	6.53	5.98	1.46	9.83
Percentile (75th)	0.03	1.30	0.25	2.93
Percentile (90th)	7.00	7.94	0.25	9.97
Number of samples	31	74	20	36

SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials; NSS, non-source-separated materials.

Table A.8. pH.

Parameter	SSGW	SSBW	MISC	NSS
Maximum	8.50	9.10	8.60	8.60
Minimum	4.80	5.20	6.10	5.00
Median	7.38	7.98	7.74	7.68
Mean	7.20	7.90	7.60	7.50
Standard deviation	0.84	0.60	0.59	0.64
Percentile (75th)	7.73	8.28	8.03	7.83
Percentile (90th)	8.14	8.52	8.28	8.14
Number of samples	75	115	27	62

SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials; NSS, non-source-separated materials.

Table A.9. Electrical conductivity.

Parameter	SSGW	SSBW	MISC	NSS
Maximum	3,820	7,760	7,900	10,560
Minimum	539	674	919	1,899
Median	1,277	5,145	2,640	5,720
Mean	1,294	4,864	2,967	5,804
Standard deviation	536	1,432	1,759	2,069
Percentile (75th)	1,530	5,658	3,343	6,950
Percentile (90th)	1,778	6,441	3,844	8,472
Number of samples	70	100	32	45

SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials; NSS, non-source-separated materials.

Table A.10. Moisture (%).

Parameter	SSGW	SSBW	MISC	NSS
Maximum	58	61	No data	67
Minimum	22	22	No data	21
Median	34	43	No data	42
Mean	36	42	No data	43
Standard deviation	8	11	No data	10
Percentile (75th)	40	51	No data	49
Percentile (90th)	43	56	No data	55
Number of samples	35	76	No data	32

SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials; NSS, non-source-separated materials.

Table A.11. Dry bulk density (g/l)

Parameter	SSGW	SSBW	MISC	NSS
Maximum	392	405	404	405
Minimum	258	147	204	144
Median	318	277	330	292
Mean	327	279	306	290
Standard deviation	44	63	71	69
Percentile (75th)	363	322	358	340
Percentile (90th)	387	362	382	367
Number of samples	12	40	10	19

SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials; NSS, non-source-separated materials.

Table A.12. Bulk density (g/l)

Parameter	SSGW	SSBW	MISC	NSS
Maximum	687	690	831	660
Minimum	357	314	288	308
Median	536	427	509	504
Mean	537	446	521	470
Standard deviation	78	86	103	103
Percentile (75th)	582	580	579	580
Percentile (90th)	626	572	543	621
Number of samples	34	66	25	12

SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials; NSS, non-source-separated materials.

Table A.13. Self-heating test (°C).

Parameter	SSGW	SSBW	MISC	NSS
Maximum	41.50	73.00	63.00	73.00
Minimum	22.20	19.00	18.00	18.00
Median	23.00	27.50	60.40	21.80
Mean	23.60	33.80	25.50	53.80
Standard deviation	3.70	14.36	17.53	11.71
Percentile (75th)	25.00	42.00	24.25	67.00
Percentile (90th)	26.00	54.90	35.10	71.00
Number of samples	52	77	15	55

SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials; NSS, non-source-separated materials.

Table A.14. Specific oxygen uptake rate (SOUR) (mg O_2/g/h)

Parameter	SSGW	SSBW	MISC	NSS
Maximum	0.90	7.48	3.14	8.40
Minimum	0.03	0.09	0.19	0.13
Median	0.30	1.11	1.26	1.74
Mean	0.37	1.58	1.31	2.51
Standard deviation	0.35	1.53	0.80	2.35
Percentile (75th)	0.57	1.98	1.70	2.90
Percentile (90th)	0.75	3.84	2.06	6.22
Number of samples	6	62	13	35

SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials; NSS, non-source-separated materials.

Table A.15. Nutrients.

