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Association „KE&B - UV&P"
VAT.Nr.: BG176245551

61 Preki pat str., Sofia 1618
Bulgaria Tel./fax:(+359 2) 857 5197
E-mail: Biowaste.BG12@gmail.com

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**Project No TA-2011-KPOS-PP-78 „Technical assistance on waste management"**
**"Development of legal framework on bio-waste management and establishment of Quality Assurance System for Compost and National Organization of Quality Assurance for the Compost"**

**Development of Legal Framework on Bio-Waste Management and Establishment of Quality Assurance System for Compost and National Organisation of Quality Assurance for the Compost**

# STAGE III

## Development of national technical requirements for installation of bio-waste treatment (composting and anaerobic digestion) - Guidance on techniques and technologies for bio-waste treatment (best practices).

## Part II
## Technical Requirements for Anaerobic Digestion

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***Main Authors:***

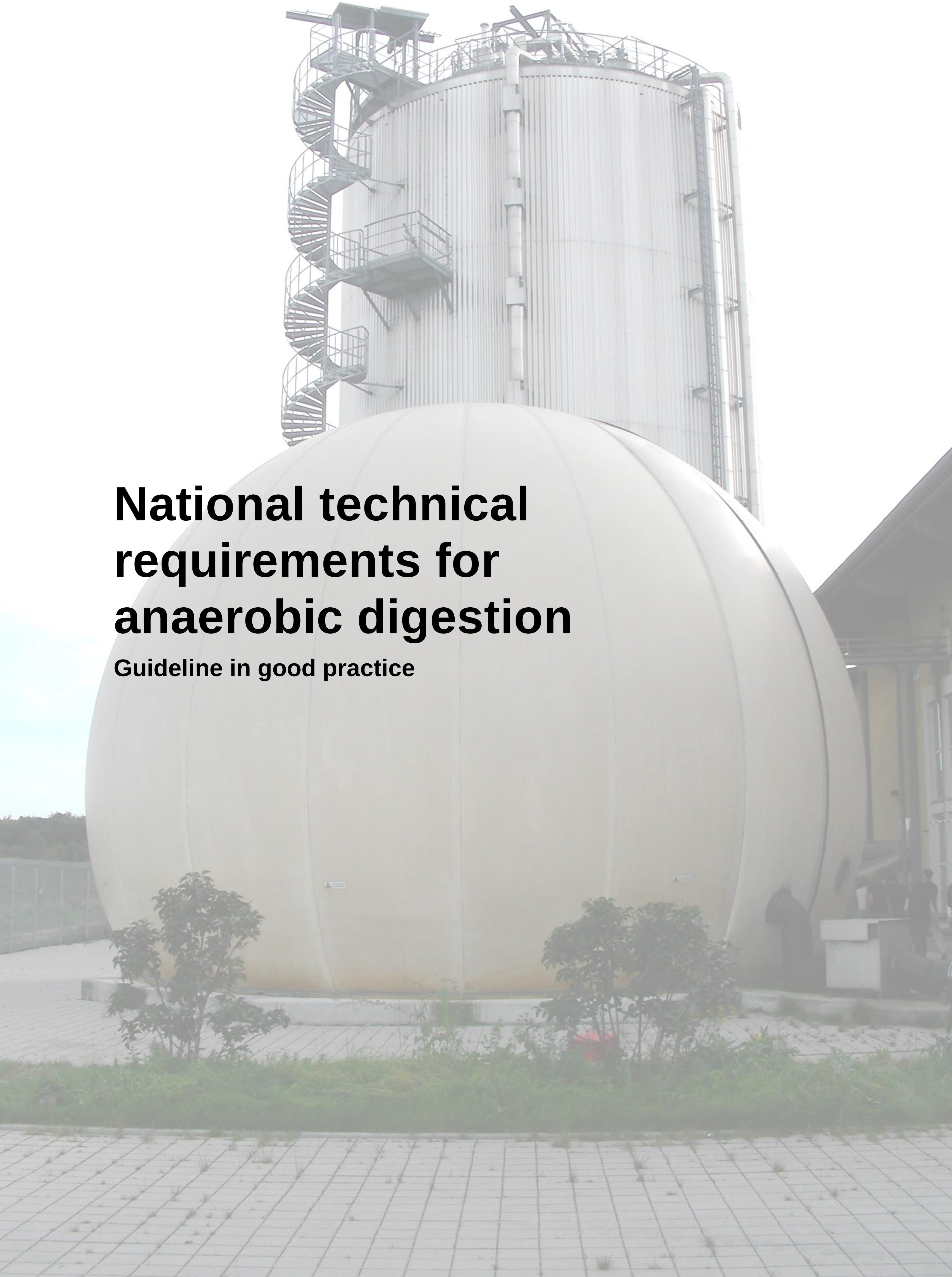
Enzo Favoino, Alberto Confalonieri, Francesco Boyer
*Scuola Agraria del Parco di Monza*

***in cooperation with:***

Florian Amlinger,
*Compost – Consulting & Development*

# National technical requirements for anaerobic digestion

## Guideline in good practice



# National technical requirements for anaerobic digestion

Guideline in good practice

**IMPRINT**

***Edited by:***
Bulgrian Ministry for Environment and Water
***Authors:*** Enzo Favoino, Alberto Confalonieri,
Francesco Boyer, Florian Amlinger
***xxxxxx:***

yyyyy 2013

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# 0 Anaerobic digestion basics

Anaerobic digestion is a process of controlled decomposition of biodegradable materials under controlled anaerobic conditions where free oxygen is absent. Applied temperatures support naturally occurring obligatory as well as facultative anaerobic bacteria, that convert (easily) degradable organic matter into biogas and digestate. The main biological steps involved in organic matter decomposition are summarised in the following chart:

