Quality assurance of compost and digestate

Experiences from Germany

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Table of Content

List of Figures 3
List of Tables 4
List of Boxes 4
List of Abbreviations 5

1 Introduction 6

2 Bio-waste treatment 7

3 EU policy on waste and bio-waste 9
3.1 EU policy framework on waste 9
3.2 EU legislation on bio-waste 10
3.3 Status of implementation of EU bio-waste legislation in the EU Member States 11

4 Bio-waste management in Germany 13
4.1 Legal framework on bio-waste in Germany 13
4.2 Development and current bio-waste management in Germany 14

5 Quality assurance of compost and digestate in Germany 17
5.1 The QAS in Germany 17
5.1.1 BGK – the QAO in Germany 17
5.1.2 RAL – the central standard setting institution in Germany 20
5.2 The quality assurance process in Germany 22
5.3 Quality requirements for compost and digestate in Germany 24
5.4 Sample taking according to the BGK Methods book 27

6 Summary and outlook 30

7 References 32

List of Figures

Figure 1: Material flow scheme of an exemplary anaerobic digestion process 8

Figure 2: Composting process in three phases 9

Figure 3: Relevant EU directives and regulations related to bio-waste 9

Figure 4: Specification of the waste hierarchy for bio-waste treatment 11

Figure 5: Share of landfilled mixed municipal waste in the EU Member States (2013) 12

Figure 6: Bio-waste legislation in Germany 13

Figure 7: Share of different biodegradable waste types in German treatment plants (2012) 15

Figure 8: Routes of bio-waste in Germany 16

Figure 9: The QAS in Germany 17

Figure 10: Structure of BGK 19

Figure 11: RAL quality labels 21

Figure 12: Process of quality assurance conducted by BGK 22

Figure 13: Process of sample taking 28

Figure 14: Technique for taking a representative sample of compost 29

List of Tables

Table 1: Number of analyses per year necessary to be taken at BGK monitored plants 23
Table 2: Quality requirements for compost according to the RAL quality standard “RAL-GZ 251” 25
Table 3: Requirements for sample takers and laboratories 27
Table 4: Sizes and numbers of individual samples 28

List of Boxes

Box 1: QAS and QAO for compost and/or digestate in EU Member States 6
Box 2: Definition of bio-waste according to the EU Waste Framework Directive 2008/98/EC 7
Box 3: EU legislation 10
Box 4: Policy and legislation in Germany 14
Box 5: Information on separate collection in Germany 16
Box 6: Information on BGK 20
Box 7: Quality requirements and assurance of compost and digestate in Germany 26
Box 8: Information on sample taking 27

List of Abbreviations

BGK	Bundesgütegemeinschaft Kompost e. V. (Federal Compost Quality Assurance Organisation of Germany)
BMUB	Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety of Germany)
Cd	Cadmium
Cr	Chromium
Cu	Copper
DE BBodSchG	Germany's Federal Soil Protection Act
DE BBodSchV	Germany's Federal Soil Protection Ordinance
DE BioAbfV	Germany's Bio-Waste Ordinance
DE DüMV	Germany's Fertiliser Ordinance
DE DüngG	Germany's Fertiliser Act
DE KrWG	Germany's Circular Economy Act
DE TierNebG	Germany's Animal By-Products Disposal Act
DE TierNebV	Germany's Animal By-Products Disposal Ordinance
DM	Dry matter
ECN	European Compost Network e. V.
ECN-QAS	European Quality Assurance Scheme
EU	European Union
EU LD	EU Landfill Directive
EU WFD	EU Waste Framework Directive
FM	Fresh matter
Hg	Mercury
LAGA	Länderarbeitsgemeinschaft Abfall (Working Group of the Federal States on Waste)
MBT	Mechanical biological treatment
MS	Member States
Ni	Nickel
PAYT	Pay-as-you-throw
Pb	Lead
QAO	Quality assurance organisation
QAS	Quality assurance system
RAL	Deutsches Institut für Gütesicherung und Kennzeichnung e. V. (German Institute for Quality Assurance and Certification)
UBA	Umweltbundesamt (German Environment Agency)
Zn	Zinc

BOX 1: QAS and QAO for compost and/or digestate in EU Member States

Austria: ARGE Kompost & Biogas Verband Österreich (ARGE Compost & Biogas Austria), *http://www.kompost-biogas.info/ (in German only)*

Austria: KGVÖ Kompostgüteverband Österreich (Austrian Compost Quality Society), *http://www.kompost.at/index.php/component/content/article?id=61&itemid=2 (in German only)*

Belgium: Vlaco and the quality assurance system, *http://www.compostnetwork.info/wordpress/wp-content/uploads/Presentation-of-Vlaco-and-the-QAS.pdf, http://www.vlaco.be/en (in English)*

Germany: Bundesgütegemeinschaft Kompost e. V. (Federal Compost Quality Assurance Organisation of Germany) and Deutsches Institut für Gütesicherung und Kennzeichnung e. V. (German Institute for Quality Assurance and Certification), *https://www.kompost.de (in German only)*

Ireland: CQAS 441 National Compost Quality Assurance Scheme, *http://certificationeurope.com/inspections/cqas-441-national-compost-quality-scheme/ (in English)*

Netherlands: Keur compost, *http://keurcompost.nl/ (in Dutch only)*

United Kingdom: Renewable Energy Assurance Limited's Certification Scheme for quality composts, *http://www.qualitycompost.org.uk/ (in English)*

1 Introduction

In order to increase material recycling, to decrease the amount of biodegradable waste[1] being landfilled, and to consequently implement the waste hierarchy in accordance with the legislation of the European Union (EU), it is an option for EU Member States (MS) to increase the composting and digesting activities of separately collected bio-waste (which is a subset of biodegradable waste). This can be supported by establishing a quality assurance system (QAS), which comprises an organisation with the competence to control the quality of compost and digestate (quality assurance organisation, QAO).

Across the EU, some countries have already successfully implemented a QAS and/or a QAO (see Box 1). Germany has been successfully operating a QAS since 1989, comprising different quality labels as well as a QAO. Consequently, Germany has not only gained experience in the establishment and operation of a QAS and a QAO, but also has many years of experiences with the treatment of bio-waste to produce compost and digestate as well as with the sample taking and analysis of these products.

This brochure intends to provide information on the QAS and QAO in Germany. It focuses on the system as well as on the process of assuring the quality of compost and digestate in Germany. Important aspects of assuring the quality of compost and digestate as well as sources for further information and helpful documents are presented. Furthermore, this brochure provides information on the legal framework related to bio-waste and the current bio-waste treatment in the EU and, in particular, in Germany.

The brochure's content has been compiled to address information needs of

- political decision-makers and administrations at national, regional and local levels with the competence to design and govern a QAS,
- (potential) operators of composting and digestion plants, and
- other experts or organisations interested in this topic – in the EU and beyond.

1 *'Biodegradable waste' means any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, paper, and paperboard (Directive 1999/31/EC on the landfill of waste).*

2 Bio-waste treatment

Bio-waste represents a subset of biodegradable waste. The EU Commission defines bio-waste as follows:

Bio-waste from municipal sources can be distinguished into two types:

- food and kitchen waste (food and kitchen waste from households and household-like commercial waste, e.g. from restaurants, retail premises, etc.)[2] and
- green waste (biodegradable garden and park waste) [EC 2008].

Type and composition of bio-waste influence, which treatment will be the most efficient. Efficiency means thereby a low environmental impact while creating a product of high quality [UBA 2016c]. **Pre-condition for an efficient treatment towards high-quality products suitable for agricultural or horticultural use is, inter alia, the separate collection of bio-waste.**

The different bio-waste types can be treated in various ways:

- anaerobic digestion,
- composting, or
- energy recovery.

Anaerobic digestion

Anaerobic digestion is a process, where bio-waste is converted into biogas as well as a liquid and/or solid digestion residue by means of microorganisms under anaerobic conditions (exclusion of oxygen). At the beginning, the input material is shredded, processed (removal of impurities, homogenisation, etc.) and filled into a closed vessel (see e.g. first steps in Figure 1). Due to the work of microorganisms, the material undergoes various stages of digestion, until methane (biogas) is produced. The energetic utilisation of this biogas usually takes place in a combined heat and power plant, where the gas is combusted and converted into electricity and heat. The remaining digestate (liquid or solid) can be used as a fertiliser. Solid digestate can also be used for a subsequent composting process. To achieve an effective anaerobic digestion, wet bio-waste, e.g. food and kitchen waste, is the most suitable input material [UBA 2016c; LUBW no year a].

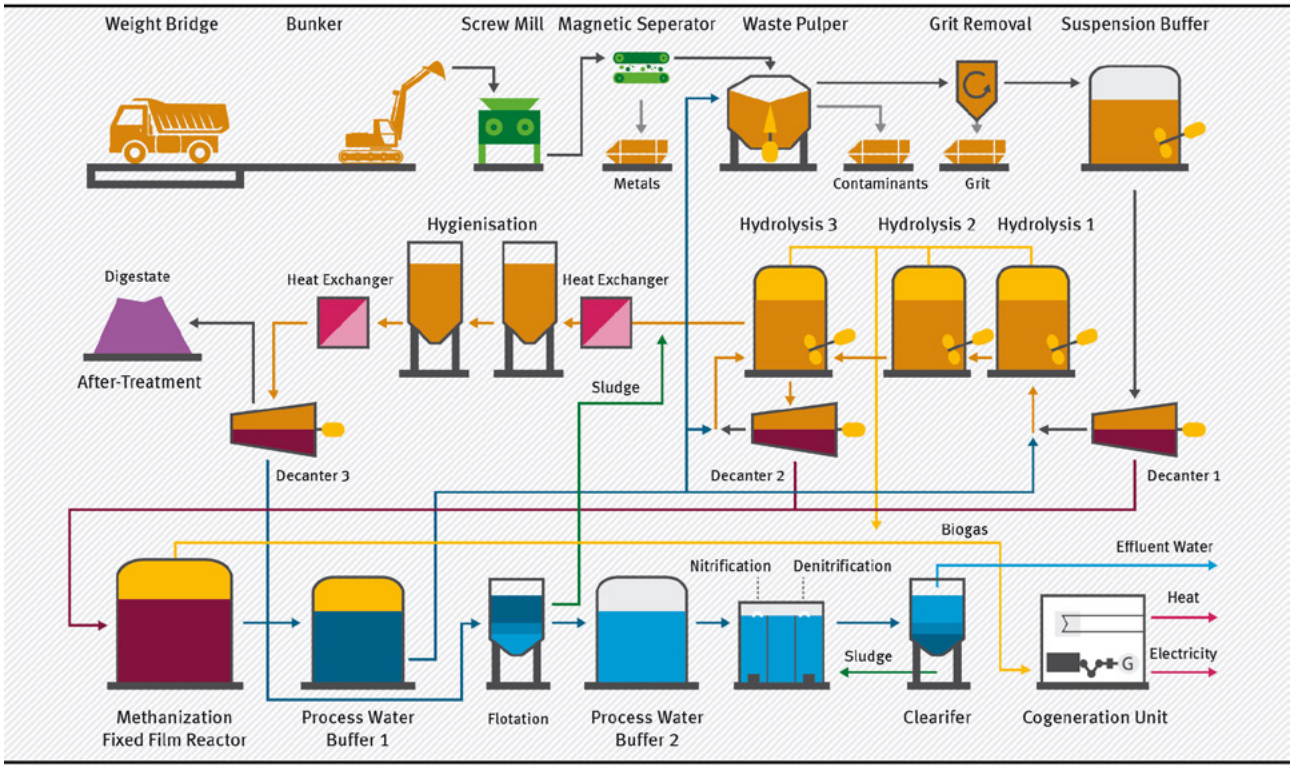
BOX 2: Definition of bio-waste according to the EU Waste Framework Directive 2008/98/EC

