Report No.375

Development of Quality Standards for Compost and Digestate in Ireland

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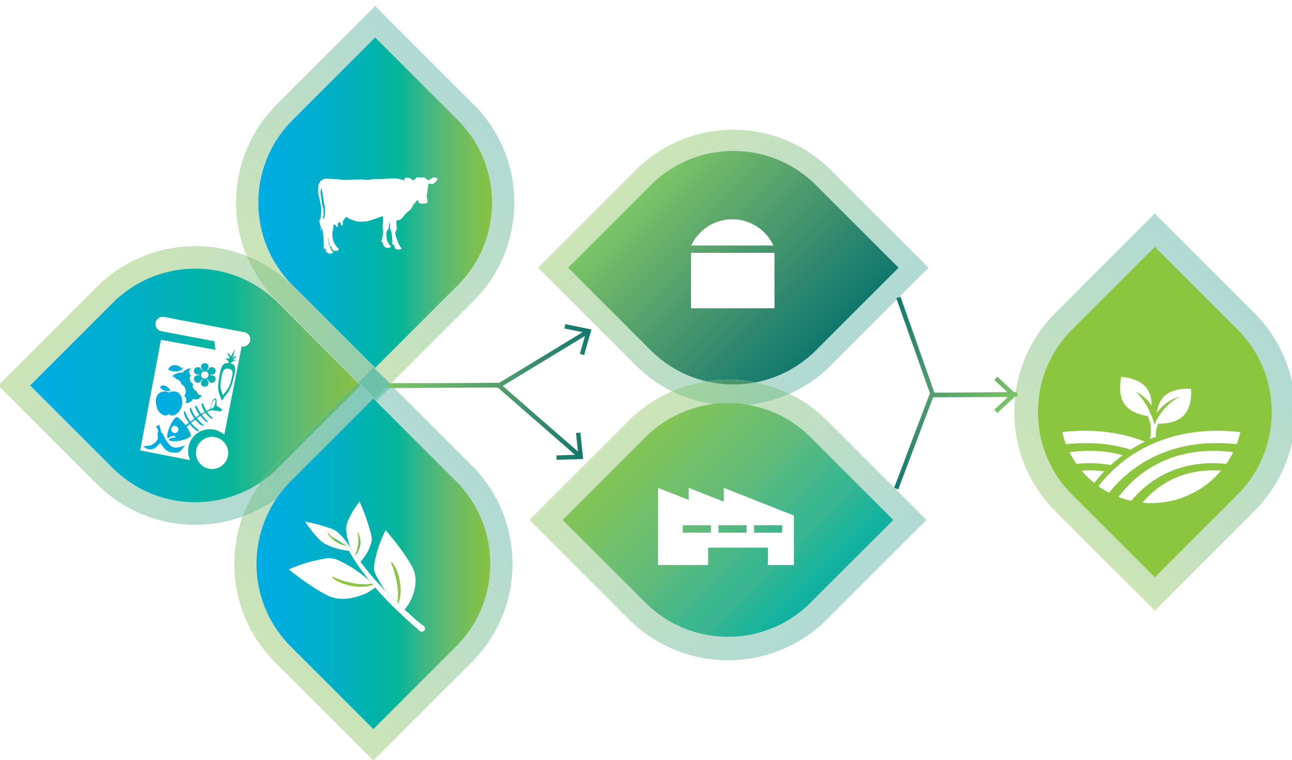

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Government of Ireland

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EPA RESEARCH PROGRAMME 2021–2030

Development of Quality Standards for Compost and Digestate in Ireland

(2018-RE-DS-10)

Prepared for the Environmental Protection Agency

by

Cré – Composting & Anaerobic Digestion Association of Ireland

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ACKNOWLEDGEMENTS

This report is published as part of the EPA Research Programme 2021–2030. The EPA Research Programme is a Government of Ireland initiative funded by the Department of the Environment, Climate and Communications. It is administered by the Environmental Protection Agency, which has the statutory function of co-ordinating and promoting environmental research.

The authors would like to acknowledge the members of the project steering committee, namely Caroline Murphy (EPA), Vivienne Ahern (Department of the Environment, Climate and Communications), Professor James Clark (University of York), Patrick Barrett (Department of Agriculture, Food and the Marine), John Clarke (Department of Agriculture, Food and the Marine) and Karen Roche (Project Manager on behalf of the EPA).

The project team would like to thank the compost and anaerobic digestion plants that provided data on their compost and digestate.

The project team thanks the following stakeholders, who provided information on standards and legislation: Susan Antler (Compost Council of Canada), Wim Vanden Auweele (VLACO), Stefanie Siebert (European Compost Network), Florian Amlinger (Compost Development and Consulting, Austria), Maria Thelan-Jungling (Bundesgütegemeinschaft Kompost e.V.), Frank Franciosi (US Composting Council), Julie Dajčl (CZ Biom), Mait Kriipsalu (Estonian University of Life Sciences), Juha Pirkkamaa (Biolaitosyhdistys ry – Finnish Association for Biological Waste Treatment), Katerina Xenopoulou (Compost Hellas), László Aleksza (Profikomp), Alberto Confalonieri (CIC), Domantas Tracevičius (Biastra Plius), Anneleen Rotering and Arjen Brinkmann (BVOR – Branche Vereniging Organische Reststoffen), Henrik Lystad (NorWaste), Susana Lopes (Lipor), Alin Murariu (Romanian Compost Association), Andrej Pristovnik (Ministry of the Environment and Spatial Planning), Caroline Steinwig (Avfall Sverige – Swedish Waste Management), Konrad Schleiss (UMWEKO GmbH), Irmgard Leifert (RETERRA Service GmbH), Thomas Colin (Compostplus) and Dimitris Tsaltas (Cyprus University of Technology).

Cover image: Organic wastes processed by composting or anaerobic digestion into good-quality compost or digestate.

EPA RESEARCH PROGRAMME 2021–2030

Published by the Environmental Protection Agency, Ireland

ISBN: 978-1-84095-994-9 May 2021

Price: Free Online version

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Executive Summary

Recent European Union (EU) circular economy and bioeconomy policies and the New European Green Deal promote the recycling of organic wastes into soil improvers and fertilisers, thereby reducing the use of mineral fertilisers. This has renewed interest in the use of compost and digestate as fertilisers.

This study collated the results of the analysis of Irish compost and digestate samples and then compared the Irish data with databases, reports and standards from other European countries. The Joint Research Centre (JRC) report *End-of-waste Criteria for Biodegradable Waste Subjected to Biological Treatment (Compost & Digestate)* and the new Fertilising Products Regulation (EU) 2019/1009 were considered in this study. From this collation and comparison process, an updated compost standard and a new digestate standard (whole, liquid and fibre) were developed.

Some of the key recommendations are as follows (see also Tables ES.1 and ES.2).

Feedstocks

- A contamination working group should be established to develop a national plan. The authors determined that the greatest risk to achieving the standards is the presence of contamination in the feedstock.

Monitoring of process and quality assurance

- End-of-waste criteria for compost/digestate could be based on either national fertiliser regulations or biowaste ordinance legislation.

- The authors are of the opinion that the criteria should include the requirement that plants proposing to produce an end-of-waste product be compliant with a quality assurance scheme.

Standards

- Using the information in this report, the National Standards Authority of Ireland (NSAI) should update Irish Standard (IS) 441 on compost and develop a new IS for digestate placed on the domestic market.
- A review of the impurity standard and limit values should be undertaken in 2025.
- The findings of this study can be used in an application to the Environmental Protection Agency (EPA) by industry for national end-of-waste standards for compost and digestate.[1]

In addition to the mandatory limits, we recommend that the value of a number of parameters, such as nutrients, should be declared by all plants so that the end-user can make informed decisions on the best way to use the product.

1 The standards developed in this project could be used for the domestic market in Ireland. Post July 2022, products that conform to the EU Fertilising Products Regulation can be traded within the EU. Adhering to the standards developed in this project does not automatically mean meeting the criterion in Article 28(1)(a)(iii). The standards would have to be assessed by the EPA through an end-of-waste application.

Table ES.1. Proposed quality standards for compost and digestate

Parameter	Compost	Digestate: whole, separated fibre or liquor
Heavy metals		
Mercury (mg/kg DM)	1	1
Cadmium (mg/kg DM)	1.5	1.5
Nickel (mg/kg DM)	50	50
Chromium (mg/kg DM)	100	100
Copper (mg/kg DM)	300	300
Zinc (mg/kg DM)	800	800
Lead (mg/kg DM)	150	150
Total arsenic (mg/kg DM)	20	20
Hexavalent chromium (mg/kg DM)	2	2
Pathogens		
Salmonella spp. (cfu/25 g)	Absent in 25 g	Absent in 25 g
Escherichia coli (cfu/g fresh mass)	1000	1000
Impurities,[a] viable weed seeds and PAH_{16}		
Total glass, metal and plastic > 2 mm diameter by dry weight	0.5%	0.5%
Plastics > 2 mm	0.25%	0.25%
Viable weed seeds per litre	≤2	≤2
PAH_{16} (mg/kg)[b]	6	6
Stability and maturity		
Oxygen uptake rate[c] (mmol O_2/kg organic solids/h)	Growing media: 15 Field application: 25	50
Residual biogas potential[c] (l/g VS)	–	0.25
Germination test for use in growing media	80%	80%
Munoo–Liisa vitality index (MLV)		
Organic matter		
Organic matter (% dry weight)	20%	20% for whole and separated fibre. No limit for liquor

[a]The impurities standard will be revised in 2025.

[b]Compost/digestate sampling frequency is used as outlined in the 2014 JRC report by Saveyn and Eder (2014).

[c]Digestate is sampled using the oxygen uptake rate or residual biogas potential.

cfu, colony-forming unit; DM, dry matter; PAH, polycyclic aromatic hydrocarbon; VS, volatile solids.

Table ES.2. Declaration of parameters in compost and digestate

Quality criterion	Parameter	Unit	Compost	Digestate
Soil improvement	pH value		✓	✓
	Liming value (CaO)	% DM	✓	×
Fertilising properties	Total nitrogen	% DM	✓	✓
	Extractable ammonium	mg/l	×	✓
	Total phosphorus	% DM	✓	✓
	Total potassium	% DM	✓	✓
	Total sulfur	% DM	✓	✓
	Total magnesium	% DM	✓	✓
General parameters	Dry matter	% DM	✓	✓
	Electrical conductivity	mS/m	✓	Mandatory where digestate is not used in agriculture
	Maximum particle size	mm	✓	×
	Bulk density	g/l FM	✓	×
	Stones > 5 mm	% DM	✓	✓
	Moisture	%	✓	✓

CaO, calcium oxide; DM, dry matter; FM, fresh matter.

1 Introduction

This project was carried out as part of the EPA Research Programme 2021–2030. The project is primarily a desktop study that was supplemented with laboratory analysis, where there were no Irish data available.

1.1 Background

Ireland's Waste Policy – A Waste Action Plan for a Circular Economy (Government of Ireland, 2020) – aims to promote the segregation of food waste as outlined in the Household Food Waste Regulations[2] and the Commercial Food Waste Regulations.[3] The successful implementation of the regulations will be enhanced by the availability of end-of-waste criteria[4] for compost and digestate. An end-of-waste status would drive the need for high-quality feedstocks to produce a compost or digestate that meets end-of-waste criteria.

At the European level, separate collection of biowaste will become mandatory by 2023 under the new Circular Economy legislative package. Recent European Union (EU) circular economy and bioeconomy policies and the New European Green Deal promote the recycling of nutrients from organic wastes into products that can be used as soil improvers and fertilisers, thereby reducing the use of mineral fertilisers. This has renewed interest in the use of compost and digestate as fertilisers. The EU Farm to Fork Strategy aims to look at how we produce food sustainably and reduce food waste.

In Ireland, there currently are no national end-of-waste criteria for compost and digestate derived from source-separated materials. Environmental Protection Agency (EPA) licences and local authority waste facility permits granted to composting and anaerobic digestion (AD) plants include a quality standard as part of the licence/permit conditions. However, the parameters and limit values vary considerably in older licences/permits. The newer compost plant licences/permits contain parameters and limit values that have been adopted from the national compost Irish Standard (IS) 441, but these are also referenced licences/permits for AD plants, an activity for which IS 441 was not developed. Some parameters, such as stability limit values, are not suitable reference values for AD plants.

All Irish plant permits and licences were reviewed during this study and it was determined that there are five different types of standards being used when issuing licences/permits. There are also seven plants that have no quality standard in place. Factors that affect the end quality of compost and digestate include feedstock composition, contamination in feedstocks, process management and the end quality standard to be achieved. Because of the different standards being used, there are varying qualities of compost and digestate being produced, which, in turn, means that there are different impacts from heavy metals, plastic and glass fragments on soil. Overall, the system needs a uniform set of quality standards for both compost and digestate, which would replace the existing multiple standards being applied. The results of this study could be used to develop standards for compost and digestate.

It is widely recognised that market development is a key element in the development of the composting and AD industry, and this is enhanced by quality standards being available for its products. A market report prepared by rx3 (2012) provided details of composting and AD plants and generally gave a positive outlook.

As part of this project an extensive survey of composting and AD plants in Ireland (excluding wastewater treatment plants) was conducted to understand the production and use of compost and

2 European Union (Household Food Waste and Bio-waste) Regulations 2013, Statutory Instrument (S.I.) 71 of 2013 and Amendment Regulations S.I. 251 of 2013.

3 Waste Management (Food Waste) Regulations 2009, S.I. 508 of 2009.

4 Depending on the feedstocks treated at a facility/installation, not all operators may pursue an end-of-waste status for their treated outputs, as they may be able to avail themselves of an exclusion from the need for waste authorisation, provided by Section 3(1)(g) of the Waste Management Act 1996, as amended.

digestate derived from source-separated materials. In 2018, 123 kt of digestate and 84 kt of compost were generated, as shown in Figure 1.1.

The primary market for digestate generated from source-separated materials is grassland (72%). This reflects the fact that the application window for use on grassland is longer than that for tillage, for which land application is restricted to periods in the spring and autumn. The primary market for compost derived from brown bin material is tillage. A much smaller amount of compost is used in grassland, which is in notable contrast to digestate use. However, there are a number of higher value markets developing in garden centres and landscaping. The primary markets for garden material compost are landscaping and dilution and replacement of peat products. Landscaping is the primary market for compost derived from sewage sludge.

This study researched the development of a digestate quality standard and updated the current compost standard developed in the previous EPA-funded project, To Develop an Industry-led Quality Standard for Source-separated Biodegradable Material Derived Compost (Prasad and Foster, 2008). The success of that project led to the results being used by the National Standards Authority of Ireland (NSAI) to develop a national compost standard, namely IS 441.

The process of revising the EU Sewage Sludge Directive (86/278/EEC) started in August 2020. The outcome of this will affect quality standards. Once the EU process is completed, the situation for Ireland should be examined. As part of this project we have collated some data and national standards that can be used in a future project to develop quality standards for sewage sludge as input feedstocks. Development of quality standards for compost and digestate derived from sewage sludge is not within the scope of this report.

1.2 Study Objectives

The objectives of the study were:

- to collate and analyse laboratory data on compost and digestate quality in Ireland since 2008;
- to compare the Irish data with those from other databases, the EU Fertilising Products Regulation (FPR) 2009/1009 and standards to propose separate quality standards for compost and digestate for public consultation;
- to review end-of-waste approaches in other European countries to recommend a strategy on how Ireland should implement national end-of-waste criteria for compost and digestate derived from source-separated waste materials;
- to determine if there are new markets emerging that have specific standard requirements.

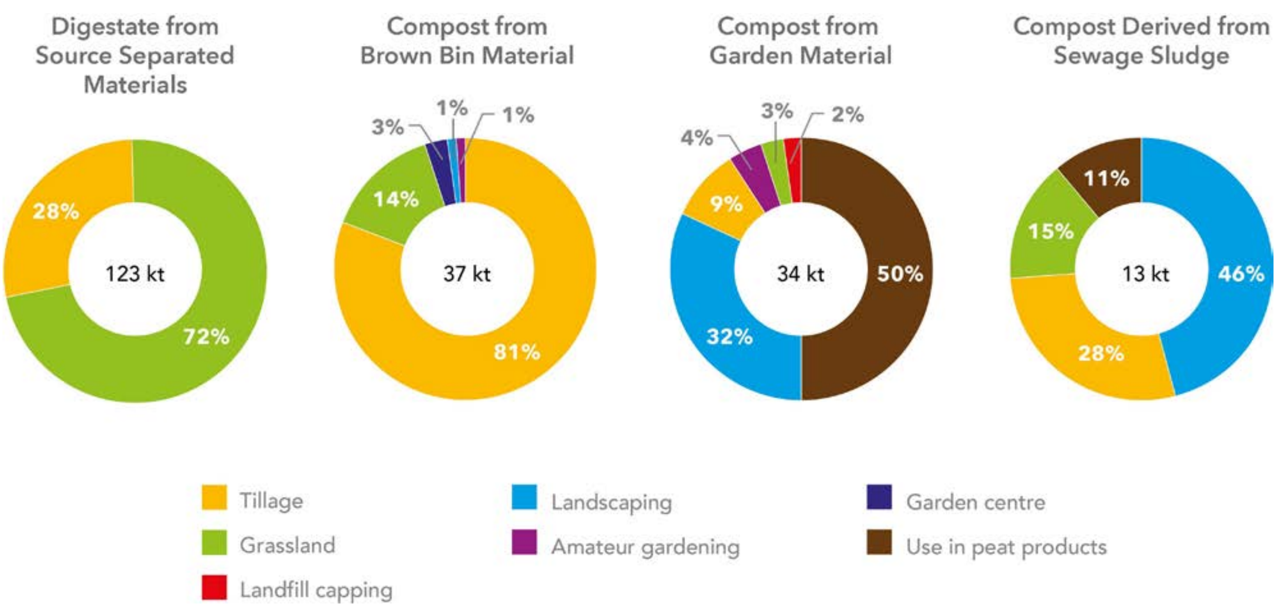

Figure 1.1. Digestate and compost production in Ireland in 2018.

2 Methodology

A desktop evaluation of compost and digestate quality results from existing compost and AD plants was conducted.

2.1 Collation of the Irish Compost and Digestate Databases

Compost and AD plants were asked to provide their quality data for the years 2009 to 2018. The data provided were collated into a database and are referred to in this study as the 2019 database, as the data were collated in 2019. The references throughout this study to the 2008 database are from the report by Prasad and Foster (2008). The database consolidated in this study was categorised into the following classes based on the feedstock used to produce the compost and digestate:

- source-separated green waste (SSGW) compost: 171 samples from five compost facilities;
- source-separated biowaste (SSBW) compost: 184 samples from seven compost facilities;
- sewage sludge compost (SSC): 86 samples from three facilities;
- source-separated digestate: six samples from six facilities;

2.2 Comparison of Irish Data to Other Databases and Standards

The Irish database was compared with other country databases and the quality standards adopted by other European countries, the USA, Canada, the United Arab Emirates (UAE) and Australia. This was followed by a technical appraisal of compost and digestate quality standards in consultation with key Quality Assurance Scheme (QAS) organisations. Relevant published reports and peer-reviewed papers in journals were examined and considered in this study.

2.3 Structure/Type/Number of Standards

Different standards apply in countries across Europe (Table 3.1). The quality criteria for digestate and guidelines applied in Germany are designated by RAL-GZ 245, which differentiates between solid and liquid digestates. RAL is the German National Committee for Delivery and Quality Assurance. In Germany there are different standards for biowaste compost and SSC. In the UK, there are different quality specifications for digestates and compost.

This approach was considered in this study to see if there is merit in using different standards. In 2008, the Joint Research Centre (JRC) published a report on end-of-waste, which included a case study on compost (JRC-IPTS, 2008). The findings of that report were used to assist in developing limits in the recommended compost standard by Prasad and Foster (2008). In this study we focused on the information in the more recent JRC report by Saveyn and Eder (2014) and the recent report on how Member States address end-of-waste (Umweltbundesamt GmBH and Arcadis, 2020).

2.4 End-of-waste

Approaches taken by other European countries and in Ireland on the implementation of end-of-waste criteria were examined to determine the trends.

2.5 Stakeholder Engagement

In this study we engaged widely with many stakeholders including other QAS bodies, compost and AD plant operators and over 30 representatives from different countries. Cré co-hosted a meeting with the European Compost Network (ECN) in Brussels with QAS organisations (Germany, Finland, Portugal, Belgium, the UK, Italy, the Netherlands and Austria) to discuss this study. The focus of the meeting was exchanging knowledge on plastic in compost/digestate, stability and overall QAS issues.

2.6 Public Consultation

The draft standards were issued for consultation. Comments were evaluated and the study amended where appropriate. The main points of feedback from the consultation were as follows:

- The key issue identified by stakeholders was plastic contamination in compost and digestate. It was felt that there should be no plastic in either, but stakeholders acknowledged how difficult it is to remove plastic from the final product. The issue of contamination with plastic and metals is an important one for a group of farmers who have stopped using compost from brown bin material. If there was no contamination, it would encourage them to use it. The long-term effect of plastic/compostable bioplastics on soil was raised and that there is a need for studies to be conducted on this.
- Stakeholders sought the establishment of a “contamination working group”, which would focus on removing plastic contamination at the source of waste generation using an education programme.
- The stakeholders felt that, if compost and digestate were to be certified to end-of-waste standards in the future, people would use them as alternatives to mineral fertilisers. There is an opportunity for the sector to provide more tailored/blended compost and digestate with a higher nutrient content. This would depend on the current contamination issue being solved.
- Stakeholders are not well informed about the properties of digestate and an education programme is required.
- Stakeholders would like to develop the trade in compost and digestate between Ireland and Northern Ireland and feel that mutual recognition of end-of-waste criteria in both jurisdictions would facilitate this.

3 Approach to Standards and End-of-waste

In our research we could not determine if Denmark, Malta, Luxembourg, Poland, Slovakia, Latvia and Croatia have standards for compost and digestate. The countries with no standards for compost are Cyprus, Lithuania and Romania. The countries with no standards for digestate are Austria, Italy, Cyprus, Lithuania, Portugal and the Netherlands.

Table 3.1 shows how some countries have different standards based on the input feedstock and whether the output is compost or digestate. The trend is that there is a standard for "waste compost". In general, when it comes to a standard for waste/biowaste compost, sewage sludge is excluded as a feedstock. Some countries, such as France, Estonia, Bulgaria and Germany, have a separate specific standard for SSC that contains additional parameters.

When it comes to digestate, it is defined as either waste-based digestate or digestate exempt from waste authorisation (e.g. purpose-grown crops and manures[5]). It should be mentioned that there could be three products from digestate, namely whole digestate (entire digestate), separated fibre and the separated liquor. In Ireland it is mostly whole digestate that is produced. The separated fibre is more economical to handle and transport. The liquor can be valorised after a biological treatment for use as a liquid fertiliser or stripped of ammonia to make ammonium sulfate.

The direct application of digestate from biowaste/food waste AD is not allowed in the Netherlands. This material needs to undergo a post-composting step, which explains why there is no digestate standard. The Dutch thinking behind this policy is that digestate from biowaste is never a fully stabilised product, as the woody components in particular will not degrade under anaerobic conditions. For this to happen, digestate is required to be composted.

In Italy the same situation applies to biowaste processed by AD – this material needs to undergo a post-composting step. Composting gives more options for the use of digestate. For example, composting digestate with garden waste results in it being able to be used in growing media. For digestate from Italian farm biogas plants, there are no quality standards; however, there have been rules for its storage and application since 2016. There are standards for a fertiliser called "dry bovine and swine manure" digestate mixed with ashes from virgin biomass combustion, with limits for moisture (maximum 10%), nitrogen (N; minimum 1.5%), phosphorus (P, as P_2O_5; minimum 2%), organic carbon (minimum 30% dry matter – DM), heavy metals and microbial parameters, as in the standard for compost. In the UK, there is a single standard for digestate that is either whole digestate, separated liquor or separate fibre. The standard also differentiates between animal by-product (ABP) and non-ABP digestate.

After reviewing the standards in Table 3.1 we recommend the approach outlined in Box 3.1 for Ireland. If the separated fibre is sent for composting, it automatically falls under the compost standard.

