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LEARNING SCENARIO	BIOGAS
MODULE 6	COMPOSTING AND DISPOSAL

COLOPHON

Authors

This module is part of the Learning Scenario *Biogas*. It is developed in the frame of the European project “BioComp”.
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PREFACE

The learning scenario Biogas has been developed as part of the Erasmus+ project BioComp. In that project, the most relevant competences for professions in the sector BBE are analysed, described and ranked. See https://navigator.biocompetences.eu/. Based on these competences this learning scenario has been developed for EQF-level 3-4. The focus is on technical competences.

Nr	Competences, ranked according importance	Modules
B1	Management - Identifying needs and mechanisms of the overall management of the biogas production process.	1, 2
B2	Operate biogas plant - Operate equipment, which treats energy crops and waste from farms, called anaerobic digesters. Ensure the equipment functions correctly in the transformation of biomass to biogas, which is used for the generation of heat and electricity.	1
B3	Resolve equipment malfunctions - Identify, report and repair equipment damage and malfunctions; communicate with field representatives and manufacturers to obtain repair and replacement components.	4
B4	Composting of organic waste (Biomass) - Identifying needs and technological responses: to know the types of bio-waste, the recovery routes (composting, digestion, incineration).	5
B5	Recycling - Identifying needs and technological responses - To know the circular economy, compost processing and the use of fermentation.	1, 3
B6	Composting of organic waste (Biomass) - Identifying needs and technological responses: to know the chemistry and biological processes of composting.	1, 5
B7	Bioconversion process - Identifying needs and technological responses - To assess needs and to identify, evaluate, and control the heating process of biological material, control the combustion process, know and be able to analyse the chemical, thermal, and biochemical methods.	3, 5
B8	Composting of organic waste and management - Identifying needs and technological responses - To assess needs and to identify, evaluate, and control the heating process of biological material, control the combustion process, know and be able to analyse the chemical, thermal, and biochemical methods.	5

These 8 most relevant competences are covered by the following 6 modules:

1. Circular economy
2. Introduction
3. Health and Safety
4. Maintenance
5. Malfunctions
6. **Composting and disposal**

Apart from these 6 text documents, the scenario also has a trailer and a WIKI with background information. To support the teacher, didactic guidance is available. It can be used for all scenarios and also includes suggestions for learning activities to develop personal and transversal competences. For this guidance, see the *Pedagogical Guidelines* in the Navigator.

CONTENT

Module 6 contains the following topics:

1. Introduction to the module

During the production of biogas, biogas digestate is produced in addition to the main product biogas (methane). This is spread onto agricultural land to supply nutrients in a similar way to liquid manure.

If the digestate is produced from plant materials from agricultural, forestry, or horticultural operations (also mixed with animal excreta), it is considered farm fertiliser.

If other materials, such as biowaste, are co-fermented, they function as organic fertilisers.

The fermentation residues produced should be available to plants, but also spread in an environmentally friendly manner. This saves on mineral fertilisers. Harmful environmental influences such as ammonia emissions and possible nitrogen discharges into the groundwater are to be reduced to an unavoidable level.

2. Types of digestate and further treatment

The fermentation residues are rich in nutrients and are usually further treated aerobically (principle of composting). Depending on the dry matter of the digestate, which is determined by the type of substrate, dewatering is carried out for post-treatment. This is done with centrifuges, screw or chamber filter presses, or belt filter presses.

The target dry matter content of solid fermentation residues should be 40-50%. The resulting process water can already be used directly as liquid fertilizer in agriculture.

As already discussed, a distinction can be made between anaerobic dry processes (e.g., biowaste processing) and wet processes (e.g., processing of animal waste, such as liquid manure).

Due to the consistency of the digestate, in the wet process the liquid components of the digestate are temporarily stored in slurry tanks or directly applied to fields for agricultural fertilization. The advantage here is the thin liquid properties of good pumpability and spread ability. Problematics are the odour-intensive components from the anaerobic (reducing) conditions (e.g., ammonia and hydrogen sulphide). Due to the high content of ammonium nitrogen, the pH values are high at approx. 8.5 and can be problematic on agriculturally used soils.

The solid residues are suitable for composting (aerobic process). Here, too, nutrient-rich fertilizer is obtained, which is of great interest for agricultural use. The advantage of aerobic conversion is that odour-intensive compounds (e.g., ammonia) react to form nitrates and are more readily available to plants.