"(...) 4. 'bio-waste' means biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants; (...)" [Art. 3 (4) EU WFD]

2 *This type of bio-waste is usually collected in so called "bio-waste bins". Bio-waste bins from households often contain also garden waste. Its occurrence in bio-waste bins, nevertheless, makes this "household garden waste" being categorized as "food and kitchen waste" instead of green waste, which is usually not collected in bio-waste bins.*

Figure 1:

Material flow scheme of an exemplary anaerobic digestion process



Source: Ganser Entsorgung 2016

Composting

Composting is the biological decomposition of bio-waste by means of micro-organisms under aerobic conditions. The remnant is a nutrient-rich compost, which can be used as soil improver and fertiliser. The main composting process can be divided into three steps:

- degradation phase,
- conversation phase, and
- maturation phase (see Figure 2).

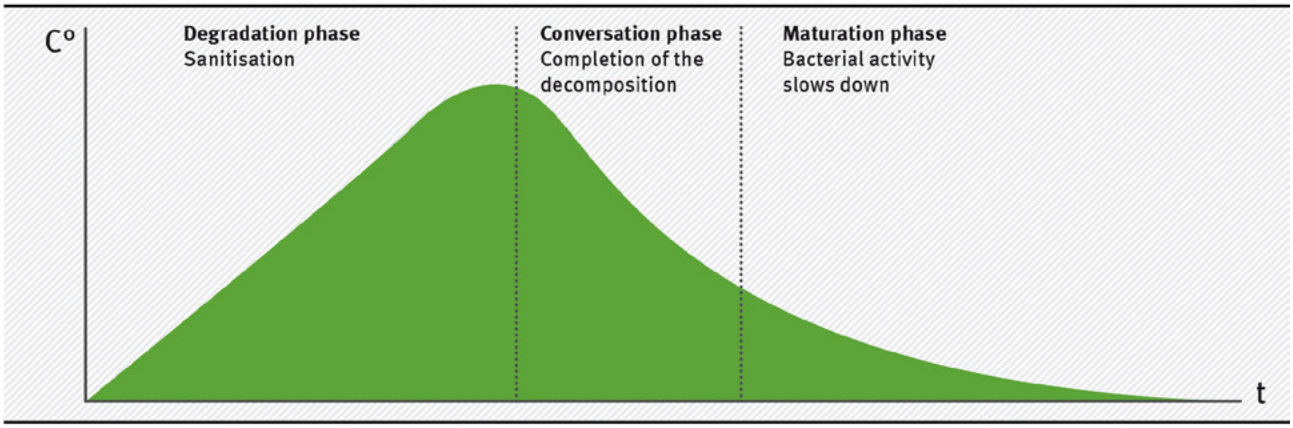
First, the input material is shredded, homogenised and impurities are removed in several steps. During the degradation phase, the bio-waste is decomposed under controlled oxygen and moisture supply. The temperature during this process reaches 60 – 70 °C, whereby pathogenic agents and bacteria are eliminated. The conversation phase completes the decomposition process at lower temperatures. During the maturation phase, the process slows down and the fresh compost is thereby stabilised and converted into humus (mature compost). For the composting process lignin and cellulosic plant material is the best suitable input material [UBA 2016c; LUBW no year b].

Energy recovery

The third option is the energy recovery in an incineration process as sole purpose. For this treatment process, only wood-containing components of green waste with high calorific value are suitable and can be used, for example, as fuel in biomass-fired combined heat and power plants [UBA 2016c].

Figure 2:

Composting process in three phases



Source: Adapted from BGK 2010

3 EU policy on waste and bio-waste

3.1 EU policy framework on waste

With the first Waste Framework Directive (EU WFD) dating back to 1975, waste policy has been one of the first environmental policy fields covered by EU legislation. Today, the EU waste policy aims not only at minimising health and environmental threats from waste and waste management, but also at resource efficiency. The EU's efforts for resource efficiency are reflected in the new ambitious Circular Economy Package[3], which underlines the value of waste as a secondary raw material [EC 2016c; UBA no year].

EU waste legislation today covers a number of regulations and directives setting out substantial and detailed requirements for the MS. These requirements relate to general principles of waste management systems, to standards for the entire management of waste, including treatment, and to specific waste streams.

Figure 3:

Relevant EU directives and regulations related to bio-waste

Waste Framework Directive 2008/98/EC (EU WFD)	Landfill Directive 1999/31/EC (EU LD)	Animal By-Products Regulation (EC) No 1069/2009	Fertiliser Regulation (EC) No 2003/2003
Contains general waste management requirements	Contains specific requirements for the landfilling of waste and bio-waste	Lays down health rules for composting and anaerobic digestion plants, which treat animal by-products	Regulates the production, composition and labelling of fertilisers

Source: BiPRO GmbH 2016

3 *http://www.europarl.europa.eu/EPRS/EPRS-Briefing-573936-Circular-economy-package-FINAL.pdf*

BOX 3: EU legislation

Waste Framework Directive:
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:312:0003:0030:en:PDF (in English)

Landfill Directive:
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1999:182:0001:0019:EN:PDF (in English)

Animal By-Products Regulation:
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:300:0001:0033:EN:PDF (in English)

Fertiliser Regulation:
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:304:0001:0194:en:PDF (in English)

3.2 EU legislation on bio-waste

Bio-waste represents one of these specific waste streams. The EU directives and regulations presented in Figure 3 are of particular importance for bio-waste management, including its treatment.

Waste Framework Directive

Article 4 of the revised EU WFD of 2008 describes the different steps of the hierarchy of waste treatment. Article 6 defines end-of-waste criteria. Article 11 determines re-use and recycling targets regarding all types of waste and Article 22 sets out specific measures for bio-waste. The MS are required to promote the separate collection of bio-waste in order to be treated according to the waste hierarchy (see Figure 4), as well as to use environmentally safe materials produced from bio-waste [EU WFD].

Landfill Directive

To ensure that the bio-waste management of MS is in accordance with the waste hierarchy, the Landfill Directive 1999/31/EC (EU LD) stipulates specific requirements for the landfilling of biodegradable waste. Not later than five years after entering into force of the national laws implementing the EU LD, biodegradable municipal waste going to landfills must be reduced to 75 %, after eight years to 50 %, and after 15 years to 35 % of the total amount (by weight) of biodegradable municipal waste produced in 1995 [EU LD].

Animal By-Products Regulation and Fertiliser Regulation

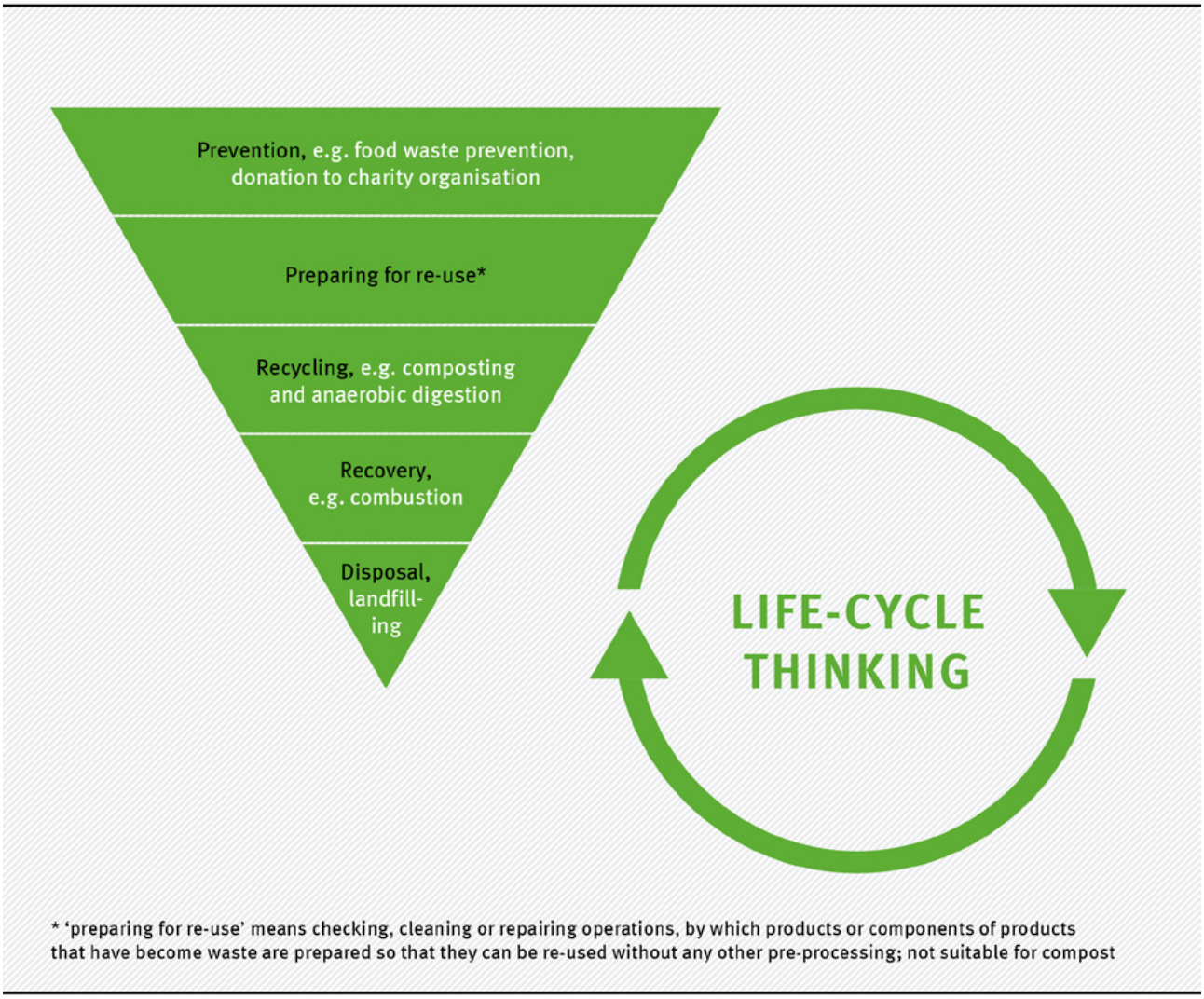
Specific requirements for input material and for the use of compost or digestate are laid down in the Animal By-Products Regulation (EC) No 1069/2009 and in the Fertiliser Regulation (EC) No 2003/2003/EC. The Animal By-Products Regulation specifies, inter alia, which animal by-products are allowed to be composted or digested and, after this, used in agriculture [EU Animal By-Products Regulation].