The scope of this research study was to examine end-of-waste standards for compost and digestate from source-separated waste materials. These standards exclude feedstocks from mixed municipal waste, sewage sludge and tannery waste. However, as part of the study we have gained knowledge from other countries on standards for feedstocks that are classified as waste authorisation exempt (crops, manures and waste exempt from waste authorisation of the Waste Management Act 1996, as amended) such as manures and energy crops. In addition, some countries have a dedicated standard for compost and digestate from sewage sludge. Although waste authorisation-exempt materials and sewage sludge

5 In this instance, Section 3(1)(g) of the Waste Management Act 1996, as amended, provides the exemption from the need for waste authorisation. It applies to feedstocks sourced from agriculture or forestry … agriculture is defined in legislation and that definition is to commercial food crops or fodder crops … it doesn't list energy crops. The local authority can require a class 13 certificate of registration (a waste authorisation) for the spreading of organic waste of specific types on land; however, this applies only to compost derived from source-segregated municipal waste, spent mushroom compost and sewage sludge used for non-agricultural purposes.

Table 3.1. Standards in various countries based on input feedstock

Country	Waste compost	Biowaste compost	Green compost	Sewage sludge	Waste digestate whole	Waste digestate separated fibre	Waste digestate separated liquor	Waste exempt digestate whole	Waste exempt digestate separated fibre	Waste exempt digestate separated liquor
Austria	Classes A, B and C									
Belgium										
Bulgaria										
Czechia										
Estonia										
Finland										
Germany										
Greece										
Hungary										
Italy										
Netherlands	Classes A, B and C									
Portugal	Three classes									
Slovenia	Two classes				Three classes based on organic matter content					
Sweden										
UK					Whole, fibre and liquor have to meet the same standard			Whole, fibre and liquor have to meet the same standard		
Norway		Four classes								
Switzerland										
Spain										
UAE										
France										
USA										
Canada										

Grey cells indicate that a standard exists.
Classes: A, organic agriculture; A+, agriculture; B, non-agricultural.

were not part of the original scope, we have made some comments on standards; these are outlined in Appendices 1 and 2.

When material achieves end-of-waste status this means that the material conforms to an agreed specification and is classified as a product and not as a waste; the waste legislation therefore does not apply. Avoiding the waste legislation removes unnecessary regulatory burden and helps develop markets in line with a circular bioeconomy (Umweltbundesamt GmBH and Arcadis, 2020). Moreover, it is an opportunity to generally recognise product standards and promote quality assurance to support the development of a value-added market. When a plant achieves end-of-waste status it opens up new markets while still respecting the precautionary principle by avoiding pollution when compost and digestate are used on soil.

Box 3.1. Standards recommended for adoption in Ireland

- Waste compost.
- Waste digestate – whole, separated fibre and separated liquor.
- Sewage sludge compost and digestate.
- Waste authorisation-exempt digestate (crops, manure and waste exempt from waste authorisation) – whole, separated fibre and separated liquor, and compost.

Article 28 ("End-of-waste Status") from the EU (Waste Directive) Regulation 2020,[6] S.I. No. 323 of 2020, transposes Article 6 of the Waste Framework Directive into national legislation. Article 28 sets out four conditions, all of which must be met for a waste to obtain end-of-waste status.

The authors are of the opinion that, in Ireland, national end-of-waste criteria for compost and digestate would be best suited for the sector instead of considering waste on a case-by-case basis. This would mean standardisation of compost and digestate quality standards to classify when they cease to be waste.

EU Member States follow different approaches when determining if compost or digestate is a waste or not. In some cases criteria are set out in specific biowaste legislation (e.g. Austria, Germany, Estonia and Bulgaria) that has very clear rules (e.g. types of input feedstocks, processing standard, end product quality standard, labelling and external quality control) or in national fertiliser regulations.

In many countries (Belgium, Czechia, Finland, Hungary, Italy, the Netherlands, Portugal, Norway, Switzerland and Spain) compost/digestate has to be registered under the national fertiliser regulations as organic fertilier/soil improver before it can be used. It is then implicitly assumed that any registered compost/digestate is a product and has ceased to be waste, i.e. it is given de facto end-of-waste status when registered as fertiliser. In 2022, the EU FPR will also provide de facto end-of-waste status when registered as a CE fertiliser.

The use of the national fertiliser regulations approach appears to be the most common route in many European countries and elsewhere as shown in Table 3.2.

3.1 EU Fertiliser Regulations

The new FPR (EU) 2019/1009 was approved by the European Parliament and the Council of the European Union on 5 June 2019. The new EU FPR will repeal the current Fertiliser Regulation (EC) No. 2003/2003 (which almost exclusively covers fertilisers from mined or chemically produced, inorganic materials) and shall apply from 16 July 2022.

The new EU FPR does not affect the so-called national fertilisers, which are solely placed on the domestic market of each Member State in accordance with national legislation. Member States can continue to authorise products in their country as "national" fertilisers. Currently, producers can choose to market a fertiliser as an "EC fertiliser" (carrying a CE mark from 2022) or as a "national fertiliser". This is referred to as optional harmonisation, which is the free choice to opt for compliance with national rules for fertilising products restricted to national markets or to comply with EU rules for CE-marked fertilisers with unrestricted access to fertiliser markets across the EU.

This new FPR will open the European market for recycled nutrient products and for nutrient recycling technologies. It covers organic, organo-mineral and mineral fertilisers, composts, digestates, food industry by-products and other products such as liming materials and fertiliser polymers. The new EU FPR will help open high-end markets for compost and digestate marketed abroad. Digestate is not traded over long distances, as it becomes financially unviable as a result of transport costs. However, dried digestate pellets may be exported (Umweltbundesamt GmBH and Arcadis, 2020).

Article 19 of the EU FPR refers to the end-of-waste status, indicating that this regulation lays down criteria for when material that constitutes waste, as defined in the revised Waste Framework Directive (WFD), can cease to be waste if it is present in a compliant EU fertilising product. Component material category (CMC) 5 (digestate other than fresh crop digestate) and CMC 3 (compost) include biowaste as input material, implying the presence of waste in the

6 http://www.irishstatutebook.ie/eli/2020/si/323/made/en/print?q=waste+directive (accessed 15 October 2020).

Table 3.2. Summary of legal approaches to determining end-of-waste status for compost and digestate

Country	Reference	End-of-waste approach/legislation
Austria	Compost Ordinance Regulation No. 292 of 2001	Austria has Compost Ordinance Regulation No. 292 of 2001 under the umbrella of the waste management law, which defines input materials, quality criteria, etc., to produce compost as a product. The ordinance is now under revision and will include a QAS for process parameters to reach product status. For digestate there is no legal end-of-waste ordinance; it falls within the fertiliser regulation, which has standards, as do the guidelines from the Ministry of Agriculture [F. Amlinger, Compost – Consulting & Development (Austria), 2 April 2020, personal communication]
Bulgaria	Biowaste Ordinance Ministerial Decree No. 235 of 2013	Bulgaria has Biowaste Ordinance Ministerial Decree No. 235 of 2013, which is similar to the Austrian Compost Ordinance Regulation, except it covers compost and digestate
Slovenia	Decree on the recovery of biodegradable waste and the use of compost or digestate (Official Gazette of the Republic of Slovenia, Nos. 99/13, 56/15 and 56/18)	The decree on the treatment of biodegradable waste contains a list of suitable feedstocks and this defines end-of-waste
Estonia	Requirements for the production of compost from biodegradable waste – 8 April 2013, No. 7 Requirements for digestion residues from biogas production from biodegradable waste – 10 May 2016, No. 12 Requirements for the manufacture of a product from sewage sludge – 19 July 2017, No. 24	There are three national end-of-waste regulations, covering biowaste compost, biowaste digestate and SSC. A QAS organisation provides accreditation for plants to the requirements of the legislation (Mait Kriipsalu, Estonian University of Life Sciences, 25 March 2019, personal communication) If manure and slurry are the input feedstocks, the quality and use do not fall under the waste act but instead under the fertiliser and water act (Umweltbundesamt GmbH and Arcadis, 2020)
Greece	Waste Regulation Gazette of the Hellenic Republic Sheet 3339 – 2014	This legislation provides the basis for the definition of compost and digestate as a product
Germany	The 2013 Ordinance on the Recovery of Bio-waste on Land Used for Agricultural, Silvicultural and Horticultural Purposes (Bio-waste Ordinance – BioAbfV) and in the German Fertiliser Ordinance on the manufacturing, marketing and use of fertilisers, soil improvers, culture media and plant aids	In Germany, the situation is complex. The Bio-waste Ordinance defines the legal status of biowaste and garden waste. Nevertheless, if a treatment plant continuously uses a quality assurance system such as the BGK, it demonstrates its quality approach and is exempted from a lot of the strict waste-related requirements, such as soil tests in advance or announcing the application to the local authority. So, compost or digestate with a BGK quality label are “likely a product” However, when the compost is applied on the soil, the German Fertiliser Ordinance takes over legally The BGK quality assurance is based on the German RAL standards. The BGK is the QAS that sets out how to comply with the ordinances. Historically only the BGK-RAL standards were used, but these have started to be used as the basis for the ordinances because they have shown effectiveness (Maria Thelen-Jüngling, BGK, 10 May 2019, and Josef Barth, INFORMA, 28 June 2020, personal communications)
Belgium	Royal Decree of 28 January 2013 on the marketing and use of fertilisers, soil improvers and growing media	The Royal Decree of 7 January 1998 was replaced by the Royal Decree of 28 January 2013 This is the federal legislation on the trading of fertilisers, soil improvers and growing media. The competent authority is the Federal Public Service Health, Food Chain Safety and Environment. Before compost can be traded, there needs to be an end-of-waste position. This is regulated at a regional level, set out in the Flemish Decree (VLAREMA). The competent authority is OVAM, the Flemish waste agency. The VLAREMA lays down the rules for treatment plants of biowaste. The specific criteria are described in the “General Rules for Certification”, which is the QAS that VLACO has to follow for certification of compost and AD plants Once compost and digestate are regulated at a regional level, the federal authorities may grant a derogation for the product, meaning that the producer can trade it on the market. All analyses carried out at a regional level can be used to obtain this derogation. The federal food safety authorities (FAVV-AFSCA) conduct market surveillance and check the treatment plants at the level of labelling, transport and packaging (Wim Vanden Auweele, VLACO, 3 April 2020, personal communication)

Table 3.2. Continued

Country	Reference	End-of-waste approach/legislation
Czechia	Fertiliser Decree No. 474/2000 on the specification of requirements for fertilisers	This legislation defines when compost and digestate are defined as a product
Finland	Decree of the Ministry of Agriculture and Forestry on Fertiliser Products (24/2011, amendments up to 7/2013 included)	The Fertiliser Product Act defines when products such as compost and digestate are defined as a product
Hungary	Fertiliser Regulation 36/2006 (V. 18.)	End-of-waste is covered by the Fertiliser Regulation (36/2006) in Hungary. There is another option if the product is not end-of-waste; in that case you need permission from the soil protection agency and then you can use compost and digestate in agriculture as treated waste (László Aleksza, ProfiKomp, 26 June 2020, personal communication)
Italy	Fertiliser Legislative Decree 75/2010	The Fertiliser Regulation covers compost. For digestate from waste feedstocks it must be composted to receive product status. For digestate from farm biogas plants, there are no quality standards; since 2016, there have only been rules for its storage and application. There are only standards for a fertiliser called "dry bovine and swine manure digestate mixed with ashes from virgin biomass combustion", setting limits for moisture (maximum 10%), N (minimum 1.5%), P_2O_5 (minimum 2%), organic carbon (minimum 30% DM), heavy metals and microbial contamination; this is the same as in the compost standard (Alberto Confalonieri, Consorzio Italiano Compostarori, 2.9.2019, personal communication)
Netherlands	The Manure and Fertilisers Act 2016	Compost in the Netherlands has no formal end-of-waste status. Effectively, as soon as the organic waste has been converted to compost and has been tested to comply with the fertiliser regulation, it falls under the scope of that regulation (or, more precisely, the fertiliser regulation precedes over the waste legislation) (Arjen Brinkmann, BVOR, 22 January 2020, personal communication) There is a difference between digestate from household biowaste/food waste composting and digestate from co-digestion of (at least 50%) animal manure with (a maximum of 50%) other organic residues. The first category requires post-composting; the product is then a compost product. The second category can be used directly on the land and is classified as animal manure. For digestate it is qualified as animal manure and falls under the Fertiliser Regulation
Portugal	Fertiliser Law 103/2015	The fertiliser law defines when compost is no longer a waste and is instead a product (Umweltbundesamt GmBH and Arcadis, 2020)
England, Wales and Northern Ireland	Quality protocols	Quality protocols include PAS 100:2018 for compost and PAS 110 for digestate for England, Wales and Northern Ireland for SSBW
Scotland	SEPA Guidance on Regulation of Outputs from Composting Processes, January 2017	SEPA has a position for compost and digestate that basically requires sites to produce according to PAS 100 or PAS 110, with addition physical contamination limits and the requirement to have a market
Norway	Regulation on fertilisers, etc. of organic origin FOR-2003-07-04-951	The fertiliser law defines when compost and digestate are no longer a waste and are instead products
Switzerland	Regulation on the Marketing of Fertilisers, 2001	The fertiliser law defines when compost and digestate are no longer a waste and are instead products
Spain	Royal Decree 506/2013, 28 June, on Fertiliser Products	The fertiliser law defines when compost is no longer a waste and is instead a product Spain has no specific legislation regarding digestate from biodegradable waste. Some parts of existing legislation can, however, be applied; digested sludge is subject to legislation on sewage sludge and digested SSBW or digested organic matter from mixed municipal waste (usually composted) is subject to legislation on compost (Umweltbundesamt GmBH and Arcadis, 2020)
UAE	Ministerial Decree No. 801 of 2015 on the By-law of the Fertilizers and Soil Conditioners	This decree defines when compost is a fertiliser

Table 3.2. Continued

Country	Reference	End-of-waste approach/legislation
France	NF U 44-051 for Soil Improvers	There are different standards depending on the type of product: (1) compost or digestate, (2) the regulatory way those products are used on land and (3) their components biowaste/sewage sludge. Compost that complies with the requirement of the standard is considered a product and is no longer considered waste
Lithuania		Lithuania has indicated plans to introduce national end-of-waste criteria for biodegradable waste in the future (Umweltbundesamt GmBH and Arcadis, 2020)

BGK, Bundesgütegemeinschaft Kompost (German Compost and Digestate Quality Assurance Organisation); FAVV-AFSCA, Federaal Agentschap voor de Veiligheid van de Voedselketen–Agence Fédérale pour la Sécurité de la Chaîne Alimentaire (Belgian Federal Agency for the Safety of the Food Chain); OVAM, Openbare Vlaamse Afvalstoffenmaatschappij (Flemish Waste Agency); PAS, Publicly Available Specification for Composted Materials; RAL, German National Committee for Delivery and Quality Assurance; SEPA, Scottish Environment Protection Agency; VLAREMA, Vlaams Reglement voor duurzaam beheer van Materialenkringlopen en Afvalstoffen (Flemish Regulation on Sustainable Materials Management and Waste).

digestate/compost. As such, upon fulfilling the criteria laid down in the EU FPR and the conditions of Article 6 of the revised WFD), digestate of CMC 5 and compost of CMC 3 may be granted end-of-waste status (Umweltbundesamt GmBH and Arcadis, 2020).

The EU FPR imposes the typical parameters of heavy metals, impurities, stability and pathogens. The main additions to the typical compost and digestate standards across Europe are the following:

- hexavalent chromium, biuret and inorganic arsenic;
- polycyclic aromatic hydrocarbons (PAH_{16}); and
- limits for N, P and potassium (K) based on fresh matter.

The regulations also make it mandatory that plants processing ABPs have to process them at the EU transformation standard of 70°C for 1 hour at a 12 mm particle size. Plants in Ireland processing to the national ABP standard are therefore excluded from the regulations.

3.1.1 Hexavalent chromium

The EU FPR also specifies a limit for hexavalent chromium. The reason, from our understanding, is that tannery waste could contain hexavalent chromium and, if used in composting and AD, would introduce this metal to the resulting compost and digestate. A list of acceptable waste to which the standards developed in this report apply should exclude tannery waste.

3.1.2 Biuret

Biuret is formed during the manufacturing of urea fertiliser. It is not relevant to compost and digestate. Biuret can be toxic to plants (Mikkelsen, 1990).

3.1.3 Inorganic arsenic

Inorganic arsenic is not routinely analysed and during this project we contacted several laboratories in Ireland, the UK and Belgium, and those that responded could not provide this analysis. We learnt that the test for total arsenic includes inorganic arsenic. Therefore, if you test for total arsenic and the level is low, by default the inorganic arsenic content is low too. High levels of arsenic can occur naturally in Irish soil on account of the local geology. The Teagasc National Soil Database states that the median value of arsenic is 7.25 mg/kg and the maximum is 122.7 mg/kg.

3.1.4 N, P and K

Having limits for N, P and K is unusual. The typical practice for standards is that nutrient level should be tested and the results declared. This is discussed further in Chapter 5.

We have looked at data available in Ireland on total N, P and K in compost and digestate (Table 3.3). The data show that green waste compost would not meet all the limits prescribed in the EU FPR.

The ECN has expressed concerns with some of the parameters, namely:

Table 3.3. Total N, P and K (as K_2O) in Irish compost and digestate compared with limits in the EU FPR

		Mean per cent by mass (standard deviation)		
Nutrient	**EU FPR (minimum requirement)**	**SSGW**	**SSBW**	**Digestate**
N	1	1.3 (0.5)	2.07 (0.92)	2.5
P_2O_5	1	0.57 (0.08)	1.01 (0.16)	5.0
K_2O	1	1.19 (0.31)	1.28 (0.45)	0.8
Sum	>4	3.06	4.36	8.3

The 2008 data were total P and K. Total P was converted to P_2O_5 by multiplying the data by 2.29. Total K was converted to K_2O by multiplying the data by 1.2.

Data from Prasad and Foster (2008) and Prasad *et al*. (2012).

- The lack of recognition that limit values for minimum nutrient and organic carbon content should be expressed on a DM basis.
- It will be difficult for digestate (liquid or solid) to fulfil the nutrient or carbon minimum content requirement for organic fertilisers or soil improvers.
- The pathogen control limit for *Escherichia coli*/Enterococcaceae as product criteria for organic fertilisers, organic soil improvers and growing media should be excluded, as these pathogens will regrow.
- The oxygen uptake rate (OUR) stability criterion for digestate is unlikely to be achieved for solid and especially for liquid digestates.
- The requirement for a quality assurance organisation to be accredited by the national body is expensive.

3.2 Irish Situation

S.I. No. 323 of 2020 – the EU (Waste Directive) Regulations 2011–2020 – currently requires that waste achieves end-of-waste status for it to be classified as a product. The quality standard contained in an EPA licence or local authority waste facility permit is not equivalent to end-of-waste criteria. The output from a licensed plant is a waste until end-of-waste criteria are in place. All recovery facilities are in the same situation across Ireland until end-of-waste criteria are established for the waste types they produce. The absence of end-of-waste status does not prevent the use of recycled products; it just means that they are managed under the waste regime.

As already mentioned, the trend across countries is to have standalone legislation, often referred to as a biowaste ordinance or more commonly referred to as national fertiliser regulations, to define when compost and digestate manufactured from waste feedstocks meet an agreed standard and are no longer considered to be a waste, but are instead are considered to be a product.

Irish Fertiliser Regulation S.I. 248 of 1978[7] is to be reviewed, and that will provide an opportunity to use these regulations to define end-of-waste criteria for the domestic market for compost and digestate. The content of the revised regulation is unknown at this time and it might merit further investigation of a separate biowaste ordinance. A dedicated biowaste[8] ordinance for the sector has the potential to cover all aspects of feedstocks, processing, quality assurance and end product quality standards.

Article 28 of S.I. No. 323 of 2020 – EU (Waste Directive) Regulations 2011–2020 – currently requires an end-of-waste application in order to facilitate the transition of waste to non-waste. The potential interaction between Article 28 of the above regulations and Article 19 of the EU FPR is currently being examined. It is recommended that the links between Article 19 of the EU FPR (and any transposition) and Article 28 on end-of-waste are examined, as other countries have used compliance with fertiliser regulation equivalents to attain their end-of-waste status for national purposes.

The mode by which waste compost and digestate is recycled into fertiliser products is set out in Article 28 of the EU (Waste Directive) Regulations 2011–2020 and Article 19 of the FPR (EU) 2019/1009. At the time of this study it had not been determined whether or not

7 http://www.irishstatutebook.ie/eli/1978/si/248/made/en/print?q=248 (15 October 2020).

8 Biowaste ordinance in other countries includes a wide range of source-separated feedstocks, not just biowaste.

specified waste streams would cease to be waste via Article 19 and/or via Article 28 as described previously.

3.2.1 Export/Import of Compost and Digestate

If a compost or digestate product that has achieved end-of-waste status in Ireland is exported to another country, the authorities in the receiving country might take a different view on its Irish end-of-waste status. In order for national end-of-waste material to be exported, the destination Member State would need to accept the Irish end-of-waste criteria. If the Member State does not accept the Irish criteria, the material is a waste and the Waste Shipment Regulation (EC) No. 1013/2006 would apply. If both Member States could agree to recognise each other's end-of-waste criteria this would be the best outcome. Examples of this in Europe already exist. Dutch exports to Germany require the participation of Dutch compost and AD plants in the German QAS and a bilateral agreement with the German Länder governments. Flemish exports to France need proof of compliance with both Flemish and French standards (Umweltbundesamt GmBH and Arcadis, 2020). Having an agreement with the other authorities[9] (e.g. Northern Ireland) for compost and digestate would be the recommended approach. A method should be put in place to support the attainment of agreements to ensure that waste that has attained national product status can be exported as a product to other jurisdictions.

In the absence of such an agreement, registration as a CE product under the EU FPR would solve this too.

In the Brexit negotiations it was agreed that Northern Ireland will continue to be treated as if it were in the EU under the Northern Ireland protocol. If that protocol were to be removed, trade could be difficult.

3.2.2 Roadmap for a possible end-of-waste decision mechanism for compost and digestate

Export

- In 2022, the EU FPR will be enacted in Ireland. If a plant wants to export compost or digestate then these products should conform to the EU FPR.
- Another option is to have a national end-of-waste status for compost and digestate and have an agreement with the receiving country.

National

One option is that, from June 2022 onwards, a plant/operator could apply to have its products recognised as CE products under the EU FPR.

Another option is to have end-of-waste status. Currently any plant can apply to the EPA for an end-of-waste determination under Article 28 in order to comply with the WFD. End-of-waste criteria specify when certain waste ceases to be waste, at which point it obtains the status of a product or a secondary raw material. According to Article 6 of the WFD (S.I. 323 of 2020), certain specified waste may cease to be waste when it has undergone a recovery operation, including recycling, and complies with specific criteria to be developed in line with the following conditions (Umweltbundesamt GmBH and Arcadis, 2020):

- The substance or product is commonly used for specific purposes.
- A market or demand exists for such a substance or object.
- The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products.
- The use of the substance or object will not lead to overall adverse environmental or human health impacts.

The trend across countries is to have standalone biowaste ordinance or national fertiliser regulations define when compost and digestate manufactured from waste feedstocks are no longer a waste, but a product. The charts in Figures 3.1 and 3.2 outline two options on how the system could work in Ireland for the domestic market to define end-of-waste criteria for compost and digestate.

9 Such agreements may have to be with the Department for Environment, Food and Rural Affairs (Defra) and not directly with the Northern Ireland Environment Agency (NIEA), as authorisation would need to come through Westminster.