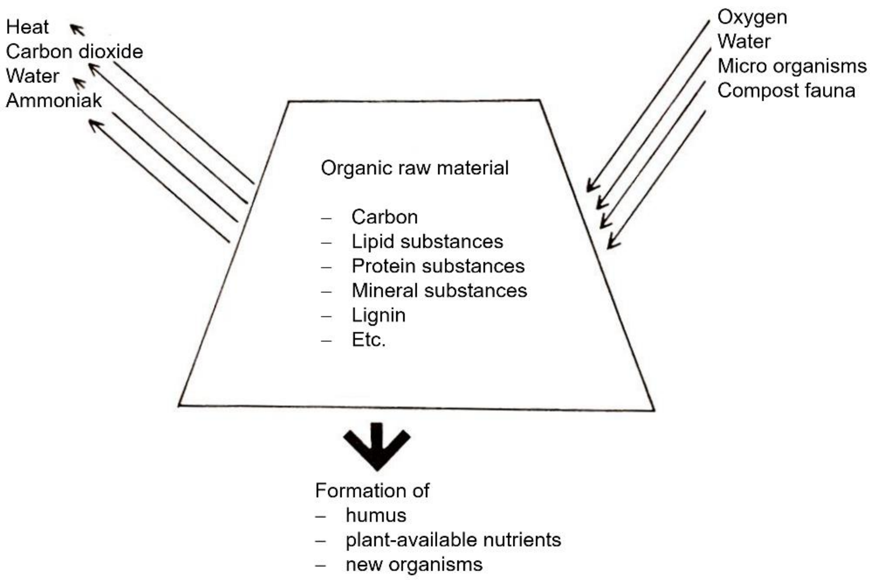
New processes also aim to pelletize (without composting) the solid fermentation residues. This requires a dry matter content > 80%. This enables a better dosage of the fertilizer. Due to the dry nature, the odour-intensive properties are minimized.

3. Digestate composting

Since the fermentation residues contain only small amounts of structural substances, admixtures of green waste are added. This guarantees a better distribution of atmospheric oxygen and water in the substrate and more efficient composting.

Composting requires oxygen, water, and suitable microorganisms. The resulting fertiliser consists of plant-available nutrients (minerals, such as nitrates, sulphates), humus, and new organisms. Heat, carbon dioxide, water, and a proportion of ammonia are emitted. (Picture 1)