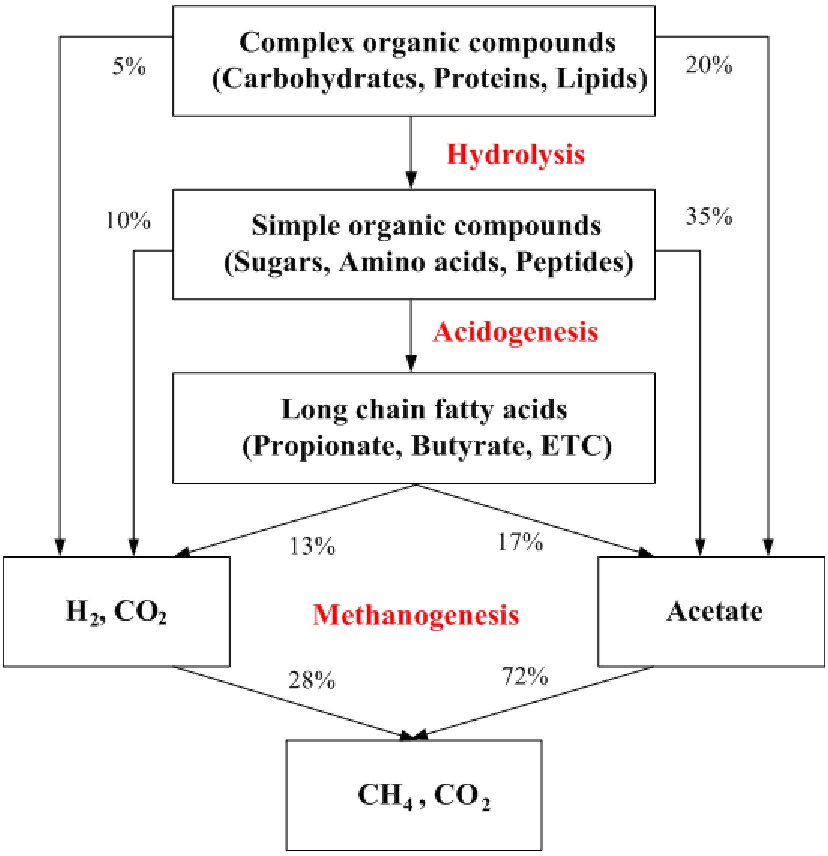



**Figure 1: Anaerobic pathway of organic matter degradation under anaerobic conditions. Source: Phoang University of Science and Technology (source http://home.postech.ac.kr/).**

**Table 1: Principle chemical process of aerobic and anaerobic metabolism**

| | |
|---|---|
| **AEROBIC COMPOSTING** | $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$<br>*set free energy = – 2875 kJ/Mol* |
| **ANAEROBIC FERMENTATION** | $C_6H_{12}O_6 \rightarrow 3\ CO_2 + 3\ CH_4$<br>*set free energy = – 132 kJ/Mol* |
| ***+ COMBUSTION*** | $3\ CH_4 + 6\ O_2 \rightarrow 3\ CO_2 + 6\ H_2O$<br>*set free energy = – 2671 kJ/Mol* |

Generally three main reactions occur during the entire process of the anaerobic digestion to methane:

- hydrolysis;
- acid forming (acidogenesis); and
- methanogenesis.

Although AD can be considered to take place in three stages all reactions occur simultaneously and are interdependent.

***Hydrolysis*** is a reaction that breaks down the complex organic molecules into soluble monomers. This reaction is catalyzed by enzymes excreted from the hydrolytic and fermentative bacteria (cellulase, protease and lipase). End products of this reaction are soluble sugars, amino acids; glycerol and long-chain carboxylic acids.

***Acetogenesis*** is facilitated by microorganisms known as acid formers that transform the products of the hydrolysis into simple organic acids such as acetic, propionic and butyric acid as well as ethanol, carbon dioxide and hydrogen. Acid forming stage comprises the two reactions of fermentation and the acetogenesis reactions. During the fermentation the soluble organic products of the hydrolysis are transformed into simple organic compounds, mostly volatile (short chain) fatty acids such as propionic, formic, butyric, valeric etc, ketones and alcohols.

The acetogenesis is completed through carbohydrate fermentation and results in acetate, $CO_2$ and $H_2$, compounds that can be utilized by the methanogens. The presence of Hydrogen is of critical importance in acetogenesis of compounds such as propionic and butyric acid. These reactions can only proceed if the concentration of $H_2$ is very low.

Important reactions during the acetogenesis stage are the conversion of glucose to acetate, the conversion of ethanol and bicarbonate to acetate.

***Methanogenesis*** is a reaction facilitated by the methanogenic microorganisms that convert soluble matter into methane. Two thirds of the total methane is produced by converting the acetic acid or by fermentation of alcohol (e.g. methanol) formed in the second stage. The other one third of the produced methane is a result of the reduction of the carbon dioxide by hydrogen.

# 1 Anaerobic digestion of biowaste: main techniques

Over the years, investigations and practice experience in processing a broad range of organic feedstock in biogas plants have brought to a differentiation of several biogas technologies.

## *1.1 Technologies and process types*

The main feedstock criteria and derived technologies and process types are:

- Dry matter content of the substrate
- Temperature profile of the fermentation process
- Loading system for the substrate (continuous – batch system)
- Number of reactors in series
- Type of reactors (vertical – horizontal; mixing technology)

### 1.1.1 Dry matter content

The main distinction is based on the dry matter of the substrate fed to the digester. In principle any fermentation process needs water. Therefore the distinction in digestion types is addressing the dry matter content of the substrate mix in the fermenter. Anaerobic digestion technologies can be divided in the following groups:

- Wet digestion, where the substrate shall have a dry matter content lower than 10%
- Dry digestion, where the substrate shall have a dry matter content higher than 20%
- Processes which are run at intermediate dry matter contents (between 10 and 20%) are less common, and are generally referred to as semi-dry.