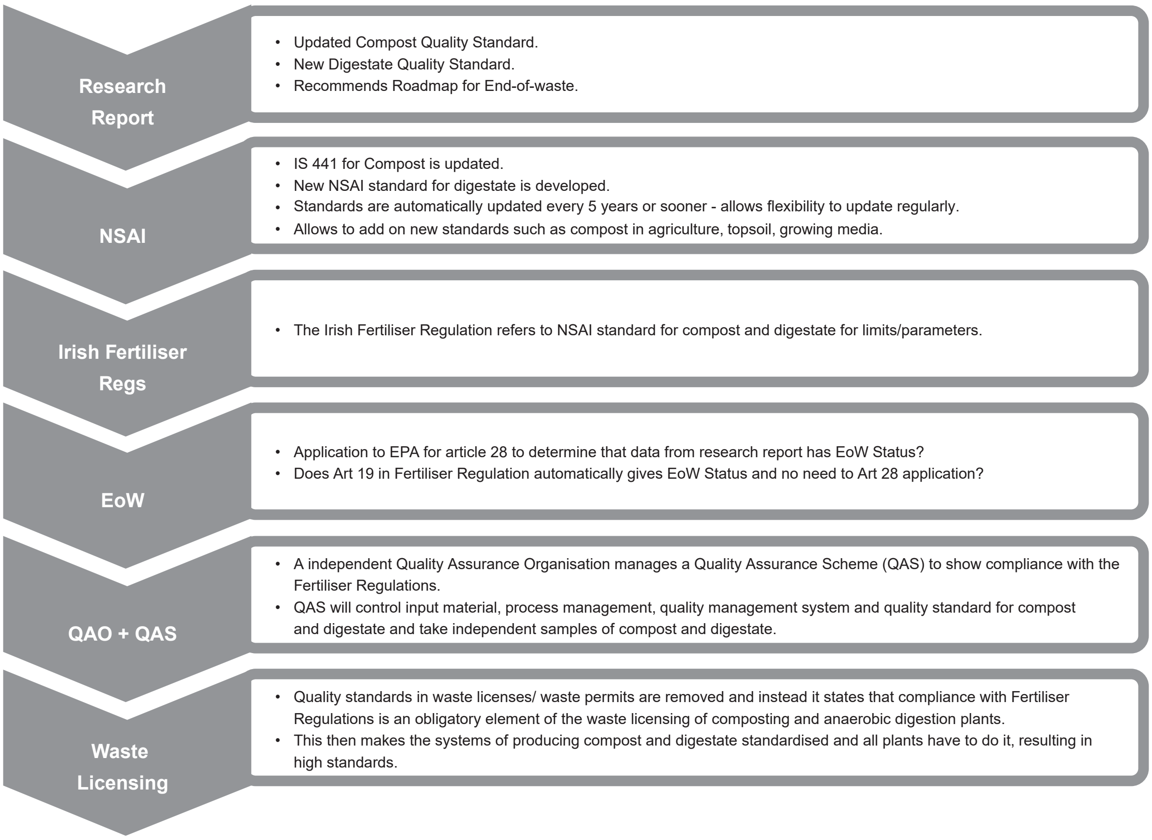

Figure 3.1. Option 1: national fertiliser regulations.

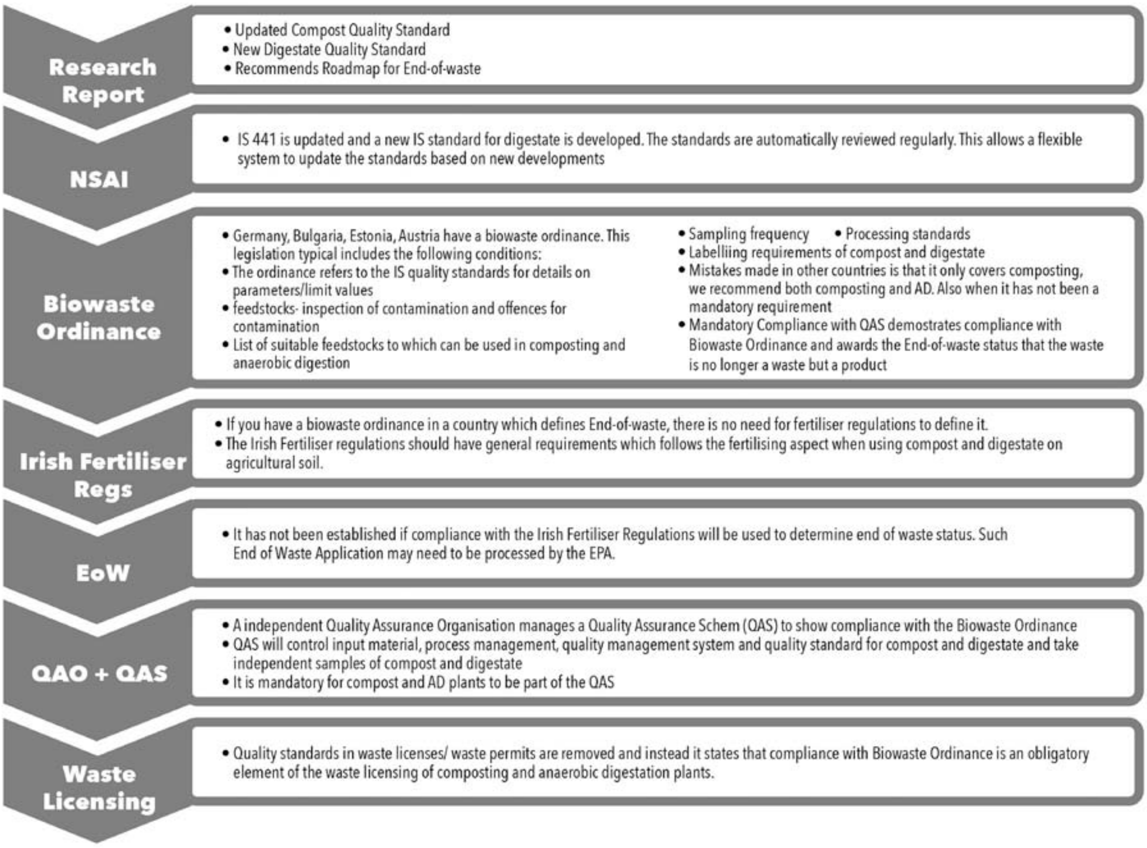

Figure 3.2. Option 2: biowaste ordinance regulations.

4 Recommended Standards and Limit Values

Testing for heavy metals in quality standards is necessary to evaluate and monitor the potential for soil and water pollution and to reduce user concerns related to risks associated with compost and digestate application. Testing may also be relevant for end-use management, especially in agriculture, as several heavy metals (e.g. copper and zinc) are also trace elements needed by plants. The 2019 database gathered for this project has been compared with the 2008 database that was developed in the previous research project by Prasad and Foster (2008).

4.1 Heavy Metals in Compost

An evaluation of the 2008 and 2019 90th percentile heavy metal data for green waste and biowaste in Table 4.1 shows the following:

- Cadmium, mercury and nickel levels are similar.
- Lead levels in biowaste compost were similar.
- Levels of lead, zinc and copper in green compost were lower in 2019 compared with 2008.
- The zinc and copper levels in biowaste compost increased in 2019 compared with 2008.
- The level of chromium in biowaste was lower in 2019 than 2008, but the level in green compost was similar in both years.

There are no data from 2008 to compare the 2019 SSC database to. The SSC appears to have similar heavy metal content to biowaste compost.

4.1.1 Heavy metal in compost databases of other countries

Databases of heavy metals in the Netherlands and Germany were obtained (Figure 4.1). The Dutch database was based on 1000 samples from 50 plants in 2017 and the German database was based on 3536 samples from 556 plants in 2018. Of the plants included in the databases, 53% just treat green waste; the remaining plants treat only biowaste.

Comparing the 90th percentile of the Irish biowaste/green compost with the Dutch (90th percentile) and German (95th percentile) database showed the following trends:

- Irish compost has a higher content of each of the heavy metals compared with the Dutch data.
- Irish compost is more like the German compost, except for copper/zinc and lead, which were higher in Irish biowaste compost.
- The metal levels were well below the limit values in the JRC end-of-waste criteria report (JRC-IPTS, 2008) and the EU FPR.

Table 4.2 shows the heavy metal limits in various standards from across Europe and the world. Generally, standards have limits for cadmium, chromium, copper, mercury, nickel, lead and zinc. Germany is the only country that has a limit for thallium. It is a metal that can be a residue of insecticides and the electronics industry.

Belgium, Czechia, France and Germany have a limit for total arsenic that is either 20 mg/kg or 40 mg/kg. The data we have for total arsenic (Table 4.1) show that a limit of 20 mg/kg is achievable. We recommend that total arsenic with a limit of 20 mg/kg is included in the standards. France, Germany and Italy and the EU FPR have a limit for hexavalent chromium. From the limited Irish data available, we recommend that hexavalent chromium with a limit of 2 mg/kg is included.

4.2 Heavy Metals in Digestate

Table 4.3 shows the limited heavy metal data from digestate. The dataset is very small but indicates that the heavy metal content is extremely low. This is probably because food waste is diluted with manures in the AD process; however, other data from Ireland and UK do not bear this out. In addition, a Swiss study by Kupper *et al*. (2014) on heavy metal in solid digestate and the liquid fraction showed low levels of heavy metal, but not to the extent of the Irish data, which are more like the data (Table 4.4) from Coelho *et al*. (2018) and Germany (Table 4.5). More data are required from Ireland, but it appears to the authors that heavy metal content in digestate is not a problem. Table 4.6 shows the standards for heavy metals in other countries.

Table 4.1. Heavy metal content (mg/kg DM) in the 2019 compost quality database

Parameter	SSGW 2008	SSBW 2008	SSGW 2019	SSBW 2019	SSC 2019
Cadmium					
Mean	0.64	0.53	0.53	0.57	3.11
Standard deviation	0.32	0.21	0.28	0.38	25.59
Percentile (90th)	0.96	0.77	1.00	0.90	0.97
Number of samples	40	99	171	184	86
Mercury					
Mean	0.11	0.14	0.11	0.17	0.19
Standard deviation	0.05	0.13	0.10	0.18	0.19
Percentile (90th)	0.15	0.30	0.20	0.31	0.36
Number of samples	42	99	172	184	86
Lead					
Mean	78.94	50.40	33.50	59.48	40.54
Standard deviation	34.48	33.37	29.15	37.49	39.67
Percentile (90th)	113.70	100.00	58.70	110.00	85.17
Number of samples	38	82	171	183	86
Nickel					
Mean	27.94	21.65	16.43	17.67	10.11
Standard deviation	11.10	17.17	29.89	11.27	14.61
Percentile (90th)	37.70	39.05	25.46	29.45	29.50
Number of samples	41	100	169	183	86
Zinc					
Mean	174.61	168.73	135.91	207.53	213.99
Standard deviation	57.49	77.21	49.21	87.87	114.45
Percentile (90th)	253.30	266.00	186.00	311.68	347.38
Number of samples	38	87	171	184	86
Copper					
Mean	62.94	60.96	35.32	80.06	74.44
Standard deviation	18.92	30.59	20.04	46.50	35.29
Percentile (90th)	81.73	100.00	52.30	138.84	117.80
Number of samples	42	86	171	184	86
Total chromium					
Mean	39.40	31.37	23.66	17.56	13.45
Standard deviation	15.06	24.44	24.27	14.26	25.30
Percentile (90th)	57.00	64.92	59.87	32.94	43.00
Number of samples	41	102	170	184	86
Hexavalent chromium (VI)					
Mean	No data	No data	1	< 1	< 1
Standard deviation	No data	No data	No data	No data	No data
Percentile (90th)	No data	No data	No data	No data	No data
Number of samples	No data	No data	1	2	2
Total arsenic					
Mean	7.08	4.83	13.3	4.03	1.36
Standard deviation	2.34	1.57	No data	3.45	No data
Percentile (90th)	9.52	6.56	No data	5.62	No data
Number of samples	6	35	1	58	1

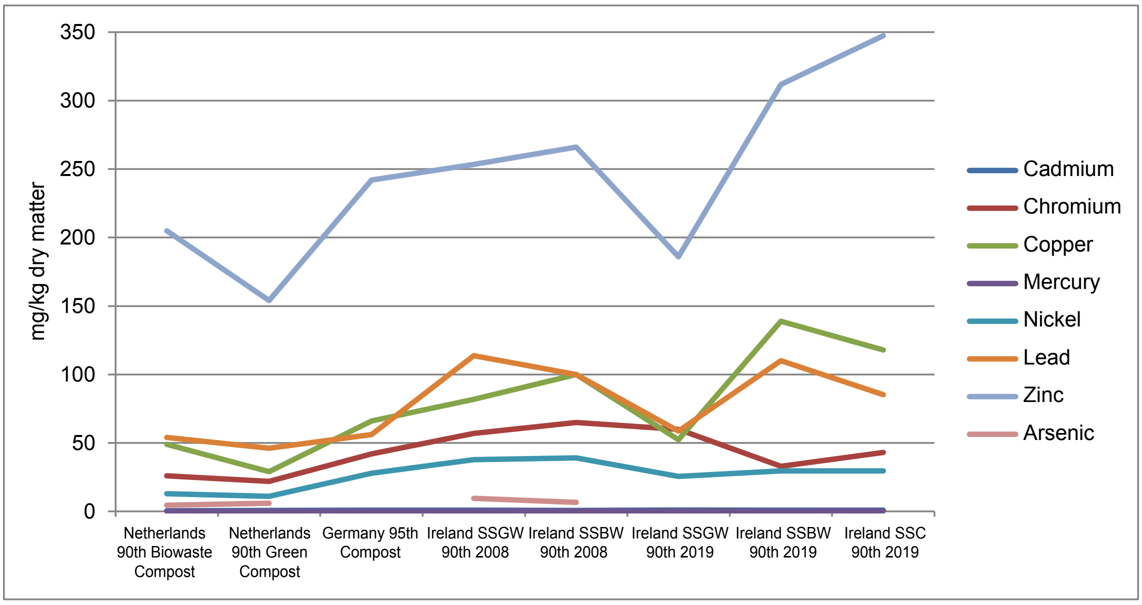

Figure 4.1. Comparison of heavy metal content in databases from the Netherlands, Germany and Ireland. Compiled from data from the Netherlands – Branche Vereniging Organische Reststoffen (Dutch Association of Biowaste Processors, BVOR) – and from Germany – Bundesgütegemeinschaft Kompost (German Compost and Digestate Quality Assurance Organisation, BGK).

4.2.1 Recent developments and recommended standard

The JRC report on biodegradable waste in 2014 (Saveyn and Eder, 2014) and the EU FPR 2019 have been the key significant publications since the previous report (Prasad and Foster, 2008).

The VITO (2013) study, *Towards Risk-based Draft Limit Values for the Use of Secondary Raw Materials as Fertilizer or Soil Conditioner*, describes a dynamic model calculating the maximum allowable concentrations of pollutants in the soil conditioner/fertiliser on the basis of the maximum permitted enrichment of the upper soil layer over a period of 100 years, taking into account all possible input–output fluxes and soil processes (Table 4.7).

The parameters are now used in the Flemish legislation for sustainable recycling of biowaste (VLAREMA – Vlaams Reglement voor duurzaam beheer van Materialenkringlopen en Afvalstoffen) and the corresponding limit values for safe use are stricter than the scientifically derived limit values and are also fully in line with the existing internationally accepted limit values for safe application, such as ECN-QAS, the JRC study on end-of-waste criteria for compost and digestate (Saveyn and Eder, 2014) and the EU FPR. In the JRC FATE COMES study (Tavazzi *et al*., 2013), numerous practical samples of compost and digestate were taken and analysed, and the importance of the separate collection of source material, although not considered a full safeguard for organic pollutants, was highlighted. As an outcome, PAH was added as a parameter, whereas other pollutants, such as polyfluoroalkyl substances, only applied in cases where sewage sludge was used. The VITO (2013) study recommended a limit of 0.8 mg/kg for polychlorinated dibenzo (PCD 7).

In all risk assessments, strict input feedstock requirements have been designated as a main driver to pursue high-quality end products. This allows the set of parameters being monitored to be kept to the essential ones, excluding those parameters unlikely to be present in separately collected biowaste.

The trend in recent standards in other countries, the 2014 JRC study and the EU FPR is to have the same heavy metal content for compost and digestate.

The 2008 database for compost was compared with the new 2019 database collected for this study. It showed that there have been no major changes in the quality of compost being produced by plants.

Table 4.2. Heavy metal content (mg/kg DM) in compost standards from other countries

Country	BE	AT			BG		CZ	EE	FR	FI	DE[a]					GR	HU	IT	NL	PT			SI		SE	UK	NO				CH	ES			UAE	CA[g]		USA
Class		A	A+	B																1	2	3	1	2			0	1	2	3		A	B	C		A	B	
Cd	2	1	1	3	2[b]	1.7[c]	2	1.3	2	1.5	1.5	1.5	1.5	1.5	1.5	<3	2	1.5	<1	0.7	1.5	5	1.5	3	1	1.5	0	0.8	2	5	1	1	2	3	3	3	20	39
Cr	70	70	70	250	100	60	100	60	100	300	100	100	100	300	300	<250	100		<50	100	150	400	100	250	100	100	50	70	100	150		70	250	300	100	120	1060	1200
Cr VI									2					2	2			0.5																				
Cu	150	150	70	500	250[d]	200[d]	100, 150,[e] 250[f]	200	300	600	100	100	100	900	900	<400	300	230	<90	100	200	600	100	500	600	200	50	150	650	1000	100	70	300	400	150	400	757	1500
Hg	1	0.7	0	3	1	0.5	1	0.5	1	1	1	1	1	1	1	<2.5	1	1.5	<0.3	0.7	1.5	5	1	3	1	1	0	0.6	3	5	1	0	1.5	2.5	1.5	0.8	5	17
Ni	30	60	25	100	80	40	50	40		100	50	50	50	80	80	<100	50	100	<20	50	100	200	50	100	50	50	20	30	50	80	30	25	90	100	50	62	180	420
Pb	150	120	45	200	180	130	100	130	120	100	150	150	150	150	150	<300	100	140	<100	100	150	500	120	200	100	200	40	60	80	200	120	45	150	200	120	150	500	300
Zn	400	500	200	1800	800[h]	600[h]	300, 600,[e] 1200[f]	600	800	1500	400	400	400	4000	400	<1200	–	500	<290	200	500	1500	400	1800	800	400	150	400	800	1500	400	200	500	1000	350	700	1850	2800
As	20						20		40		40	40	40	40	40																				15			41
Th											1	1	1	1	1																							
Co																																				24	150	
Mo							5,[e] 20[f]																													5	20	
Se																																						36

Classes: A, organic agriculture; A+, agriculture; B, non-agricultural.

[a]From left to right the composts are fresh compost, finished compost, substrate compost, fresh sewage sludge compost, finished sewage sludge compost.

[b]Limit value during transitional period, 2013–2020.

[c]Limit value after transitional period, from 2021.

[d]Labelling threshold >100. If labelling threshold for copper or zinc is exceeded, the content must be stated on the label of the end product.

[e]Organic and farmyard fertilisers – dry matter content exceeding 13%.

[f]Organic and farmyard fertilisers – dry matter content not exceeding 13%.

[g]Canada has categories rather than classes.

[h]Labelling threshold >400.

AT, Austria; BE, Belgium; BG, Bulgaria; CA, Canada; CH, Switzerland; CZ, Czechia; DE, Germany; EE, Estonia; ES, Spain; FI, Finland; FR, France; GR, Greece; HU, Hungary; IT, Italy; NL, Netherlands; NO, Norway; PT, Portugal; SE, Sweden; SI, Slovenia.

Table 4.3. Heavy metal content (mg/kg DM) in the 2019 Digestate Quality Database

	Cadmium	Chromium	Copper	Mercury	Nickel	Lead	Zinc
Mean	0.24	6.17	43.39	0.08	10.99	2.97	211.82
Standard deviation	0.16	6.13	82.10	0.02	10.28	0.93	643.18
Percentile (90th)	0.63	14.21	89.79	0.12	25.45	6.57	452.32
Number of samples	8	8	8	7	8	8	8

Note: the data are a combination of data received from plants and data from an analysis of digestate conducted as part of this project.

Table 4.4. Heavy metal content (mg/kg DM) in Irish and UK digestate

Digestate	Chromium	Copper	Nickel	Lead	Zinc
Average food waste AD ($n=7$)	23	172	18	11.3	468
Average cattle slurry AD ($n=2$)	66	115	3.3	1.2	236

Data from Coelho *et al*. (2018).

Table 4.5. Germany – heavy metal content (mg/kg DM) of liquid digestate

Heavy metal	Mean	95th percentile
Cadmium	0.4	0.81
Chromium	18.5	38.9
Copper	61.3	120
Mercury	0.07	0.21
Nickel	14.7	28
Lead	12.2	44.8
Zinc	277.4	522

Database based on 1047 samples from 170 plants in 2018. Data from BGK (2019).

We recommend the following:

- The limited dataset for digestate suggests that the heavy metals limits previously developed for compost can be adopted for digestate.
- The copper, zinc, lead, mercury and cadmium limits should be aligned with the EU FPR.
- The lead limit should be rounded up from 149 mg/kg to 150 mg/kg.
- The nickel limit should be rounded down from 56 mg/kg to 50 mg/kg.
- The total chromium limit should be changed from 92 mg/kg to 100 mg/kg to align with the 2014 JRC study.
- Hexavalent chromium and total arsenic limits should be included.

4.3 Stability

4.3.1 Stability in compost

This section examines methods used for monitoring biological stability of compost and digestate. In addition, a link between the limit value and compost applications is examined. There have been some detailed reviews on stability by the Waste and Resources Action Programme (WRAP) if the reader would like to learn more about it (e.g. Walker *et al*., 2010; Dimambro *et al*., 2015).

Stability is the potential level of biological activity in compost. It is an important parameter in quality standards because unstable compost consumes nitrogen and oxygen (O_2) in significant quantities to support biological activity and generates heat, water vapour and carbon dioxide (CO_2). Stable compost consumes little nitrogen and oxygen and generates little heat and CO_2. If stored improperly or unaerated, unstable compost can become anaerobic, giving rise to methane, nitrous oxide and ammonia, which creates 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 N or the presence of phytotoxicity compounds.

The authors in a previous report (Prasad and Foster, 2008) recommended a stability test method for compost using the OUR (EN 16087-1 2011) with a limit of 13 mmol O_2/kg/organic matter/h.

Table 4.6. Evaluation of standards for heavy metals (mg/kg DM) in digestate in other countries

Country	BE	BG[a]		CZ	EE	FR	FI	DE[b]				GR	HU	UK										SI[c]			SE	NO				CH	ES			USA
Class														<1	1–1.9	2–2.9	3–3.9	4–4.9	5–5.9	6–6.9	7–7.9	8–8.9	≥9					0	1	2	3		A	B	C	
Cd	2	2[d]	1.7[e]	2	1	2	2	2	2	2	2	3	2	0.1	0.2	0.4	0.5	1	0.7	0.8	1	1.1	1	3	2	3	1	0	0.8	2	5		1	2	3	20
Cr	100	100	60	100	60	100	300	100	100	100	100	250	100	8	1	24	32	40	48	56	64	72	80	100	100	250	100	50	70	100	150	1	70	250	300	–
Cu	800			100, 150,[f] 250[g]	200	2	600	100	100	[h]		400	100	16	32	48	64	80	96	112	128	144	160	200	200	500	600	50	150	650	1000		70	300	400	750
Hg	1	250[i]	200[i]	1	0	300	1	1	1	1	1	3	1	0.1	0.2	0.2	0.3	0	0.5	0.6	0.6	0.7	1	1	1	3	1	0	0.6	3	5	1	0	2	3	8.5
Ni	50	1	0.5	50	40	1	100	50	50	50	80	100	50	4	8	12	16	20	24	28	32	36	40	50	50	100	50	20	30	50	80	1	25	90	100	210
Pb	150	80	40	100	130		100	150	150	150	150	300	100	16	32	48	64	80	96	112	128	144	160	120	120	200	100	40	60	80	200	30	45	150	200	150
Zn	1500	180	130	300, 600,[f] 1200[g]	600	120	1500	400	400	[h]		1200	–	32	64	96	128	160	192	224	256	288	320	400	400	1800	800	150	400	800	1500	400	200	500	1000	1400
Mo		800[j]	600[j]	5,[f] 20[g]		800																														
As	20					40		40	40																											21
Th								1	1																											–

Classes: A, organic agriculture; A+, agriculture; B, non-agricultural.

[a]If labelling threshold for copper or zinc is exceeded, the content must be stated on the label of the end product.

[b]From left to right the composts are fresh compost, finished compost, substrate compost, fresh sewage sludge compost, finished sewage sludge compost.

[c]From left to right the thresholds are for digestate containing <20% dry weight, digestate containing ≥20% dry weight and digestate containing ≥20% dry weight.

[d]Limit value during transitional period, 2013–2020.

[e]Limit value after transitional period, from 2021.

[f]Organic and farmyard fertilisers – dry matter content exceeding 13%.

[g]Organic and farmyard fertilisers – dry matter content not exceeding 13%.

[h]Plausibility values apply and must not be exceeded

[i]Labelling threshold >100.

[j]Labelling threshold >400.

BE, Belgium; BG, Bulgaria; CH, Switzerland; CZ, Czechia; DE, Germany; EE, Estonia; ES, Spain; FI, Finland; FR, France; GR, Greece; HU, Hungary; NO, Norway; SE, Sweden; SI, Slovenia.