Parameter	SSGW	SSBW	MISC	NSS
Carbon:Nitrogen				
Maximum	111.00	93.00	97.00	149.00
Minimum	9.10	6.60	0.00	1.10
Median	16.15	15.39	18.67	19.14
Mean	23.70	19.50	23.00	31.70
Standard deviation	21.49	13.19	18.51	33.58
Percentile (75th)	25.06	21.71	25.65	25.47
Percentile (90th)	38.42	36.78	29.22	90.07
Number of samples	66	111	37	71
Carbon:Phosphorus				
Maximum	207.00	291.00	365.00	275.00
Minimum	26.00	13.00	16.00	13.00
Median	72.81	57.89	56.80	77.78
Mean	83.60	69.70	99.30	69.60
Standard deviation	37.20	44.37	56.88	58.82
Percentile (75th)	96.62	78.51	72.10	138.00
Percentile (90th)	121.18	122.45	96.47	184.77
Number of samples	34	105	37	69
Carbon %				
Maximum	50.00	51.00	49.00	51.00
Minimum	16.00	12.00	13.00	7.00
Median	27.06	31.97	29.55	27.69
Mean	27.00	30.00	28.00	27.00
Standard deviation	8.80	7.53	9.72	9.78
Percentile (75th)	30.40	33.08	33.47	33.43
Percentile (90th)	37.22	35.68	37.44	36.09
Number of samples	28	56	15	54
Organic matter (%)				
Maximum	61.00	75.00	89.00	67.00
Minimum	21.00	27.00	13.00	14.00
Median	33.70	56.35	63.50	45.60
Mean	37.00	55.00	61.00	45.00
Standard deviation	9.49	9.97	17.71	13.50
Percentile (75th)	40.65	62.08	71.90	44.50
Percentile (90th)	49.63	68.57	85.88	48.70
Number of samples	37	114	37	67

Table A.15 *contd*

Parameter	SSGW	SSBW	MISC	NSS
Total nitrogen (% dry matter)				
Maximum	2.34	4.34	2.21	7.26
Minimum	0.27	0.20	0.22	0.23
Median	1.30	2.04	1.69	1.44
Mean	1.30	2.07	1.28	2.11
Standard deviation	0.50	0.92	1.46	0.55
Percentile (75th)	1.56	2.70	2.03	1.65
Percentile (90th)	1.85	3.22	4.49	1.84
Number of samples	37	112	70	32
Total phosphorus (% dry matter)				
Maximum	0.45	0.70	1.53	2.53
Minimum	0.05	0.15	0.05	0.08
Median	0.25	0.42	0.58	0.30
Mean	0.25	0.44	0.35	0.69
Standard deviation	0.08	0.16	0.46	0.22
Percentile (75th)	0.28	0.59	0.75	0.41
Percentile (90th)	0.34	0.64	1.22	0.58
Number of samples	35	73	73	37
Total potassium (% dry matter)				
Maximum	1.52	2.10	2.25	1.15
Minimum	0.38	0.24	0.21	0.10
Median	1.06	1.16	0.53	0.58
Mean	0.99	1.07	0.56	0.69
Standard deviation	0.31	0.45	0.28	0.36
Percentile (75th)	1.16	1.42	0.77	0.88
Percentile (90th)	1.34	1.58	0.98	1.21
Number of samples	36	104	31	69
CAT Nitrogen mg/L*				
Maximum	431.00	932.00	1810.00	817.00
Minimum	1.00	0.50	1.00	1.00
Median	35.00	230.00	202.00	234.50
Mean	90.00	263.00	332.00	270.00
Standard deviation	118.03	189.90	404.29	225.02
Percentile (75th)	172.00	373.50	364.00	367.75
Percentile (90th)	273.30	555.00	630.00	510.60
Number of samples	52	30	19	74

Table A.15 *contd*

Parameter	SSGW	SSBW	MISC	NSS
CAT phosphorus (mg/l*)				
Maximum	198.00	315.00	319.00	256.00
Minimum	5.00	2.00	1.00	5.00
Median	36.00	31.00	37.50	35.50
Mean	51.00	56.00	65.00	54.00
Standard deviation	39.43	58.70	78.18	58.99
Percentile (75th)	80.00	96.00	86.75	68.81
Percentile (90th)	132.00	132.00	194.10	122.30
Number of samples	71	71	32	48
CAT potassium (mg/l*)				
Maximum	2330.00	3684.00	2047.00	2373.00
Minimum	9.00	6.00	92.00	60.00
Median	711.50	1250.00	620.00	1005.00
Mean	830.00	1311.00	742.00	1118.00
Standard deviation	489.31	707.15	478.50	535.61
Percentile (75th)	980.75	1497.00	1088.50	1425.50
Percentile (90th)	1567.60	2332.00	1373.40	2024.00
Number of samples	95	118	43	67
Nitrate-N (mg/l*)				
Maximum	365.00	435.00	809.00	325.00
Minimum	0.00	0.00	0.00	0.00
Median	19.50	92.00	102.00	18.50
Mean	59.00	139.00	152.00	79.00
Standard deviation	92.98	126.56	166.68	109.84
Percentile (75th)	66.25	227.00	203.00	135.50
Percentile (90th)	137.00	317.00	319.00	324.40
Number of samples	52	73	27	18
Ammonium-N (mg/l*)				
Maximum	465.00	1502.00	843.00	931.00
Minimum	1.00	0.00	1.00	7.00
Median	42.00	104.00	160.00	207.00
Mean	81.00	204.00	248.00	254.00
Standard deviation	109.08	256.98	241.56	227.71
Percentile (75th)	114.50	258.75	381.75	403.00
Percentile (90th)	172.80	561.90	530.00	514.80
Number of samples	20	78	24	37

*Weight/volume basis.
SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials; NSS, non-source-separated materials.