The Fertiliser Regulation on the other hand, regulates the production, the composition and the labelling of fertilisers. For this purpose, the regulation contains requirements on the permitted input material, the content and the efficacy of nutrients. In addition, it limits the quantity of undesirable substances [EU Fertiliser Regulation].

With the objective of achieving an EU-wide circular economy with closed loops of resources, new regulations are under discussion, e.g. a revised EU Fertiliser Regulation, which promotes the use of organic and waste-based fertilisers. The draft of the revised EU Fertiliser Regulation “contains several elements that will help create a level playing field for all fertilising products, while at the same time ensure high safety and environmental protection standards” [EC 2016b].

Figure 4:

Specification of the waste hierarchy for bio-waste treatment



Source: BiPRO GmbH 2016

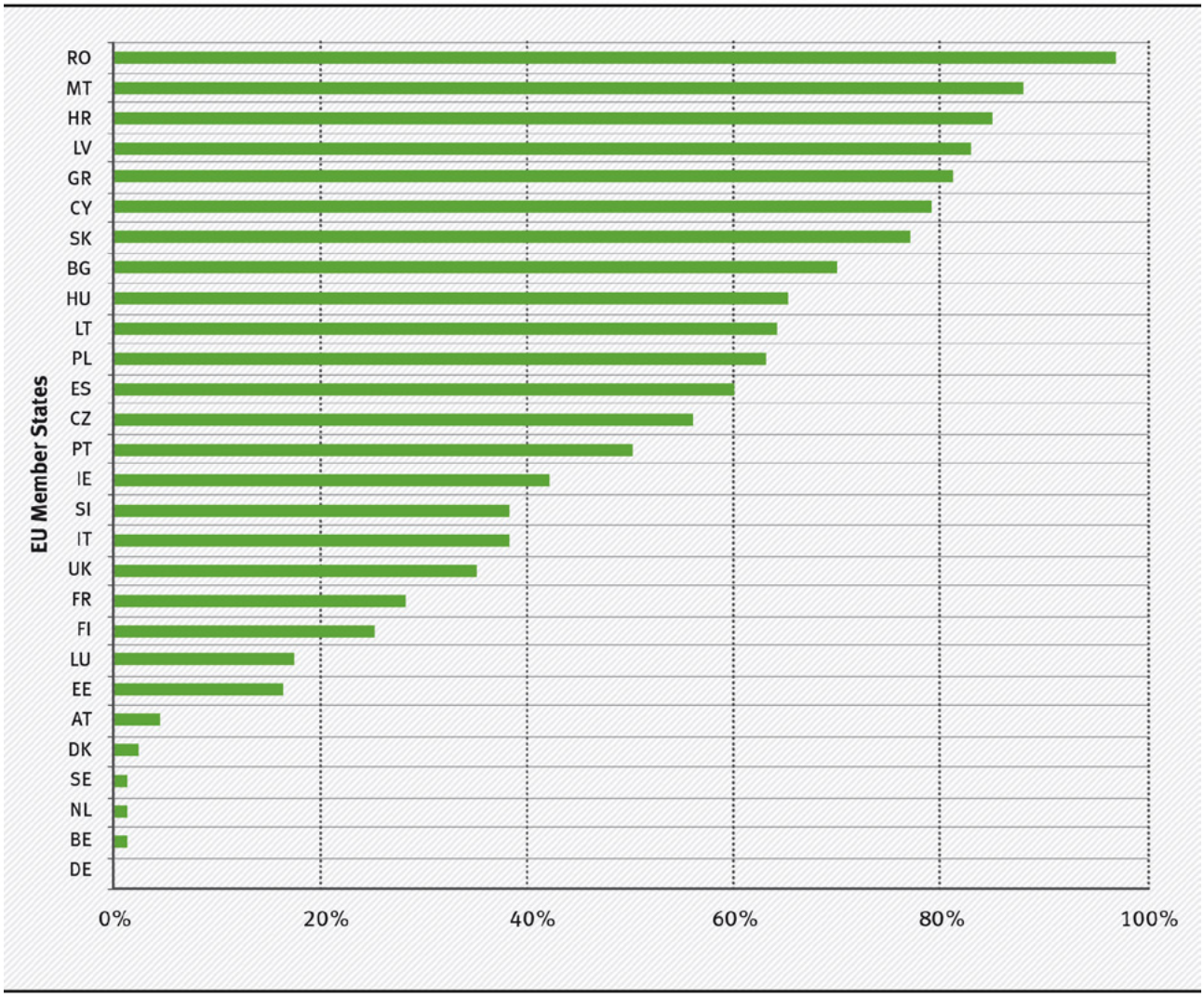
3.3 Status of implementation of EU bio-waste legislation in the EU Member States

Despite the fact that EU waste policies today include a number of legal documents, which define substantial and detailed requirements for MS, and despite several guidance documents on how to meet these requirements, various sources show that the state of implementation in the MS differs largely, in particular regarding municipal waste management. For instance, the "Assessment of separate collection schemes in the 28 capitals of the EU" shows that some MS have established well-functioning municipal waste management systems with high recycling rates. However, as many as 12 MS do not collect bio-waste separately, meaning that the five-step waste hierarchy cannot be implemented for bio-waste in those MS [EC 2015]. As Figure 5 shows, in many MS landfilling is still the preferred treatment option for mixed municipal waste, containing bio-waste.

This fact is of particular significance, because 20 – 60 % of the municipal solid waste consists of bio-waste. The actual potential for recycling of bio-waste from municipal solid waste in Europe (EU 28, Switzerland, and Norway) is about 90 million tonnes per year. Only 30 million tonnes of bio-waste in Europe are currently recycled per year. Therefore, the resources of 60 million tonnes of bio-waste, e.g. nutrients, are lost [ECN 2017].

Figure 5:

Share of landfilled mixed municipal waste in the EU Member States (2013)



Source: [EUROSTAT 2015] Press release Environment. 54/2015, 26 March 2015

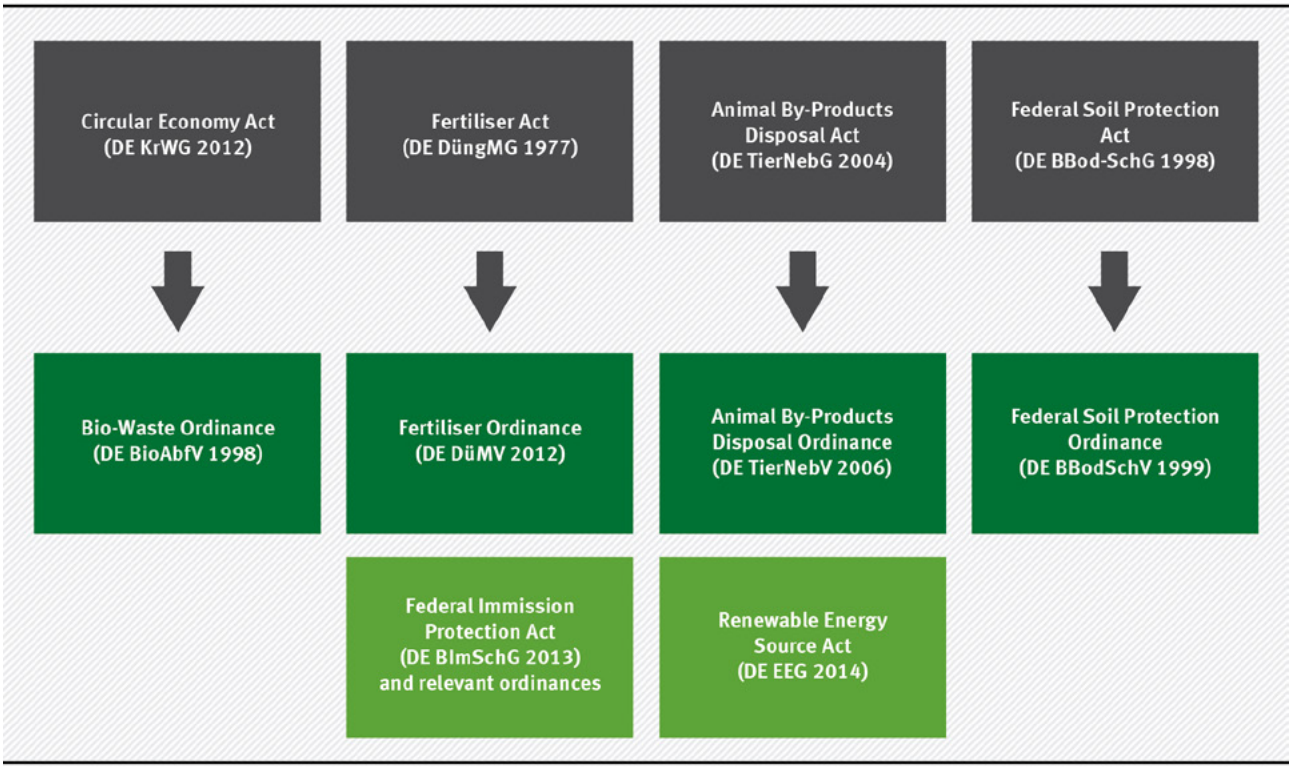
4 Bio-waste management in Germany

4.1 Legal framework on bio-waste in Germany

Germany has implemented the EU bio-waste legislation into the national legal and policy framework and has enacted additional acts and ordinances regarding bio-waste (see Figure 6).