Table 4.7. Comparison of heavy metals (mg/kg DM) in regulations, standards and databases

Parameter	EU FPR 2019		2014 JRC study end-of-waste biodegradable waste[a]	ECN QAS for compost/ digestate 2018	IS 441 2011[b]	Flemish Decree (VLAREMA)/ VITO study[c] (safety limits based on dynamic model)	Flemish Decree (VLAREMA) 2012 (compost applications)	Ireland green compost 2019[d]	Ireland biowaste compost 2019[d]	Ireland SSC 2019[d]	Ireland digestate 2019[d]	Recommended standard compost and digestate
	Product function category 1 – fertiliser	Product function category 3 – soil improver										
Cadmium	1.5	2	1.5	1.3	1.3	6	2	1.00	0.90	0.97	0.63	1.5
Hexavalent chromium	2	2	–	–	n/a	–	–	1	< 1	–	< 1	2
Total chromium			100	60	92	150	70	59.87	32.94	43.00	14.21	100
Mercury	1	1	1	0.45	0.4	1	1	0.20	0.31	0.36	0.12	1
Nickel	50	50	50	40	56	100	30	25.46	29.45	29.50	25.45	50
Lead	120	120	120	130	149	300	150	58.70	110.00	85.17	6.57	150
Inorganic arsenic	40	40	–	–	n/a	–	–	–	–	–	–	–
Total arsenic	–	–	–	–	n/a	20	20	13.3	5.62	–	1.36	20
Biuret	Must not be present	n/a	–	–	n/a	–	–	–	–	–	–	–
Copper	300	300	200	300	149	800	150	52.30	138.84	117.80	89.79	300
Zinc	800	800	600	600	397	–	400	186.00	311.68	347.38	452.32	800

[a]Saveyn and Eder (2014).

[b]Values are the same as those in Prasad and Foster (2008).

[c]VITO (2013).

[d]90th percentile.

–, no limit or standard; n/a, not applicable.

4.3.2 Stability databases from other countries

The average temperature and OUR in green and vegetable, fruit and garden waste (VFG) compost from Belgium were similar (Table 4.8).

The OUR data (Table 4.9) from the Netherlands show that the average OUR value is 21 for biowaste compost and 12 for green waste compost. The data are very relevant, as the way that biowaste is processed in the Netherlands is similar to processing in Ireland.

4.3.3 Evaluation of standards for the measurement of compost stability in other countries

Several countries (Australia, Austria, Estonia, Norway,[10] Sweden,[11] Czechia, France, Hungary, Greece, UAE and Portugal) currently have no requirements, legal or voluntary, for a standard for compost stability. The countries that have no compost standards are Cyprus, Romania and Lithuania.

Table 4.10 shows that the two methods most widely used for compost stability testing in countries that have standards are the OUR and the self-heating test limit value.

Of all the stability parameters in use for compost, scientists seem to have the greatest confidence in those methods that assess microbial respiration as evidenced by O_2 uptake or CO_2 evolution. Hence, respiration has become the standard. There are several ways to measure respiration such as OUR, specific OUR (SOUR), CO_2 evolution rate, Solvita and a self-heating test (Rynk, 2003).

The self-heating test (EN 16087-2:2011), which has been around for several years, using Dewar flasks, measures self-heating of a compost sample in an

Table 4.8. Compost stability data in 2015 from Belgium

	Average	Median	Standard deviation	25th percentile	75th percentile	95th percentile
Green compost						
Self-heating test limit value[a]	V	V	–	V	V	V
Temperature (°C)	24.9	23.7	5.4	21.7	26.1	33.0
OUR (mmol O_2/kg organic matter/h)	5.3	3.7	3.5	2.5	5.3	9.2
Biowaste compost (known as VFG[b])						
Self-heating test	V	V	–	V	V	V
Temperature (°C)	25.8	24.3	6.5	22.1	27.1	40.0
OUR (mmol O_2/kg organic matter/h)	5.5	4.1	5.7	2.5	5.9	16.1

Data from Vanden Auweele (2019).

[a]Self-heating test limit values range from I to V.

[b]In regions in Belgium the brown bin collection is restricted to pure non-meat sources of vegetables, fruit and garden waste known as VFG.

Table 4.9. OUR stability data in 2017 from the Netherlands

Parameter	Average household biowaste compost	90th percentile biowaste compost	Average green waste compost	90th percentile green compost
OUR (mmol O_2/kg organic solids/h)	21	27	12	19

Database based on 1000 samples from 50 plants.

Data from BVOR (2017).

10 There is no requirement to test; there are only product requirements ("to be stable") without any description of how to document that.

11 Sweden has no requirements for stability, other than that it should be included in the declaration of properties and determined using the self-heating test method.

Table 4.10. Methods to determine stability in compost standards

Country	Standard name/reference	Stability method	Limit value[a]
Belgium	Standards for green compost	Self-heating test	< 40°C (IV or V)
		OUR	< 15 mmol O_2/kg VS/h
	Standards for VFG (food) compost	Self-heating test	< 40°C (IV or V)
		OUR	< 15 mmol O_2/kg VS/h
Ireland	IS 441 and in EPA waste licences	OUR	13 mmol O_2/kg organic solids/h
Finland	–	CO_2 production	< 6 mg CO_2/g VS/day
Germany	RAL-GZ 251 for compost	Self-heating test	Fresh = II; mature = IV; substrate = V
Germany	RAL-GZ 258 for SSC	Self-heating test	Fresh = II, III; Mature = IV, V
Netherlands	Keurcompost	OUR	No limit specified
Slovenia	Decree on the recovery of biodegradable waste and the use of compost or digestate (Official Gazette of the Republic of Slovenia, Nos. 99/13, 56/15 and 56/18)	AT4	< 15 O_2/g DM
UK	PAS 100	CO_2 microbial respiration rate	< 16 mg CO_2/g organic matter/day
USA	US EPA	No standard	
	State requirement	Varies by state	
	USCC STA	No standard	
	USCC STA–Consumer Use Program Acceptable Ranges	Self-heating test	Less than IV
	USCC STA–Consumer Use Program Preferable Ranges		Less than II
Canada	National guideline under the CCME. The CCME guidelines are “taken back” to each province/territory to be adopted or adjusted. In total, 7 out of 10 provinces and all three territories have completely adopted the CCME, with British Columbia, Ontario and Quebec having adjusted them	Maturity/stability of compost – cured for 21 days and one of the following: • Respiration rate ≤ 400 mg O/kg VS (or organic matter) per hour • CO_2 evolution rate ≤ 4 mg of carbon in the form of CO_2 per gram of organic matter per day • The temperature rise of the compost above ambient temperature is less than 8°C	
Italy	Humic and fulvic acids		7% dry weight
EU FPR		Self-heating test and OUR	III and 25 mmol/ O_2kg
JRC study (2014)		Self-heating test and OUR	III and 25 mmol O_2/kg
ECN QAS		Self-heating test and OUR	Declaration

[a]Limit values range from I to V.

AT4, respirometric activity test; CCME, Canadian Council of Ministers of the Environment; PAS, Publicly Available Specification for Composted Materials; STA, Seal of Testing Assurance Program; USCC, US Composting Council; VS, volatile solids.

insulated flask, a consequence of respiration. It is one of the tests recommended in a study by the European Commission JRC (Saveyn and Eder, 2014) and the new EU FPR. The self-heating test is limited in the sense that it mostly only distinguishes between very mature and very immature compost and is not as good at measuring stability between the two extremes. Because of the limitation it is not a good enough test for compost used in growing media, but it is suitable for compost plant operators to use themselves to monitor the stability of compost easily at their plant. Operators in plants (e.g. in Belgium and Portugal) use the test to monitor the process before a sample is sent to an independent laboratory for testing. The classes in the self-heating test are outlined in Table 4.11.

NiChualain and Prasad (2007) investigated the relationship between composting time and the results of three tests: the OUR method, the self-heating test and Solvita. They found that the OUR method gave the best relationship with time ($R^2 = 0.68$). Veeken *et al.* (2003) also evaluated the OUR method and found a similar good correlation between OUR and composting

Table 4.11. Dewar self-heating increments, rating and description of stability classification based on the European system

Temperature rise above ambient in °C	Official class of stability	Descriptors of class or group	Major group
0–10	V	Very stable; well-aged compost	Finished compost
10–20	IV	Moderately stable; curing compost	
20–30	III	Material still decomposing; active compost	Active compost
30–40	II	Immature, young or very active compost	
40–50 (or more)	I	Fresh, raw compost, just mixed ingredients	Fresh compost

Source: Brinton *et al.* (1995).

time. Both these findings indicate it is related to the biodegradation of organic matter.

Table 4.12 outlines the advantages and disadvantages of the different methods used to measure stability in digestate.

4.3.4 Recent developments

There have been recent developments in the measurement of compost stability using near Infrared spectroscopy for determining compost stability (Erhart *et al.*, 2017). It is a rapid analysis and requires no chemicals, but it still requires calibration and validation and is therefore not advanced enough to consider as a routine test in Ireland at present.

4.3.5 Recommended method for the measurement of compost stability

We recommend that the OUR test is continued for compost. In recent years it has garnered support, as it is now a European Committee for Standardization (CEN) method. It is accepted as a stability method

Table 4.12. Summary of the advantages and disadvantages of the stability methods for digestate

Test	Advantages	Disadvantages
OUR	Used by some European countries and in the new EU FPR and the JRC end-of-waste criteria report (JRC-IPTS, 2008) Good indicator of stability, as shown by good relationship with time of composting Automated and reasonable price	Needs controlled temperature condition of 30°C Needs trained technician
Self-heating test	Used by some European countries and in the new EU FPR and the JRC end-of waste criteria report (JRC-IPTS, 2008) Has a long history of use Relatively easy to operate Very reasonable price	Not so good relationship with composting time, hence not very good indicator of stability particularly compost of intermediate stability
CO_2 production	Limited studies show this test is related to OUR values	Used mostly in the UK (PAS 100) and non-EU countries Less research done in relation to composting time Not automated More expensive than OUR test
AT4	Has a long history of successful use Uses a large sample and likely to get a more representative result Limited work in Teagasc has shown it is well related to OUR	Equipment very expensive Used mostly on organic fines and not much on compost in Ireland

PAS, Publicly Available Specification.

in the 2014 JRC study, the new FPR and the Irish voluntary compost standard IS 441.

4.3.6 Limit value for compost stability for field application

The only European countries that make a link between compost end use and stability are those that are members of the Compost and Digestate Quality Assurance Organisation (Bundesgütegemeinschaft Kompost, BGK) QAS, i.e. Germany and Luxembourg. The link is with fresh compost used in agriculture, mature compost in horticulture and very mature compost used in growing media. We have summarised some research work that relates to the use and benefits of using moderately stable (active) compost for field application.

Petersen and Stoppler-Zimmer (1996) studied the effects of extremely fresh (self-heating value II, composted for 12–25 days) and mature (self-heating value IV–V) compost that had been composting for 4 months. Biowaste composts were compared with inorganic fertiliser on a range of crops. In an arable trial, the composts were applied at two rates (30 t/ha with mineral N, and 100 t/ha compost only) on two soils. On a sandy soil there were no differences in yield between the mineral fertiliser and compost treatments within a 4-year period, whereas on a loess soil, application of 100 t/ha of fresh compost resulted in a significantly higher yield in comparison with mineral fertiliser and mature compost.

Hartmann (2002) conducted a study in Germany to compare the effect of fresh and mature compost (stability undefined) on a range of crops during 1996–1997. The compost was produced from a mixture of biowaste and green waste. The fresh compost was produced after 14 days of composting, and the mature compost was at least 100 days old. All of the compost treatments performed better than the control, with the addition of inorganic N to the compost treatments increasing the yield further.

Bloom (2003) examined the effects of different organic fertilisers on white asparagus in Germany in 1997. The two composts applied were biowaste compost [self-heating III, carbon to nitrogen ratio (C:N) 13] and fresh green waste compost (self-heating III, C:N 26). During the first year of the trial the fresh compost caused a slight reduction in asparagus shoots (ferns) as a result of N immobilisation, but this was not statistically significant. In subsequent years there were no significant differences in yield in any of the treatments.

Two Swiss studies (Fuchs *et al.*, 2008a,b) investigated a range of six mature composts (all self-heating V) with different end uses. The trend was that slightly less mature compost resulted in lower yields than the slightly more mature composts. With additional fertilisation, however, it was possible to compensate for this effect, which was attributed to N lock-up.

A study in Luxembourg (Groll, 2007) compared fresh (stability undefined) and mature compost (stability undefined) and inorganic fertiliser in a field trial over 15 years with an arable rotation of cereals, oilseed rape and maize. No significant differences between fresh and mature compost were observed.

Dimambro *et al.* (2015), who undertook some trial work, discussed research publications on compost application timings and the level of stability in the self-heating test. The majority of evidence found on the use of fresh (or immature) composts is from Germany, where agricultural and field horticultural trials have generally shown agronomic benefits on crop yield and soil properties when less mature composts have been used.

In a few cases, short-term N lock-up was experienced when using fresh or mature compost. To avoid detrimental effects on crop yield, those studies have recommended applying the compost well in advance, such as in the autumn before a spring-sown crop, or to apply additional inorganic N fertiliser to compensate for any locked-up N.

The German method of applying fresh compost in the autumn has been considered unlikely to cause significant leaching during the cold winter months, with N becoming available to crops the following spring as the temperature increases (Dimambro *et al.*, 2015).

The stability standard for the OUR used in IS 441 currently stands at 13 mmol O_2/kg organic solids/h, but if one looks at how the standard was developed more than a decade ago, it was based on the premise that the compost would be used mostly as a component of growing media (peat dilution). The authors of this study recommend that the limit be increased to 15 mmol O_2/kg organic solids/h for compost used in growing media. This would align the limit value of 15 mmol O_2/kg organic solids/h in the advanced growing media with industry in the Netherlands and the ECN *Guidelines Specification for the Use of Quality Compost in Crowing Media* (Siebert and Gilbert, 2018).

For field application in agriculture and horticulture this value (13 mmol O_2/kg organic solids/h) is rather low based on the summary of the research presented about German research and US recommendations (see Table 4.15; see also Brinton *et al.*, 1995). Compost in Ireland is based on not only green waste as in the earlier years but also biowaste. From our survey of the market, biowaste compost is mainly used in agricultural land.

On the basis of the above we should now increase this figure to 25 mmol O_2/kg organic matter/h for the use of compost in field applications. This would be in line with the self-heating stability test III standards in Germany. This would also be in line with the US Woods End laboratory recommendation of using limits II and III for field application (Brinton *et al.*, 1995; Table 4.13).

Table 4.14 provides a summary of the recommended stability method and limits depending on compost application.

Table 4.13. Proposed relationship between self-heating class and best use of compost

Class of stability based on self-heating test	Best use of compost
V	Potting mixes, seedling starter
IV	General-purpose gardening, greenhouse cultivation
III	Grapes, fruit, apples
II	Field cultivation, e.g. maize, tomatoes, broccoli, greenhouse hotbeds
I	Compost, raw feedstock, mushroom compost

Source: Brinton *et al.* (1995).

Table 4.14. Summary of recommended stability method and limit value for compost applications

Compost application	Method and limit
Growing media	OUR with limit of 15 mmol O_2/kg organic solids/h
Other applications – field/landscaping	OUR with limit of 25 mmol O_2/kg organic solids/h

4.3.7 *Digestate stability*

Stability testing helps ensure that digestate is fit for purpose and does not pollute soil and water resources. A reasonable question one may ask is why there is a need for a stability standard for digestate. One reason is the fact that it is included in both the new EU FPR and the JRC end-of-waste criteria report (JRC-IPTS, 2008) as a stability standard for digestate. The second reason is that a minimum stability should avoid unwanted emissions, including strong odour, during transport and storage, and prevent materials from entering the market without proper treatment.

In EPA licences prior to 2011 and local authority waste facility permits the parameters and limit values vary considerably and, in recent licences, the parameters and limit values have been adopted from the national compost IS 441 for compost, but these have also been applied to AD plants. IS 441 was not developed for AD plants. Some parameters, consequently, such as stability, may or may not be suitable and the limit values for compost may be meaningless to digestate.

4.3.8 *Stability in digestate in Ireland*

Digestate stability can be measured by the residual biogas potential (RBP) test or by OUR. The use of OUR for digestate is relatively new as the method was originally developed for compost. Six plants tested the same sample for RBP and OUR (Table 4.15). The data showed that the plants met the RBP limit of 0.25 l/g volatile solids (VS). However, three samples did not meet the OUR limit of 50 mmol O_2/kg organic solids/h. The data are limited and more sampling is required. The correlation between the two methods was very good (R^2 = 0.8006; Figure 4.2).

4.3.9 *Stability database in Belgium*

Table 4.16 shows that about half of the samples (50%) comply with the limit value for OUR (< 25 mmol O_2/kg VS/h) for solid fraction at 20°C. If the same limit value would apply at 30°C, only 25% of the samples would comply. About 45% of the samples comply with the limit value for OUR (< 25 mmol) for dried digestate at 20°C. If the same limit value would apply at 30°C, only 15% of the samples would comply. Lower temperature gives lower OUR values, as the method is very temperature dependent. The parameters used to monitor stability of digestate used in Europe

Table 4.15. Irish digestate samples tested for RBP and OUR for this study

Plant and feedstock	RBP (l/g VS)	OUR (mmol O_2/kg organic solids/h)
Plant A (sludges/manures)	0.018	34.2
Plant B (food waste)	–0.034	32.4
Plant C (food waste/manures)	0.048	37.5
Plant D (industrial sludges)	0.166	84.9
Plant E (sewage sludges/industrial sludges)	0.083	77
Plant F (food waste/manures)	No data	64.4
Sample 1[a] (food waste/manures)	0.059	No data
Sample 2[a] (food waste/manures)	0.05	No data

[a]Previous results from a plant in 2018.

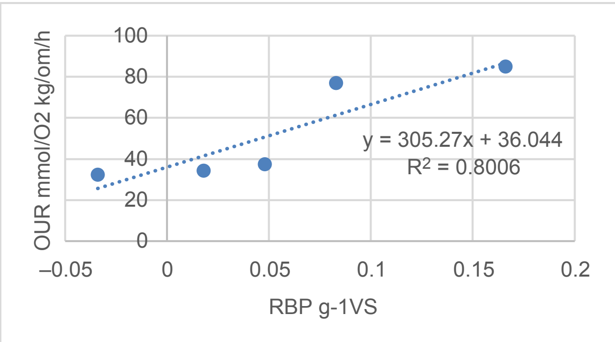

Figure 4.2. Relationship between RBP and OUR in Irish digestate samples (*n*=5).

Table 4.16. Stability database of digestate in Belgium

Product	RBP (l/g VS)	OUR	
		mmol O_2/kg VS/h at 20°C	mmol O_2/kg VS/h at 30°C
Dried digestate (without manure)	0.16	22	35.2
Solid fraction digestate (without manure)	0.05	9.0	16.2
Solid fraction digestate (with manure)	0.07	16.0	28.8

Source: Vanden Auweele (2019).

are RBP organic acids (volatile fatty acids – VFAs) (RAL GZ 245), carbon dioxide and, recently, OUR (Table 4.17). Most of the stability standards proposed for AD digestate (mostly for whole digestate) are based on RBP (UK) or organic acids (Germany), although recently the JRC end-of-waste criteria (JRC-IPTS, 2008) report and the EU FPR have included the OUR method and give limit values.

Fifteen European countries currently have no requirements, either legal or voluntary, for a standard for digestate stability. Table 4.17 outlines the countries in Europe and in other countries around the world that have standards. The countries with no standard for stability as part of their overall standard are Austria, Estonia, Czechia, France, Hungary, Greece, Poland, Portugal, Sweden, Norway and Switzerland. The countries that have no digestate standards at all are Cyprus, Romania, Lithuania, Italy and the Netherlands.

4.3.10 Evaluation of standards for stability in digestate in other countries

Organic acids (volatile fatty acids)

A review of English- and German-language sources was carried out by the researchers at the University of Southampton for WRAP (Banks *et al.*, 2013) to establish the scientific rationale and basis for the adaption of the VFA standard under the JRC end-of-waste criteria report. The evidence found that the measurement of VFAs is not adequate and this parameter is best used as an indicator of the stability process rather than of the quality of the final product used in soil. In addition, the German RAL quality standard for digestate, which includes a VFA limit, has a requirement for a minimum retention time in the digester to ensure effective degradation. Analysis of 20 samples was carried out and it was determined that the correlation between RBP and VFA is fairly good ($R^2=0.449$; $n=24$) (Banks *et al.*, 2013). There are very little grounds for using VFA concentration in Ireland as a product stability criterion. This parameter at its best indicates stability of the process rather than the product.

Table 4.17. Stability methods used in digestate standards

Country	Standard reference	Stability method	Limit value
Belgium	Flemish Decree (VLAREMA)	OUR	< 50 mmol O_2/kg VS/h
Finland	Decree of the Ministry of Agriculture and Forestry on Fertiliser Products (24/2011, amendments up to 7/2013)	CO_2 production: microbiological activity	
Germany	RAL GZ 245 – biowaste	Organic acids	≤ 1500 mg/l FM
	RAL GZ 246 for digestate made of renewable energy crops and manure	Organic acids	≤ 1500 mg/l FM
UK	PAS 110	RBP	< 0.45 l/g VS
Slovenia	Category 1 – threshold for digestate containing less than 20% DM	VFAs	< 300 mg/l
	Category 1 – threshold for digestate containing more than 20% DM	VFAs	< 100 mg/l
	Category 2 – threshold for digestate containing more than 20% DM	VFAs	< 300 mg/l
USA	American Biogas Council Digestate Standard Testing and Certification Programme	Must be measured using VFA or CO_2 respiration; no limits set	
EU	FPR (for solid and liquid digestate)	RBP	0.25 l/g VS
		OUR	25 mmol O_2/kg VS/h
	JRC end-of-waste criteria for biodegradable waste subjected to biological treatment (compost and digestate)	RBP	0.25 l/g VS
		OUR	50 mmol O_2/kg VS/h
		Organic acids	1500 mg/l

FM, fresh matter.

A VFA analysis takes 10 days to complete. When a VFA analysis is done first and fails, this is an indication that it will certainty fail the RBP test. Thus, in the UK it is used as an initial test to avoid the more onerous and expensive RBP test.

Residual biogas potential

The RBP test is designed to measure the stability of digestate samples under anaerobic conditions. Stability is assessed by the measurement of the total quantity of biogas produced by the digestate sample during a specified period of time, which is an indicator of its residual biodegradability. However, these two tests (RBP and VFA) are designed to test for the efficiency of the biogas process rather than for its suitability for use on soil. The data available on digestate stability potential from the RBP test are not designed to look at the suitability of the digestate for use on soil, whereas compost stability methods are.

Identifying which tests of stability and maturity are appropriate is essential to ensure digestate valorisation and their sustainable market, especially in light of the EU policy on the circular economy, bioeconomy and the new FPR. A suitable stability test will ensure the safe and direct agricultural use of digestate as an organic fertiliser (a useful by-product). If it is biologically stable it will not be a significant source of emissions of methane, ammonia or CO_2.

As previously stated, both the RBP and VFA tests are more relevant to process management to ascertain whether an effective digestion process has been completed rather than whether these materials are suitable for use as fertiliser products in agricultural soils, as envisaged by the new EU FPR. The RBP test normally takes 28 days to complete and prices quoted by various laboratories at the time of compiling this report ranged up to €600 per test.

Respiration methods

A small number of comparative studies carried out showed a good correlation between RBP and respirometric tests (Banks *et al.*, 2013). The five Irish samples tested also showed a good correlation. According to WRAP it may also be worth reconsidering the use of aerobic respiration measurements, as Banks *et al.*'s (2013) literature review confirmed that these can show a good correlation with the RBP or BMP of the digestate.

The UK respirometric test (PAS 110) has been found to be well correlated to the CEN OUR test on composts. A good correlation has also been found between OUR and AT4 in compost-like organics (Gaffney *et al.*, 2088).

Cossu and Raga (2008) compared the 4-day cumulative oxygen consumption (respiratory index, AT4) with the 21-day biogas potential on excavated samples taken from three sanitary landfills. The correlation between the results (R^2) was 0.80 (Schievano *et al.*, 2008). The study looked at the correlation between oxygen uptake and biogas potential for different substrates. These were first dried and then tested for a range of parameters including oxygen demand (20 hours) and biogas potential using a serum bottle method (Schievano *et al.*, 2008). The results showed a significant linear regression between these two parameters ($R^2 = 0.73$). However, the OUR test is simpler and cheaper than AT4 and therefore there has not been much incentive to look at the AT4 test for digestate.