Table A.16. Growing trials (% growth is in relation to the control (peat)).

Parameter	SSGW	SSBW	MISC	NSS
Growing trial 10% (10% compost and 90% peat)				
Maximum	118	147	93	91
Minimum	118	147	93	91
Median	100	99	71	71
Mean	95	94	70	70
Standard deviation	20	27	20	30
Percentile (75th)	111	110	83	81
Percentile (90th)	117	127	89	88
Number of samples	11	28	4	2
Growing trial 25% (25% compost and 75% peat)				
Maximum	113	140	117	108
Minimum	17	19	66	43
Median	85	82	60	87
Mean	82	80	88	68
Standard deviation	30	30	28	23
Percentile (75th)	104	106	105	74
Percentile (90th)	111	113	112	95
Number of samples	9	23	5	4
Growing trial 30% (30% compost and 70% peat)				
Maximum	116	105	No data	No data
Minimum	61	83	No data	No data
Median	93	97	No data	No data
Mean	92	96	No data	No data
Standard deviation	13	9	No data	No data
Percentile (75th)	99	101	No data	No data
Percentile (90th)	109	104	No data	No data
Number of samples	25	4	No data	No data
Growing trial 50% (50% compost and 50% peat)				
Maximum	93	140	92	86
Minimum	47	2	19	9
Median	73	67	68	35
Mean	71	63	63	41
Standard deviation	15	35	25	33
Percentile (75th)	82	85	75	54
Percentile (90th)	89	96	84	73
Number of samples	13	28	6	4

SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials; NSS, non-source-separated materials.

Table A.17. Cress (germination) test (percentage germination of peat control).

Parameter	SSGW	SSBW	MISC	NSS
Cress test 100% (100% compost and 0% peat)				
Maximum	100	100	100	100
Minimum	70	5	22	62
Median	90	60	80	100
Mean	86	52	74	82
Standard deviation	11	37	11	37
Percentile (75th)	90	90	100	90
Percentile (90th)	96	100	100	91
Number of samples	5	19	5	10
Cress test 50% (50% compost and 50% peat)				
Maximum	100	100	100	100
Minimum	52	5	10	22
Median	90	70	90	70
Mean	83	81	82	69
Standard deviation	21	29	27	25
Percentile (75th)	100	80	98	85
Percentile (90th)	100	100	100	98
Number of samples	6	57	10	23
Cress test 25% (25% compost and 75% peat)				
Maximum	100	100	100	100
Minimum	10	20	90	40
Median	80	90	100	90
Mean	67	84	96	83
Standard deviation	39	19	5	19
Percentile (75th)	85	100	100	100
Percentile (90th)	94	100	100	100
Number of samples	4	53	6	18

SSGW, source-separated green waste; SSBW, source-separated biowaste; MISC, miscellaneous source-separated biodegradable materials; NSS, non-source-separated materials.

Appendix B List of Laboratory Methods

Table B.1 lists the referenced laboratory methods to test compost for various parameters in the industry compost standard. The I.S. EN standards can be obtained from http://www.standards.ie.

Table B.1. Referenced laboratory methods for compost testing.

Parameter	Method of Analysis
Lab sample preparation	I.S. EN 13040:2007 Soil Improvers and Growing Media – Sample Preparation for Chemical and Physical Tests, Determination of Dry Matter Content, Moisture Content and Laboratory Compacted Bulk Density
Particle size distribution	I.S. EN 15428:2007 Soil Improvers and Growing Media – Determination of Particle Size Distribution
Organic matter (dry combustion)	I.S. EN 13039:2000 Soil Improvers and Growing Media – Determination of Organic Matter Content and Ash
Dry bulk density, air volume, water volume, shrinkage value and total pore space	I.S. EN 13041:2000 Amd 1 2006 Soil Improvers and Growing Media – Determination of Physical Properties – Dry Bulk Density, Air Volume, Water Volume, Shrinkage Value and Total Pore Space
Electrical conductivity	I.S. EN 13038:2000 Soil Improvers and Growing Media – Determination of Electrical Conductivity
pH	I.S. EN 13037:2000 Soil Improvers and Growing Media – Determination of pH
Potentially toxic elements	I.S. EN 13650:2001 Soil Improvers and Growing Media – Determination of Aqua Regia Soluble Elements
Calcium chloride soluble elements	I.S. EN 13651:2002 Soil Improvers and Growing Media – Extraction of Calcium Chloride/DPTA (CAT) Soluble
Physical contaminants	Annex E, BSI PAS 100:2005
Escherichia coli	ISO 11866-2:2005 Milk and Milk Products – Enumeration of Presumptive *Escherichia coli* – Part 2: Colony count technique at 44°C using membranes
***Salmonella* spp.**	I.S. EN ISO 6579:2002 Amd 1:2007 Microbiology of Food and Animal Feeding Stuffs – Horizontal Method for the Detection of *Salmonella* spp.
Determination of nitrogen	I.S. EN 13654-2:2002 Soil Improvers and Growing Media – Determination of Nitrogen – Part 2: Dumas Method
OxiTop® measuring system for determination of respiration rate	Veeken, A.H.M., de Wilde, V. and Hamelers, H.V.M., 2003. OxiTop® measuring system for standardised determination of the respiration rate and N mineralization rate of organic matter in waste material, compost and soil. Department of Environmental Technology, Wageningen University, PO Box 8129, 6700 EV Wageningen, The Netherlands
Determination of phosphorus and potassium	O'Neill, J.V. and Webb, R.A., 1970. Simultaneous determination of nitrogen, phosphorus, and potassium in plant materials by automatic methods. *Journal of Science and Agriculture* **21:** 217–219.