Picture 1. Overview of composting

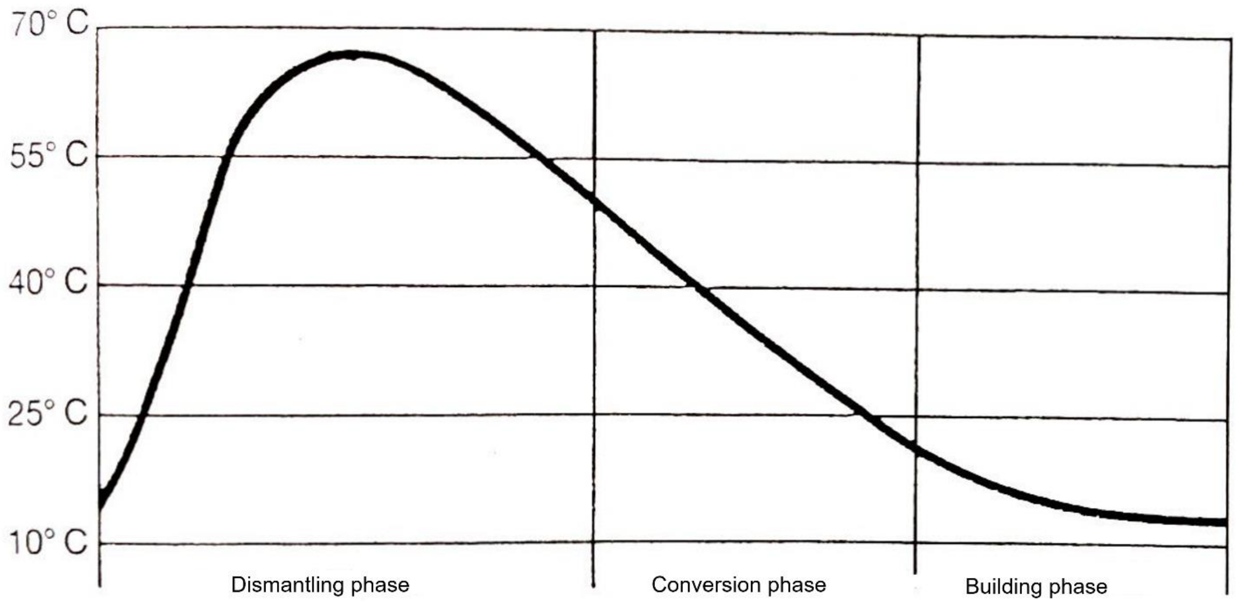


Source: Handbuch für Umwelttechnische Berufe – Band 4 Kreislauf- und Abfallwirtschaft, 2004.

The following processes during composting are considered in a differentiated manner:

In the **decomposition phase**, the temperature rises to approx. 70°C. The **conversion phase** is characterised by a continuous decrease in temperature and reaches a minimum in the **build-up phase**, which is influenced by the ambient temperatures. (Picture 2)

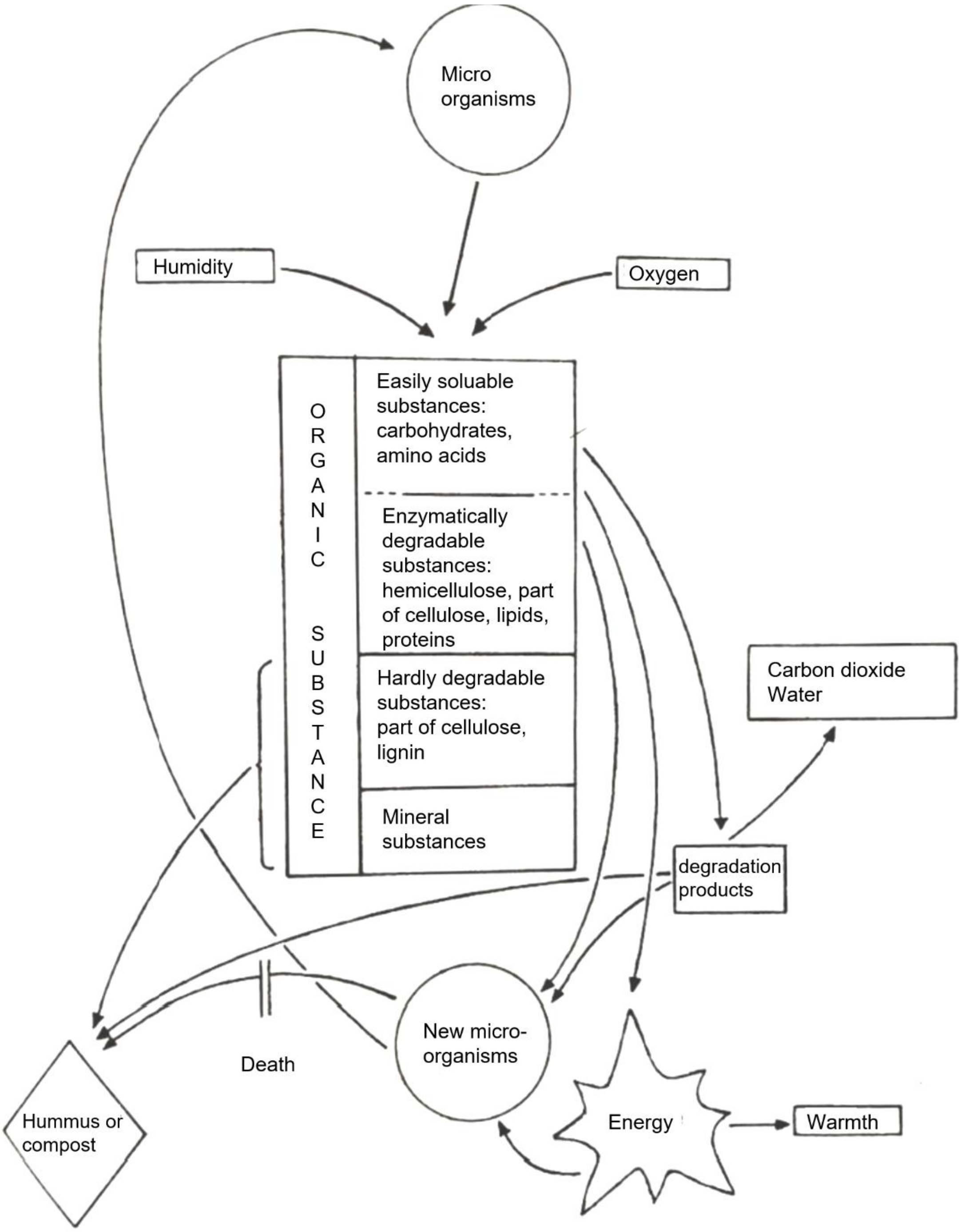
Picture 1. Composting - Temperature profile