Oxygen uptake rate

The small number of comparative studies carried out have indicated good correlation between biogas potential tests and respirometric tests on digestate (Banks *et al.*, 2013). The OUR method was validated by CEN for compost. It has not been validated by CEN for digestate analysis. In Belgium, the Compendium of Sampling and Analysis of Waste (CMA) has adapted the method for digestate testing. The data from Belgium, and the limited testing of Irish digestate for this study, show that only 50% of Belgian, and none of the Irish, samples met the EU FPR limit of 25 mmol O_2/kg VS/h. The OUR method for digestate needs to be validated and more widespread analysis needs to be conducted to gain knowledge on how more plants can achieve the OUR limits. There are a number of materials that are applied on land and Table 4.18 shows their typical OUR value, which for many is above 25. In our view and in consultation with colleagues in Belgium, 25 mmol O_2/kg OM/h is low. We recommend a value of 50 mmol O_2/kg OM/h as in the 2014 JRC study (Saveyn and Eder, 2014).

Table 4.19 provides a summary of the advantages and disadvantages of the methods used to test the stability of compost.

4.3.11 Conclusions and recommendations on method for digestate stability

Based on the results of this work, as summarised previously, the following conclusions can be drawn:

- The RBP test is a satisfactory method to demonstrate that an effective digestion process has taken place and the test gives repeatable results.
- An RBP value of 0.25 l/g VS appears appropriate and achievable, as shown in data from Belgium and Ireland.

Table 4.18. Comparison of OUR of different organic materials

Product	OUR (mmol O_2/kg VS/h)[a]	Reference
Cattle manure	52.38	ILVO
Solid fraction cattle slurry	65.52	ILVO
Composted cattle manure	14.94	ILVO
Processed chicken manure	108	ILVO
Biothermal dried chicken manure and biowaste	126–180	VLACO
Green compost	3.6–9	VLACO
Solid fraction digestate	21.6–45	VLACO
Dried digestate	27–63	VLACO
Post-composted solid fraction digestate and substrate	4.3–12.78	Arbor, Biorefine
Post-composted solid fraction digestate and substrate	23.58	Arbor, Biorefine

Source: Vanden Auweele (2019).

[a]Results were converted to 30°C.

ILVO, Flanders Research Institute for Agriculture, Fisheries and Food; VLACO, Flemish Compost Organisation. The Arbor project was an initiative under Biorefine Cluster Europe.

Table 4.19. Summary of the advantages and disadvantages of the stability methods

Stability test	Advantages	Disadvantages
RBP	Capability available in Irish laboratories. Recommended methodology in the EU FPR	28 days to complete Cost ranges up to €600 It is designed for process rather than suitability for use in soil
Organic acids	Recommended in the JRC end-of-waste criteria report	Only used in Germany
VFA	Relatively cheap	Only an indicative test. If the results are negative, RBP test has to be done
OUR	Test recommended in the EU FPR Automated, quick and reasonable price	Little experience on use for measuring stability on digestate in Ireland, but it is routinely used in Belgium

- There is limited evidence of using VFA concentration as a product stability criterion, except as an initial test to indicate if an RBP test should be done.
- The small number of comparative studies carried out has indicated the correlation between the RBP test and the respirometric test on digestate. This strengthens the case for the OUR test method.

We recommend the plants first preference should be to use the OUR test to measure biological stability of the whole digestate and separated digestate fibre. This recommendation is based on the evaluation above and reflects the importance of the final use of digestate. However, the RBP test should also be an option if plants want to use it. The RBP test is very expensive and takes a long time (28 days) in comparison with OUR. The tests are recommended for digestate in the EU FPR and the JRC end-of-waste criteria report. We recommend that, when more analysis is done on digestate with the methods and a review of the standard is completed, consideration should be given to requiring that only the OUR test method be used to measure stability.

4.3.12 Limit value for digestate stability method

The EU FPR has a limit of 25 mmol O_2/kg OM/h and the 2014 JRC study recommended 50 mmol O_2/kg OM/h. In our view, and in consultation with colleagues in Belgium, 25 mmol O_2/kg OM/h is low. We recommend a value of 50 mmol O_2/kg OM/h, as in the JRC 2014 study. The limit for the RBP value should be 0.25 l/g VS, as in the 2014 JRC study and the EU FPR.

4.4 Maturity

4.4.1 Compost

Compost maturity refers to the degree of decomposition of phytotoxic organic substances produced during the active composting stage. Maturity is a measure of the compost's readiness for use. It can be assessed by seed response germinated in a Petri dish. These methods have been used for a long time (Zucconi *et al*., 1981), but a lack of standardisation made the comparison of results from various sources difficult. A European standard for maturity has been developed (EN 16086-2, 2011) and has been widely used, particularly when compost is used for plants grown in containers.

Compost maturity is now beginning to be more recognised as a significant parameter to evaluate composts. The reason is that immature and poorly stabilised composts pose known problems during storage, marketing and use. In storage, immature composts may become anaerobic, which often leads to odour and/or the development of toxic compounds, as well as bags swelling and bursting. Immature composts may heat up on pallets during shipment. Continued active decomposition when these composts are added to soil or growing media may have negative impacts on plant growth because of reduced O_2 in the soil-root zone, reduced available N or the presence of phytotoxic compounds. The European method for testing for phytotoxicity (EN 16086-2, 2011) is simple, rapid and relatively cheap. Seeds are placed with the compost in a square Petri dish and 3 days later the number of germinated seeds are counted and compared with the control.

4.4.2 Digestate

Digestate (including digestate fibre and liquor) needs to be tested for phytotoxicity compounds if used as biofertiliser for sensitive crops. A phytotoxicity test on the whole digestate is recommended. This was recommended in a draft standard prepared by the Irish Bioenergy Association (IrBEA) (2013). Researchers from the Waterford Institute of Technology (Coelho *et al.*, 2018) used the phytotoxicity test with 11 digestates using a round Petri dish and found it satisfactory. However, they did not use the CEN method, which uses a square Petri dish where the seed is sown directly into the substrate or in soil and substrate; instead they used an extract. Researchers in Finland (Manukskela *et al.*, 2012) found the cress germination test on a square Petri dish to be both sensitive enough to detect variation in the quality of digestate and simple enough to serve as a feasible test in quality monitoring requiring rapid throughput times. Accordingly, MTT Agrifood Research Finland, which tested the CEN phytotoxicity test for digestate, recommend this method for digestate testing and quality monitoring of organic fertiliser products. MTT Agrifood Research Finland states that “it is a promising assay for routine testing, because of its simplicity, sensitivity and turnaround time and is relative low cost” (Mauneksela *et al*., 2012). The CEN phytotoxicity test was modified by Israeli researchers (Saadi *et al*., 2013) for use in mineral soil, and they determined its accuracy by testing the phytotoxicity of liquid olive waste. This modification could be used as a blueprint for the development of this test for digestate, both whole and liquid fraction. The advantage of the Israeli modification of the test is that it takes into consideration the soil type and the rate of application. Figure 4.3 illustrates the test set-up.

Table 4.20 shows that a germination test is used in Austria, Bulgaria and Switzerland when compost is used by hobby gardeners. Bulgaria also uses this test when digestate is used in hobby gardening. In addition, the UK uses a plant growth test with tomatoes to determine if there are any abnormalities. The germination test will ensure that no phytotoxicity problems arise as a result of the use of digestate and compost. The CEN method was developed for compost; this method needs to be adapted and validated for digestate. Once this work has been done, we recommend it is used for digestate.

We recommend that the CEN germination test is used for testing of compost (and digestate when validated) in the horticultural sector, especially when used as a component of growing media, where plants are grown in containers or where rates of compost/digestate application are very high, e.g. in preparation of top soil. The limit would be a Munoo–Liisa vitality index (MLV) of 80%.

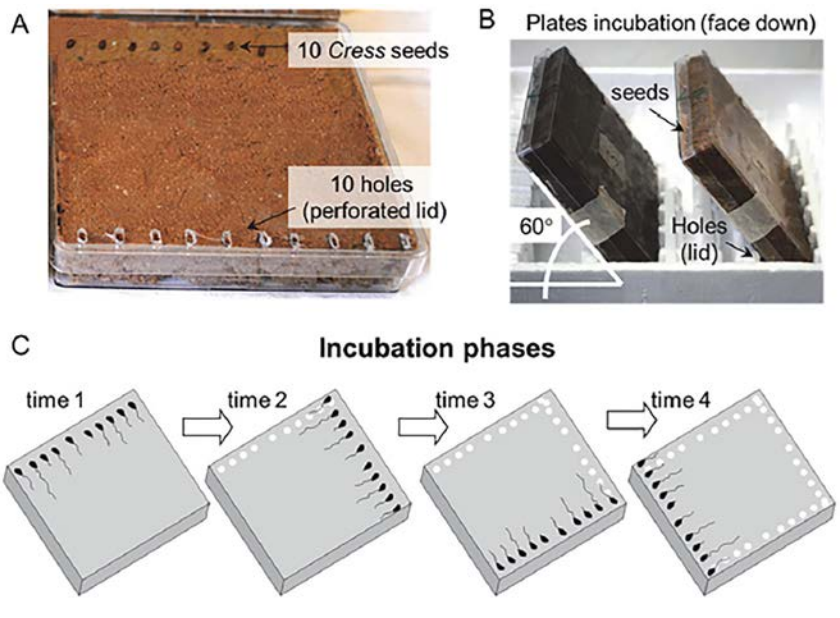

Figure 4.3. Illustration of cress test set-up. Source: Saadi *et al.* (2013). Reproduced with permission of the American Society of Agronomy, Crop Science Society of America and Soil Science Society of America.

Table 4.20. Germination and plant growth standards for compost and digestate

Country/ standard	Application	Limit value	
		Compost	Digestate
Austria	Cress test – application for when compost is used in hobby gardening	15% m/m or 25% by volume (v/v) compost: PFM 100% of the comparative substrate; germination rate > 95%, germination delay 0 days	
		30% m/m or 50% v/v compost: PFM > 90% from the comparative substrate; germination rate > 90%; germination delay 0 days	
Bulgaria	Private gardening/growing media	25% by volume compost in the substrate mix: PFM > 90% compared with the standard substrate without compost; germination rate compared with the substrate without compost > 90%; germination delay 0 days	25% by volume digestate in the substrate mix: PFM > 90% compared with the standard substrate without digestate; germination rate compared with the substrate without digestate > 90%; germination delay 0 days
		50% by volume compost in the substrate mix: PFM > 80% compared with the standard substrate without compost; germination rate compared with the standard substrate without compost > 80%; germination delay 0 days	50% by volume digestate in the substrate mix: PFM > 80% compared with the standard substrate without digestate; germination rate compared with the standard substrate without digestate > 80%; germination delay 0 days
Switzerland	Compost for outdoor gardening		
	Cress open	> 50% of ref.[a]	
	Cress covered	> 25% of ref.[a]	
	Salad	> 50% of ref.[b]	
	Bean		
	Ryegrass		
	Compost for indoor gardening		
	Cress open	> 75% of ref.[a]	
	Cress covered	> 50% of ref.[a]	
	Salad	> 70% of ref.[a]	
	Bean	> 70% of ref.[b]	
	Ryegrass	> 70% of ref.[b]	
UK	Tomato plant	Germinated plants in peat compost test mix trays as a percentage of germinated plants in peat control trays – 80%	
	Tomato plant	Average plant mass in peat compost test mix trays as percentage of germinated plants in peat control trays – 80%	
	Tomato plant abnormalities	Plants grown in peat compost test mix trays: description of any abnormalities – no abnormalities	
ECN QAS		Declaration required only if compost is used in growing media	

[a]**Minimum requirement.**

[b]**Recommended value.**

PFM, plant fresh mass.

The EU FPR and the 2014 JRC research report did not include a germination test in their recommendations.

4.5 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 put into the composting and AD process, these materials do not decompose. Although there may be some health/safety and environmental implications of using compost/digestate that is physically contaminated, such as product handling (e.g. glass) and litter generation from windblown plastic film, aesthetic issues are a greater long-term concern. When compost is used as a component in growing media, health and safety aspects are of special importance because of the, often quite intense, direct contact workers have with the material. Macroscopic glass fragments, for example, must not be present. Composts containing physical contaminants, such as plastic, have a reduced market value. These materials can decrease the value of the finished compost/digestate products because they do not enhance the compost/digestate and, in many cases, are aesthetically offensive.

The European Environment Agency published a report on the potential opportunities for biowaste across Europe. The report warned that one of the barriers to exploiting the benefits is contamination in biowaste. When putting compost and digestate on the market, several countries mention plastics as a key contaminant to be addressed (EEA, 2020).

The EU FPR allows up to 2.5 g plastics per kilogram compost (DM); however, some countries apply more stringent limits. The quality standards for impurities, including plastics, have recently been made stricter in Germany, and these standards are expressed in terms of not only weight but also surface area.

Additional measures and policies are required to reduce contamination of biowaste with plastics during collection. Avoiding contamination with plastics at the source is the most effective and efficient approach, as removing plastic contamination from biowaste during treatment is both expensive and limited in its effect (Kehres, 2017). Overall, more attention needs to be given to avoiding contamination of biowaste with plastics. This chapter will review the current state of play and provide a roadmap on how all stakeholders should work towards the aim of zero plastics in biowaste.

There were only limited data provided by operators for impurities in Ireland and it would be difficult to make any meaningful assessment of it. There is a need for data to be collected in Ireland independently to determine the true contamination levels.

Data from the Netherlands determined that, from 1000 samples from 50 plants, the average contamination in biowaste compost was 0.03% DM (the 90th percentile was 0.06%).

The BGK in Germany has done some investigations on the impurity content in compost and digestate. It found that green waste compost (1803 samples) contained a very small amount of hard and light plastics; the mean content of total plastic (hard and soft) above 2 mm was 0.019 mg/kg dry weight. The content of total plastic over 2-mm diameter was higher in biowaste compost, on average 0.029 mg/kg dry weight. The BGK also investigated the presence of smaller plastics in 19 biowaste samples. It found no hard plastics in the 1- to 2 mm fraction, but it did find soft plastics at a level of 0.001 mg/kg dry weight. In 10 samples of liquid digestate, the average content of plastics less than 1 mm was 0.021 mg/kg in the case of soft plastics and 0.019 mg/kg in the case of hard plastics.

Table 4.21 is a collation of impurity standards in compost and digestate from various countries in Europe and other countries around the world. A total impurity content of 0.5% above 2 mm is the main trend in standards.

In the UK, the impurity limit in digestate varies depending on the N content (Table 4.22). The rationale behind this is that the concern is the level of plastic being applied to soil; therefore, since the limiting factor for digestate application is the ability to spread N, the limits vary according to N loading. Table 4.23 shows that the total impurity content in compost is set at 0.25%.

Compost and digestate can be produced in England, Wales and Northern Ireland to the standards contained in the British Standards Institution (BSI) PAS 100 and PAS 110. When it comes to obtaining end-of-waste status, this is done via the quality protocols.

Table 4.21. Standards for impurities in compost and digestate in other countries

Country/ standard	Standard reference	Class	Compost (DM) Glass, metal, plastic, other >2 mm	Compost (DM) Plastic >2 mm	Digestate (DM) Glass, metal, plastic, other >2 mm	Digestate (DM) Plastic >2 mm
Belgium	Flemish Decree (VLAREMA)		<0.5%	No limit	<0.5%	No limit
Estonia	End-of-waste		<0.5%		<0.5%	
Finland	Fertiliser Products (24/2011, 7/2013)		0.5%	0.5%	0.50	0.50
France	NF U 44-051		3.1% plastics, not counting plastics 2–5 mm; 2% glass/metals	0.3% films + EPS >5 mm; 0.8% other plastics >5 mm		
Germany	RAL GZ 251 – fresh compost RAL GZ 251– finished compost RAL GZ 251– substrate compost RAL-GZ 258 – sewage sludge fresh RAL-GZ 258 – sewage finished		0.5% for all impurities; 0.1% for plastic foils; 0.4% for glass/ metal	0.1% (only deformable plastics, e.g. foils)		
	RAL GZ 245 – digestate liquid RAL GZ 245 – digestate – solid RAL GZ 245 – whole digestate				0.5% for all impurities; 0.1% for plastic films and 0.4% for glass/metal	0.1% plastics (films)
Greece	Gazette of the Hellenic Republic 3339		<3%		<3%	
Hungary			It must not contain any foreign material			
Netherlands	Keurcompost		Dutch law: <0.5%		No standard exists	
		A	<0.05%	<0.05%		
		B	<0.1%	<0.1%		
		C	<0.2%	<0.2%		
Portugal	Decree Law 103/2015	1	0.5%		No standard exists	
		2	1%			
		2 (A)	2%			
		3	3%			
Slovenia	Official Gazette of the Republic of Slovenia (99/13, 56/15 and 56/18)	1	<0.5	–	<0.5%	–
		2	<2%	–	<2%	–
Sweden	Compost QAS SPCR 152 Note: visible impurities are defined as plastic, glass, metal and composite materials >2 mm		0.5%		Plastic >2 mm: 20 cm²/kg liquid digestate (<20% DM) or 60 cm²/kg solid digestate (>20% DM). As of 1 January 2020 the limit value is 10 cm²/kg (liquid) and 30 cm²/kg (solid)	

Table 4.21. Continued

			Compost (DM)		Digestate (DM)	
Country/ standard	Standard reference	Class	Glass, metal, plastic, other >2mm	Plastic >2mm	Glass, metal, plastic, other >2mm	Plastic >2mm
England, Wales, Northern Ireland	PAS 100:2018 and PAS 110:2014 Definition is total glass, metal, plastic and any other non-stone man-made fragments >2mm		<0.25%	<0.12%	0.36kg/t=0.36% FW[a]	No limit
Scotland			<0.25%	<0.08%	28.8g/t =0.0288% FM[a]	No limit
Italy	Legislative Decree 75/2010		<0.25			
Norway	Regulations on fertilisers, etc. of organic origin FOR-2003-07-04-951	0 1 2 3	0.5% >4mm (to be changed to 0.5% >2mm and 0.25% >2mm in 2023)	No specific requirements	0.5% >4mm (to be changed to 0.5% >2mm and 0.25% >2mm in 2023)	No specific requirements
Switzerland	Fertiliser Ordinance 2001		0.4%	0.1%	0.4%	0.1%
Spain	Royal Decree 506/2013, June 28, on Fertilizer Products	A B C	Must not contain inert impurities of any kind, such as stones, gravel, metal, glass and plastics			
UAE	Ministerial Decree No. 801 of 2015		No requirement			
Canada	Canada – national guideline under the CCME	A	Sharps: no foreign matter >3mm per 500ml. Other foreign matter: no more than one piece of foreign matter >25mm per 500ml			
		B	Sharps: no foreign matter content ≤3mm per 500ml. Compost cannot be used in pastures, parks or for residential purposes. Other foreign matter: no more than two pieces of foreign matter >25mm in any dimension per 500ml			
USA	Limits are US EPA requirements that are adopted by the US Composting Council QAS		US EPA: n/a. State: varies. USCC STA: n/a USCC STA–Consumer Use Program Requirements – 1% (acceptable), 0.5% (preferred)			
USA	American Biogas Council Digestate Standard Testing and Certification Programme				<1% total by dry weight >4mm, of which <0.25% by dry weight is film plastic, and no sharps	
Australia (4454-2012)			Glass, metal and rigid plastics >2mm=0.5%	Light plastics/film >5mm=0.05%		
ECN QAS			0.5%		0.5%	
IS 441	Compost		0.5%			
EU FPR	Compost/digestate		Total impurities – glass, plastic, metal above 2mm=5g/kg dry matter Impurities – in form of glass, plastic or metal above 2mm=3g/kg DM After 7 years, the total impurities limit is reduced from 5 to 2.5g/kg dry matter			
JRC study (2014)	Compost/digestate		0.5% for glass, plastic, metal above 2mm			

[a]Separated liquor is only exempt from physical contaminants tests if the separation technology used by the producer results in all particles being <2mm in the separated liquor fraction.

CCME, Canadian Council of Ministers of the Environment; FM, fresh matter; FW, fresh weight; n/a, not applicable; STA, Seal of Testing Assurance Program; SPCR, Technical Research Institute of Sweden Certification Rules; USCC, US Composting Council.

Table 4.22. Impurity limits in relation to total N content in UK PAS 110 for digestate (PAS 110:2014)

Impurity	Total N (kg/t)									
	<1	1–1.9	2–2.9	3–3.9	4–4.9	5–5.9	6–6.9	7–7.9	8–8.9	≥9
Total stones (kg/t)	3.2	6.4	9.6	12.8	16	19.2	22.4	25.6	28.8	32
Total physical contaminants (excluding stones) (kg/t)	0.04	0.07	0.11	0.14	0.18	0.22	0.25	0.29	0.32	0.36

Total N is the limiting factor for physical contaminant contents.

Separated liquor is exempt from physical contaminants tests only if the separation technology used by the producer results in all particles being <2 mm in the separated liquor fraction.

Table 4.23. Impurity limit in UK PAS 100 for compost (PAS 100:2018)

Parameter	Limit
Physical contaminants	
Total glass, metal, plastic and any other non-stone fragments >2 mm	0.25%, of which 0.12% is plastic
Stones	
Stones >4 mm in grader other than mulch	8%
Stones >4 mm in mulch grade	10%

In order to ensure that soil quality is protected through the use of food waste-derived compost and digestate, the Scottish Environment Protection Agency (SEPA) has amended its position on plastic contaminant limits allowable in compost and digestate outputs by reducing the associated limits as shown in Tables 4.24 and 4.25.

Aspray and Tompkins (2019) conducted a study for SEPA researching plastic contamination in domestic and commercial food waste received at composting sites and made recommendations for improvement. Their analysis showed that feedstock with 5%, or even 1%, contamination requires significant clean-up if the final compost is to achieve either PAS 100 or the new regulatory limits. In short, achieving such reduction levels is extremely difficult.

Some of the key recommendations of Aspray and Tompkins (2019) are:

Table 4.24. Scotland – quality standards in compost and implementation timescale (SEPA, WST-G-50, 2017)

Date	Parameter	Limit
From 1 December 2018	Plastic	0.08% (66% of current PAS 100)
From 1 December 2019	Plastic	0.06% (50% of current PAS 100)

- Engage relevant stakeholders to target common domestic “in bag” plastic contaminants, such as cucumber films and plastic (and paper-based) fruit stickers.
- Develop a food waste feedstock monitoring programme. This could be overseen by a trade body (as in Italy) or become part of the regulatory framework, e.g. through a site licence or permit condition (as in California, where minimum inspection and monitoring requirements are mandated).

The Austrian and Bulgarian limits for impurities diverge from the general trend in other countries, which simply set a single limit for total impurities. The Austrian (compost) and Bulgarian (compost and digestate) approaches apply different limits depending on the use or the application of the product. This approach could be difficult to manage on a composting site, as separate piles of compost would need to be kept for different uses. In Austria, the total impurities above 2 mm allowed are 0.5% in compost for agricultural use and 1% in compost for landscaping/landfill restoration. There is also a specific limit of 0.2% for plastic, glass or metals above 2 mm in compost for agricultural use.

In Bulgaria, if compost/digestate is used in landfill restoration and mines, a more relaxed limit of <2.5% contaminants above 2 mm is allowed. In landscaping the limit is <1%. The limit in compost for agricultural use is also 1%, but a stricter limit of 0.5% is being introduced over a period of 7 years; this will bring Bulgaria in line with other European countries. Digestate is only analysed for impurities if it contains biowaste.

4.5.1 Recent developments

Since the report by Prasad and Foster (2008) there have been changes across Europe on quality standards for compost and digestate. A key change

Table 4.25. Scotland – quality standards for plastic (g/t) relative to total N content in digestate and implementation timescales (SEPA, WST-PS-16, 2017)

	Total N (kg/t)										
Date	< 1	1–1.9	2–2.9	3–3.9	4–4.9	5–5.9	6–6.9	7–7.9	8–8.9	≥ 9	Target
From December 2017	20	35	55	70	90	110	125	145	160	180	50% of current PAS 110
From December 2018	10	17.5	27.5	35	45	55	62.5	72.5	87.5	90	25% of current PAS 110
From December 2019	3.2	5.6	8.8	11.2	14.4	17.6	20	23.2	25.6	28.8	8% of current PAS 110

has been stricter limits for impurities and applying specific limits for plastics.