Figure 6:

Bio-waste legislation in Germany



Source: BiPRO GmbH 2016

Circular Economy Act

The Circular Economy Act 2012 (DE KrWG) implements the EU WFD and promotes a circular economy in order to conserve natural resources and to ensure the protection of human health and the environment when generating and managing waste. The DE KrWG – in Section 11 – for the first time, prescribes the mandatory separate collection of bio-waste in the whole country from 1 January 2015 onwards at the latest. Section 12 of the DE KrWG lays down the framework conditions for the quality assurance of compost and digestate [UBA 2016a; DE KrWG].

Bio-Waste Ordinance

A variety of legal ordinances supplements and specifies the DE KrWG, e.g. the Bio-Waste Ordinance 1998 (DE BioAbfV) (revised 2013). It applies to

BOX 4: Policy and legislation in Germany

Germany's Circular Economy Act: *https://www.gesetze-im-internet.de/krwg/KrWG.pdf (in English)*

Germany's Bio-Waste Ordinance: *http://www.gesetze-im-internet.de/bundesrecht/bioabfv/gesamt.pdf (in German), http://www.bmub.bund.de/fileadmin/Daten_BMU/Download_PDF/Abfallwirtschaft/bioabfv_engl_bf.pdf (in English)*

Germany's Fertiliser Act: *https://www.gesetze-im-internet.de/bundesrecht/d_ngg/gesamt.pdf (in German only)*

Germany's Fertiliser Ordinance: *https://www.gesetze-im-internet.de/bundesrecht/d_mv_2012/gesamt.pdf (in German only)*

Germany's Animal By-Products Disposal Act: *https://www.gesetze-im-internet.de/bundesrecht/tiernebg/gesamt.pdf (in German only)*

Germany's Animal By-Products Disposal Ordinance: *https://www.gesetze-im-internet.de/bundesrecht/tiernebv/gesamt.pdf (in German only)*

Germany's Federal Soil Protection Act: *https://www.gesetze-im-internet.de/bundesrecht/bbodschg/gesamt.pdf (in German only)*

Germany's Federal Soil Protection Ordinance: *http://www.gesetze-im-internet.de/bundesrecht/bbodschv/gesamt.pdf (in German only)*

treated (compost, digestate) and untreated bio-waste that is used on land for agricultural, silvicultural and horticultural purposes, as well as to all parties involved in bio-waste production, collection, transport, treatment, and use. Furthermore, it contains information and requirements on suitable input materials, processes, quality, and hygiene of the products and their application, as well as obligations to prove the compliance with aforementioned requirements [DE BioAbfV].

Fertiliser Act and Ordinance

For compost or digestate intended to be used as fertiliser, soil improver, growing media, or plant additives, the Fertiliser Ordinance 2012 (DE DüMV), as the implementing ordinance to the Fertiliser Act 2009 (DE DüMG), specifies minimum contents or tolerances of the ingredients and also limit values for contaminants like heavy metals [DE DüMV].

Animal By-Products Disposal Act and Ordinance

The Animal By-Products Disposal Ordinance (DE TierNebV), as the implementing ordinance to the Animal By-Products Disposal Act (DE TierNebG), defines that food and kitchen waste from restaurants and canteens has to be collected and stored separately from bio-waste from households and that requirements of the DE KrWG have to be followed, when this waste is treated in an anaerobic digestion plant [DE TierNebV; DE TierNebG].

Federal Soil Protection Act and Ordinance

The Federal Soil Protection Act (DE BBodSchG) and the Federal Soil Protection Ordinance (DE BBodSchV) are relevant for the application of compost for landscaping and re-cultivation. The DE BBodSchV regulates the amount of compost that can be applied for specific landscaping purposes, e.g. specific limit values for contaminants (polychlorinated biphenyls, naphthalene, etc.) [DE BBodSchG; DE BBodSchV].

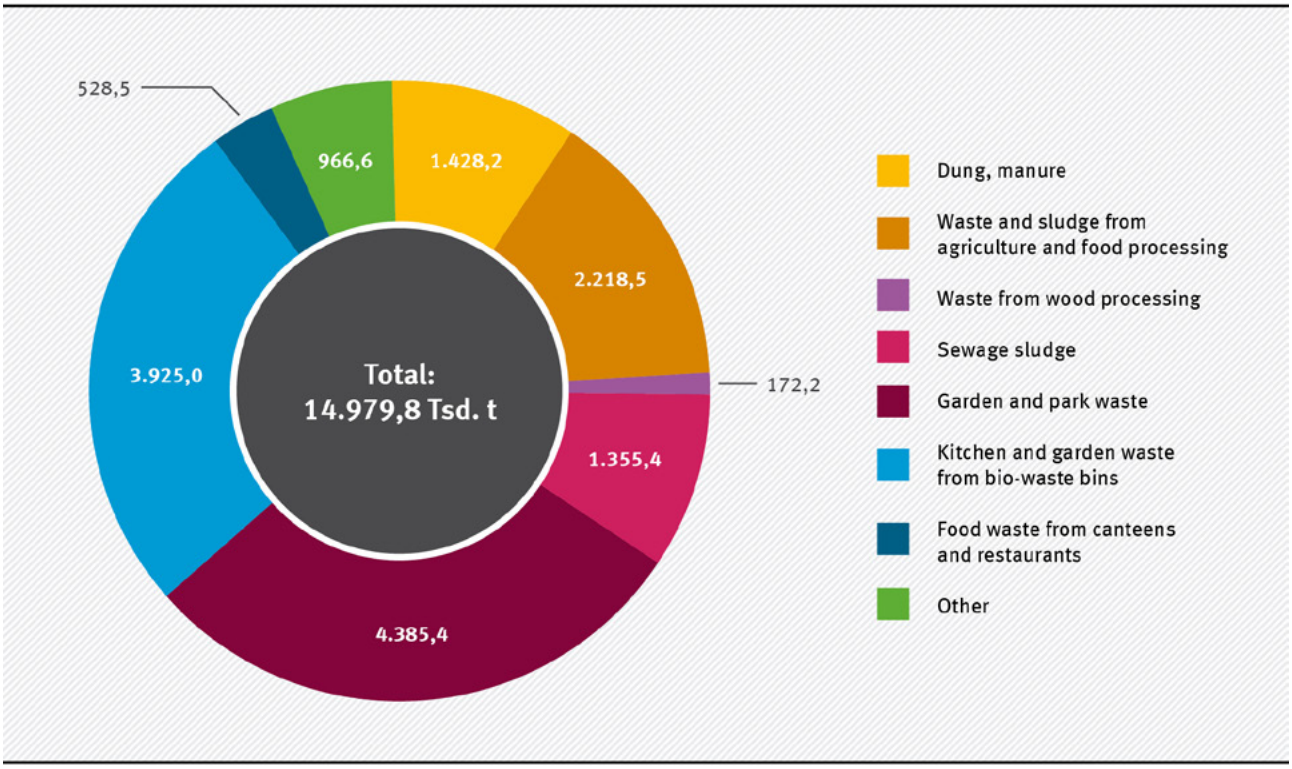
4.2 Development and current bio-waste management in Germany

About 25 years ago, several municipalities in Germany began to collect bio-waste separately on a voluntary basis. Until today, many projects, measures, and legislation have created a well-established collection system with a subsequent effective use of bio-waste.

In 1982, the first pilot project for the separate collection of bio-waste in so-called "bio-waste bins" started in the city of Witzenhausen, in the German state of Hesse, which was the pulse generator for many follow-up projects across Germany [Fricke et al. 2003]. At that time, the separate collection of bio-waste was not yet required by German legislation. In 1986, the German Waste Act stipulated the separate collection of waste for the first

Figure 7:

Share of different biodegradable waste types in German treatment plants (2012)



Source: UBA 2016b

time. Each municipality could decide independently whether or not to introduce the separate collection of bio-waste at household level. Consequently, at that time, the separate collection of bio-waste on household level was not compulsory throughout Germany. Nevertheless, many municipalities obviously did introduce the separate collection of bio-waste on a voluntary basis. Therefore, in the following years (until 1989), up to 100 composting plants were constructed in Germany to treat the collected bio-waste.

Due to reservations against compost as a product, composting plant operators established a QAO for compost, the Bundesgütegemeinschaft Kompost e. V. (BGK), in 1989. The landfill ban for waste containing organic components[4], the DE BioAbfV, and the compulsory separate collection of bio-waste from 2015 onwards according to the DE KrWG further facilitated the separate collection of bio-waste and, thereby, increased the quantities of compost – and later also of digestate – produced [BGK 2016a; UBA 2016a; 2016b].

In compliance with the definition of the EU WFD, in Germany, bio-waste comprises food and kitchen waste[5] and green waste. **Green waste** is collected in bring-systems at composting plants or recycling stations. **Food and**

4 *This landfill ban was introduced by Germany's Waste Storage Regulation (http://ka4-umwelt.de/uploads/media/AbfallablagerungsVO_AbfAblV.pdf, in German only, not bio-waste specific) in 2001 and has been binding from 2005 onwards.*

5 *Including "household garden waste", see Chapter 2.*

BOX 5: Information on separate collection in Germany

National factsheet on separate collection in Germany:
http://ec.europa.eu/environment/waste/studies/pdf/Final%20national%20factsheets.zip (in English)

Compulsory implementation of separate collection of bio-waste:
https://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/summary_texte_84_2014.pdf (in English)