Appendix C Stability Graphs

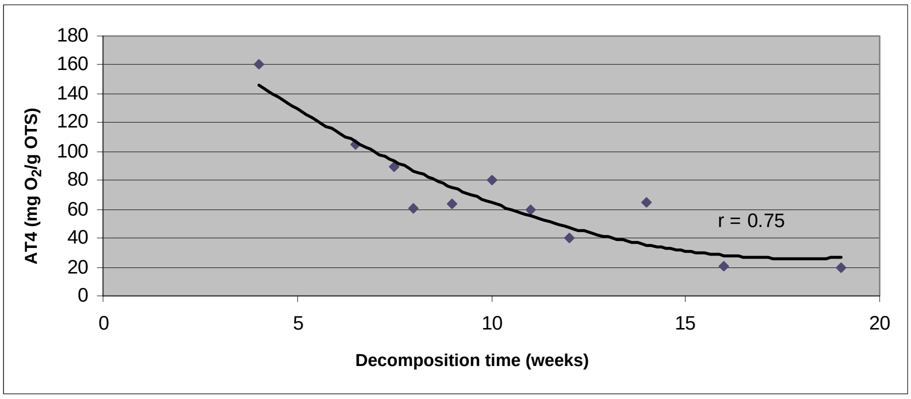

Figure C.1. AT4 test *versus* duration of the composting process (after van Becker, 1998). OTS, organic total solids.

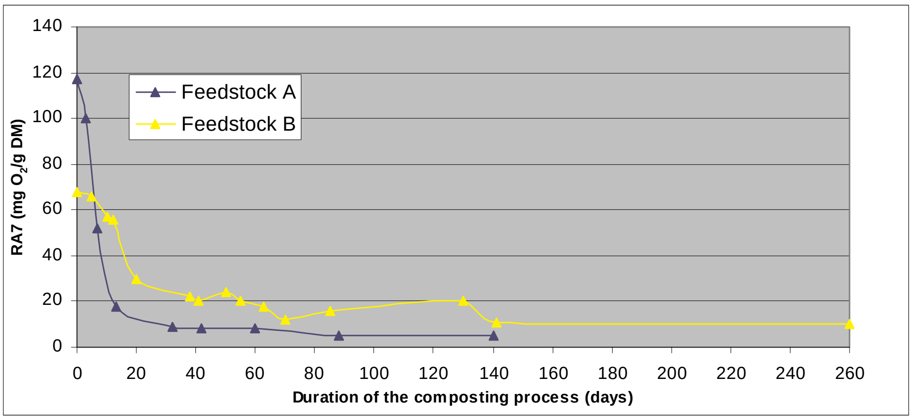

Figure C.2. RA7 *versus* duration of the composting process (after Binner, 2006).

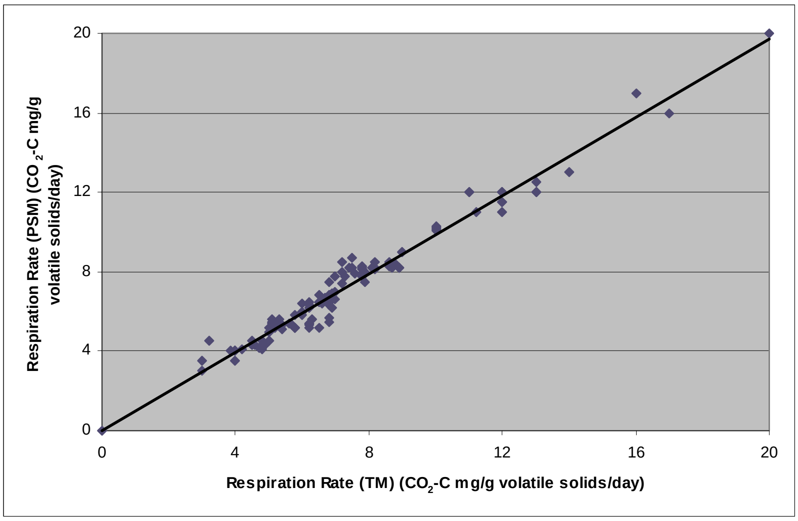

Figure C.3. Comparison between respiration rate resulting from the titration method (TM) and the pressure sensor method (PSM) (after Sadaka *et al.,* 2006).