Source: Handbuch für Umwelttechnische Berufe – Band 4 Kreislauf- und Abfallwirtschaft, 2004.

Especially in the degradation phase, the long-chain organic molecules are degraded via biochemical processes by thermophilic microorganisms (hydrolysis and acidification). In the conversion and build-up phase, humus and minerals are released. This is primarily controlled by mesophilic organisms. (Picture 3)

Picture 2. Overview of Composting



Source: Koch, Seeberger und Petrik: Ökologische Müllverwertung; Stiftung Ökologie und Landbau, Verlag C.F. Müller Karlsruhe, 1991.

Note: During anaerobic fermentation, easily degradable organic compounds are already degraded. Subsequent composting further humifies or mineralises the less degradable components.

Problems: At temperatures above 80°C the microorganisms die, which reduces the rotting and spontaneous combustion can occur. This can be prevented by suitable turning of the substrate.

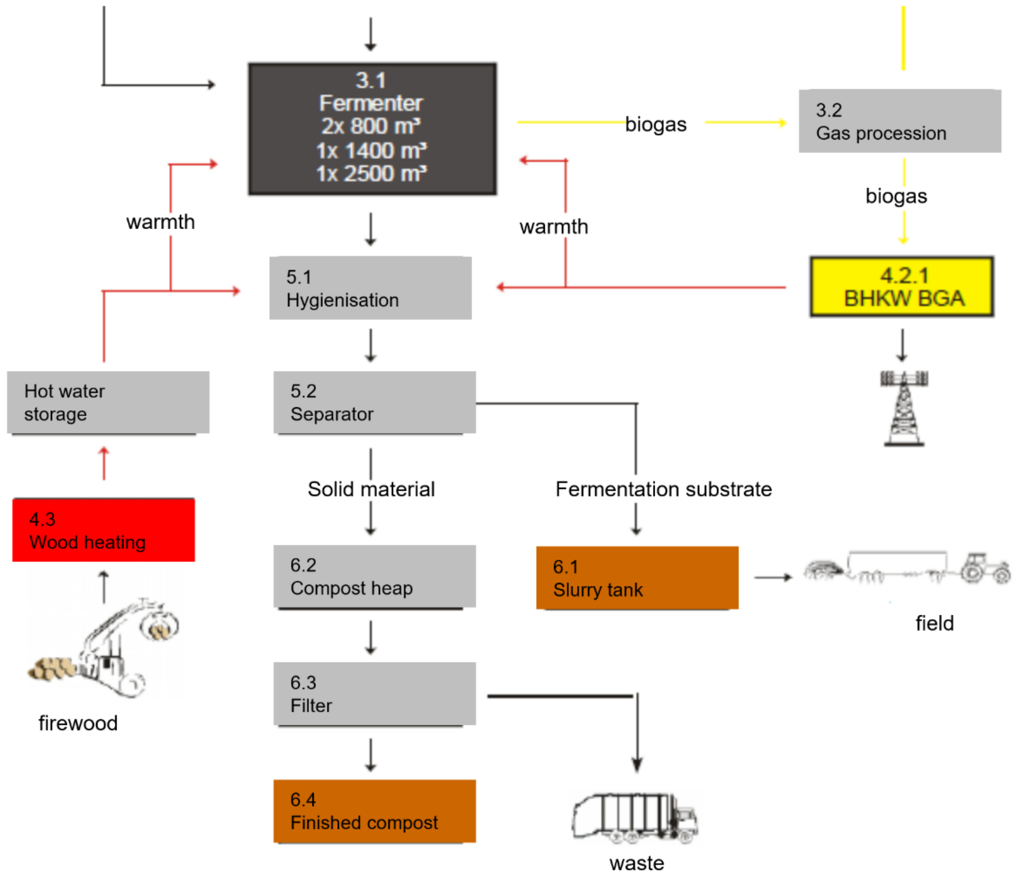
The optimal water content depends largely on the substrate and its composition. At values below 25%, rotting can come to a standstill. An optimal water-air composition is crucial. If the oxygen content drops, this leads to undesired fermentation processes (anaerobic). In large plants, air circulation takes place via nozzles at the rotting floor and trickling of water above the rotting. Composting in such rotting boxes enables so-called intensive rotting (7-14 days). This is always followed by post-composting in heaps or open composting boxes (28-42 days) with several rotations.