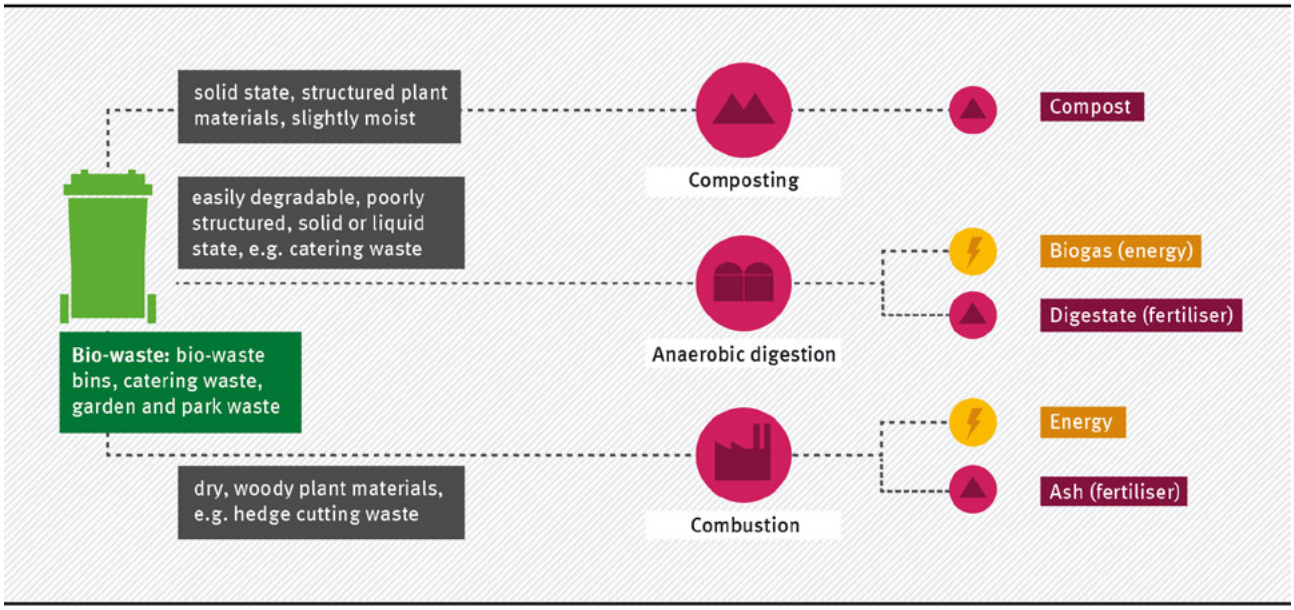
kitchen waste on the other hand is collected separately from households, companies, restaurants, canteens, and (super-)markets in kerbside systems (door-to-door) in bio-waste bins. Different types of financing exist across the German municipalities. Most of them are characterised as pay-as-you-throw (PAYT) systems, in which citizens pay less for separately collected bio-waste than for mixed residual waste [UBA 2016b].

Today, about 46 % (estimated) of German households collect their food and kitchen waste in bio-waste bins. The remaining 54 % (estimated) have either no access or do not want to collect food and kitchen waste separately [UBA 2016a]. Nevertheless, around 15 million tonnes of bio-waste (184 kg per capita) are collected separately, are treated and are used per year (see Figure 7). Of these, 26 % (47.8 kg per capita) is food and kitchen waste from households (bio-waste bins) and 3 % (5.5 kg per capita) is food waste from canteens and restaurants. Therefore, food and kitchen waste amounts to 29 % of the whole bio-waste or 53.3 kg per capita [UBA 2016b].

Separately collected bio-waste is either directed towards recycling composting or anaerobic digestion) or in case of woody green waste towards energy recovery (see Figure 8), while bio-waste remaining in mixed municipal waste is incinerated in waste incineration plants, which means a loss of valuable nutrients and resources. In 2014, 884 composting plants and 1,386 digestion plants were in operation in Germany, which produced 3.96 million tonnes of compost and 3.9 million tonnes of digestate (including digestion plants for renewable raw materials) [BMUB 2016].

Figure 8:

Routes of bio-waste in Germany



Source: Adapted from UBA 2016b

5 Quality assurance of compost and digestate in Germany

In order to produce marketable compost and digestate, it is important to guarantee high quality and compliance with relevant standards and legislation.

5.1 The QAS in Germany

The development of the QAS in Germany started in 1989 when the BGK, the German QAO, was founded. Today, the QAS in Germany represents a system, in which two organisations are responsible for particular tasks:

- the German Institute for Quality Assurance and Certification (RAL) and
- the BGK.

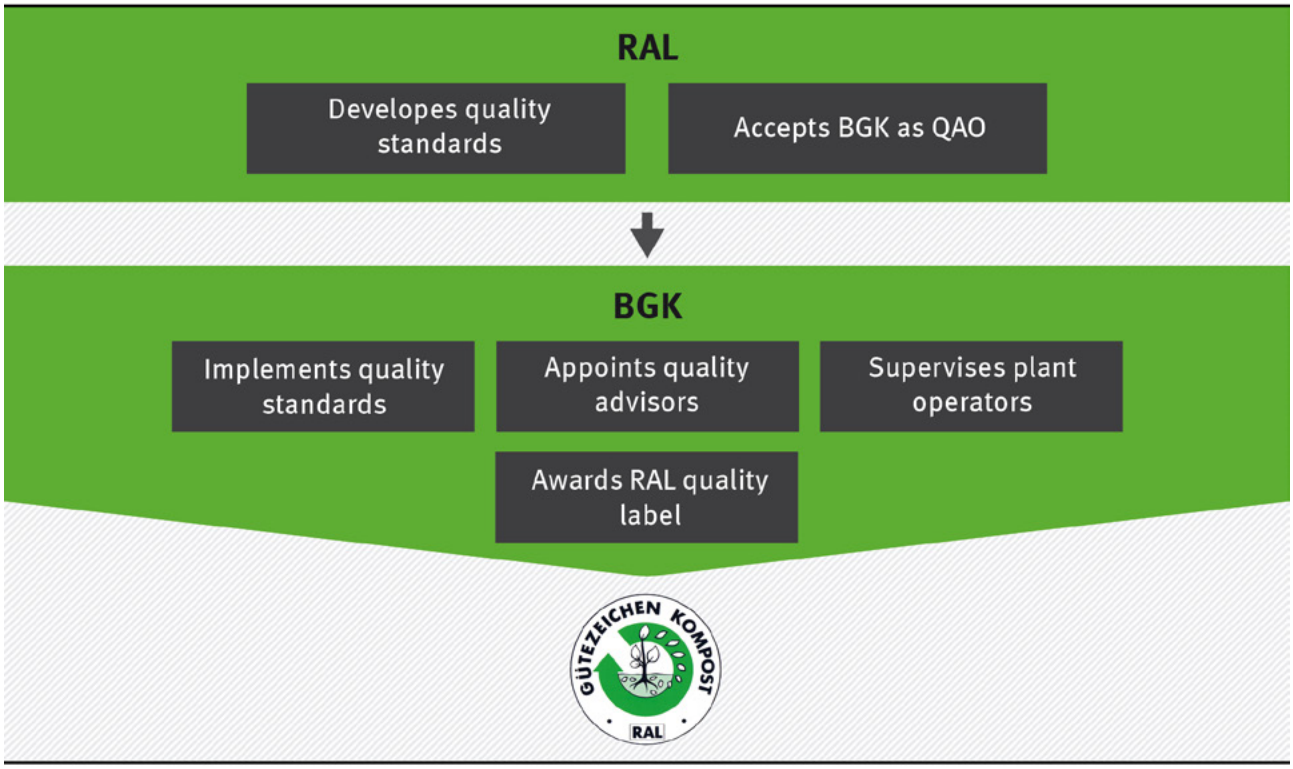
Figure 9 illustrates hierarchy and areas of responsibility of RAL and BGK.

5.1.1 BGK – the QAO in Germany

When the separate collection of bio-waste started in Germany (see Chapter 4.2), composting plant operators faced the challenge to determine the quality of the compost they produced and the specific market value of these products. In addition, they faced the challenge to improve their product's marketability. This led to the idea of defining product-specific quality standards based on particular requirements, which not only plant operators but also consumers could rely on.

Figure 9:

The QAS in Germany



Source: Adapted from BGK 2016a

In 1989, composting plant operators initiated the founding of the BGK, the QAO for compost – and later also for digestate – in Germany, with the intention to achieve a homogenous quality of compost and digestate by its member composting and digestion plants. When the BGK was founded, approximately 100 composting plants were in operation in Germany and their number increased significantly during the course of the following years. By meeting the quality standards set by the BGK, the quality of the products could be demonstrated [BGK 2017c]. Since the quality standards for compost and digestate have been determined by the RAL (see Chapter 5.1.2), the BGK has been responsible for implementing them, including the awarding of the RAL labels.

The BGK is engaged in the European Compost Network (ECN) and is one of four QAOs in the EU, which have been awarded the ECN-QAS conformity label for national QAOs.[6]

The BGK is an independent self-governing organisation, i.e. a registered association. Its organisation is structured in

- organisational units,
- operational units, and
- members (see Figure 10).

Organisational units of BGK

The BGK board comprises a chairman, deputies and eight additional members. It is elected by the BGK members during members' meetings every two years. The Federal Quality Committee ("Bundesgüteausschuss") consists of independent representatives of institutions dealing with research and development, analysis, consulting and applications of compost and digestate [BGK 2016a; BGK 2017b]. The BGK office is located in Cologne and is managed by a managing director.

The main function of the organisational units of the BGK is to monitor the compliance of composting and digestion plants with quality standards for processing bio-waste and for their products. These standards apply to compost and digestate, which shall be certified and labelled according to the RAL quality standards (see Chapter 5.1.2). This monitoring implies a series of other tasks ranging from the accreditation of sample takers and testing laboratories, the appointment of quality advisors, the assessment of the plants, the awarding of certification, as well as the facilitation of an exchange of knowledge [BGK 2016a].