The first one has its roots in the first applications of anaerobic digestion to sewage sludge in waste water treatment plants; liquid waste and organic waste characterised by a high moisture content and a relatively low contamination by contraries are the main substrates. Dry anaerobic digestion was specifically developed for approaching the treatment on unsorted waste (MSW), or organic waste rich in dry or hardly dilutable fractions such as wood, plastics, etc, in order to avoid hard pre-treatments, maintenance and consequent costs.

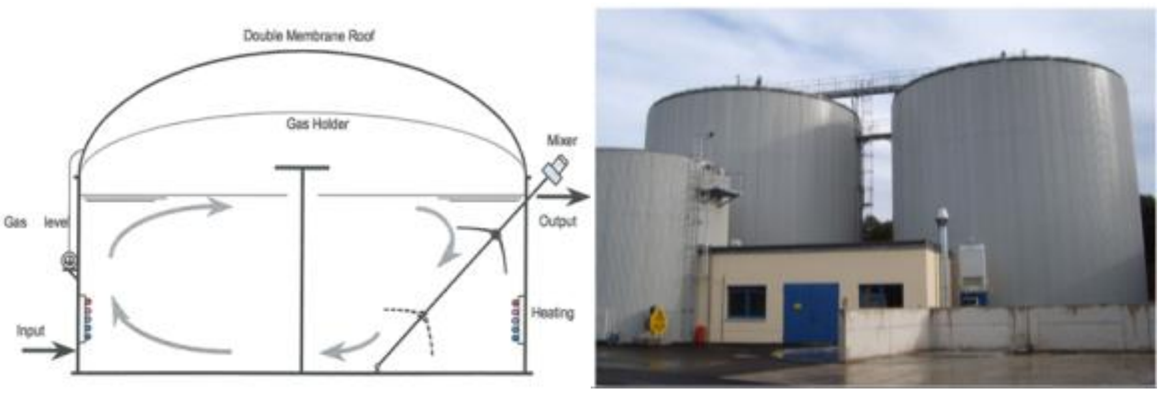



**Figure 2: Wet digestion system in a vertical shaped reactors**

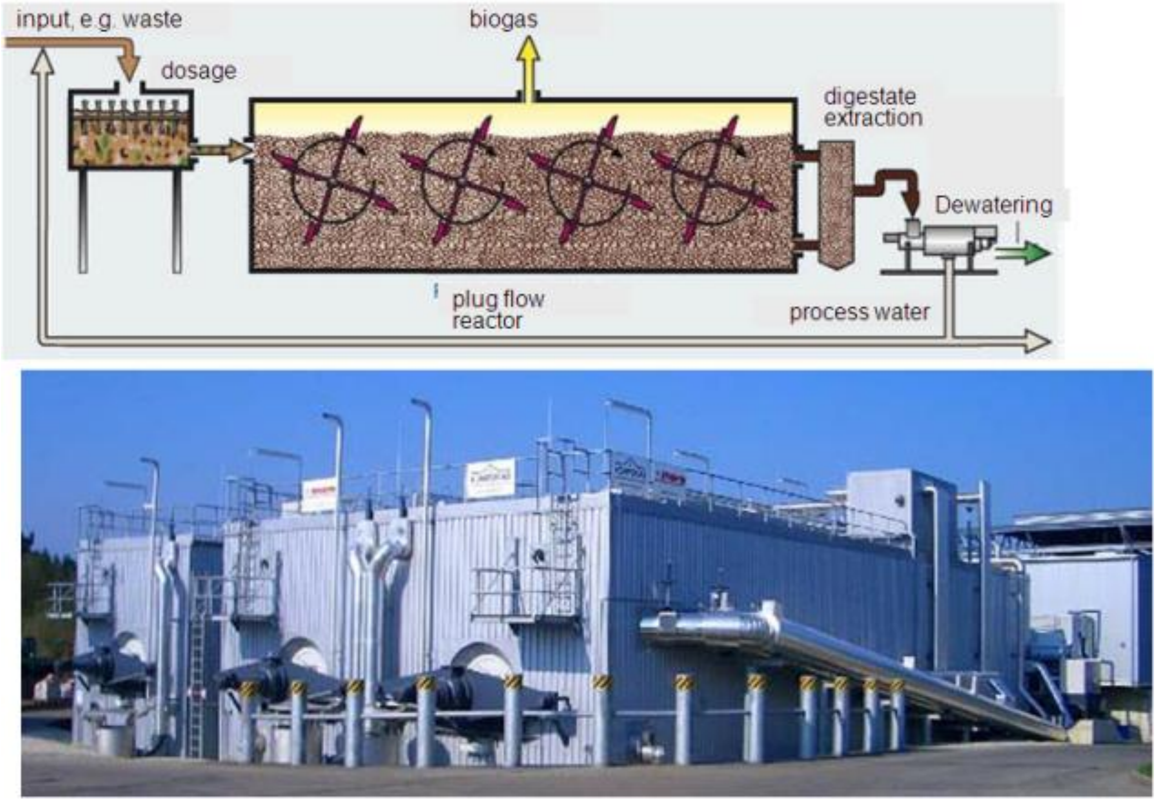



**Figure 3: Horizontal, dry digestion system (Source: Kompogas)**

### 1.1.2 Temperature profile

A second classification is based on the temperature at which the anaerobic process is performed. The following classes of process are then identified:

- Psychrophile processes (average temperature 20°C)
- Mesophile processes (average temperature 38°C)
- Thermophile processes (average temperature 55°C)

Mesophile and thermophile processes are the most diffused ones at industrial scale; the first ones are generally characterised by lower capital and management costs, and by “robust” biological processes. Thermophile reactors, on the other hand, can achieve a faster biogas production, although maintaining a proper process balance can be harder and more expensive.