4. Process engineering examples

Picture 4 shows an example of the process engineering sequence of a plant in Borchen/Germany. Biowaste is processed in this plant.

Sanitization is carried out using the waste heat from the CHP units and separators are used to separate the liquid and solid fermentation residues. The liquid fermentation residues are made available directly to agriculture, the solid fermentation residues are composted, screened to remove impurities, and delivered to agriculture as finished compost.

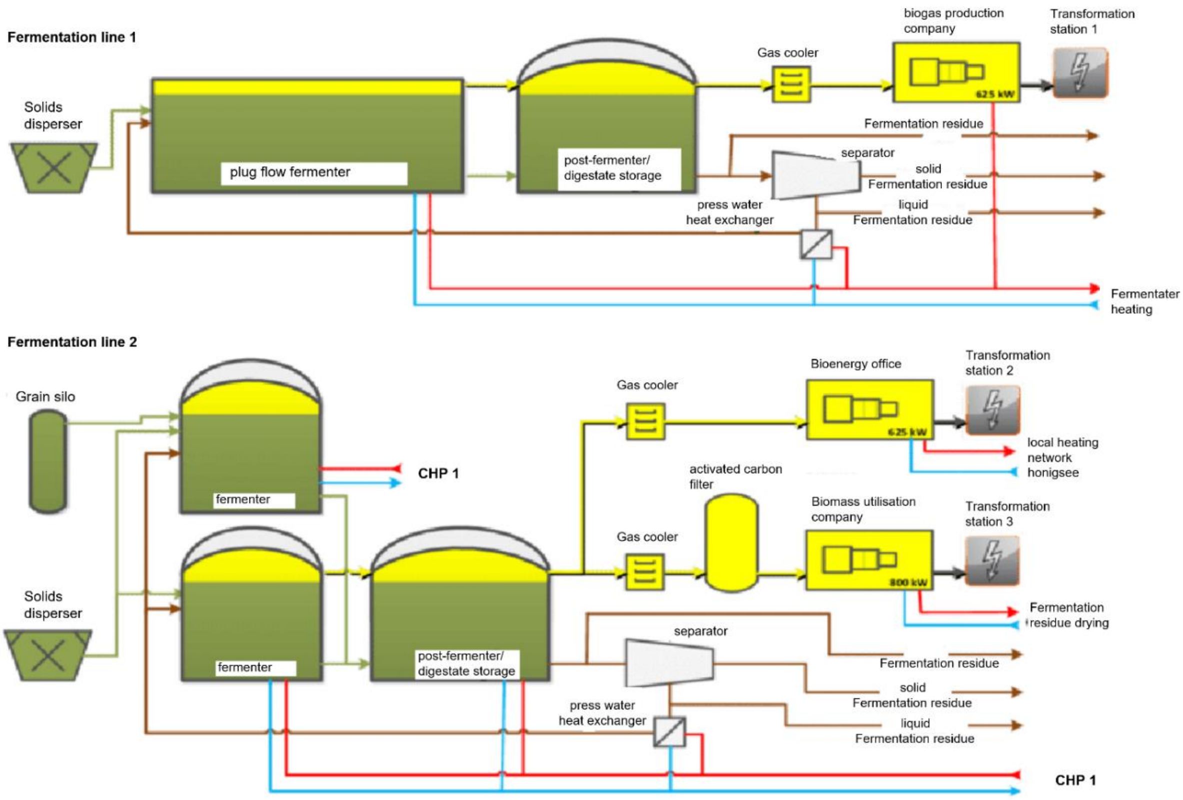
Picture 4. Process engineering sequence



Source: Franke; „Abschlussbericht franke transportbiogas.pdf“ 2009.