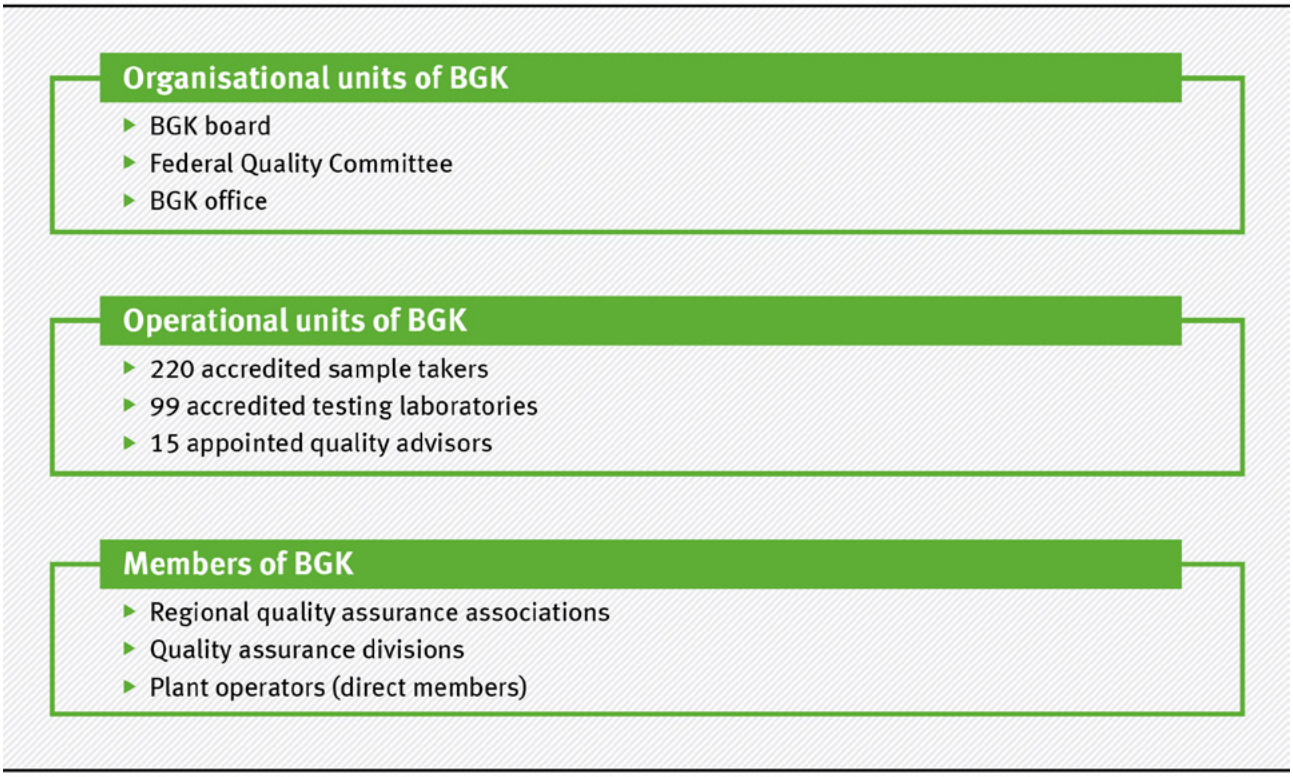
Operational units of BGK

The operational units consist of accredited sample takers, accredited laboratories, and appointed quality advisors. The quality advisors have the duty to support plant operators when implementing quality standards as well as self-monitoring systems in order to fulfil the quality standards, targeting high process and product quality. Therefore, quality advisors carry out regular assessments.

6 *More information on the ECN and its labels can be found in http://www.compostnetwork.info/ (in English).*

Figure 10:

Structure of BGK



Source: Adopted from BGK 2016a

Members of BGK

The members of the BGK comprise regional quality assurance associations, quality assurance divisions ("Spartengütergemeinschaften") and direct members, such as plant operators. The BGK works through five regional quality assurance associations[7] and three quality assurance divisions, which provide local support for the member plant operators and candidates. Each association and division determines quality advisors for plant inspections and visits. These quality advisors are approved by the BGK Federal Quality Committee. The BGK, the regional quality assurance associations and the quality assurance divisions are financed by membership fees.

Since the DE BioAbfV has been adopted in 1998, membership in the BGK has become even more attractive for composting and digestion plant operators, because this ordinance granted privileges to member companies. Advantages of membership in the BGK are, inter alia:

- advice on possible improvements in the operation of the plant in order to generate a greater quantity and quality of the product,
- information and guidelines on laws and regulations, which is becoming more and more important as the laws become increasingly complex and incomprehensible,

7 *These regional quality assurance organisations cover only a part of Germany, see https://www.kompost.de/fileadmin/docs/shop/Regionen-UEberblick-bunt-2014_11.pdf (in German only).*

BOX 6: Information on BGK

Overview of BGK:
http://www.compostnetwork.info/wordpress/wp-content/uploads/Presentation-BGK-2014-03-12.pdf (in English)

BGK homepage:
https://www.kompost.de (in German only)

- permission to follow a simplified documentation procedure if the product is foreseen for agricultural use[8],
- guarantee for operating in accordance with the requirements of the DE BioAbfV[9],
- marketing benefits for the products guaranteeing a broad acceptance from the customers [BGK 2017a].

5.1.2 RAL – the central standard setting institution in Germany

The RAL has been a standard setting institution in Germany since 1925. It determines requirements for standards, which a specific product group has to meet in order to be certified with a RAL quality label – a label, which is acknowledged widely among producers and experts in Germany and beyond. These standards include quality and testing requirements. For quality assurance organisations of several sectors, the RAL represents their umbrella organisation. The RAL is an independent self-governing organisation, i.e. a registered association.

With reference to compost and digestate, the RAL advanced the quality standards of the BGK towards own RAL quality standards and created own labels for them. In 1991, the RAL established a quality standard for compost; in 2000, it established a quality standard for digestate; and in 2003, it established a quality standard for sewage sludge and sewage sludge compost (comprises composted sewage sludge mixtures). In addition, fertiliser from ashes from wood incineration can be certified with a RAL quality label, too [BGK 2010; 2016a].

Nowadays, the respective RAL quality standards represent the core element of the QAS for compost and digestate in Germany. They are publically available on the homepage of the BGK, which – being the QAO – is responsible for implementing these quality standards. Plant operators, processing companies (e.g. substrate producing companies), consumers, farmer associations, as well as testers are involved in the discussions on the development of the requirements for these quality standards.

The motivation of applying RAL quality standards is to enhance process and product quality as well as to receive the RAL quality label for products of a guaranteed homogenous quality in order to improve their marketing. With reference to compost and digestate, the labelling of high quality products furthermore intends to increase their recognition, inter alia, by legal authorities, farmers, substrate producing companies and by the food processing industry.

8 *If the product is foreseen for agricultural use, a delivery note must be issued and sent to the authority without delay including information on the exact batch number, analytical results, laboratory results, signature of the customer etc. Plant operators that are members of the BGK can follow a simplified procedure where the only required information is, how much compost or digestate has been provided to which farmer.*

9 *The internal BGK requirements implemented by a system of test certificates and annual certificates go beyond the legal requirements of the DE BioAbfV and ensure the plants an operation within this framework.*

In 2014, 489 composting plants and 126 digestion plants in Germany produced compost and digestate according to the RAL quality standards. In the same year, ca. 6.7 million tonnes of bio-waste have been treated in composting plants, which are members of the BGK, resulting in an output of 3.35 million tonnes of certified compost. Digestion plants have treated ca. 4 million tonnes of input material [BGK 2015].

Figure 11:

RAL quality labels*

Compost label **Bio-waste** | Digestate label **Bio-waste** | Digestate label **Renewable plants** | **Sewage sludge** label | **Sewage sludge compost** label | Fertilizer label **Ashes** from wood incineration

* Requirements according to www.kompost.de/Gütesicherung

Source: BGK

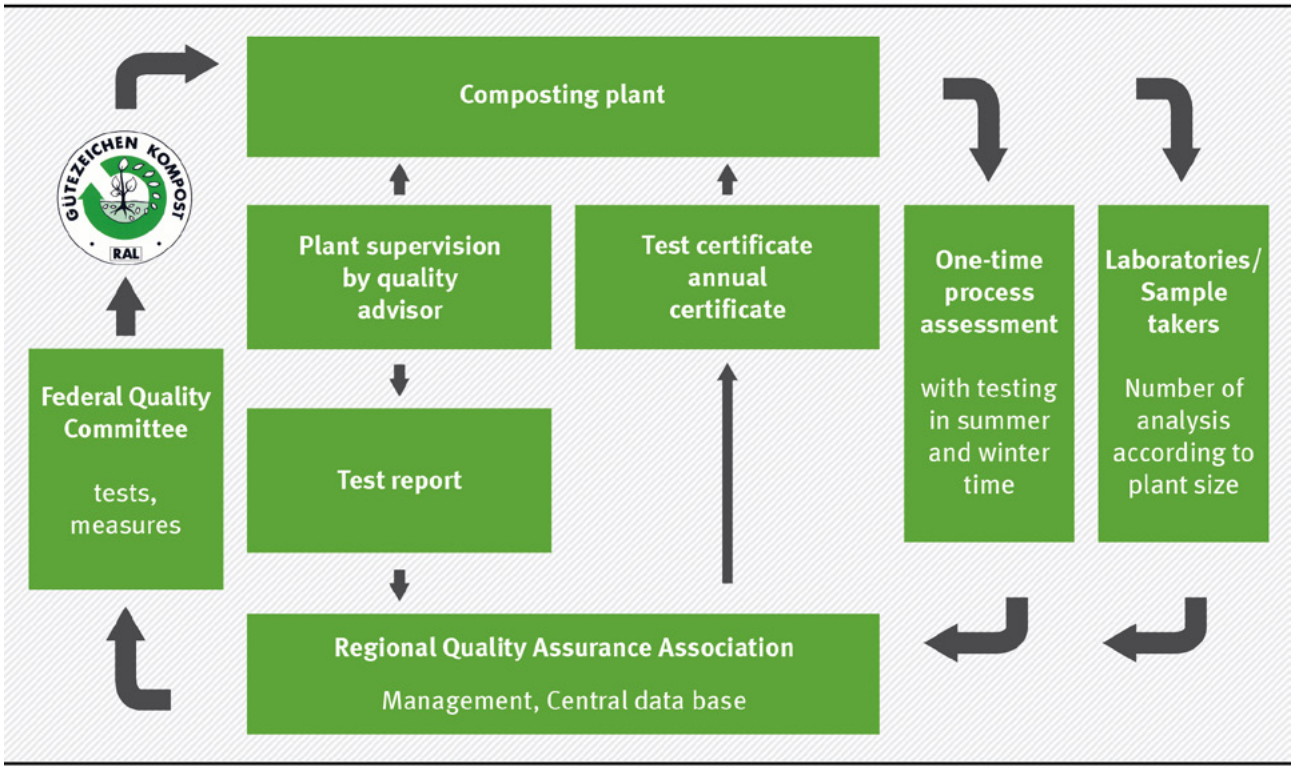
5.2 The quality assurance process in Germany

In order to benefit from the quality assurance conducted by the BGK, a plant operator has to undergo a prescribed process. Firstly, the plant operator must submit an application for membership in the BGK or in an associated regional quality assurance organisation or in a quality assurance division and sign a commitment to comply with the RAL quality and testing requirements and the statute of the BGK. The quality assurance process is conducted by quality advisors appointed by the BGK (see Chapter 5.1.1) and proceeds as shown in Figure 12:

1. Initial on-site visit: During an on-site visit, a quality advisor conducts a short assessment of the plant and examines if the plant complies with the quality and testing requirements.
2. One-time process assessment: After a successful initial on-site visit, the one-time process assessment verifies, whether the treatment process of the plant is suitable for the sanitation of bio-waste. It has to be carried out according to the regulations of the DE BioAbfV, once in summer and once in winter. The one-time process assessment consists of a temperature measurement, a process assessment and a compost analysis. The required compost sample is taken by accredited sample takers and is analysed by accredited laboratories.