Appendix D Oxygen Uptake Rate

Figure D.1 presents the equipment used in the oxygen uptake rate (OUR) method, which measures the change in pressure over time in the head space of a closed container containing a compost sample and liquid nutrient mix at a constant temperature. In the case of active samples, oxygen is consumed from the head space and respired carbon dioxide is absorbed by the soda lime, resulting in an overall decrease in pressure. Therefore, the respiration can be directly correlated to a pressure drop within the vessel. The procedure involves suspending a fresh sample of 3 g organic matter in liquid nutrient solution within a 1 litre vessel. Phosphate buffer (pH 7) is added to stabilise the pH, and a nitrification inhibitor (allylthiourea) is added to prevent nitrification of any ammonia. The sample is then allowed to equilibrate for 4 h in an orbital incubator at 30°C. The pH is then rechecked. Soda lime pellets are then added at the top of the vessel to absorb the respired carbon dioxide. The vessel is then sealed using the pressure sensor top (OxiTop® OC110 WTW), and monitored continuously over 5 days. A hand-held sensor controller is used to upload the data to a computer. Moisture is determined using standard methods and organic matter is determined using the ash method.

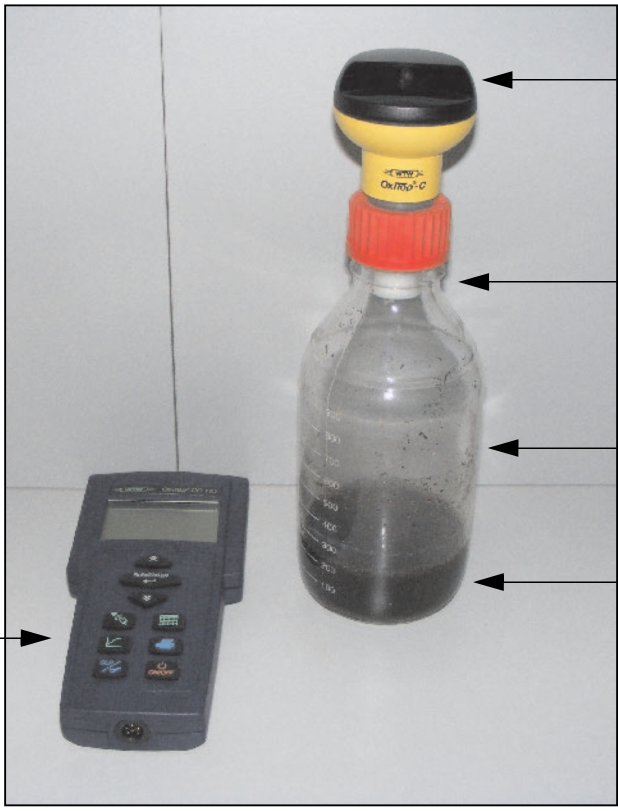

Figure D.1. Photograph of oxygen uptake rate equipment.

Appendix E Stakeholder Consultation

E1 Consultation

As part of the development process for the compost standard, when a draft standard was produced two workshops were held to present and discuss the draft. One was with the compost producers and the other was for everyone with an interest in the project.

Thirty-two compost producers attended the first workshop on 16 May 2007 in Enfield, County Meath. After the meeting Enrich Environmental Ltd kindly hosted a site visit for the compost producers to its compost and horticultural product manufacturing facility.

In a second workshop for everyone in Ireland, 50 stakeholders attended on 29 May 2007 in Enfield, County Meath. In addition, there were other presentations on *Market Development Group Organics Plan* from John O'Neill, Department of the Environment, Heritage and Local Government, the *WRAP Organics Programme & Funded Crop Trial in Ballinderry Farm* from Ian Garner, Waste Resource Action Programme, and *A Tillage Farmer's Requirements for Compost Use* from Julian Martin, Agrilife.

After this workshop, Enrich Environmental Ltd again kindly hosted a site visit to its facility. OCAE Consultants also kindly hosted a field visit to Ballinderry Farm to see a wheat crop trial using compost made from garden and landscape materials. In addition, Agrilife gave a demonstration of the application of compost to land (Fig. E.1).