In Switzerland, visible impurities are defined as plastic, glass, metal and composite materials > 2 mm. The limit for impurities was changed in 2015 from 0.5% DM by weight to 20 cm^2/kg in the case of liquid digestate (less than 20% DM) or 60 cm^2/kg in the case of solid digestate (more than 20% DM). The change of unit and analysis method was because most impurities are lightweight plastic film. In 2020 the limit values were halved.

The German Fertiliser Ordinance recently changed the measurement of impurity size from > 2 mm to > 1 mm. The value of the limit has not changed; it remains 0.4% DM for metal, glass and rigid plastics, and 0.1% for plastic films. This came into force on 1 January 2021. The German Biowaste Ordinance currently sets a limit of 0.5% for total impurities above 2 mm. The ordinance is being revised and this limit is expected to change.

In addition to the gravimetric limits in Germany, the BGK QAS has a visual assessment of impurities by surface area with a limit value of 15 cm^2/l; this was reduced from 25 cm^2/l in July 2019. The Bioland/Naturland organic farming guidelines have had a limit of 10 cm^2/l since January 2019.

In June 2020, CEN TC223 examined the method for assessing impurities, which included looking at the surface area method. The outcome of this CEN review should be examined as part of the review of the standard in 2025. This is an alternative method in which plastics are spread and pasted as flat as possible on a contrasting surface, such as a sheet of bright-blue paper, of known dimensions. A photograph is then taken with a digital camera and processed with software for image analysis. From the resulting area of known dimensions, the part showing the contrasting colour of the sheet is then estimated as a percentage of the total area. The area of the plastics is then calculated as a percentage of the area filled by background paper colour divided by 100.

WRAP undertook an interesting study (Aspray *et al.*, 2016), which looked at physical contaminants in compost and digestates. The study involved spiking samples and evaluating laboratories' performance. The study also looked at the German surface area method. The conclusions of the study were that there is variability between the laboratories in identifying contaminants and it merits further investigation of the surface area method. We recommend that a similar study be carried out in Ireland.

For end-of-waste purposes, Scotland has taken a stricter approach on plastic content in compost and digestate than set out in PAS 100 and PAS 110.

Saveyn and Eder's (2014) JRC study recommended a limit of 0.5% for glass, plastic and metal above 2 mm in compost and digestate. The EU FPR sets a limit of 5 g/kg (0.5%), moving down to 2.5 g/kg (0.25%) after 7 years, for total impurities of glass, metals and plastic above 2 mm. It includes a specific limit of 3 g/kg (0.3%) for any single impurity.

There are research projects ongoing in Germany assessing the implications of microplastics. Current methods and available modelling are not reliable for microplastics (Corden *et al.*, 2019). As scientific methods and knowledge develop, the subject of microplastics should be revised on a regular basis.

The EPA-funded project VALOR (Valorisation Alternatives to Landfill for Organic Residues) is currently assessing the potential plastic contamination of soil due to the use of compost and digestate. The project has collected compost and digestate samples to assess the plastic content (macroplastics and microplastics). The preliminary results show that the content of plastics

> 2 mm in the compost/digestate samples (food waste, green waste and food digestate) analysed is between 0.009% and 0.21%. In relation to soils where compost has been applied, a field where 5–10 t/ha of food waste was applied once a year for the past 5 years contained, on average, 0.009% plastics > 2 mm compared with a field with no history of compost application that showed no plastics in the samples.

Currently there is no co-ordinated effort in Ireland of key stakeholders to work towards reducing the level of contamination in biowaste material. The authors recommend that a working group of key bodies – regulators, policymakers, collectors and processors – is established.

This group could exchange views, promote best practice and examine technical solutions to remove contamination in biowaste. Compost and digestate are carriers of microplastics, and are not sources of microplastics, and we welcome any measures that reduce plastic contamination at source. The prevention of impurities in the untreated biowaste is the most effective way to prevent impurities in compost and digestate. The Austrian Compost and Biogas Association reported that 80–90% of impurities in organic waste collected from households come from conventional, non-compostable bags (Favoino and Giavini, 2020).

Examples of items the group could explore are:

- National legislation to exclude single-use plastic bags could be introduced. Italy did this in 2011, contrary to EU law. Since then, the carrier Bag Directive changed EU law[12] and other countries have banned certain types of bags. Spain banned lightweight bags in 2018. Very lightweight bags (used for fruit and vegetables) were banned by France and Spain in 2021. Austria banned plastic bags in January 2020.
- Awareness campaigns on segregation of biowaste could be organised.
- Legislative change such as consideration of introducing fixed penalty notices for improper segregation of biowaste (e.g. Milan).
- Best practice to encourage usage of brown bins, e.g. compostable paper bags, could be promoted.
- An understanding that compost used for food must have zero contamination could be promoted.

BGK carried out a theoretical exercise to calculate the impurity content of compost depending on the level of impurities in untreated biowaste and the efficiency of impurity removal in the process. To obtain a marketable compost product with an impurity content of 0.1% DM from input material with an impurity content of 3% fresh matter, it is necessary to remove 99% of the impurities in the source material. If the input material is biowaste feedstock with an impurity content of 5%, the use of separation technologies will result in a level of contamination of the final compost of 0.5%. In practice this highly technical effort is combined with a high amount of screen overflow (impurities and also organic matter that is excluded from recycling). The message from this BGK calculation is that it is more effective to solve the problem at the source.

A national pilot project was carried out in Sligo (Cré, 2019) from July 2014 to March 2015, as follows:

- A door-to-door campaign was organised to provide information on the brown bin scheme.
- A locally tailored brown bin information leaflet was distributed.
- Householders were supplied with a kitchen caddy and compostable liners.

The pilot project found that the contamination level in biowaste reduced from 18% to 1%. The results of the project showed that, by giving people the right information and a kitchen caddy and compostable liners (EN 13432) to use, contamination levels reduced dramatically.

The EPA’s 2018 waste characterisation report found that 16% of the weight of the material in household brown bin collections was non-target material, i.e. had been placed in the wrong bin (EPA, 2018). Contaminants primarily comprised plastics and textiles. A further report by the EPA (2018) on commercial

12 Article 11 of Directive 2015/720 amending Directive 94/62/EC as regards reducing the consumption of lightweight plastic carrier bags. Measures to be taken by Member States may involve the use of economic instruments such as pricing, taxes and levies, which have proved particularly effective in reducing the consumption of plastic carrier bags, and marketing restrictions such as bans in derogation of Article 18 of Directive 94/62/EC, provided that these restrictions are proportionate and non-discriminatory.

waste found a 6% contamination rate.[13] The surveys were done on 14 businesses and six household collection routes. More waste characterisation studies should be done around Ireland to get a clear view on contamination levels.

The Government of Flanders decided to change the definition of household biowaste (vfg-waste) in Flanders from 1 January 2019. Coffee pods and tea bags are no longer allowed because they can contain plastics. Fruit stickers are a source of plastic in compost/digestate. They will be banned from 2021 unless they are compostable or are really necessary because they contain information that is mandatory.

There have been claims that some products, such as tea bags, paper towels and fruit stickers, contain plastic. From a survey of tea bag brands in Ireland, it appears that two or three brands advertise that their tea bags are compostable and do not contain plastic. We recommend that as well as these products, other similar products in Ireland be analysed to determine if they contain plastic.

4.5.2 Recommendations

In addition to the standard for impurities, the following are recommended to reduce impurities:

- Develop a national education programme for households on contamination.
- Introduce a system in which householders who contaminate brown bins receive two warnings before being fined the third time, like the system in Milan.
- Provide kitchen caddies to all households.
- Analyse products such as fruit stickers, tea bags and paper towels to determine if they contain plastic. If plastic is found, legislate for its removal.
- Establish a contamination working group.
- Develop a food waste feedstock monitoring programme similar to the one in Italy.

We recommend a specific limit for plastic, regardless of whether it is soft or rigid plastic, to reduce and minimise the plastic content of final products. We recommend that for compost and digestate produced from waste feedstocks the total impurity content (glass, metal and plastic) greater than 2 mm is 0.5% dry weight. Within this total limit, there would be a limit for plastic of 0.25%. More efforts are needed by waste generators, collectors and processors to prevent contamination of the final products. The sector needs to develop protocols to prevent contamination, educate the public on contamination and invest in equipment to remove contamination in processing sites. If this does not happen, it will be difficult to meet the limit value, and this could possibly result in a loss of markets for compost and digestate. Table 4.26 outlines the recommended standards for impurities in compost and digestate.

This review of the impurity standard and limit values in 2025 will entail the following:

- a review of the latest scientific knowledge on plastics limits and methods of analysis, which will include the surface area method;
- assessment of the performance of a separate collection of biowaste;
- independent evidence-based data on levels of contamination in feedstocks conducted by a regular waste characterisation;
- independent evidence-based data on levels of contamination (plastic, glass and metal) in compost and digestate;
- a ring test of laboratories conducting impurity analyses similar to the work done by WRAP in 2016;

Table 4.26. Recommended standard for impurities in compost and digestate

Parameter	Limit (mass/mass dry weight)
Year 2020	
Total impurity content (glass, metal and plastic) above 2 mm	0.5%
Plastics > 2 mm	0.25%
Year 2025	
The standard will be reviewed in 2025 using the NSAI standard review process	

13 This was based on a limited sample (14 businesses) and it is understood that businesses were informed of the survey taking place in advance, which could have resulted in changed behaviours, meaning that the actual level of contamination may be higher than that reported.

- assessment of national awareness initiatives educating householders and businesses on the correct use of the food waste bin.

The prevention of impurities in the untreated biowaste is the most effective way to prevent impurities in compost and digestate, and this should also be included in the 2025 review. The key to addressing the issue of contamination is the establishment of a contamination working group with key stakeholders who will work to solve the problem. The group could look at all waste streams, not just food waste. The recommended activity of the group is to:

- review best practice from other countries on how to reduce contamination by the waste generator through education, rejections of waste and fines for contamination;
- examine how to enforce contamination control on waste generators;
- examine technologies that could remove contamination; and
- agree and implement a co-ordinated national plan to solve the issue of contamination.

Once the review is completed, the policymakers and NSAI should update the standards and legislation.

4.6 Stones

Stone content is a parameter that is really based on the end use requirement. The particle size and limit vary across the few standards (Table 4.27) that include stones as a parameter. The database of samples in Ireland (Table 4.28) varies, as the 2008 data relate to total stones and do not differentiate between particle sizes.

Some countries set a limit of 5% on stones larger than 5 mm. The UK has limits based on the N content of digestate (Table 4.29). Germany has a limit of 5% on stones larger than 10 mm. Previously the limit applied to stones larger than 5 mm. Neither the EU FPR nor the 2014 JRC research report (JRC-IPTS, 2014) recommends a limit for stones.

We propose that for compost and digestate in Ireland stones larger than 5 mm be declared. The markets in which the compost and digestate will be used will have different requirements.

4.7 Pathogens

Pathogen testing as part of a quality standard is important. Pathogens are living microorganisms, such as bacteria, viruses or fungi, that can cause plant,

Table 4.27. Standards for stones in compost and digestate in other countries

Country	Standard reference	Compost	Digestate
Belgium	VLAREMA	Stones > 5 mm = 2%	
UK	PAS 100	> 4 mm in grades other than mulch = 8%	
UK	PAS 110		> 5 mm value declared on fresh weight basis
Ireland	IS 441	Stones > 4 mm = 8%	
Italy		Stones > 5 mm = 5%	
Netherlands		Stone > 5 mm: Keurcompost class A < 1%; classes B and C < 2%	
Portugal		Stones > 5 mm = 5% in classes 1 and 2	
Slovenia		Stones > 5 mm = 5% in classes 1 and 2	
Germany	RAL GZ 251 – fresh compost	Stones > 10 mm = 5%	
	RAL GZ 251 – finished compost	Stones > 10 mm = 5%	
	RAL GZ 251 – substrate compost	Stones > 10 mm = 0.5%	
	RAL-GZ 258 – sewage sludge fresh compost	Stones > 10 mm = 5%	
	RAL-GZ 258 – sewage sludge finished compost	Stones > 10 mm = 5%	
	RAL GZ 245 – digestate, liquid		Stones > 10 mm = 5%
	RAL GZ 245 – digestate, solid		Stones > 10 mm = 5%
	RAL GZ 245 – whole digestate		Stones > 10 mm = 5%

Table 4.28. Standards for stones in the Irish database – 2008 (%) and 2019 (mass/mass of air-dry sample)

	SSGW 2008 (%)	SSBW 2008 (%)	SSGW 2019 (>4 mm)	SSBW 2019 (>5 mm)
Maximum	11	47.79	1.17	5.72
Minimum	0.00	0.0	0.01	0.00
Median	0.00	0.12	0.50	0.00
Mean	1.36	4.00	0.43	0.45
Standard deviation	2.73	7.83	0.19	0.71
Percentile (75th)	0.91	4.25	0.50	0.38
Percentile (90th)	6.17	11.82	0.50	1.54
Number of samples	42	100	82	64

Table 4.29. Standards for stones in relation to total N content in the UK PAS 110 digestate standard

	Total N (kg/t)									
	<1	1–1.9	2–2.9	3–3.9	4–4.9	5–5.9	6–6.9	7–7.9	8–8.9	≥9
Total stones (kg/t)	3.1	6.4	9.6	12.8	16	19.2	22.4	25.6	28.8	32

animal or human disease, e.g. *E. coli* and *Salmonella* spp. Pathogen monitoring is necessary to evaluate and monitor the health and safety risks associated with use and reduce user concerns related to spreading disease. *E. coli* and *Salmonella* spp. are indicator microorganisms.

The database of Irish results shows that the *E. coli* content in biowaste and green compost has fallen since 2008. *Salmonella* was not detected in compost in 2008 or the more recent database of 2019. There were no data provided by AD plants.

The Austrian Biowaste Ordinance applies different limits and requirements for pathogens dependent on the end use of compost: bags, agriculture, landscaping or landfill restoration. For compost in bags/sport fields and children's playgrounds, there should be no pathogens (*E. coli, Salmonella, Campylobacter, Listeria* spp.) present. In landscaping and agriculture, testing of certain pathogens (*E. coli, Campylobacter, Listeria*) is not a requirement. For compost used as landfill cover there is no requirement to test for *E. coli.* The approach is a little complex and we feel that all compost at a facility should be tested to the same standards, because it might not be practical to keep separate piles of compost in the plants based on the different pathogen testing requirement.

In addition to the information provided in Table 4.30, the following information on pathogen standards in various countries is available:

- In Canada there are two options: (1) a test for pathogens as outlined in Table 4.30 or (2) a test in vessel composting/an aerated static pile at 55°C for 3 days *or* windrow composting at 55°C for 15 days and turned as least five times.
- Hungary only monitors for faecal streptococci (< 10 colony-forming units (cfu)/g fresh mass in compost) and *Pseudomonas aeruginosa* (< 10 cfu/g fresh mass in compost).
- France monitors for *Listeria* (0 in 1 g or in 25 g in compost for gardening).
- Estonia tests for helminth eggs (no eggs in 10 g).
- France tests for helminth eggs (0 in 1 g or in 25 g in compost for gardening).
- Australia has no requirements.
- The USA has the following requirements: < 1000 most probable number (MPN)/g dry weight for *E. coli* and 3 MPN/4 g dry weight for *Salmonella.*
- In the UAE, compost should be clear of any viruses, bacteria or fungi.
- Norway has the following requirement: 2500 "thermotolerant coliform bacteria" (a Norwegian unit).
- In Hungary, for *E. coli*, there should be < 10 cfu/g fresh mass in compost.
- In Belgium there is no limit value for *E. coli*.

4.7.1 Recent developments

The EU FPR published in 2019 allows for testing of *E. coli* or Enterococcaceae and *Salmonella.* The

Table 4.30. Evaluation of standards for pathogens in compost and digestate

Country/standard	Compost		Digestate		
	E. coli (cfu/g FM)	*Salmonella* spp. (cfu/25 g)	*E. coli* (cfu/g FM)	*Salmonella* spp. (cfu/25 g)	Enterococcaceae (cfu/g FM)
Twelve standards	< 1000	0 in 25 g	< 1000	0 in 25 g	–
Germany	–	0 in 50 g	–	0 in 50 g	–
Czechia • Substrates • Organic and farmyard fertilisers – DM content exceeding 13% • Organic and farmyard fertilisers – DM content not exceeding 13%	≤ 100[a] (1000[b])	0 in 25 g	5000 = digestate from waste 1000 = digestate from non-waste	(digestate from waste and non-waste) 0 in 25 g	Compost ≤ 100[a] (1000[b]) Digestate from waste < 5000 Digestate from non-waste < 5000

cfu, colony-forming unit.
[a]Limit for bagged compost.
[b]Limit for bulk compost.

trend in standards and regulations in many countries is less than 1000 cfu/g for *E. coli* and is absent for *Salmonella* spp.

4.7.2 *Recommendation for pathogens standards*

We recommend that compost and digestate should be tested for *E. coli* (< 1000 cfu/g fresh mass) and *Salmonella* (absent in 25 g). This is aligned with the EU FPR.

4.8 Weed Seeds

Weed seed testing is an important parameter for end-users of compost or digestate. Farmers, in particular those growing food crops, want reassurance that if compost or digestate is used it will not introduce weeds into the field/crop. From a review of standards in different countries (Table 4.31), weed seed is a common standard for compost and digestate and the limit value is generally consistent at a maximum of two viable weed seeds per litre.

The limited data from compost samples in Ireland show that two viable weed seeds per litre is readily achievable (Table 4.32).

The countries that do not have a weed seed as a parameter are the USA, Canada, the UAE, Czechia, France, Italy, Spain, the UK and Switzerland. The UK does not require weed seeds to be tested in digestate because the CEN method has not been validated for digestate. Surprisingly, the EU FRP does not have a requirement to measure compost or digestate for weed seeds, whereas the 2014 JRC study on end-of-waste criteria recommends a maximum of two viable weed seeds for compost and digestate.

We recommend that the weed seeds parameter in IS 441 be continued for compost and adopted for digestate too. The limit is a maximum of two viable weed seeds per litre.

4.9 Organic Contaminants

Testing for organic contaminants is important and necessary to evaluate and monitor the potential for soil and water pollution. In our previous report in 2008 on a compost standard (Prasad and Foster, 2008), we recommended that it is not a requirement to measure organic contaminants in compost made from source-separated materials.

In 2008, we had only Irish data from a few samples. The results were for organic contaminants (polychlorinated biphenyls – PCBs – and PAHs) in compost made from SSBW (five or six samples). All of the PCB results were less than 120 µg/kg. The PAH contents of compost samples from one composting plant were 2.7, 5.4, 2.6, 2.0 and 3.7 mg/kg. Another site had a content of 20.8 mg/kg. The PAH results are based on only six samples and really should not be taken seriously on account of the limited number of samples. One sample (20.8 mg/kg) skewed the overall results for compost made from SSBW and

Table 4.31. Weed seed standards in compost and digestate in other countries (viable seeds per litre)

Country	Standard reference	Class	Compost (DM)	Digestate
Belgium	VLAREMA		Maximum 1	Maximum 1
Austria	Compost Ordinance Regulation 292 of 2001	Growing media and hobby gardening	≤2	No limit
Bulgaria	Biowaste Ordinance Decree 235 of 2013	Growing media and hobby gardening	≤2	≤2
Finland	Fertiliser Products (24/2011, amendments up to 7/2013 included)		5	5
Germany	RAL GZ 251 – fresh compost		≤2	
	RAL GZ 251 – finished compost		≤2	
	RAL GZ 251 – substrate compost		≤2	
	RAL-GZ 258 – sewage sludge fresh compost		≤2	
	RAL-GZ 258 – sewage sludge finished compost		≤2	
	RAL GZ 245 – digestate, liquid			≤2
	RAL GZ 245 – digestate, solid			≤2
	RAL GZ 245 – whole			≤2
Greece	Gazette of the Hellenic Republic 3339		≤3	≤3
Hungary	36/2006 (V. 18.) FVM		0	0
Netherlands	Keurcompost		≤2	No standard
Portugal	Decree Law 103/2015	1, 2, 3	≤2	No standard
Slovenia	Decree on the recovery of biodegradable waste and the use of compost or digestate (Official Gazette of the Republic of Slovenia, Nos. 99/13, 56/15 and 56/18)	1	≤2	≤2
		2	≤2	≤2
		Category 1 has a subcategory for <20% organic matter – no limit		
Sweden	Compost QAS SPCR 152/SPCR 120		≤2	≤2
United Kingdom	PAS 100:2018 and PAS 110		0	–
Switzerland	Fertiliser Ordinance 2001	Indoor gardening		
		Outdoor gardening		
Estonia	Law – end-of-waste of compost/digestate		≤2	≤2
Norway	Regulations on fertilisers, etc. of organic origin FOR-2003-07-04-951		0 wild oat seeds	
JRC report			≤2	≤2
EU FPR			No limit	
ECN QAS			≤2	≤2

SPCR, Technical Research Institute of Sweden Certification Rules.

Table 4.32. Weed seed standards from the Irish database 2019 (seeds per litre)

	SSGW 2019	SSBW 2019
Mean	0	0
Standard deviation	0	0
Percentile (90th)	1	0
Number of samples	90	41

the likelihood is that this high value resulted from the composting of construction and demolition waste timber containing preservatives.

In 2020 we tested compost (<1, 0.1 and 2.5 mg/kg DM) and a digestate sample (1.2 mg/kg DM) for PAH_{16}.

In 2008, compost standards that include organic pollutants only existed in two countries: Germany (in Baden-Württemberg) and Denmark. In the early 1990s, there was a lot of controversy about organic contaminants (JRC-IPTS, 2008), which was followed up by a lot of research, which detected low levels in compost derived from source-separated material. In their study, Amlinger *et al.* (2004) found that the concentrations of organic contaminants (PCBs, polychlorinated dibenzo(p)dioxin and furan – 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.

4.9.1 Latest developments

Since our work in 2008, scientific knowledge has grown. In 2014, the JRC published the study *End-of-waste Criteria for Biodegradable Waste Subjected to Biological Treatment (Compost & Digestate)* (Saveyn and Eder, 2014). The study brought together the latest information and data on organic pollutants in compost and digestate. As part of the study the authors sampled compost and digestate from across Europe. There is a comprehensive analysis of this subject in Saveyn and Eder (2014) if readers would like to learn more.

The European Commission JRC study known as FATE-COMES collected 139 samples of compost and digestate from 15 countries in the summer of 2011 (Tavazzi *et al.*, 2013). The aim was to look at trace elements and organic compounds. The main recommendations of the study were:

- An end-of-waste product quality requirement should provide an additional safeguard against undesired pollutants that cannot be avoided or removed solely through the selection of input feedstocks.
- When developing end-of-waste criteria, it is recommended especially that there should be testing and a limit value for PAHs because no single technology provides an absolute barrier to inorganic or organic pollutants, so regular testing is required.

Neither in the 2008 pilot study on possible end-of-waste criteria for compost (JRC-IPTS, 2008) nor in the initial stages of the 2014 JRC study were proposals made for limit concentrations for organic pollutants. However, at the end of the review and sampling of compost and digestate, the JRC study recommends testing compost and digestate for PAH_{16}.[14] This was further adopted in the EU FPR as a parameter (Table 4.33). A nuance that is missed by many parties is that the JRC report did not recommend that every sample be tested (Saveyn and Eder, 2014). It recommended that during the first year of sampling (referred as the recognition year) an intensive sampling regime be conducted based on the tonnage processed at the site. The following years would have a reduced sampling frequency (Table 4.34).

In the JRC study it is stated that possible limit values may be derived from a number of approaches, including risk assessments and techno-economic evaluations. Nonetheless, it is reasonable to assume that limit values encountered in legislation are based on a multitude of criteria and take into account market conditions as well as possible adverse environmental and human health effects. Therefore, the discussions in the JRC study were oriented towards limit values encountered in relevant existing legislation.

EU legislation with specific organic pollutant limit values for composts and digestates did not exist until the new EU FPR. In a broader context, Council Regulation (EC) No 1195/2006 of 18 July 2006 amending Annex IV to Regulation (EC) No 850/2004 (Persistent Organic Pollutants – POPs – Regulation) prescribes general maximum concentration limit values in waste for PCBs (50 mg/kg) and PCDD/F (15 µg/kg). If these limits are exceeded, the waste must be treated in such a way as to ensure that the POP content is destroyed or irreversibly transformed (Saveyn and Eder, 2014).