Picture 5 shows an example of the procedural sequence of a plant in Honigsee/Germany. In this plant, corn silage (60%), sugar beet (20%) and grain silage (20%) are processed with two fermentation lines. Details here show that a separate secondary fermentation takes place.

Picture 5. Procedural sequence



Source: Schaubach, Postel, Trommler, Nebel und Dotzauer; Deutsches Biomasseforschungszentrum; „Leistungs-fähigkeit von Biogasanlagen im Energiemix der Zukunft am konkreten Beispiel Honigsee“; 2014)

In this example, too, liquid, and solid fermentation residues are separated. The fermentation residues are thickened and dried via a press screw separator. Thus, it follows the classical processing as mentioned above. The further processing is not evident from the diagram.

5. Environmental regulations and framework conditions

Biogas plants are subject to inspection and approval requirements regarding their construction, due to the following legal provisions:

- **The Waste Management Act** (KrW-/AbfG) to the extent that biogas plants are generally classified as recycling plants in the case of co-fermentation of non-agricultural biological residues and the Fertiliser Act (DMG) regarding the use of biogas slurry as economic fertiliser.

- **Fertiliser legislation** (DMG) regarding the use of biogas slurry as farm fertiliser.

- the Immission Control Act (BImSchG) insofar as agricultural biogas plants are regarded as plants requiring a permit in the case of a functional unit with a CHP unit with a thermal capacity of more than 1 MW pursuant to § 4 BImSchG in conjunction with the 4th BImSchV.

- **the Water Resources Act** (WHG) to the extent that groundwater protection in the handling of substances hazardous to water (the necessary operating materials oils and greases, for example) and the handling and spreading of liquid manure are subject to requirements under water law.

- **Nature conservation law** (BNatSchG), if the construction of the biogas plant affects the flora and fauna.

- **Building law** (BauGB) insofar as the construction of the plant is a new building or a significant change in the use of existing buildings.

- **Plant safety and energy law** (EEC, EEG), which is not part of environmental law in the narrower sense.

The legal classification of digestate differs depending on the substrates used and the place of application. If only farm manure and renewable raw materials are processed in biogas plants, the digestate is considered farm manure. If biowaste is also fermented, the fermentation residue is also considered biowaste and must therefore comply with both fertiliser and waste law requirements, among other things regarding epidemic-hygienic harmlessness. In this case, the digestate must often be sanitised before being spread. Sanitation usually takes place before fermentation by heating to 70 °C for one hour or by thermophilic fermentation, in which 50 °C must be reached for the proven minimum retention time. For biowaste, this is prescribed by the Biowaste Ordinance."

In the Fertiliser Ordinance, particular attention must be paid to the specifications of the nitrogen values. Due to the protection of drinking water resources and the avoidance of further accumulation of nitrogen (via ammonium or nitrate), the limits and possibilities of fertilisation have been further restricted.

6. Examples

Example 1:

The feedstock for fermentation is farm manure (slurry, chicken manure, stable manure, straw, etc.) or by-products from agricultural production (fodder residues, silage maize).

a) The plant is operated by a farmer who applies the digestate exclusively to his own land.

Result: Even after anaerobic digestion, it is a commercial fertiliser; the KrW/AbfG does not apply if the application is carried out within the framework of good agricultural practice. The requirements of the Fertiliser Ordinance must be observed (blocking period, nutrient load, etc.).

b) The farmer or another enterprise passes on the fermentation residues (farm manure) or a part thereof to others for their own consumption.

Result: In addition to the consequences listed under a), it applies that the farm manure may only be placed on the market, i.e., dispensed, if it is hygienically safe. Approval as a fertiliser type is not required. However, according to § 4 of the German Fertiliser Ordinance, labelling requirements must be observed.

Example 2:

In addition to farm manure, source materials for fermentation are substances whose disposal is prescribed under the Animal Rendering Disposal Act, e.g.: leftovers, slaughterhouse waste, fats (see differentiation KrW/AbfG).

a) Recycling on the plant operator's own land

Result: These substances are not subject to waste legislation (§ 2 para. 2 no. 1 KrW-/AbfG). After anaerobic fermentation, it is a secondary raw material fertiliser. The regulations of the Fertiliser Ordinance must be observed (blocking period, nutrient load, etc.).

b) Utilisation on external land, i.e., placing the fermentation residues on the market.