Figure 12:

Process of quality assurance conducted by BGK



Source: Adapted from BGK 2016a

3. Certification: The results are submitted to the Federal Quality Committee of the BGK. If all requirements are in accordance with the respective RAL quality standard, the BGK Federal Quality Committee awards the respective RAL quality label.
4. Monitoring: After the reception of the label, the monitoring process begins. It requires inspection reports of follow-up assessments of the plant and results of product samples. In the first three years, the plant needs to be visited and monitored once a year or until the process works perfectly. Afterwards, the plant is monitored every two years. The number of analyses per year depends on the amount of input material delivered to a plant (one analysis per 2,000 tonnes, measured in tonnes treated material per year) (see Table 1).
5. Termination: If the requirements are no longer met, the BGK can withdraw the certification of the plant [BGK 2016c, BGK 2017c].

Table 1:

Number of analyses per year necessary to be taken at BGK monitored plants

Amount of input material per plant and year	Number of analyses per year
Up to 8,000 tonnes treated material	▸ 4 analyses
Up to and above 24,000 tonnes treated material	▸ Max. 12 analyses (if relieved of the duty to do further analyses)

Source: Adapted from BGK 2016c; BGK 2017c

Costs of the quality assurance process

The quality assurance process generates costs, which can be divided into four major lots. The level of these costs as stated in the following refers to the framework conditions in Germany[10].

1. The costs for the **one-time process assessment** amount to 8,500 €, including costs for the preparation of tracers, the summer sample, the winter sample, the analysis and the report.
2. The costs for the **sample takers** amount to approximately 1,050 € per year in case of plants with a capacity of 10,000 tonnes per year and with five samples taken.
3. The costs for a complete **analysis of one mixed sample** according to RAL requirements amount to 300 €, which is 1,500 € per year in case of five samples.
4. The **fee** that the BGK charges directly from members consists of a **basic fee** of 710 € for BGK internal costs, including the quality advisor, and a **variable fee** of 0.085 € per tonne input material for the composting or digestion plant [BGK 2016b].

10 *Please note that the numbers indicated here refer to the German price level and are thus not necessarily comparable to price levels in other countries.*

In Germany, the costs of the quality assurance process, including the BGK fee, are included in the waste treatment costs. Waste treatment costs are financed by waste management fees. The quality assurance of compost and digestate can improve the marketability of the products and can improve the possibilities to bring the nutrients and the organic matter back to the soil. Depending on the situation, it can also increase the revenues of the products.

5.3 Quality requirements for compost and digestate in Germany

Currently, the quality standards require, inter alia, the declaration of the following aspects:

- plant nutrients,
- declaration of the compost according to the DE DüMV (see Chapter 4),
- determination of fertiliser and humus value,
- physical parameters (bulk density, dry matter (DM), rotting degree, etc.),
- biological parameters (salmonella, odour, etc.), and
- heavy metal content.

The declaration of properties of the compost or digestate also guide farmers and landscapers in the proper application of the products.

In order to be certified according to the RAL quality standards, compost or digestate has to meet specific quality requirements. The five major aspects are:

- harmlessness,
- usefulness,
- appearance,
- reliability, and
- marketability.

Harmlessness

As compost or digestate are mainly used as fertiliser and soil improver, their harmlessness must be guaranteed. For this purpose, the respective RAL quality standard defines exact quality requirements. These are differentiated for compost (mature, fresh, substrate), digestate (liquid, solid), digestate from renewable raw materials (liquid, solid) and compost produced from sewage sludge. As an example, requirements and limit values for matured compost are presented in Table 2.

Usefulness

The levels of the nutrients nitrogen, phosphate, potassium and lime, as well as the humus value are determined during the compost and digestate analysis. The levels of nutrients must be taken into account by farmers in

Table 2:

Quality requirements for compost according to the RAL quality standard "RAL-GZ 251"

Quality characteristics	Quality requirements
Sanitation	▸ Proof that can be tested on epidemic-hygienic effectiveness of the decomposition process (compliance test or "Konformitätsprüfung") ▸ Compliance with time and temperature requirements (process control) ▸ Exclusion of germinable seeds and sprouting plant parts ('free' means ‹ 2 plants/l compost) ▸ Exclusion of salmonellae
Impurities (limit values)	▸ Max. 0.5 weight-% in DM selectable, species-inappropriate material › 2 mm diameter ▸ Total surface area of impurities ‹ 25 cm²/l FM (if more impurities than 0.1 weight-% DM were found) ▸ Stones › 10 mm: max. 5 weight-% in DM
Tolerance of plants	▸ Plant compatibility for the provided area of application ▸ Free of phytotoxic substances, not nitrogen fixing
Rotting degree	▸ IV or V*
Water content	▸ Bulk material max. 45 % ▸ Bagged material max. 35 % ▸ Higher contents of water are admissible for compost with more than 40 % ignition loss according to Annex 4 of the BGK Methods Book
Organic matter	▸ At least 15 weight-% in DM measured as ignition loss
Heavy metal content (limit values) [mg/kg DM]	▸ Cd: 1.5; Cr: 100; Cu: 100; Hg: 1.0 ▸ Ni: 50 ; Pb: 150; Zn: 400;
Declaration	▸ Product type (matured compost) ▸ Name of producer ▸ Bulk density (volume weight) ▸ DM content ▸ pH-value ▸ Salt content ▸ Plant nutrients (total) (N, P_2O_5, K_2O, MgO, CaO) ▸ Plant nutrients (soluble) (N, P_2O_5, K_2O) ▸ Micro-nutrients (according to fertiliser legislation) ▸ Organic matter ▸ Alkaline effective matter (CaO) ▸ Net weight or volume ▸ Instructions for proper use

Source: Adapted from BGK 2016a

** The rotting degree indicates the ability of compost to heat itself under testing conditions. Stage IV and V mean temperatures of < 30 – 40 °C (BGK Methods Book 2002, https://www.kompost.de/fileadmin/docs/shop/Grundlagen_GS/Methods_Book_2002.pdf, in English).*

their calculation of the amount of fertiliser to be applied on land. From the levels of nutrients, the fertiliser value of the compost can be calculated in relation to mineral fertiliser. When using compost, the farmer can reduce the amount of mineral fertiliser used, which saves him money. Another positive effect of using compost is the supply of humus-C to improve or maintain the soil fertility and the water retention in the soil.

Appearance

Separately collected bio-waste enables the production of compost that differs not only in its physical appearance, but also regarding its content of pollutants and impurities from compost produced from mixed residual

BOX 7: Quality requirements and assurance of compost and digestate in Germany

RAL quality assurance:
https://www.kompost.de/guetesicherung/ (in German only)

Quality requirements and quality assurance of compost in Germany:
http://www.compostnetwork.info/wordpress/wp-content/uploads/Presentation-BGK-2014-03-12.pdf (in English)

Quality requirements and quality assurance of digestate in Germany:
http://www.kompost.de/uploads/media/Quality_Requirements_of_digestion_residuals_in_Germany_text_01.pdf (in English)

Impurities were sorted out of a 1 l digestate test sample.

waste. However, even in the separately collected bio-waste, misthrows are always contained, which are still included in the finished product. A series of measures should be taken in order to reduce the contents of impurities, in particular of glass and of plastics. The requirements of the RAL quality standards in relation to impurities are much stricter than the ones defined by the DE BioAbfV. This is an advantage, because compost that contains impurities does not leave a good impression on the end-users and is not marketable in the long term. Therefore, the production of good-looking compost and digestate is an essential task of composting and digestion plants.

Reliability

Continuous assessments of the incoming bio-waste, of the composting and digestion processes and of their products according to the RAL quality standards guarantee sanitation and high quality of the certified products. Basically, certified compost and digestate have a consistent quality and the levels of contaminants are far below the limit values. Consequently, customers can rely on the products' constant quality.

Marketability

Only compost and digestate with low polluting potential, an appropriate composition of nutrients, good appearance and a reliable quality can easily be marketed. The BKG supports the plant operators in complying with these criteria (see Chapter 5.1.1) [BGK 2017c; 2016].

5.4 Sample taking according to the BGK Methods book

The testing of a sample of compost or digestate allows the verification of compliance with the quality requirements. Proper sample taking is crucial to achieve meaningful analytical results. The performance of the testing within the quality assurance process, which is conducted by the BGK, is presented in the BGK's "Methods book for the analysis of organic fertilizer, soil improvers and substrates"[11] (BGK Methods book). The fundaments of the BGK Methods book are

- the guideline of Germany's Working Group of the Federal States on Waste (Länderarbeitsgemeinschaft Abfall, LAGA): "Rules for the sample taking from solid waste and landfilled materials" (see Box 8) and
- the requirements of the DE BioAbfV, Annex 3 [AGROLAB 2017].

According to the BGK Methods book, the samples must be representative for an entire batch of compost or digestate. A batch is defined as a unit, produced under the same conditions and at the same time. It must be differentiated between three types of samples:

- **Individual sample**, as a small portion taken of any point of the batch,
- **Collective sample**, as the total quantity of all individual samples from a batch, and
- **Laboratory sample**, as a small part of the collective sample, reduced to the quantity needed to carry out the laboratory and hygiene test.

When selecting the sample taker and the laboratory for the analysis, there are a number of criteria to consider. These are listed in Table 3.

The process of sample taking can be divided into five steps [INFU mbH 2016]:

1. Preparation and planning,
2. Taking of individual samples,
3. Creating of a collective sample,
4. Creating of a laboratory sample, and
5. Transport.