Table 4.33. PAH_{16} standard in the EU FPR and the JRC study

	Parameter	Unit	Limit
EU FPR	CMC 3 compost CMC 4 fresh crop digestate – solid or liquid fraction CMC 5 digestate – solid or liquid fraction	mg/kg dry matter	6
JRC study (2014)	PAH_{16}[a]		

[a]Naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, indeno[1,2,3-cd]pyrene, dibenzo[a,h]anthracene and benzo[ghi]perylene.

14 Including PFCs (perfluorinated compounds or fluorosurfactants) if sewage sludge is used as a feedstock (only if sewage sludge-derived materials were to be allowed).

Table 4.34. Sampling frequency for PAH_{16} based on tonnage processed

Recognition year		Following years	
Annual input (tonnes)	**Samples/year**	**Annual input (tonnes)**	**Samples/year**
< 3000	1	< 10,000	0.2 (once per 5 years)
3001–10,000	2	10,001–25,000	0.5 (once per 2 years)
10,001–20,000	3	25,001–50,000	1
20,001–40,000	4	50,001–100,000	2
40,001–60,000	5	100,001–150,000	3
60,001–80,000	6	150,001–200,000	4
80,001–100,000	7	200,001–250,000	5
100,001–120,000	8	250,001–300,000	6
120,001–140,000	9	300,001–350,000	7
140,001–160,000	10	350,001–400,000	8
160,001–180,000	11	400,001–450,000	9
> 180,000	12	450,001–500,000	10
		500,001–550,000	11
		> 550,000	12

At the country level, national and regional legislation can be found that is directly or indirectly intended to regulate organic pollutant limits in compost and digestate. In our survey of standards from various countries we found four countries that have limits for organic pollutants (Table 4.35).

Some countries (Austria, Germany and the Netherlands) have specific legislation for compost and digestate, which do not require the measurement of organic pollutants, provided that the compost/digestate is from source-separated materials listed on a positive list.

The study by Tavazzi *et al.* (2013) mentions that there is a limit of 4 mg/kg for PAH_{16} in Switzerland and 10 mg/kg for PAH_{16} in Luxembourg. In several Member States, other legislation may also affect

Table 4.35. Standards for pollutants in Belgium, Hungary, Slovenia and Greece

			Hungary		Slovenia		
Parameter	**Unit**	**Belgium**	**Compost**	**Digestate**	**Compost**	**Digestate**	**Greece**
PAHs[a]	mg/kg dry weight				Classes 1 and 2 = 6		≤3
PCBs[b]					Class 1 = 0.2; class 2 = 1		≤0.4
PAH (10)		No limit, voluntary measurement					
Total PAHs			< 10	< 11			
Benzo[a]pyrene			< 0.1	< 0.2			
TPH C_5–C_{40}			< 100	< 101			
PCB (PCB-28, -52, -101, -118, -138, -153, -180)			< 0.1	< 0.2			
PCDD/F (WHO TEQ)	ng/kg dry weight TEQ		< 5	< 5			

[a]The sum of naphthalene, acenapphtylene, acenaphtene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, indeno[1,2,3-cd]pyrene, dibenzo[a,h]anthracene and benzo[ghi]perylene.

[b]The sum of 2,4,4′-trichlorobiphenyl (PCB-28), 2,2,5,5′-tetrachlorobiphenyl (PCB-52), 2,2′,4,5,5′-pentachlorobiphenyl (PCB-101), 2,3′,4,5,5′-pentachlorobiphenyl (PCB-118), 2,2′,3,4,4′,5′-hexachlorobiphenyl (PCB-138), 2,2′,4,4,5,5′-hexachlorobiphenyl (PCB-153) and 2,2,3,4,4′,5,5′-heptachlorobiphenyl (PCB-180).

TEQ, toxic equivalency; TPH, total petroleum hydrocarbons; WHO, World Health Organization.

the allowable concentrations of organic pollutants in compost/digestate, such as sewage sludge legislation (e.g. for SSCs). For example, the German Sewage Sludge Regulation prescribes limits for sewage sludge products, including sewage sludge-based composts: 0.2 mg/kg DM for each of the PCB-6 congeners and 100 ng TEQ/kg DM for the 17 PCDD/Fs. Flanders has compost/digestate limits for 40 organic compounds, including 10 PAHs. The French compost norm NF U44-051 sets limit values for three PAH compounds: fluoranthene (4 mg/kg DM), benzo[b]fluoranthene (2.5 mg/kg DM) and benzo[a]pyrene (1.5 mg/kg DM). The French sludge compost norm NF U44-095 also provides an additional limit of 0.8 mg/kg DM for PCBs.

4.9.2 *Conclusion*

In light of the recent work by the JRC and the limited Irish data we recommend that PAH_{16} should be a requirement, with a limit value of 6 mg/kg. This is aligned with the EU FPR limit. We recommend that not every sample be tested. The sampling regime should follow the frequency outlined in the JRC report (Saveyn and Eder, 2014).

In addition, it is recommended that the standards be applicable to a strict positive list of acceptable input feedstocks; this would be a precaution to prevent any waste containing high levels of organic pollutants being used.

4.10 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. The inclusion of the parameter in a quality standard aims to:

- prevent dilution of compost with inorganic materials (e.g. sand) to reduce the heavy metal content; and
- ensure the basic usefulness of compost used as a soil amendment.

In the previous report by the authors (Prasad and Foster, 2008) the database for Ireland showed that only 0.5% of the samples had a value below 20%. A 20% minimum organic matter limit was proposed.

Table 4.36. Organic matter content (% DM) of compost and digestate from the database in Ireland

	SSGW 2019	SSBW 2019	SSC 2019	Digestate 2019
Mean	40	44	64	60
Standard deviation	11	41	13	11
Percentile (90th)	57	73	82	67
Number of samples	26	64	70	6

Organic carbon refers only to the carbon component of materials. Organic matter is different to organic carbon in that it includes all the elements (hydrogen, oxygen, nitrogen, etc.) that are components of organic compounds, not just carbon.

The EU FPR uses organic carbon instead of organic matter. Organic matter is the parameter most commonly regulated in standards and we propose to use it instead of an organic carbon analysis. Organic carbon can be calculated from organic matter by dividing the organic matter by a factor of 1.72.

The recent database for Ireland (Table 4.36) shows that the data for compost up to 2019 also meet the 20% limit for organic matter. We recommend that the limit be continued and not changed for compost.

Whole digestate, as well as separated liquor and separated fibre can return useful amounts of organic matter to soils, which can improve soil fertility and function. From a review of standards for digestate in other countries (Table 4.37), it would seem reasonable to propose that digestate would have a limit of a minimum content of 20% organic matter for whole and separated fibre and no limit for separated liquor. There is no limit in other standards because separated liquor has very low organic matter content.

The authors recommend testing the organic matter content of compost and digestate (Table 4.38).

The countries that do not have a limit on organic matter are the USA, Canada, UAE, Czechia, Estonia, France and Norway.

Table 4.37. Review of organic matter standards in compost and digestate (% dry weight basis)

Country/ standard	Standard reference	Class	Compost	Digestate
Belgium	VLAREMA		> 14% (FW)	No limit
Austria	Compost Ordinance Regulation 292 of 2001	All classes	> 20%	No limit
Bulgaria	Biowaste Ordinance Decree 235 of 2013		> 15	No limit
Finland	Decree of the Ministry of Agriculture and Forestry on Fertiliser Products (24/2011, amendments up to 7/2013 included)		> 78	> 73
Germany	RAL GZ 251 – fresh compost		> 30	
	RAL GZ 251 – finished compost		> 15	
	RAL GZ 251 – substrate compost		> 15	
	RAL-GZ 258 – sewage sludge fresh compost		> 30	
	RAL-GZ 258 – sewage sludge finished compost		> 15	
	RAL GZ 245 – digestate, liquid			No limit
	RAL GZ 245 – digestate, solid			> 30
	RAL GZ 245 whole			> 30
Greece	Gazette of the Hellenic Republic 3339		No limit	
Hungary	36/2006. (V. 18.) FVM		> 25	No limit
Italy	Legislative Decree 75/2010		> 20	No limit
Netherlands	Keurcompost		> 10	
Portugal	Decree Law 103/2015	1, 2, 3	> 30	NS
Slovenia	Decree on the recovery of biodegradable waste and the use of compost or digestate (Official Gazette of the Republic of Slovenia, Nos. 99/13, 56/15 and 56/18)	1	> 15	> 20
		2	> 15	> 20
		Category 1 has a subcategory for less than 20% organic matter		
Sweden	Compost QAS SPCR 152/SPCR 120		> 20	> 20
UK	PAS 100:2018		No limit, recommended to declare it	
Switzerland	Fertiliser Ordinance 2001	Indoor gardening	< 50	No limit
		Outdoor gardening	< 40	
Spain	Royal Decree 506/2013 on Fertilizer Products	A, B, C	> 35	–
JRC study (2014)			15	15
EU FPR	PFC 3 Soil improver – 10% organic carbon			
	PFC 1 Solid organic fertiliser – 15% organic carbon			
	PFC 1 Liquid organic fertiliser – 5% organic carbon			
ECN QAS			15	15

PFC, perfluorinated compounds.

Table 4.38. Recommended organic matter content in compost and digestate

Type	Parameter	Minimum requirement
Compost	Organic matter (% dry weight)	20%
Whole digestate and separated fibre	Organic matter (% dry weight)	20%
Separated liquor	Organic matter (% dry weight)	No limit

5 Declaration

In addition to the mandatory limits for heavy metals, pathogens, impurities, PAH_{16}, weed seeds and stability, we recommend that the value of a number of parameters such as nutrients (Table 5.1) should be declared by all plants in order for the end-user of compost and digestate to make informed decisions on the best way to use them. A certificate of analysis (e.g. nutrients) that is representative of the batch should be provided to the end-user.

Table 5.1. Declaration of parameters in compost and digestate

Quality criterion	Parameter	Unit	Compost	Digestate
Soil improvement	pH value		✓	✓
	Liming value (CaO)	% DM	✓	×
Fertilising properties	Total N	% DM	✓	✓
	Extractable ammonium	mg/l	×	✓
	Total P	% DM	✓	✓
	Total K	% DM	✓	✓
	Total sulfur	% DM	✓	✓
	Total magnesium	% DM	✓	✓
General parameters	DM	% DM	✓	✓
	Electrical conductivity	mS/m	✓	Mandatory if digestate is not used in agriculture
	Maximum particle size	mm	✓	×
	Bulk density	g/l FM	✓	×
	Stones > 5 mm	% DM	✓	✓
	Moisture	%	✓	✓

CaO, calcium oxide.

6 New Markets

Organic farming and carbon sequestration were identified as markets that merited further examination and it was determined that they had no specific new parameter that is not already included in the proposed standards.

6.1 Organic Compost

Lipor municipality, Porto, Portugal, was visited as part of this project because it is processing food waste using the same technology used in Ireland to produce certified organic compost that is sold at a high price. The purpose of the visit was to understand how it is technically possible to meet the limit value for organic compost produced from food waste, which has, to date, in Ireland been considered not possible to achieve with food waste compost. The input material is food waste (from separate collection) and green waste (from separate collection). During the visit to the plant it was determined that a possible reason for their achieving the required standard was that Lipor was adding at least 40% by volume of garden waste to the food waste. The garden waste balances the levels of heavy metals.

The authors compared the Irish data with the heavy metal limits in the EU Organic Farming Regulation 884/2008.[15] Generally, digestate and green waste compost can meet the limits for organic farming. This shows that operators in the market need to consider getting their compost and digestate certified for use in organic production. There is an opportunity for food waste composting to use more green waste, as seen in Lipor, to meet the heavy metals limits.

6.2 Carbon Sequestration

Sequestration of carbon in soils is increasingly recognised as a measure to combat climate change. One way to increase carbon uptake by soils is the application of compost, as compost contains a high percentage of stable organic matter. For the compost sector this is relevant, as organic carbon stored in agricultural soils counts towards the contribution of the land use, land use change and forestry (LULUCF[16]) sector. In other words, more storage of organic carbon via the application of organic soil improvers such as compost is counted as a CO_2-emission reduction.

Humic acids are part of the stable organic matter in composts. During composting, and presumably in the AD process, there is an increase in the concentration of humic acids as lignin breaks down and its degradation products combine to form increasingly recalcitrant molecules. Humic acids, on account of their favourable properties for composts/digestate fibres (and soil) and plants and their role in carbon sequestration, are considered a quality criterion for composts and probably also for digestate fibres. Prasad *et al.* (2012) conducted some analysis of humic acid content of compost and digestate. The results showed that food waste digestate (10% cow slurry and 90% commercial food waste) had a low humic acid content but that levels were higher in digestate fibre (municipal biowaste) and composting of the digestate fibre increased levels still further. Humic acid measurement of the compost and digestate would give an indication of its ability for carbon sequestration.

6.3 Agricultural Manures

Manures provide a potential feedstock stream. There is an estimated 13 Mt of manures and slurries generated in Ireland annually (Cré, 2016). Currently, untreated chicken manure can be spread to land in Ireland, offering a low-cost outlet for farmers that also provides nutrients for soils. However, a land-spreading ban is being considered as a result of health concerns and the associated risk of spreading diseases such as botulism.

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15 Commission Regulation (EC) No. 889/2008 of 5 September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control.

16 European Commission proposal for a Regulation on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework. COM(2016) 479 final; 2016/0230 (COD).

The mushroom composting sector uses manures to produce a growing medium for mushrooms. In 2018 it was estimated that the plants used 66 kt of chicken manure and 27 kt of horse manure (Representatives of Carbury Compost & Custom Compost, personal communication). With the growing prospect of farming being supported under the Common Agricultural Policy to store carbon in soils, there might be more processing of raw manures for this purpose.

7 Discussion

The standards have been developed having regard to the 2014 JRC report 2014 *End-of-waste Criteria for Biodegradable Waste Subjected to Biological Treatment (Compost & Digestate)* (Saveyn and Eder, 2014); the levels of metals, pathogens and impurities found in Irish compost and digestate made from source-separated waste, and its stability; quality standards already adopted by a number of other European countries; recent developments in stability measurements; the EU FPR; and our previous research report *Development of an Industry-led Quality Standard for Source-separated Biodegradable Materials Derived Compost* (Prasad and Foster, 2008).

The establishment of quality standards for compost and digestate offers environmental and economic benefits, as it improves the certainty of when a waste becomes a product, promotes the production of high-quality compost/digestate and facilitates its use by avoiding unnecessary regulatory burden (JRC-IPTS, 2008).

The 2008 end-of-waste criteria report states that there should be minimum compost product quality requirements to ensure the usefulness of compost and to achieve the desired levels of protection of human, plant, soil and animal health (JRC-IPTS, 2008).

Table 7.1 compares the Irish database with the recommended standards in this report and the EU FPR. The main differences in the recommended standard developed in this report are outlined in Table 7.2.

Table 7.2 shows that the standards developed in this research project are similar those in Saveyn and Eder's (2014) end-of-waste criteria report and the EU FPR parameters and limit values. The parameters and limits in the report and legislation were risk assessed. Assuming that there is very little variation in the recommended standards, they will protect human, plant, soil and animal health.

A research consortium led by Cranfield University conducted a study to examine the hazards present in compost feedstocks, and the resulting risks to receptors, including humans, animals, the environment and crops. The conclusion was that the risks associated with source-separated PAS 100 compost in agriculture and field horticulture are negligible (Tompkins, 2017).

7.1 List of Acceptable Source-separated Material

This project proposes a separate standard for compost and digestate manufactured from source-separated biodegradable materials. This standard would not be applicable to mechanical biological treatment (MBT) outputs, sewage sludge, invasive plant species (e.g. knotweed) or tannery waste.

A list of acceptable non-hazardous raw/source-separated biodegradable material feedstocks to which the quality standard applies was not in the initial scope of this project, as the types of materials suitable for composting and AD 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 part of a QAS, to enable it to be changed easily and reasonably.

Table 7.1. Comparison of the Irish data with the recommended compost and digestate quality standard in this project and the EU FPR

Parameter	Irish data compost SSBW 2019 – 90th percentile	Irish data compost SSGW 2019 – 90th percentile	Irish data digestate 2019 – 90th percentile	Do the Irish data meet the limits for the recommended standards?	Do the Irish data meet the limits for the FPR?
Mercury (mg/kg DM)	0.31	0.2	0.12	Yes	Yes
Cadmium (mg/kg DM)	0.90	1.00	0.63	Yes	Yes
Nickel (mg/kg DM)	29.45	25.46	25.45	Yes	Yes
Chromium – total (mg/kg DM)	32.94	59.87	14.21	Yes	Yes No limit in FPR
Copper (mg/kg DM)	138.84	52.30	89.79	Yes	Yes
Zinc (mg/kg DM)	311.68	186.00	452.32	Yes	Yes
Lead (mg/kg DM)	110.0	58.70	6.57	Yes	Yes
Inorganic arsenic (mg/kg DM)	–	–	–	Not a parameter	No data
Total arsenic (mg/kg DM)	5.62	13.1 (1 sample)	1.36 (1 sample)	Yes	Not a parameter
Hexavalent chromium (mg/kg DM)	< 1	1	< 1	Yes	Yes
Biuret (mg/kg DM)	–	–	–	Not a parameter	No data
Salmonella spp. (cfu/25 g)	Absent in 25 g	Absent in 25 g	Absent in 25 g	Yes	Yes
E. coli (cfu/g fresh mass)	10	244	No data, but all plants have to meet this limit under ABP	Yes	Yes
Total glass, metal and plastic > 2 mm diameter by dry weight[a]	2008 data: 0.3%	2008 data: 0.06%	< 0.01 (four samples)	No data for compost. Yes for digestate	
Plastics > 2 mm DM	2008 data: 0.12%	2008 data: 0.01%	< 0.01 (four samples)	No data for compost. Yes for digestate	
PAH_{16}[b] (mg/kg DM)	< 1 and 2.5 (two samples)	0.1 (one sample)	1.2 (one sample)	Yes	Yes
Viable weed seeds per litre	0	1	No data	Yes for compost. No data for digestate	Not a parameter
Germination test (%)	100 (2008 data)	94 (2008 data)	No data	Yes for compost. No data for digestate	Not a parameter
OUR (mmol O_2/kg organic solids/h)	2008 data: six samples, ranged from 8.8 to 15.5		32.4 to 84.9 (6 samples)	Yes for compost 50% of Digestate samples meet limit	Yes for compost No digestate samples meet limit in FPR
RBP (l/g VS)	n/a	n/a	–0.034 to 0.166 (7 samples)	Yes	Yes
Organic matter minimum (% dry weight)	57	73	67	Yes	Not a parameter
Organic carbon (% by mass)	32	41	38	Not a parameter	Yes
N (% mass)	1.3	2.07	2.5	Declaration on value	Yes
P_2O_5 (% mass)	0.57	1.01	5		No. Green waste and biowaste is just at the limit
K_2O (% mass)	1.19	1.28	0.8		No. Digestate did not meet limit
Sum of NPK (% mass)	3.06	4.36	8.3	Not a parameter	Green waste compost does not meet it

[a]The impurities limit values will be reviewed in 2025.

[b]Compost/digestate sampling frequency as outlined in the 2014 JRC report by Saveyn and Eder (2014).

n/a, not applicable.

Table 7.2. Difference between recommended standards and the EU FPR (FPR) and comparison with JRC report by Saveyn and Eder (2014)

Parameter	Recommended compost standard	Recommended digestate standard: whole digestate, separated fibre or separated liquor	JRC report (Saveyn and Eder, 2014)	FPR	What is the difference between FPR and recommended Irish standards?
Mercury (mg/kg DM)	1	1	1	1	
Cadmium (mg/kg DM)	2	2	1.5	PFC 1: 1.5 PFC 3: 2	
Nickel (mg/kg DM)	50	50	50	50	
Chromium – total (mg/kg DM)	100	100	100	–	No limit in FPR
Copper (mg/kg DM)	300	300	200	300	
Zinc (mg/kg DM)	800	800	600	800	
Lead (mg/kg DM)	150	150	120	120	FPR is stricter. The VITO (2013) study describes a model calculating the maximum allowable concentrations of pollutants in the soil on the basis of the maximum permitted enrichment of the upper soil layer over a period of 100 years. The study showed that a 300 mg/kg limit for lead is acceptable. The Irish data show that biowaste compost is close to the EU FPR limit. The limit is the same as in IS 441, Germany and Belgium and other classes in Portugal, Spain and Canada
Inorganic arsenic (mg/kg DM)	–	–	–	40	Inorganic arsenic is not routinely measured. Instead we have included total arsenic, which in theory includes inorganic arsenic. We have set the limits strict by default it will be low for inorganic arsenic
Total arsenic (mg/kg DM)	20	20	–	–	
Hexavalent chromium (mg/kg DM)	2	2	–	2	
Biuret (mg/kg DM)	–	–	–	0	Biuret is formed during the production of urea. It is not applicable to compost and digestate
Salmonella spp. (cfu/25 g)	Absent in 25 g	Absent in 25 g	Absent in 25 g	Absent in 25 g	
E. coli (cfu/g fresh mass)	1000	1000	1000	1000	Enterococcaceae is also an option in FPR
Total glass, metal and plastic > 2 mm diameter by dry weight[a]	0.5%	0.5%	0.5%	0.5%	
Plastics > 2 mm DM	0.25%	0.25%	–	0.25%	
PAH_{16}[b] (mg/kg DM)	6	6	6	6	
Viable weed seeds per litre	≤2	≤2	≤2	–	Not a parameter in FPR
Germination test (%)	80% MLV of the control for use in growing media		–	–	Not a parameter in FPR. This is an additional requirement for compost used in growing media

Table 7.2. Continued

Parameter	Recommended compost standard	Recommended digestate standard: whole digestate, separated fibre or separated liquor	JRC report (Saveyn and Eder, 2014)	FPR	What is the difference between FPR and recommended Irish standards?
OUR (mmol O_2/kg organic solids/h)	Growing media: 15 Field: 25	50	Digestate: 50 Compost: 25	25	Yes for compost Digestate does not meet limit in FPR
RBP (l/g VS)	n/a	0.25	0.25	0.25	
Organic matter minimum (% dry weight)	Compost: 20%	20% for whole and separated fibre. No limit for separated liquor	15%	–	Organic matter is the most common parameter used in standards and we propose to use it instead of organic carbon.
Organic carbon minimum (% by mass)	–	–	–	PFC 3: 10% organic carbon PFC 1: 15% organic carbon PFC 1: 5% organic carbon	Organic carbon can be calculated from organic matter by dividing organic matter by a factor of 1.72. For separated liquor we do not recommend a limit because of the low organic matter content, whereas FPR has a limit of 5% for organic carbon
N	Declaration on value		n/a	1	FPR has a limit, but we recommend that the value is declared
P_2O_5	Declaration on value		n/a	1	
K_2O	Declaration on value		n/a	1	
Sum of NPK	n/a	n/a	n/a	4	FPR has a total sum of nutrients; we do not

[a]The impurities limit values will be reviewed in 2025.

[b]Compost/digestate sampling frequency as outlined in the 2014 JRC report by Saveyn and Eder (2014).

n/a, not applicable; PFC, perfluorinated compounds.

8 Conclusions

The study's objectives were met:

- to collate and analyse laboratory data on compost and digestate quality in Ireland since 2008;
- to compare the Irish data with those in other databases and standards to propose a draft quality standard for compost and another for digestate (whole, liquid and fibre) for public consultation; and
- to review end-of-waste approaches in other European countries to recommend a strategy on how Ireland should implement national end-of-waste criteria for compost and digestate derived from source-separated waste materials.

Tables 8.1 and 8.2 set out the proposed quality standards for compost and digestate.