### 1.1.3 Loading system

Reactors loading systems define either batch processes, and continuous processes; in the latter case, the digesters are periodically (daily or every few hours) fed with a given amount of waste, and an equal amount of digestate is withdrawn. If batch technologies are considered easier to be managed, a higher specific biogas production is generally granted by continuous processes, where microbial kinetics are constantly kept at their best.

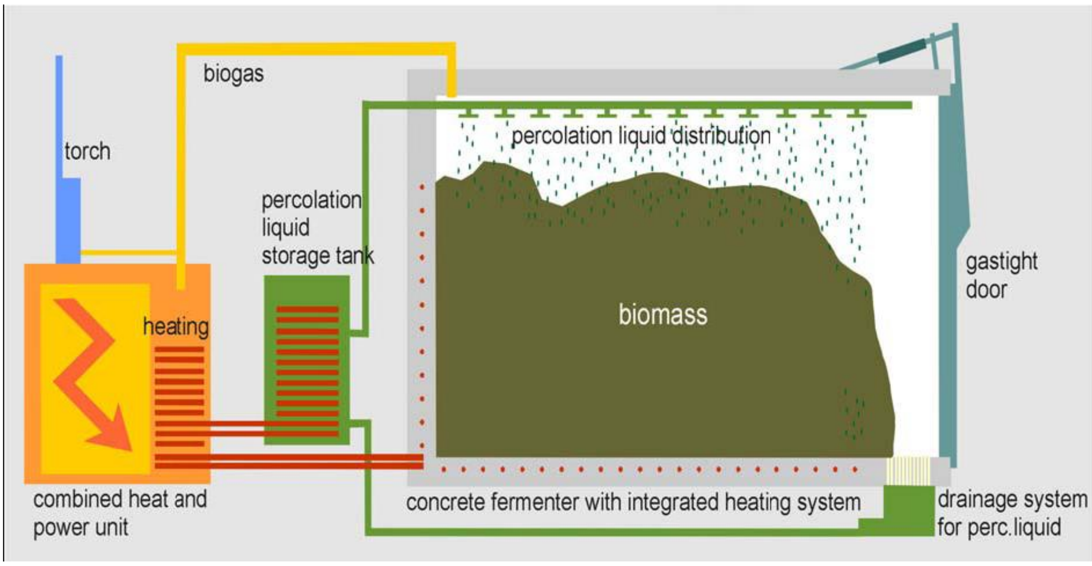



**Figure 4: Batch type digestion (Source: Bekon)**

### 1.1.4 Single or multi-stage technologies

A last technological dichotomy is related to the number of bioreactors employed in the anaerobic process. In fact, the chain of reactions which bring to the production of methane from the complex organic matter produces intermediate metabolites which can negatively interfere with other steps of the process. More specifically, the first hydrolytic steps produce high amounts of Volatile Fatty Acids (VFA) which slow down the formation of methane by methanogenic bacteria. On this presumption, the physical separation of in-gestate at different stages can enhance the overall process performances. This is realised by multi-stage technologies provided by two or more digesters, in contrast to one-stage technologies where the complete process is performed in a single bioreactor (or several ones put in parallel).

10-20% increase in biogas production can be achieved in multi-stage technologies compared to single stage ones, alongside with a simpler biological process control. Besides, in case of failures in one of the reactors, it is possible to temporarily bypass it performing a single stage process without compromising the overall production. on the other hand, as one can imagine, single-stage technologies advantages can be found in their being less expensive and less space demanding than multi-stage ones.

### 1.1.5 Type of reactors

As far as the digesters shape is concerned, one can divide the different technology as follows:

- continuous systems can be
  - fully mixed vertical systems (generally coincident with wet systems, see fig. 2)
  - upright vertical plug flow systems (dry technologies)
  - horizontal plug flow reactors (dry technologies, see fig. 3)
- discontinuous systems are mainly batch processes. Usually the fermentation units are designed as batteries of a certain number of containers (biocells) in order to reach a quasi-continuous process with almost consistent gas production (see fig. 4)