Result: The fermentation residues must correspond to an approved fertiliser type according to the Fertiliser Ordinance. There is a labelling obligation according to the Fertiliser Ordinance. The requirements of the Fertiliser Ordinance must be observed (retention period, nutrient load, etc.).

Example 3:

In addition to farm manure, the feedstock for fermentation are substances that are subject to the KrW/AbfG as biowaste or only biowaste.

a) Utilisation on the plant operator's own land

Result: It is a secondary raw material fertiliser (biowaste) that is to be recycled according to the BioAbfV. The requirements of the Fertiliser Ordinance must be observed (blocking period, nutrient load, etc.).

b) Utilisation on external land, i.e., placing the digestate on the market.

Result: In addition to the consequences according to a), the product must correspond to an approved fertiliser type. There is a labelling obligation according to the Fertiliser Ordinance.

Note: In cattle and especially pig slurry, the heavy metal contents (copper and zinc) are often above the maximum limits provided for in the BioAbfV (100 mg Cu and 400 mg/kg Zn per kg dry matter). According to § 4 para. 3 sentence 4 of the BioAbfV, it is at the discretion of the competent authority (lower waste authority), in agreement with the competent technical authority (Saxon State Institute for Agriculture), to permit an exceedance of individual heavy metals according to § 4 para. 3 sentence 1, if impairments of the public welfare are not to be expected.

A prerequisite for the approval of exemptions pursuant to § 4 para. 3 sentence 4 BioAbfV (SMUL decree of 20.07.1999) for operators of biogas plants co-fermenting farm manure with other biowastes is that:

1. in the dry matter of the digestion residue only the contents of copper and/or zinc pursuant to § 4 Para. 3 Sentence 1 BioAbfV are exceeded, and

2. it can be assumed that, if the principles of good professional practice in accordance with the Fertiliser Ordinance are observed, no more than 8,000 g of zinc and 2,000 g of copper per hectare will be supplied with the application quantity of digestion residues over an average of three years, whereby 4 times the maximum copper content and 3 times the maximum zinc content in accordance with § 4 Para. 3 Sentence 1 BioAbfV must not be exceeded, or

3. the digestion residues are recycled on land that has been proven to be contaminated with copper or zinc by soil tests.

After examination of the existence of the prerequisites according to No. 2 and No. 3, a statement of the agricultural authority is to be requested.

Farms participating in the Saxon support programme "Environmentally Sound Agriculture" may only apply biowaste once within 5 years on one and the same area, whereby the legal provisions of the BioAbfV must be observed regarding quality and application quantity.

The provider of biowaste compost must be a member of a quality association.

7. Treatment or disposal of other residuals and interfering materials & contamination hazards

Operating materials produced in the plant that cannot be fed into a composting process or may not be recycled due to contamination are released for waste disposal.

For example, the compost resulting from the composting of solid fermentation residues is screened to remove coarse materials. This screened residue is sent to the residual waste incineration plant.

Operating materials such as rinsing water are recycled as far as possible. Rinsing water obtained from remission processes or cleaning is purified in wastewater treatment plants and cannot be used as farm fertiliser.

The fermentation residues are used as fertiliser for agriculture. Generally, fertilisation also causes an oversupply of nutrients in the soil. These can enter water bodies through rain and leaching and lead to eutrophication. Furthermore, groundwater can be enriched with nitrates and other nutrients that must be removed at great expense in drinking water treatment.

Heavy metal pollution from agricultural animal waste (slurry and manure) is controlled by appropriate legislation. Nevertheless, heavy metals are increasingly entering soils, groundwater, and ultimately the food chain through anthropogenic processes.

If waste from the food industry is used for the biogas plant, plastic packaging can enter the plant. Economic reasons lead to food residues with packaging entering the plant if these contaminants are insufficiently separated or removed - before feeding the plant.

This results in macro- and microplastics in the compost. Screening removes these as far as possible after rotting, but if the plastics are small enough, they are also spread on the fields. Through processes of decomposition, the plastics break down further and can thus enter the food chain.

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8. Quiz

This module contains a quiz. The quiz can be answered on-line, by using QR code below. The student receives per question an answer of either **correct** or **incorrect** and has to correct each wrong answer before proceeding to the next question.