In most cases, the comments supported the draft standard. In addition, comments stated that the standard is based on solid scientific research and methods. Consultative comments were used to improve the standard and the oxygen uptake rate (OUR) equipment for stability measurement was purchased. Stability analysis of compost samples from different composting sites was then conducted by Cré.

Outlined below are the major issues raised by the stakeholders at the two workshops and an explanation as to how the comments were addressed.

Figure E.1. Demonstration of the application of compost onto land.

E2 Comments from Stakeholders and Responses

Stability

- **There were a number of comments on the stability method limit proposed. Because it is a new method, stakeholders recommended that additional testing of compost from different facilities be conducted to ensure that the proposed limit is reasonable and achievable by well-managed composting sites in Ireland.**

- The stability testing equipment was purchased and Cré conducted analysis of six different well-managed composting sites. Details are given in Section 3.4.5.

Updating the standard

- **Because the standard is based on a low level of compost samples, there is a need to review the standard on a regular basis over the next few years as there will be a greater increase in composting and compost samples.**

- The standard will be a preliminary standard and will be updated as required by monitoring and collating data from the compost quality assurance scheme (QAS). Cré is co-funding with the Border, Midlands Regional Assembly the development of a software program to collate compost quality data from participants in the compost QAS. This will facilitate efficient monitoring of compost quality within Ireland in the coming years.

Level of zinc in fish-derived compost

- **Fish are naturally rich in zinc. Will fish-based compost meet the zinc standard?**

- Yes, fish-based compost samples will meet the proposed zinc standard. The compost quality database includes fish-based compost samples in the Source-Separated Miscellaneous category. The 90th percentile for this database is 277 mg/kg which is below the zinc standard of 397 mg/kg.

End-user understanding of compost parameters

- **Will compost analysis parameters such as pH, nutrients and electrical conductivity be explained from an end-user point of view in the final project report or in other compost marketing initiatives associated with the standard?**

- Compost analysis parameters are defined and explained in this final report. Fact sheets on the various uses of compost, such as horticulture, are currently being adapted for Ireland. These will explain what compost analysis parameters are, why they are important, and what the test results mean from an end-user's point of view.

Mulch

- **Will the standard cover a compost mulch product from a composting site?**

- Yes, if the compost mulch product passes the limits in the standard.

Levels of metal standard

- **Mercury, copper and lead levels are significantly lower (stricter) than in other standards in the EU. For example, mercury is 50% lower, copper is 20% lower, lead is 25% lower than PAS 100. With more brown bins and sewage composting, these levels may need to change. To allay concerns about the metal limits, field trials can be used as a tool to monitor metal accumulation in soil and mobility into herbage.**

- The methods used to determine the metals standards are based on the quality of Irish compost samples. Yes, the standard is stricter for some metals than in PAS 100, but the proposed Irish industry standard for heavy metals is also similar to other standards from other European countries. The quality of Irish compost will be monitored over the next few years and will be updated as required. The EPA provides research funding to conduct growth trials and the monitoring of metal accumulation in soil and herbage could be a project it might consider funding.

Phytotoxins and weed propagules

- **There are no limits for phytotoxins and weed propagules.**

- CEN is examining two methods (seed germination and seedling growth trial) and will make a decision soon to conduct a ring test on these methods. After the ring tests, if CEN approves these methods, the Irish industry standard could be updated to include them. In the meantime, the stability standard will ensure that compost is stable, and stable compost does not generally produce phytotoxins. In the future compost QAS, there will be appropriate time–temperature regimes which will ensure weed seed destruction.

Rounded-off limits

- **Would rounding up/down the standard limits to the next number be easier to defend?**

- Yes. The standard limits were changed and rounded up or down to the next whole number.

Quality systems

- **Will the selected standard ensure that the necessary quality systems will be put in place at compost facilities?**

- The future compost QAS will ensure that quality systems are in place in regard to the compost standard.

90th percentile

- **How was the correct percentile range (90th) and variation (50%) selected?**

- The methodology is recommended by Amlinger *et al.* (2004) in a report commissioned by the EC and based on data from a variety of other European countries.

National standard

- **In relation to the adoption of this proposed standard, what are the next steps to be taken in order to make it into a national standard? Are laboratory testing methods agreed with the National Standards Authority of Ireland (NSAI)?**

- The next steps to make it a national standard are as follows. The NSAI notifies its board and CEN of the proposed standard. If the board agrees, the NSAI prepares a draft standard and provides a public consultation period of 2–3 months, after which the standard is agreed and published. There are standard methods for compost analysis in Ireland, which have been published by the NSAI and these are listed in Appendix B.

Hazard assessment critical control point

- **With regard to the quality assurance system to be formulated, some guidance as to the preparation of hazard assessment critical control point (HACCP) plans should be included or referred to. This is something that should be considered, either as part of the QAS or as a stand-alone document.**

- Cré is developing a standard HACCP plan template for composting sites and this will be published as a stand-alone document.