These proposed standards have been designed so that they are mutually supportive in helping to develop high-value markets for compost and digestate products while protecting human, plant, soil and

Table 8.1. Proposed quality standards for compost and digestate from source-separated waste materials

Parameter	Compost	Digestate: whole or separated fibre or liquor
Heavy metals		
Mercury (mg/kg DM)	1	1
Cadmium (mg/kg DM)	1.5	1.5
Nickel (mg/kg DM)	50	50
Chromium (mg/kg DM)	100	100
Copper (mg/kg DM)	300	300
Zinc (mg/kg DM)	800	800
Lead (mg/kg DM)	150	150
Total arsenic (mg/kg DM)	20	20
Hexavalent chromium (mg/kg DM)	2	2
Pathogens		
Salmonella spp. (cfu/25 g)	Absent in 25 g	Absent in 25 g
E. coli (cfu/g fresh mass)	1000	1000
Impurities,[a] viable weed seeds and PAH_{16}		
Total glass, metal and plastic > 2 mm diameter by dry weight	0.5%	0.5%
Plastics > 2 mm	0.25%	0.25%
Viable weed seeds per litre	≤2	≤2
PAH_{16} (mg/kg[b])	6	6
Stability and maturity		
OUR[c] (mmol O_2/kg organic solids/h)	Growing media: 15 Field application: 25	50
RBP[c] (l/g VS)	–	0.25
Germination test for use in growing media	80%	80%
MLV		
Organic matter		
Organic matter (% dry weight)	20%	20% for whole and separated fibre. No limit for liquor

[a]The impurities standard will be reviewed in 2025.

[b]Compost/digestate sampling frequency as outlined in the 2014 JRC report (Saveyn and Eder, 2014).

[c]Digestate is sampled using OUR or RBP.

Table 8.2. Declaration of parameters in compost and digestate

Quality criterion	Parameter	Unit	Compost	Digestate
Soil improvement	pH value		✓	✓
	Liming value (CaO)	% DM	✓	×
Fertilising properties	Total N	% DM	✓	✓
	Extractable ammonium	mg/l	×	✓
	Total P	% DM	✓	✓
	Total K	% DM	✓	✓
	Total sulfur	% DM	✓	✓
	Total magnesium	% DM	✓	✓
General parameters	DM	% DM	✓	✓
	Electrical conductivity	mS/m	✓	Mandatory if digestate is not used in agriculture
	Maximum particle size	mm	✓	×
	Bulk density	g/l FM	✓	×
	Stones > 5 mm	% DM	✓	✓
	Moisture	%	✓	✓

animal health. Ultimately, the standards will ensure product satisfaction and provide consumer confidence in compost- and digestate-based products.

In addition to the mandatory limits for heavy metals, pathogens, impurities, PAH_{16}, weed seeds and stability, we recommend that the value of a number of parameters, such as nutrients, should be declared by all plants so that the end-user of compost and digestate can make informed decisions on the best way to use the products.

9 Recommendations

The findings of this study could be used in the development of standards for compost and digestate. A number of recommendations are summarised below.

9.1 Feedstocks

- A contamination working group should be established to develop and execute a national campaign to solve the issue of contamination. This is because the authors have determined that the greatest risk to achieving the standard is the contamination of the input feedstock.
- There have been claims that some products, such as tea bags, paper towels and fruit stickers, contain plastic. We recommend that these products and other similar products be analysed to determine if they contain plastic.
- The scope of this research study was to examine quality standards for compost and digestate from source-separated waste materials. These standards exclude feedstocks from mixed municipal waste, sewage sludge and tannery waste. However, as part of the study, knowledge has been gained from other countries on standards for feedstocks that are classified as manures/energy crops. In addition, some countries have a dedicated standard for compost and digestate from sewage sludge. Although manures/energy crops and sewage sludge were not part of the original scope of the study, we have made some provisional observations on these.

9.2 Monitoring of Process and Quality Assurance

- The recommended approach to be taken in Ireland to define end-of-waste criteria for compost/digestate is implementing either a national fertiliser regulation or biowaste ordinance legislation. The authors are of the opinion that it should include the requirement that compost or AD plants proposing to produce an end-of-waste product be compliant with a QAS that is monitored by a quality assurance organisation. This would form part of any end-of-waste application and demonstrate that the requirements of Article 28(2)(d) of S.I. No. 323 of 2020 – EU (Waste Directive) Regulations 2011–2020 have been met.
- A QAS system would monitor the process used in composting and AD plants, including acceptable feedstocks, independent sample taking and the analysis of the compost/digestate by approved laboratories. A QAS system may not be required in a plant that has authorisations in place that regulate these critical control points. In addition, a quality assurance organisation would evaluate the results independently and award a QAS certificate to successful plants.
- A sampling protocol for taking compost and digestate samples should be developed. It is standard practice in QAS systems in other countries for trained independent sampling technicians to visit plants to take samples.

9.3 Standards

- Using the information in this report, the NSAI should update the IS 441 compost standard and develop a new IS for digestate.
- The findings of this study can be used in an application to the EPA by industry for national end-of-waste standards for compost and digestate.[17]
- The impurities standard should be revised in 2025 based on a review of the state of play on contamination. Standards on microplastic are likely to continue to change as new information emerges. It is therefore important that the standard in Ireland is updated regularly.
- Based on other EU countries' approaches, there are two options to define end-of-waste status: a specific biowaste ordinance or by national fertiliser regulations. The content of the revised

17 The standards developed in this project could be used for the domestic market in Ireland. Post July 2022, products that conform to the EU FPR can be traded within the EU. The standards developed in this project do not automatically mean meeting the criterion in Article 28(1)(a)(iii). The standards would have to assessed by the EPA using an end-of-waste application.

Irish fertiliser regulations is unknown at this time and further investigation of a separate biowaste ordinance may be merited.

- When the regulation (biowaste ordinance or fertiliser regulation) is enacted, the EPA and local authorities should rescind the quality standards in all compost and AD plants' licences and permits (when they come up for renewal). This will then ensure that they are all working to uniform standards.
- The standard developed for the national market could be viewed as a baseline standard. Feedback from stakeholders indicated that there is a need for standards for specific uses, e.g. biological active compost for use in agriculture, topsoil manufacture and growing media. We recommend that standards for specific products be developed in partnership with end-users; this will help to develop wider markets for compost and digestate.
- A ring test of all the methods used by laboratories for compost and digestate should be done to ensure consistency of results.
- Further research is required to validate the CEN germination test for digestate.
- Once an updated quality standard, or legislation setting a standard, is in place this national standard could then be used to define end-of-waste criteria [Article 28(1)(a)(iii)]. This would be done by making an application to the EPA, the competent authority for end-of-waste decisions, on suggested end-of-waste criteria for compost and digestate under the waste regulations. At the time of the publication of this study, it had not yet been determined whether specified waste streams could also cease to be waste in any future updated national fertiliser regulations under Article 19 of the FPR (EU) 2019/1009. This could be considered in future discussions between policymakers.

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Abbreviations

ABP	Animal by-product
AD	Anaerobic digestion
BGK	Bundesgütegemeinschaft Kompost (Compost and Digestate Quality Assurance Organisation)
BSI	British Standards Institution
CEN	European Committee for Standardization
CFU	Colony-forming unit
CMC	Component material category
DM	Dry matter
ECN	European Compost Network
EPA	Environmental Protection Agency
EU	European Union
FM	Fresh matter
FPR	Fertilising Products Regulation
IrBEA	Irish Bioenergy Association
IS	Irish Standard
JRC	Joint Research Centre
MLV	Munoo–Liisa vitality index
NSAI	National Standards Authority of Ireland
OUR	Oxygen uptake rate
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PCDD/F	Polychlorinated dibenzo(p)dioxin and furan
PFC	Perfluorinated compounds
POP	Persistent organic pollutant
QAS	Quality Assurance Scheme
RAL	German National Committee for Delivery and Quality Assurance
RBP	Residual biogas potential
SEPA	Scottish Environment Protection Agency
SSBW	Source-separated biowaste
SSC	Sewage sludge compost
SSGW	Source-separated green waste
VFA	Volatile fatty acid
VFG	Vegetable, fruit and garden waste
VS	Volatile solids
VLAREMA	Vlaams Reglement voor duurzaam beheer van Materialenkringlopen en Afvalstoffen (Flemish Regulation on Sustainable Materials Management and Waste)
WFD	Waste Framework Directive
WRAP	Waste and Resources Action Programme

Appendix 1 Energy Crop/Manure Standards

This applies to waste that is exempt from waste authorisation.

Developing a standard for feedstocks that are classified as "waste exempt from authorisation", such as manures, was not part of the original scope of this study. However, we have made some provisional suggestions which could be explored more if a standard was required.

It was observed during the research that some countries have standards for manure/energy crop digestate. The EU FPR provides an exemption from PAH_{16} testing.

The Czechia Decree No. 474/2000 has a slight variation on heavy metals for digestate produced from manures. It allows a higher level of zinc (250 mg/kg) and copper (1200 mg/kg). The German RAL-GZ 246 standard is for digestate made of renewable energy crops and manure. It allows for relaxed limits on zinc and copper too. In Italy, there is a standard for a fertiliser called "dry bovine and swine manure digestate mixed with ashes from virgin biomass combustion". It has a limit of maximum 10% moisture, N (minimum 1.5%), P_2O_5 (minimum 2%) and organic carbon (minimum 30% DM); the heavy metals and pathogen limits are the same as in the compost standard. IrBEA, in its research, recommended some exemptions (heavy metals, impurities and maturity) in a digestate standard for on-farm manure AD plants.

The Austrian Ministry of Agriculture has produced a guide on standards for digestate from manures (Pfunotner, 2007). Table A1.1 summarises the standards.

The Austrian approach is that digestate is not monitored as frequently as in the biowaste ordinance for compost. For example, for plants with a manure throughput >4000 m^3 per year one sample is tested. For throughputs of <4000m^3, one sample is tested every 2 years.

To make things simple in Ireland, we recommend that the standards for waste-based compost and digestate are also used for manure/energy crop compost and digestate. The only difference is that the frequency of samples is significantly reduced to one sample per year.

Table A1.1. Austrian Ministry of Agriculture standards for digestate from manures

Parameter	Limit value
Mercury (mg/kg DM)	1
Cadmium (mg/kg DM)	3
Nickel (mg/kg DM)	100
Chromium (mg/kg DM)	100
Lead (mg/kg DM)	100
Salmonella (in 25 g)	0
PAH_{16} (mg/kg DM)	6
AOX (sum)	500
READ	2600

AOX is the sum of the adsorbable halogenated organic chlorine compounds. READ is defined in the second draft of the EU Sewage Sludge Directive.

Appendix 2 Sewage Sludge Standards

Developing a standard for sewage sludge was not part of the original scope of this study. Sewage sludge is not an acceptable feedstock under the EU FPR. Some countries have specified standards for compost and digestate from sewage sludge. Further work and a risk assessment are required before developing a standard. An application to the EPA to define end-of-waste status for compost and digestate from sewage sludge is required.

The specific standards for the manufacture of a product from sewage sludge in Estonia (19.07.2017 No. 24) can be found at https://www.riigiteataja.ee/akt/128072017004.

For Germany, the standards for SSC (RAL-GZ 258) can be viewed at:

- Dok._258-006-1_Qualitaetskrit_AS-Humus.pdf (kompost.de)
- Dok._258-006-4_Schwellenwerte_und_Grenzwerte.pdf (kompost.de)

The European Commission had a public consultation until August 2020 on the "roadmap" for re-evaluation of the EU Sewage Sludge Directive (86/278). The Commission's proposed roadmap underlines that the directive aims to encourage the use of sludge in agriculture, under safety conditions, and that nutrient recovery (citing P) should be a core objective, coherent with the EU Circular Economy Action Plan and the New European Green Deal, Bioeconomy Strategy and Farm-to-fork Strategy. The outcome of this review of the directive should be evaluated before developing a standard in Ireland.

Appendix 3 Sampling Frequency

The ECN QAS for compost and digestate has specified sampling frequencies. The authors recommend that this be adopted for Ireland. The frequency of compost/digestate analyses and sample taking should be calculated on the basis of the following equation as a minimum requirement:

> Amount of input material/10,000 [t] + 1 = analyses per year

There should be 12 analyses per year at a maximum. For digestate from energy crops and manure there should be four analyses per year at a maximum.

In the first year of recognition of a QAS at least four samples for plants with a treatment capacity > 4000 t input material (for composting plants) and > 6000 t input material (for AD plants) should be carried out – one for every season – to assess the essential quality characteristics over the course of the year.

Appendix 4 Time–temperature

In Ireland the time–temperature regime of plants has not been standardised, except at plants processing ABP materials. Table A4.1 and Box A4.1 show the recommended time–temperature profiles for composting and AD plants.

Table A4.1. Composting times and temperatures for sanitisation

System	Time–temperature profiles
Open windrow system	55°C > 10 days
	65°C > 3 days
Closed system	60°C > 3 days
	ABP – EU transformation standard
	ABP – national ABP standards
	ABP – alternative process validation

Box A4.1. AD Time–temperature profiles

Thermophilic AD at 55°C for 24 hours with a hydraulic retention time of 20 days.

Thermophilic AD at 55°C with pasteurisation at 70°C for 1 hour.

Thermophilic AD at 55°C followed by composting at 55°C ≥ 10 days or 65°C ≥ 3 days or 60°C ≥ 3 days.

Mesophilic AD at 37–40°C with pasteurisation at 70°C for 1 hour.

Mesophilic AD at 55°C followed by composting at 55°C ≥ 10 days or 65°C ≥ 3 days or 60°C ≥ 3 days.

Appendix 5 List of Laboratory Methods

This is the list of referenced laboratory methods to test compost and digestate for various parameters. The IS EN standards can be obtained from www.standards.ie

Parameter	Method of analysis
Lab sample preparation	IS EN 13040:2007 – soil improvers and growing media – sample preparation for chemical and physical tests, determination of DM content, moisture content and laboratory-compacted bulk density
Particle size distribution	IS EN 15428:2007 – soil improvers and growing media – determination of particle size distribution
Organic matter (dry combustion)	IS 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	IS EN 13041:2000 and 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	EN 13038 2002 – determination of electrical conductivity
pH	EN 13037 2002 – determination of pH
Potentially toxic elements	IS EN 13650:2001 – soil improvers and growing media – determination of aqua regia soluble elements
Calcium chloride soluble elements	EN 13651–2002 – extraction of calcium chloride/DTPA (CAT) soluble nutrients
Physical contaminants	Annex E, BSI PAS 100:2005
E. coli	ISO 11866-2:2005 – milk and milk products – enumeration of presumptive *E. coli* – part 2: colony count technique at 44°C using membranes
Salmonella spp.	IS EN ISO 6579:2002 and 1:2007 – microbiology of food and animal feeding stuffs – horizontal method for the detection of *Salmonella* spp.
Determination of N	IS EN 13654-2:2002 – soil improvers and growing media – determination of N – part 2 Dumas method
Determination of total P	IS EN 13650
Determination of total K	IS EN 13650
Oxitop measuring system for determination of respiration rate	EN 16087-1 2011 – part 1 determination of aerobic biological activity – part 1 OUR
Self-heating test	EN 16087-2 2011 – determination of the aerobic biological activity – part 2 self-heating test
Weed seeds	BGK e.V 2006
Phytotoxicity	EN 16086-2 2011 – part 2 determination of plant response petri dish test using cress
RBP	OFW004-005

DTPA, diethylenetriamine pentaacetate.

AN GHNÍOMHAIREACHT UM CHAOMHNÚ COMHSHAOIL

Tá an Ghníomhaireacht um Chaomhnú Comhshaoil (GCC) freagrach as an gcomhshaol a chaomhnú agus a fheabhsú mar shócmhainn luachmhar do mhuintir na hÉireann. Táimid tiomanta do dhaoine agus don chomhshaol a chosaint ó éifeachtaí díobhálacha na radaíochta agus an truaillithe.

Is féidir obair na Gníomhaireachta a roinnt ina trí phríomhréimse:

Rialú: *Déanaimid córais éifeachtacha rialaithe agus comhlíonta comhshaoil a chur i bhfeidhm chun torthaí maithe comhshaoil a sholáthar agus chun díriú orthu siúd nach gcloíonn leis na córais sin.*

Eolas: *Soláthraímid sonraí, faisnéis agus measúnú comhshaoil atá ar ardchaighdeán, spriocdhírithe agus tráthúil chun bonn eolais a chur faoin gcinnteoireacht ar gach leibhéal.*

Tacaíocht: *Bímid ag saothrú i gcomhar le grúpaí eile chun tacú le comhshaol atá glan, táirgiúil agus cosanta go maith, agus le hiompar a chuirfidh le comhshaol inbhuanaithe.*

Ár bhFreagrachtaí

Ceadúnú

Déanaimid na gníomhaíochtaí seo a leanas a rialú ionas nach ndéanann siad dochar do shláinte an phobail ná don chomhshaol:

- saoráidí dramhaíola *(m.sh. láithreáin líonta talún, loisceoirí, stáisiúin aistrithe dramhaíola)*;
- gníomhaíochtaí tionsclaíocha ar scála mór *(m.sh. déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta)*;
- an diantalmhaíocht *(m.sh. muca, éanlaith)*;
- úsáid shrianta agus scaoileadh rialaithe Orgánach Géinmhodhnaithe *(OGM)*;
- foinsí radaíochta ianúcháin *(m.sh. trealamh x-gha agus radaiteiripe, foinsí tionsclaíocha)*;
- áiseanna móra stórála peitril;
- scardadh dramhuisce;
- gníomhaíochtaí dumpála ar farraige.

Forfheidhmiú Náisiúnta i leith Cúrsaí Comhshaoil

- Clár náisiúnta iniúchtaí agus cigireachtaí a dhéanamh gach bliain ar shaoráidí a bhfuil ceadúnas ón nGníomhaireacht acu.
- Maoirseacht a dhéanamh ar fhreagrachtaí cosanta comhshaoil na n-údarás áitiúil.
- Caighdeán an uisce óil, arna sholáthar ag soláthraithe uisce phoiblí, a mhaoirsiú.
- Obair le húdaráis áitiúla agus le gníomhaireachtaí eile chun dul i ngleic le coireanna comhshaoil trí chomhordú a dhéanamh ar líonra forfheidhmiúcháin náisiúnta, trí dhíriú ar chiontóirí, agus trí mhaoirsiú a dhéanamh ar leasúchán.
- Cur i bhfeidhm rialachán ar nós na Rialachán um Dhramhthrealamh Leictreach agus Leictreonach (DTLL), um Shrian ar Shubstaintí Guaiseacha agus na Rialachán um rialú ar shubstaintí a ídíonn an ciseal ózóin.
- An dlí a chur orthu siúd a bhriseann dlí an chomhshaoil agus a dhéanann dochar don chomhshaol.

Bainistíocht Uisce

- Monatóireacht agus tuairisciú a dhéanamh ar cháilíocht aibhneacha, lochanna, uiscí idirchriosacha agus cósta na hÉireann, agus screamhuiscí; leibhéil uisce agus sruthanna aibhneacha a thomhas.
- Comhordú náisiúnta agus maoirsiú a dhéanamh ar an gCreat-Treoir Uisce.
- Monatóireacht agus tuairisciú a dhéanamh ar Cháilíocht an Uisce Snámha.

Monatóireacht, Anailís agus Tuairisciú ar an gComhshaol

- Monatóireacht a dhéanamh ar cháilíocht an aeir agus Treoir an AE maidir le hAer Glan don Eoraip (CAFÉ) a chur chun feidhme.
- Tuairisciú neamhspleách le cabhrú le cinnteoireacht an rialtais náisiúnta agus na n-údarás áitiúil *(m.sh. tuairisciú tréimhsiúil ar staid Chomhshaol na hÉireann agus Tuarascálacha ar Tháscairí)*.

Rialú Astaíochtaí na nGás Ceaptha Teasa in Éirinn

- Fardail agus réamh-mheastacháin na hÉireann maidir le gáis cheaptha teasa a ullmhú.
- An Treoir maidir le Trádáil Astaíochtaí a chur chun feidhme i gcomhair breis agus 100 de na táirgeoirí dé-ocsaíde carbóin is mó in Éirinn.

Taighde agus Forbairt Comhshaoil

- Taighde comhshaoil a chistiú chun brúnna a shainaithint, bonn eolais a chur faoi bheartais, agus réitigh a sholáthar i réimsí na haeráide, an uisce agus na hinbhuanaitheachta.

Measúnacht Straitéiseach Timpeallachta

- Measúnacht a dhéanamh ar thionchar pleananna agus clár beartaithe ar an gcomhshaol in Éirinn *(m.sh. mórphleananna forbartha)*.

Cosaint Raideolaíoch

- Monatóireacht a dhéanamh ar leibhéil radaíochta, measúnacht a dhéanamh ar nochtadh mhuintir na hÉireann don radaíocht ianúcháin.
- Cabhrú le pleananna náisiúnta a fhorbairt le haghaidh éigeandálaí ag eascairt as taismí núicléacha.
- Monatóireacht a dhéanamh ar fhorbairtí thar lear a bhaineann le saoráidí núicléacha agus leis an tsábháilteacht raideolaíochta.
- Sainseirbhísí cosanta ar an radaíocht a sholáthar, nó maoirsiú a dhéanamh ar sholáthar na seirbhísí sin.

Treoir, Faisnéis Inrochtana agus Oideachas

- Comhairle agus treoir a chur ar fáil d'earnáil na tionsclaíochta agus don phobal maidir le hábhair a bhaineann le caomhnú an chomhshaoil agus leis an gcosaint raideolaíoch.
- Faisnéis thráthúil ar an gcomhshaol ar a bhfuil fáil éasca a chur ar fáil chun rannpháirtíocht an phobail a spreagadh sa chinnteoireacht i ndáil leis an gcomhshaol *(m.sh. Timpeall an Tí, léarscáileanna radóin)*.
- Comhairle a chur ar fáil don Rialtas maidir le hábhair a bhaineann leis an tsábháilteacht raideolaíoch agus le cúrsaí práinnfhreagartha.
- Plean Náisiúnta Bainistíochta Dramhaíola Guaisí a fhorbairt chun dramhaíl ghuaiseach a chosc agus a bhainistiú.

Múscailt Feasachta agus Athrú Iompraíochta

- Feasacht chomhshaoil níos fearr a ghiniúint agus dul i bhfeidhm ar athrú iompraíochta dearfach trí thacú le gnóthais, le pobail agus le teaghlaigh a bheith níos éifeachtúla ar acmhainní.
- Tástáil le haghaidh radóin a chur chun cinn i dtithe agus in ionaid oibre, agus gníomhartha leasúcháin a spreagadh nuair is gá.

Bainistíocht agus struchtúr na Gníomhaireachta um Chaomhnú Comhshaoil

Tá an ghníomhaíocht á bainistiú ag Bord lánaimseartha, ar a bhfuil Ard-Stiúrthóir agus cúigear Stiúrthóirí. Déantar an obair ar fud cúig cinn d'Oifigí:

- An Oifig um Inmharthanacht Comhshaoil
- An Oifig Forfheidhmithe i leith cúrsaí Comhshaoil
- An Oifig um Fianaise is Measúnú
- Oifig um Chosaint Radaíochta agus Monatóireachta Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáideacha

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag comhaltaí air agus tagann siad le chéile go rialta le plé a dhéanamh ar ábhair imní agus le comhairle a chur ar an mBord.

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Development of Quality Standards for Compost and Digestate in Ireland

Authors: Percy Foster and Munoo Prasad

Identifying Pressures

In Ireland, there are no national end-of-waste criteria for compost and digestate derived from source-separated materials. There are varying quality standards being used by composting and anaerobic digestion plants. Overall, the system needs a uniform set of quality standards for compost and digestate, which would replace existing standards being applied. This study will also recommend a strategy on how Ireland should implement national end-of-waste criteria for compost and digestate.

Informing Policy

Recent European Union (EU) circular economy and bioeconomy policies and the New European Green Deal promote the recycling of nutrients from organic wastes into products that can be used as soil improvers and fertilisers, thereby reducing the use of mineral fertilisers. This has renewed interest in the use of compost and digestate as potential fertilisers. This study developed a quality standard for digestate and an updated standard for compost. It also examined best practice in other countries and options for having end-of-waste criteria.

Developing Solutions

The research developed should be used by the National Standard Authority of Ireland to update Irish Standard (IS 441) on compost and develop a new IS standard for digestate. The findings of this study can be used in an application to the Environmental Protection Agency by industry for national end-of-waste standards for compost and digestate.

The possible approach that could be taken in Ireland to define end-of-waste criteria is by implementing either biowaste ordinance legislation or a national fertiliser regulation. It should include the requirement that compost or anaerobic digestion plants proposing to produce an end-of-waste product be compliant with a Quality Assurance Scheme that is monitored by a quality assurance organisation.

By achieving end-of-waste status, it generates a level playing field. It also supports the development of a circular economy while still respecting the precautionary principle by avoiding pollution when compost and digestate are used on soil.

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