(Scan with your Smartphone camera / QR Code reader app to access the quiz)

1. **Which products produce a biogas plant? (**Multiple answers**)**

   a. *Methane*
   b. *Liquid manure*
   c. *Nutrient-rich manure*
   d. *Farm manure*
   e. *Compost*
   f. *Energy and heat*

   Answer: all

2. **Which substrates are suitable for a biogas plant? (**Multiple answers**)**

   a. *Plants (corn, silage)*
   b. *Agricultural residues (like liquid manure, dung, green waste)*
   c. *Residues and waste from the food industry (like fats, residues of alcoholic production, biowaste)*

   Answer: a+b+c

3. **Which possibilities of processing fermentation residues must take place? (**Multiple answers**)**

   a. *Separation of liquid and solid components by separators*
   b. *Thickening, removal of water*
   c. *Mixing with structural substrate*
   d. *Heating*

   Answer: a+b+c

4. **What properties must liquid fermentation residues fulfil? (**Multiple answers**)**

   a. *Odourless*
   b. *Nutrient-rich*
   c. *Nutrient-less*
   d. *Viscous*
   e. *Less viscous*

   Answer: b+d

5. **Which 3 temperature-dependent phases are differentiated in composting? (**Multiple answers**)**

   a. *Degradation phase*
   b. *Conversion phase (cooling)*
   c. *Construction phase (isothermal)*
   d. *Hydrolysis*

Answer: a+b+c

6. **Until which temperature can the degradation phase takes place?**

  a. *50°C*
  b. *60°C*
  c. *70°C*
  d. *80°C*

Answer: c

7. **Which emissions are produced during composting? (**Multiple answers**)**

  a. *Heat*
  b. *CO_2*
  c. *Water*
  d. *Ammonia (CH_4)*
  e. *Energy*
  f. *Water*

Answer: a+b+c+d

8. **Which resources do aerobic microorganisms require during composting? (**Multiple answers**)**

  a. *Water*
  b. *O_2 (Oxygen)*
  c. *CO_2 (Carbon dioxide)*

Answer: a+b

9. **Which resources do anaerobic microorganisms require during composting?**

  a. *Water*
  b. *O_2 (Oxygen)*
  c. *CO_2 (Carbon dioxide)*

Answer: a

10. **Which resources are poisonous for anaerobic microorganisms?**

  a. *Water*
  b. *O_2 (Oxygen)*

Answer: b

9. Sources

Video

Link	Tags
https://www.youtube.com/watch?v=C-tysslWvHg	Biowaste fermentation Example Hamburg; fermentation residue utilisation through open composting in the city of Mieten
https://www.youtube.com/watch?v=uGVzReGRQFU	Digestate processing, thick sludge, separation of solids and aqueous fraction Especially: digestate refinement
https://www.youtube.com/watch?v=SXMaHCEKOz8	Fermentation residues are dried with the waste heat from the CHPs (10% residual moisture) and pelletised.
https://www.youtube.com/watch?v=13kry53eudk	Screw press for slurry or liquid fermentation residues well illustrated, separation of solid and liquid components. Liquids can be sent for biogas utilisation.
https://www.youtube.com/watch?v=NnK2f1G2ofo https://www.youtube.com/watch?v=G1LPY3EDjLU	General overview of wet process; Animated
https://www.youtube.com/watch?v=nMdpQkd8cek	Field report biogas plant
https://www.youtube.com/watch?v=sfpOJwT5Clc	General overview of drying processes; real images
https://www.youtube.com/watch?v=mIUG0bd31PE	Plastic in organic waste; composting plant (no fermentation), screening drum in function

Web

https://www.landwirtschaft.sachsen.de/biogas-in-sachsen-12858.html

Fertiliser Ordinance 2021 https://www.landwirtschaft.sachsen.de/duengeverordnung-duengegesetz-20287.html

From digestate to fertiliser - legal conditions
https://www.landwirtschaftskammer.de/duesse/znr/pdfs/2013/2013-04-25-biogastagung-02.pdf

German Recycling Management Act under revision
https://www.bmu.de/gesetz/kreislaufwirtschaftsgesetz/

Plastic contamination during fermentation and in the digestate.
https://www.merkur.de/lokales/schongau/schongau-ort29421/mikroplastik-von-biogasanlage-auf-felder-vorwuerfe-gegen-altenstadter-firma-13827785.html