Acceptable feedstocks

- **There were comments that agreed that a list of acceptable feedstocks needs to be established in the future compost QAS. Composting of sewage sludges and other sludges is an established method. The exclusion of sewage sludge should be further examined before following the UK example of excluding it from the QAS for high-quality compost.**

- In the future compost QAS, there will be a consultation phase on the list of acceptable feedstocks. This will provide an opportunity for comment before the list is incorporated into the QAS and finalised.

E3 European Organisations

In addition to the stakeholder workshop, Cré consulted other organisations for their guidance and information on how they developed a compost quality standard. These were:

- BGK (Bundesgütemeinschaft Kompost e.V.- German Quality Assurance Scheme organisation) (Fig. E.2)

- The European Compost Network

- WRAP.

BGK is the main organisation in Germany, operating a compost QAS for around 500 facilities. Managed from the BGK offices in Cologne and built on 14 years of

Figure E.2. Members of BGK demonstrating the compost quality assurance scheme computer program to Cré and the European Compost Network.

Figure E.3. Gerry Bird of OCAE Consultants explaining the WRAP-funded wheat trials using green waste compost to the workshop stakeholders.

experience, the whole operation is efficiently managed by a sound IT software program, which keeps BGK's administrative costs down. This enables approved laboratories to enter sample results onto the system which then analyses them and produces reports, including advice on the end uses of compost. A network of BGK-approved local consultants provides support to the compost producers. Part of the assessment fee each producer pays to BGK is passed on to the local consultants to retain their services.

BGK produces a yearly report of compost tests results for each compost site. Compost sites that are part of the scheme are able to find valuable markets for their compost. One of the added benefits for compost producers who are members of the BGK certification scheme is that the competent authority requires less reporting from them.

An Ghníomhaireacht um Chaomhnú Comhshaoil

Is í an Gníomhaireacht um Chaomhnú Comhshaoil (EPA) comhlachta reachtúil a chosnaíonn an comhshaol do mhuintir na tíre go léir. Rialaímid agus déanaimid maoirsiú ar ghníomhaíochtaí a d'fhéadfadh truailliú a chruthú murach sin. Cinntímid go bhfuil eolas cruinn ann ar threochtaí comhshaoil ionas go nglactar aon chéim is gá. Is iad na príomh-nithe a bhfuilimid gníomhach leo ná comhshaol na hÉireann a chosaint agus cinntiú go bhfuil forbairt inbhuanaithe.

Is comhlacht poiblí neamhspleách í an Ghníomhaireacht um Chaomhnú Comhshaoil (EPA) a bunaíodh i mí Iúil 1993 faoin Acht fán nGníomhaireacht um Chaomhnú Comhshaoil 1992. Ó thaobh an Rialtais, is í an Roinn Comhshaoil agus Rialtais Áitiúil a dhéanann urraíocht uirthi.

ÁR bhFREAGRACHTAÍ

CEADÚNÚ

Bíonn ceadúnais á n-eisiúint againn i gcomhair na nithe seo a leanas chun a chinntiú nach mbíonn astuithe uathu ag cur sláinte an phobail ná an comhshaol i mbaol:

- áiseanna dramhaíola (m.sh., líonadh talún, loisceoirí, stáisiúin aistrithe dramhaíola);
- gníomhaíochtaí tionsclaíocha ar scála mór (m.sh., déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta);
- diantalmhaíocht;
- úsáid faoi shrian agus scaoileadh smachtaithe Orgánach Géinathraithe (GMO);
- mór-áiseanna stórais peitreail.

FEIDHMIÚ COMHSHAOIL NÁISIÚNTA

- Stiúradh os cionn 2,000 iniúchadh agus cigireacht de áiseanna a fuair ceadúnas ón nGníomhaireacht gach bliain.
- Maoirsiú freagrachtaí cosanta comhshaoil údarás áitiúla thar sé earnáil - aer, fuaim, dramhaíl, dramhuisce agus caighdeán uisce.
- Obair le húdaráis áitiúla agus leis na Gardaí chun stop a chur le gníomhaíocht mhídhleathach dramhaíola trí comhordú a dhéanamh ar líonra forfheidhmithe náisiúnta, díriú isteach ar chiontóirí, stiúradh fiosrúcháin agus maoirsiú leigheas na bhfadhbanna.
- An dlí a chur orthu siúd a bhriseann dlí comhshaoil agus a dhéanann dochar don chomhshaol mar thoradh ar a ngníomhaíochtaí.