### 1.1.6 Mixing technology

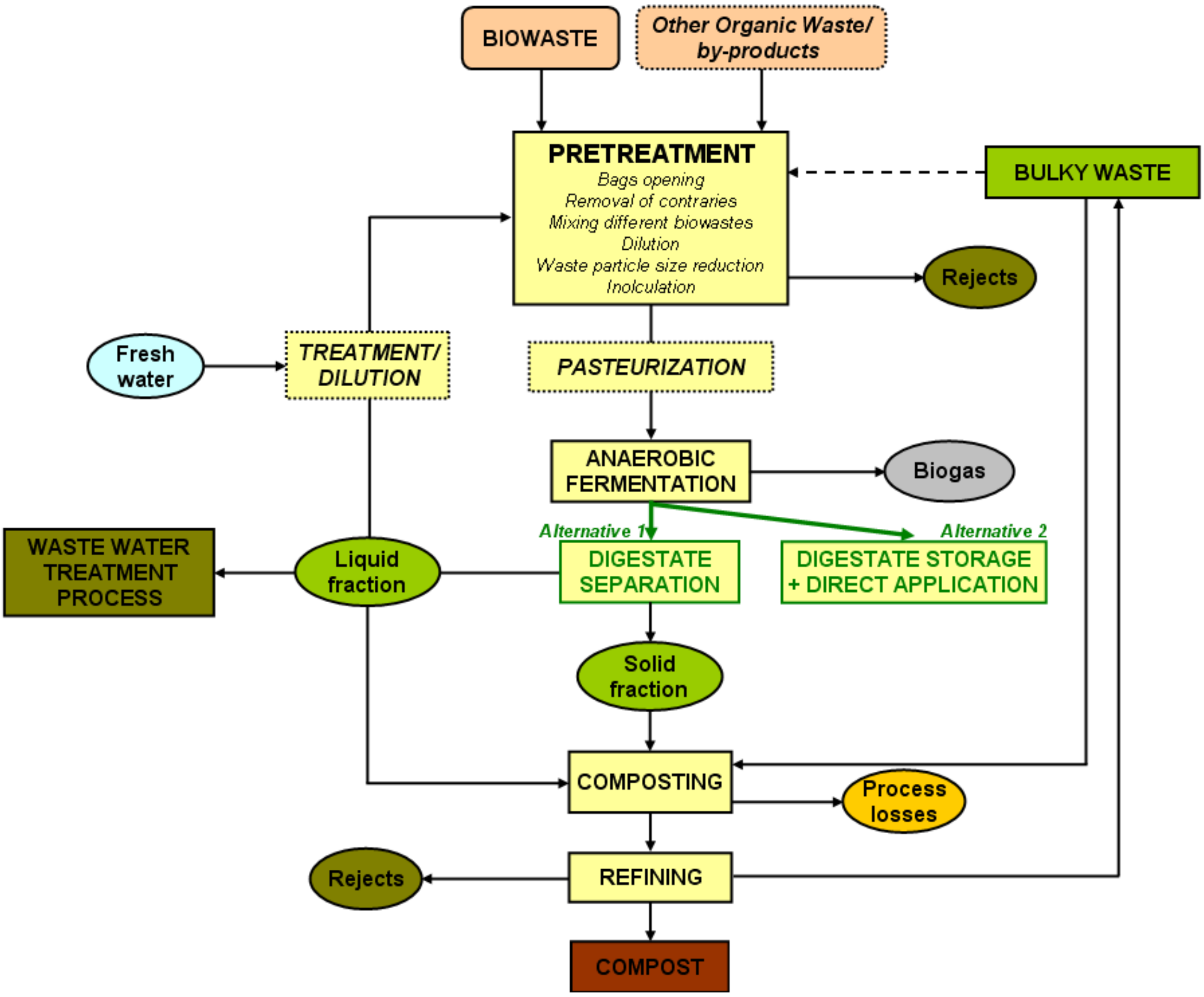
The fully mixed vertical reactors are regarded the "classical wet digestion" and still the most common (see Figure 2). They are generally mixed by agitators or hydraulically; to be capable of being mixed thoroughly the material has to be fairly wet.

In the dry continuous AD systems, the material moves through the reactor without being mixed with fresher or older material to a large extent.

For the dry batch systems the material has to be palable, namely sufficiently solid to allow it to be handled with a front-end loader (Figure 4). As for dry continuous ones, dry batch systems are not provided with any mixing devices.

### 1.1.7 Process flowsheet and description

Depending on the technology, biowaste anaerobic digestion is performed according to a number of different operational steps which can be summarised by the following general flow chart.




*Notes: Dotted arrows mean optional applications, and dotted boxes mean optional operations. The digestate produced at the end of the anaerobic fermentation step, can either be stored and directly applied into soils or, preferably, be further processed by means of composting.*

**Figure 5: General flow chart of an anaerobic digestion process**

# 2 Input materials and additives

## 2.1 Main feedstocks

As summarised in fig. 8, among the different possible feedstock differences exist in terms of suitability for anaerobic digestion and in the choice of the best fitting technology.

Generally speaking, due to its biochemical features, lignin is a hardly digestible material, when not inhibitory for anaerobic micro-organisms. Lignin rich feedstock (green waste or biowaste commingling food and green waste) are thus the least suitable materials for anaerobic processes. On the other hand, highly putrescible materials are provided with a high energy content which can be converted in biogas. It is the case for example of food-waste and organic by-products from food processing industries.

Anaerobic processes are strictly related to liquid environments. Thus water rich materials (and liquid organic waste above all) can be anaerobically recovered on their own, where composting technologies would require those substrates to be mixed with bulky materials (i.e. green waste) in order to reduce moisture content and increase the permeability to oxygen.

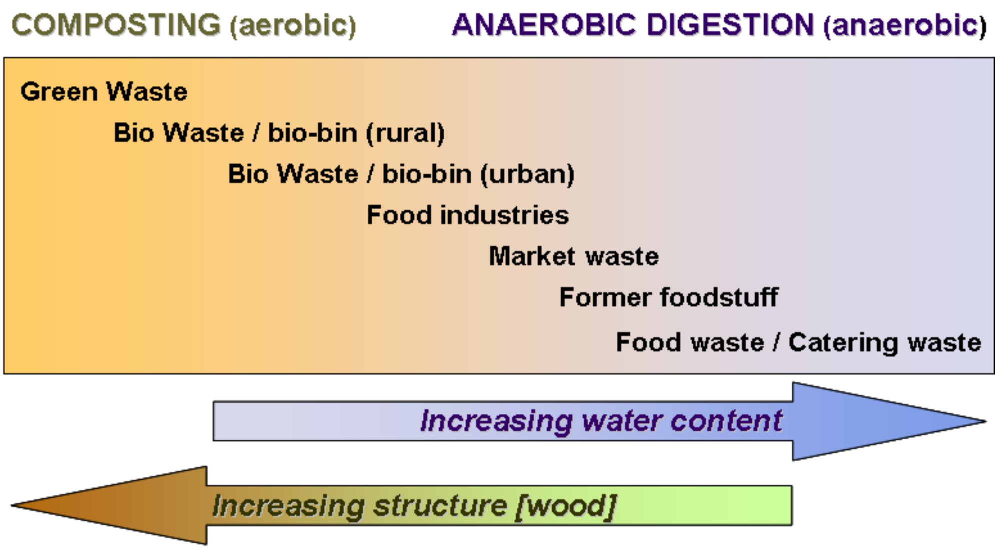



**Figure 6: Principle suitability of main material groups for composting or anaerobic digestion**

Depending on their chemical composition, feedstock have different biogas production potentials and compositions (see Table 2) whose actual expression depends of course on the process technology, parameters and conditions chosen.