BOX 8: Information on sample taking

Methods book for the analysis of organic fertilizer, soil improvers and substrates (2006). Editor: BGK. ISBN 978-3939790006. Not available online *(in German only)*

Methods Book for the Analysis of Compost (2002): *https://www.kompost.de/fileadmin/docs/shop/Grundlagen_GS/Methods_Book_2002.pdf (in English)*

Waste classification, sample taking and analysis: *https://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/waste_classification_sampling_analysis.pdf (in English)*

Rules for the sample taking from solid waste and landfilled materials: *https://www.umwelt-online.de/recht/abfall/laga/pn98_ges.htm (in German only)*

Table 3:

Requirements for sample takers and laboratories

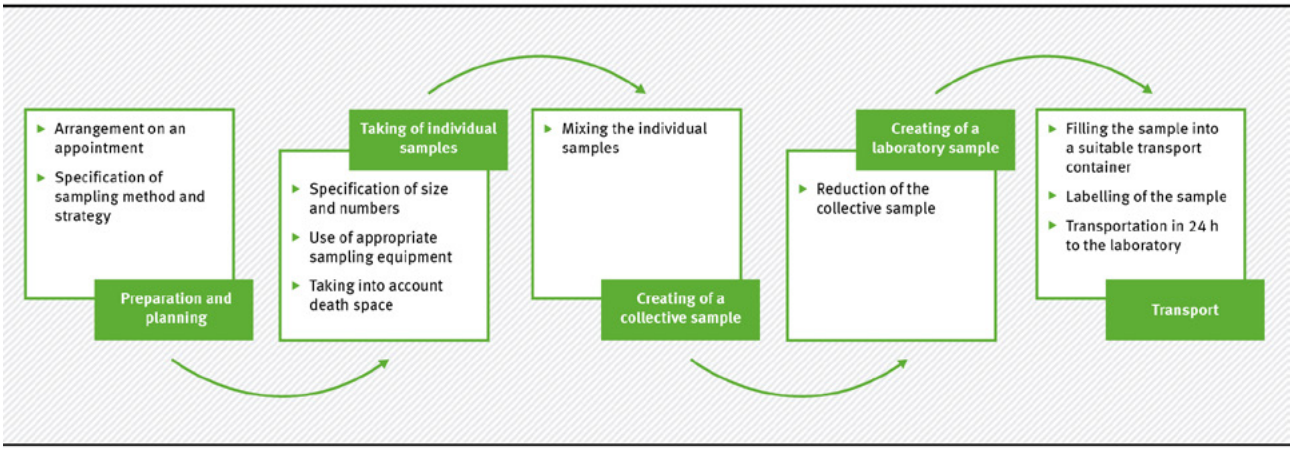
Sample takers	Laboratories
Accredited by the BGK	Accredited by the BGK
Independent	Having established a quality management system (e.g. ISO 17025)
Participating in regular training courses every three years	Having experience with all test methods
Having practical experience with relevant standards (EN 12579:2000; EN ISO 5667-13:2011)	Regular and successful participation in roundrobin tests
	Standardised reporting of results

Source: Adapted from INFU mbH 2016b; 2016c

11 *The current edition of 2006 is not available online, but the edition of 2002 is: https://www.kompost.de/fileadmin/docs/shop/Grundlagen_GS/Methods_Book_2002.pdf (in English).*

Figure 13:

Process of sample taking



Source: Adapted from INFU mbH 2016a

First of all, an appointment for the sample taking at the composting or digestion plant has to be arranged. Before taking the sample, the type of the sample as well as the method and strategy of sample taking has to be defined. Questions that need to be clarified are:

- Which is the purpose of sample taking (internal/external quality control)?
- Which are the relevant sampling methods (EN ISO Standards/ BGK Methods book)?
- Which product should be sampled (intermediate product/input material)?
- At what point should be sampled (stored material, moving material, packaged material)?

Taking of individual samples

It is important that the individual samples are taken evenly dispersed over the entire batch and that all have the same size. The size and number of the samples are depending on the material and the batch size.

Table 4:

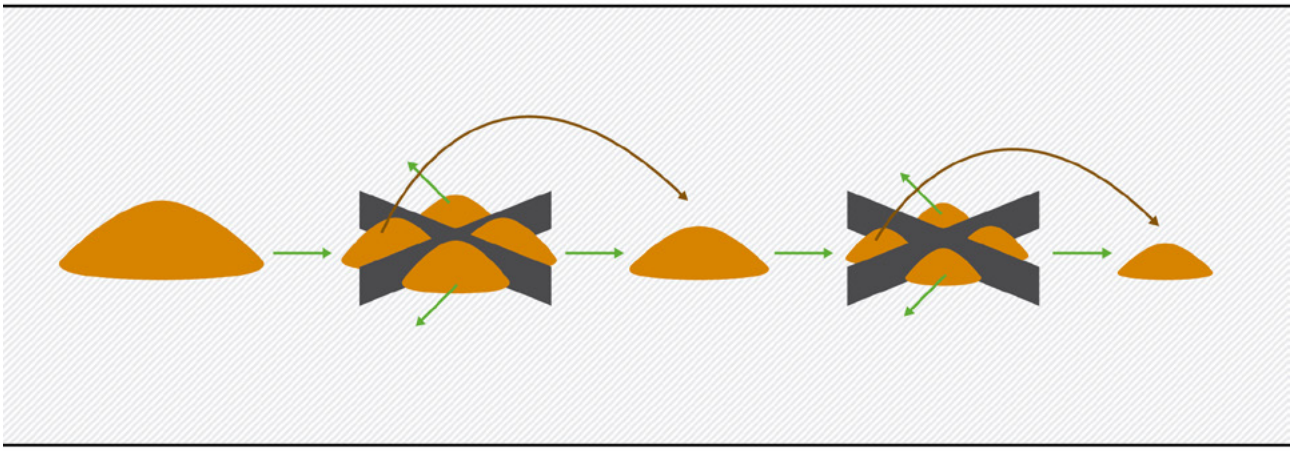
Sizes and numbers of individual samples

Solid material	
Size, if grain size ‹ 20 mm	Min. 2 litre per individual sample
Size, if grain size › 20 mm	Min. 3 litre per individual sample
Number of individual samples , if volume of batch ‹ 500 m³	20 individual samples
Number of individual samples, if volume of batch ‹ 1,000 m³	40 individual samples
Liquid material	
Size per individual sample	Min. 1 litre per individual sample
Number of individual samples, if volume of batch ‹ 1,000 m³	Min. 12 individual samples
Number of individual samples, if volume of batch ‹ 3,000 m³	Min. 20 individual samples
Number of individual samples, if volume of batch ‹ 5,000 m³	Min. 30 individual samples

Source: Adapted from INFU mbH 2016b; 2016c

Figure 14:

Technique for taking a representative sample of compost



Source: UBA 2015

The selection of the appropriate sampling equipment depends on the consistency of the batch. While a wheel loader, metal shovel/hoe, containers, screw drillers, and square rubber or plastic sheets are used for the sample taking of solid material, for liquid material a vessel to collect and mix the individual samples, a pump to extract the samples, a sample scoop and lockable packaging vessels for the final sample are necessary. When taking the sample, death space volume needs to be taken into account. These are the sections of the pipeline to the sample taking taps, where the material does not drain continuously. Therefore, dead spaces must be sufficiently flushed before taking the sample [INFU mbH 2016a].

Creating a collective and a laboratory sample

All individual samples are spread out on a rubber or plastic sheet and are mixed. This collective sample is divided into four equal squares with two opposing squares selected to create a new sample. This process is repeated until the appropriate size of the laboratory sample (at least 20 litres) is remaining [INFU mbH 2016a].

Transport

The last step is the filling of the laboratory sample into a suitable container for transport purpose. This container should be labelled with the following facts:

- origin of the sample batch,
- date of sample taking, and
- name of the sample taker.

The transportation to the laboratory should proceed within 24 hours, while the sample is cooled constantly. Finally, after each sample taking, all sampling equipment must be thoroughly cleaned [INFU mbH 2016a].

6 Summary and outlook

Bio-waste management and QAS for compost and digestate in Germany

In Germany, the separate bio-waste collection and subsequent production of compost started already in the mid-1980s on a voluntary basis. However, the acceptance of compost was low. To increase the quality of the compost and thereby its acceptance and in the end its marketability, composting plant operators founded the state-independent quality assurance organisation BGK in 1989. In the following years, bio-waste management was introduced stepwise by relevant German legislation. Since 2015, the separate collection of bio-waste is required by law and has already been successfully implemented in many municipalities. This has enabled an effective recycling of bio-waste through composting or anaerobic digestion.

Today, the BGK is the responsible organisation for the quality assurance of compost and digestate produced by certified composting or digestion plants. The requirements for the certification are defined by a standard setting institution, the RAL. The BGK implements these requirements and awards qualified products (compost and digestate) the respective RAL labels. Further tasks of the BGK are, inter alia, advising its members, public relations, and the promotion of research and development.

In order to review the quality of compost and digestate according to defined quality requirements, the BGK accredits and approves independent sample takers and laboratories. Therefore, an accreditation procedure for both, the sample takers and the laboratories, has been established by the BGK.

Plant operators wishing to depict a RAL label have to pass the quality assurance process conducted by the BGK. This includes sample taking during a site visit by a BGK sample taker and subsequent analysis of the sample by an accredited laboratory. The objective is that the operator proves to the BGK quality advisor that he is able to ensure the self-control during the plant operation. Once the production process, the intermediate and final products, as well as the plant itself fulfil all RAL requirements, the compost and digestate produced by the plant can be awarded the RAL label.

General steps towards a QAS

When thinking of introducing a QAS and reflecting, which properties and experiences of the QAS and its QAO of Germany may be of interest for designing and establishing a QAS, it is recommended to focus first on functions, which a QAS shall perform, and then on organisational aspects.

The range of possible functions could comprise:

- developing quality standards for compost and digestate that at least meet the requirements of the respective acts and ordinances to increase the acceptance of compost and digestate as new products,

- regularly monitoring
  - the composting or digestion process at the plant and
  - the compost or digestate at the plant

  in order to assess the compliance with the required quality standards, including
  - regular sample taking of the compost or digestate and
  - regular analysis of the compost or digestate samples according to the respective requirements,
- (if appropriate) designing a quality label to make the product's quality easily visible (consequently, integrating a process for awarding the label into the process of the quality assurance),
- monitoring the whole quality assurance process and, if requested, awarding the label,
- training and accrediting independent sample takers and laboratories,
- developing an appropriate pricing and financing system.

Which organisations could perform which functions, can only be decided upon when assessing existing institutional structures and options for new structures in the particular framework conditions.

In any case, in order to achieve effective bio-waste treatment and subsequent use, following steps should be considered:

- implementing and enforcing the respective ordinances concerning the separate collection and the treatment of bio-waste,
- facilitating the construction of sufficient composting and digestion plants,
- facilitating that sufficient capacities for sample taking and analysis are available,
- if appropriate, supporting the promotion of quality assured compost and digestate to further develop and improve the marketability for these products.

According to experiences from Germany, a QAS with high quality standards and a reliable monitoring improves the quality of compost and digestate – and as a consequence can improve their marketability. It has proven to be a good supporting instrument in increasing composting and digestion activities and therefore to decrease the amount of biodegradable waste being landfilled and to increase material recycling.

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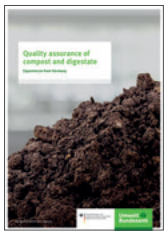

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