MONATÓIREACHT, ANAILÍS AGUS TUAIRISCIÚ AR AN GCOMHSHAOL

- Monatóireacht ar chaighdeán aeir agus caighdeáin aibhneacha, locha, uiscí taoide agus uiscí talaimh; leibhéil agus sruth aibhneacha a thomhas.
- Tuairisciú neamhspleách chun cabhrú le rialtais náisiúnta agus áitiúla cinntí a dhéanamh.

RIALÚ ASTUITHE GÁIS CEAPTHA TEASA NA HÉIREANN

- Cainníochtú astuithe gáis ceaptha teasa na hÉireann i gcomhthéacs ár dtiomantas Kyoto.
- Cur i bhfeidhm na Treorach um Thrádáil Astuithe, a bhfuil baint aige le hos cionn 100 cuideachta atá ina mór-ghineadóirí dé-ocsaíd charbóin in Éirinn.

TAIGHDE AGUS FORBAIRT COMHSHAOIL

- Taighde ar shaincheisteanna comhshaoil a chomhordú (cosúil le caighdéan aeir agus uisce, athrú aeráide, bithéagsúlacht, teicneolaíochtaí comhshaoil).

MEASÚNÚ STRAITÉISEACH COMHSHAOIL

- Ag déanamh measúnú ar thionchar phleananna agus chláracha ar chomhshaol na hÉireann (cosúil le pleananna bainistíochta dramhaíola agus forbartha).

PLEANÁIL, OIDEACHAS AGUS TREOIR CHOMHSHAOIL

- Treoir a thabhairt don phobal agus do thionscal ar cheisteanna comhshaoil éagsúla (m.sh., iarratais ar cheadúnais, seachaint dramhaíola agus rialacháin chomhshaoil).
- Eolas níos fearr ar an gcomhshaol a scaipeadh (trí cláracha teilifíse comhshaoil agus pacáistí acmhainne do bhunscoileanna agus do mheánscoileanna).

BAINISTÍOCHT DRAMHAÍOLA FHORGHNÍOMHACH

- Cur chun cinn seachaint agus laghdú dramhaíola trí chomhordú An Chláir Náisiúnta um Chosc Dramhaíola, lena n-áirítear cur i bhfeidhm na dTionscnamh Freagrachta Táirgeoirí.
- Cur i bhfeidhm Rialachán ar nós na treoracha maidir le Trealamh Leictreach agus Leictreonach Caite agus le Srianadh Substaintí Guaiseacha agus substaintí a dhéanann ídiú ar an gcrios ózóin.
- Plean Náisiúnta Bainistíochta um Dramhaíl Ghuaiseach a fhorbairt chun dramhaíl ghuaiseach a sheachaint agus a bhainistiú.

STRUCHTÚR NA GNÍOMHAIREACHTA

Bunaíodh an Ghníomhaireacht i 1993 chun comhshaol na hÉireann a chosaint. Tá an eagraíocht á bhainistiú ag Bord lánaimseartha, ar a bhfuil Príomhstiúrthóir agus ceithre Stiúrthóir.

Tá obair na Gníomhaireachta ar siúl trí ceithre Oifig:

- An Oifig Aeráide, Ceadúnaithe agus Úsáide Acmhainní
- An Oifig um Fhorfheidhmiúchán Comhshaoil
- An Oifig um Measúnacht Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáide

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag ball air agus tagann siad le chéile cúpla uair in aghaidh na bliana le plé a dhéanamh ar cheisteanna ar ábhar imní iad agus le comhairle a thabhairt don Bhord.

National Development Plan 2007 - 2013

Science, Technology, Research and Innovation for the Environment (STRIVE) 2007-2013

The Science, Technology, Research and Innovation for the Environment (STRIVE) programme covers the period 2007 to 2013.

The programme comprises three key measures: Sustainable Development, Cleaner Production and Environmental Technologies, and A Healthy Environment; together with two supporting measures: EPA Environmental Research Centre (ERC) and Capacity & Capability Building. The seven principal thematic areas for the programme are Climate Change; Waste, Resource Management and Chemicals; Water Quality and the Aquatic Environment; Air Quality, Atmospheric Deposition and Noise; Impacts on Biodiversity; Soils and Land-use; and Socio-economic Considerations. In addition, other emerging issues will be addressed as the need arises.

The funding for the programme (approximately €100 million) comes from the Environmental Research Sub-Programme of the National Development Plan (NDP), the Inter-Departmental Committee for the Strategy for Science, Technology and Innovation (IDC-SSTI); and EPA core funding and co-funding by economic sectors.

The EPA has a statutory role to co-ordinate environmental research in Ireland and is organising and administering the STRIVE programme on behalf of the Department of the Environment, Heritage and Local Government.

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

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SSTI Strategy for Science, Technology and Innovation

Comhshaol, Oidhreacht agus Rialtas Áitiúil
Environment, Heritage and Local Government