**Table 2: Biogas Potential Production of the main substrates**

| Organic Waste | $Nm^3/tVS$** | $\%CH_4$ |
|---|---|---|
| Organic fraction of MSW* | 650-750 | 52 |
| Market waste | 450-550 | 54 |
| Fruit scraps | 450-550 | 56 |
| Fat | 950-1.100 | 56 |
| Whey | 400-550 | 57 |
| Slaughter waste | 700-900 | 53 |
| Sewage sludge | 200-300 | 70 |
| Pig slurry | 350-450 | 59 |
| Cattle slurry | 400-500 | 55 |

* separately collected from garden waste

** VS … volatile solids

The Annex lists feedstock as defined by Annex 1 of the Biowaste Ordinance, specifically suited for AD.

## *2.2 Additives*

Additives to the fermentation may be applied in order to stabilise and optimise the anaerobic digestion process. The maximum quantity should be 2 % (based on fresh mass) of the input material. Only those additives should be used with declared and proven effect to improve the biogas process. The following effective substance groups may be used:

- flocculation agents and flocculation aids
- trace elements
- precipitants
- enzymes
- free and immobilized archaeal, prokaryotic and eukaryotic biomass
- emulgators (e.g. tensides)
- anti foam agents
- complexing agents
- antiscalants
- macromolecules (Na, Mg, Ca, Carbonate and Phosphate)

## 2.3 *The process steps*

### 2.3.1 Reception and pre-treatment

Biowaste of domestic origin holds the peculiarity of being a heterogeneous material both in its organic matter composition, its physical state and in the presence of contraries. The aims of the pretreatment can be roughly grouped in the following:

- opening of bags and unpacking of (expired) former foodstuff
- removal of contraries which could potentially negatively interfere with the further mechanical and biological process steps (plastics, sand and inert materials, metals)
- mixing with different kind of organic feedstock, in case of co-digestion
- diluting or concentrating waste in order to reach a proper dry matter content, coherent with the biological technology chosen; water, digestate or a mixture of waste at different moisture content are the most common solutions adopted
- reducing material particle size (generally within a diameter of about 50mm, or down to 12 mm in case of cat. 3 animal-by-products) in order to maximise the surface available to microbial attack
- inoculating "fresh" feedstock with pre-adapted anaerobic micro-flora. This is generally made possible by adding a certain amount of digestate to the starting mix.

Pre-treatment may be designed by combining typically the following features:

A. bags opening, (possible) screening, centrifuge/hydropulping/pressure, grit (low density inerts) removal

B. bags opening, screening, Ferrous metal removing, densimetric separation, (possible) dilution

C. bags opening, mixing with digestate (10 to 50% by weight) and possible mixing with bulky-waste

The first layout mainly refers to wet digestion processes and the third one to dry-batch processes (performed in bio-cell shaped reactors), the second one is mainly suitable for dry or semi-dry anaerobic digesters.

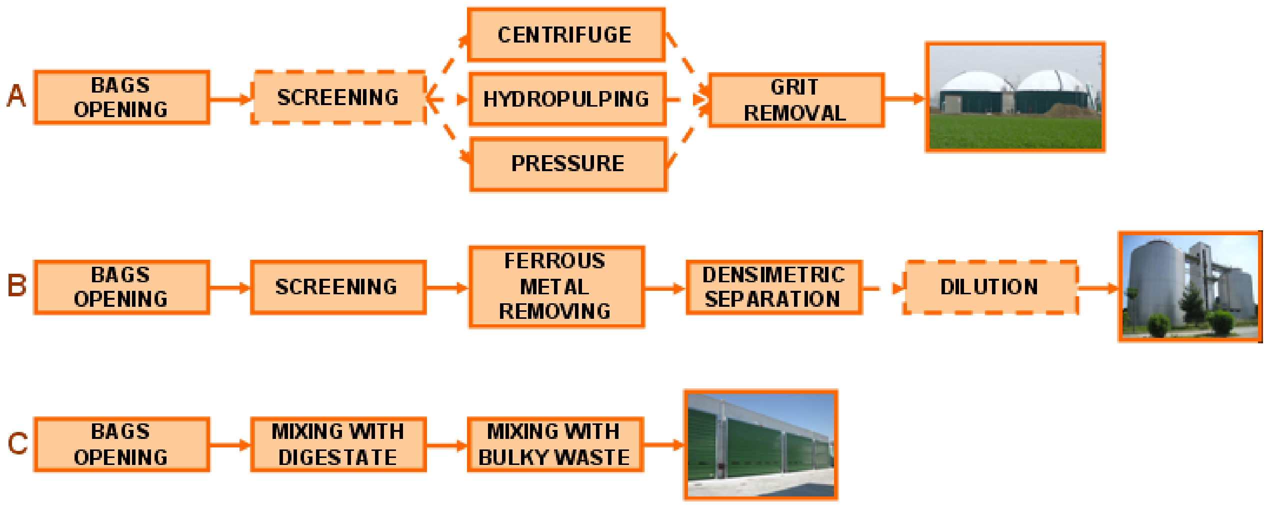


**Figure 7: Comparative flow-charts of different pre-treatments**

### 2.3.2 General requirements hygienisation / pasteurisation

A pre-pasteurisation of biowaste shall be performed, in accordance with *Biowaste Ordinance* and the *EU Animal By-Products Regulation* which allows the mass to undergo thermal treatment at the required temperature for a minimum time period, in order to guarantee far reaching eradication of pathogens.

In accordance with the ABPR, the pasteurisation unit for Category III materials must guarantee a theramal treatment of a t least 1hour at 70 °C and a maxiu particle size of 12 mm. However the

*Biowaste Ordinnace* establishes national exemption for Catering Waste also if treated together with:

- manure;
- digestive tract content separated from the digestive tract;
- milk; milk-based products; milk-derived products; colostrum; colostrum products;
- eggs; egg products;
- animal by-products referred to in art. 10(f) of Regulation (EC) No 1069/2009, which have undergone processing as defined in art. 2(1)(m) of Regulation (EC) No 852/2004.
- All other ABP that have been processed in accordance with regulation (EC) No 1069/2009 elsewhere.

For those materials no pasteurisation unit is required if the following time-temperature profiles or processing schemes are applied:

- Thermophile anaerobic digestion at 55°C during at least 24h and a hydraulic retention time of at least 20 days
- Thermophile anaerobic digestion at 55°C followed by pasteurization (70°C, 1h)
- Thermophile anaerobic digestion at 55°C, followed by composting in compliance with the hygienisation rules for composting as defined by the *Biowaste Ordinance*
- Mesophile anaerobic digestion at 37-40°C, followed by pasteurization (70°C, 1h)
- Mesophile anaerobic digestion at 37-40°C, followed by composting as defined by the *Biowaste Ordinance*

**Figure 8: Example of pasteurisation unit (Source: Bios1 Gmbh)**

## *2.4 The fermentation process*

The following provides a short description of the main sections of the anaerobic digestion, highlighting the main differences the most common technologies and process designs.

### 2.4.1 Reactor loading

Pre-treated biowaste, is fed to the digester (or the primary digester, in case of multi-stage technologies).

The following loading systems are in use:

- Pipelines in combination with hydraulic pumps applied for continuous feeding systems, for semi-liquid ingestate,
- Wheel loaders in case of dry-batch technologies.

The first ones are generally considered cleaner (since the feedstock flows inside the pipelines) while the second one are regarded as being more robust, since less complicated and technologically simpler.


**Figure 9: Ingestate loading systems: pipeline (top, source Veltrass) and wheel loader (down)**

### 2.4.2 The digester and related equipments

Depending on the technology, the fermenter can be equipped with facilities for:

- mixing ingestate;
- keeping the targeted process temperature;
- collecting heavy inerts at the bottom of the fermenter (stones, sand)
- collect light inerts from the surface of the digestion substrate (e.g. plastics)
- recirculate digestate

***Mixing equipments***

Mixing equipments have the role of increasing the degradation rate of fermentable organic matter, with the advantage of shortening process duration and/or increasing biogas specific production.

Common types of mixing devices are summarised in Table 3.

**Table 3: Pros and cons of different types of mixing devices (source CITEC, 2004)**

| Type of mixing device | Advantages | Disadvantages |
|---|---|---|
| Gas injection – cover – mounted lances | Lower maintenance and less hindrance to cleaning than bottom-mounted diffusers.<br>Effective against scum buildup | Corrosion of gas piping and equipment.<br>High maintenance for compressor. Potential gas seal problem.<br>Compressor problems if foam gets inside.<br>Solids deposition.<br>Plugging of gas lances. |
| Gas injection – bottom mounted diffusers | Better movement of bottom deposits than cover-mounted lances | Corrosion of gas piping and equipment.<br>High maintenance for compressor. Potential gas seal problem. Foam problem. Does not completely mix fermenter contents. Scum formation. Plugging of diffusers. Bottom deposits can alter mixing patterns. Breakage of bottom-mounted gas piping. Requires fermenter dewatering for maintenance. |
| Gas lifter | Better mixing and gas production and better movement of bottom deposits than cover-mounted lances. Lower power requirements | Corrosion of gas piping and equipment.<br>High maintenance for compressor. Potential gas seal problem. Corrosion of gas lifter. Lifter interferes with fermenter cleaning. Scum buildup. Does not provide good top mixing. Variable pumping rates. Requires fermenter dewatering for maintenance if bottom-mounted. Plugging of lances. |
| Mechanical stirring – low-speed turbines | Good mixing efficiency | Wear of impellers and shafts. Bearing failures. Long overhung loads. Interferences of impellers by rags. Requires oversized gear boxes. Gas leaks at shaft seal. |
| Machanical stirring – low-speed mixers | Break up scum layers | Not designed to mix entire tank contents. Bearing and gear box failures. Wear of impellers. Interference of impellers by rags. |
| Mechanical pumping – internal or external draft tubes | Good top to bottom mixing. Minimal scum buildup. | Sensitive to liquid level. Corrosion and wear of impeller. Bearing and gear box failures. Requires oversized gear box. Plugging of draft tube by rags. |
| Biogas blowing from bottom | Good even in high solids content system | Higher energy costs due to biogas compression |

**Figure 10: Example of biogas blowing from bottom of a Valorga fermenter (left) and a mechanical low speed mixer (right)**

***Thermal adjustment***

Ingestate must be brought and kept at the temperature required by the specific technology chosen. Thermal adjustment can be made outside or inside the reactor. In the first case, ingestate is preheated before being fed to the reactor by means of heat exchangers. In the second case, besides heat exchangers it is possible to make use of vapour injection inside the fermenter. In this case, an efficient mixing equipment must be assured, in order to prevent local temperature gradients with possible ingestate overheating and thermal shocks to the microflora.

**Figure 11: Example of heat exchanger for ingestate pre-heating**

***Managing heavy inerts (sand and stones)***

Inerts sedimenting on the reactors floor is prevented by:

1. removal by means of mechanical separaration during pre-treatment (in particular, pulping systems provided with grit removal systems have been proven to be sufficiently effective);
2. continuous mixing inside the fermenter, keeping inerts floating in the substrate and thus supporting to be thrown out with digestate
3. proper slope design of the fermenter's floor facilitating the allocation of heavy inerts in a positions from which it can be  easily extracted,

***Removing light inerts (above all plastics)***

This can be best done by periodically removal through superficial inspection/removal points.

***Digestate recirculation***

Digestate is partially recirculated in order to:

- to dilute the feedstock mix, by this reducing the demand of fresh water;
- inoculate the fresh substrate with anaerobic microflora, in order to speed up fermentation rates; and
- pre-heat ingestate (see above)

Digestate recirculation is carried out

- via pipelines in wet and continuous dry technologies;
- with simple wheel loaders in dry batch systems mixing fresh feedstock with digestate extracted from the fermentation reactors.

### 2.4.3 Process management and control

Ingestate is fed to the fermenter in quantities calculated according to a the technology-specific *Organic Loading Rate* (OLR) (see Table 4).

Because some organic materials are hardly accessible for anaerobic degradation a complete transformation of the entire organic matter would require extreme long retention times in the fermenter(s) and thus, enormous fermenter volumes. Consequently, and considering an acceptable cost to benefit ratio the challenge is to achieve an optimised degradation quota.

Therefore, the *Organic Loading Rate* (OLR) is an important operational parameter, indicating the quantity of *Volatile Solids* (in kg dry matter) that can be fed into the fermenter per m³ of fermenter volume and per time unit (normally per day)

$$B_R = (Q*TS*VS)/(VR) \qquad [kgVS*m^{-3}*d^{-1}]$$

*Where:*

*Q: daily load [t*d-1]*

*TS: Total Solids [% of fresh weight]*

*VS: Volatile Solids [%TS]*

*VR: Volume of reactor [m3]*

Ranges of *Organic Loading Rate*  depending on the fermentation system at given in Table 4.

**Table 4: Organic Loading Rate (OLR) range with respect to fermentation technology**

| Technology | OLR ($kgVS*m^{-3}_{fermenter}*d^{-1}$) |
|---|---|
| Wet | 2-4 |
| Dry | 3-8 |

Several parameters have to be monitored along the process, in order to assure optimal performances. The following table summarises the main ones. It is important to stress that if some of the parameters have ranges of acceptability which allow the process to be performed under optimal conditions, other ones are strictly dependent by the technology chosen, the kind of biomass treated and other local conditions. For this reason, it is important to define for each plant a database collecting the history and evolution of each parameter, monitoring in particular their constancy over time rather than their absolute values.

**Table 5: Main parameters to be monitored in ingestate and digestate along the process**

| | Parameter | Optimum range | Approximate frequency of controlling |
|---|---|---|---|
| MATERIAL IN FERMENTATION | Biogas composition | e.g. 55 – 65% | Daily |
| | pH | 7-8 | |
| | Volatile Fatty Acids (VFA) | 500-3.000 mg acetic acid equivalent/liter | Weekly |
| | Alkalinity | 3.000-5.000 mg$CaCO_3$/l | |
| | VOA/Alkalinity ratio | 0.3-0.5 | |
| | Redox potential | <-400 mV | |
| | Total Solids | <12% for Wet Digestion<br>10-20% for Semy-dry digestion<br>>20% for dry-digestion | |
| | Volatile Solids | >75% of DM | Monthly |
| | Nitrogen | Depending on the type of matrices fed | |
| | Ammonia | Always <3.000 mg/l (optimum 200-1.500 mg/l) | |
| | Carbon/Nitrogen ratio | <30 | |
| | COD | 100.000-140.000 mg$O_2$/l | |
| | $BOD_5$ | 50.000-90.000 mg$O_2$/l | |
| | Organic Carbon | Depending on the type of matrices fed | |
| | Micro-elements | Co <1-5 ppm, Ni 5-20 ppm, Se < 0,05ppm, W<1 ppm, Fe 10-5000 ppm | Yearly |
| DIGESTATE | pH | 7,5-8,5 | Weekly |
| | Electrical conductivity | | |
| | Total Solid | Depending on the type of matrices fed | Monthly |
| | Volatile Solids | Reduction about 60-70% of ingestate | |
| | COD | 25.000-45.000 mg$O_2$/l | |
| | $BOD_5$ | 15.000-30.000 mg$O_2$/l | |
| | Total Nitrogen | Depending on type of feedstock | |
| | Ammonium (NH4) | Depending on type of feedstock | |

A further important parameter for the Dimensioning of the fermenter is the Hydraulic Retention Time (HRT), the calculated mean time the feedstock is retained in the fermenter until being thrown out in a continuous system. Here the reactor volume is put in relation to the daily fed quantity of ingestate.

$$HRT = V_R/V \qquad [d]$$

*Where:*

*$V_R$: Volume of reactor [$m^3$]*

*V: Daily volume of ingestate [$m^3 \cdot d^{-1}$]*

Depending on the technology, the process can have a range of durations, or Hydraulic Retention Time (HRT) generally between 15 and 30 days. Possible variations depend on thermal profile and number of stages.

**Table 6: Hydraulic Retention Times (HTR) in dependence of the type of fermentation**

| Number of stages of fermentation reactors | HRT (days) | Thermal profile |
|---|---|---|
| Single stage | 20-28 | Mesophile |
| | 18-25 | Thermophile |
| Multi stage | 18-23 | Mesophile |
| | 15-20 | Thermophile |

# 3 Illustrative mass balances

In order to give a figure of the differences among the technological approaches to bio-waste anaerobic digestion, three illustrative mass balances are proposed, referred to:

- a wet fermentation approach
- a dry-continuous fermentation approach
- a dry-batch fermentation approach

In all cases, digestate is further treated for compost production

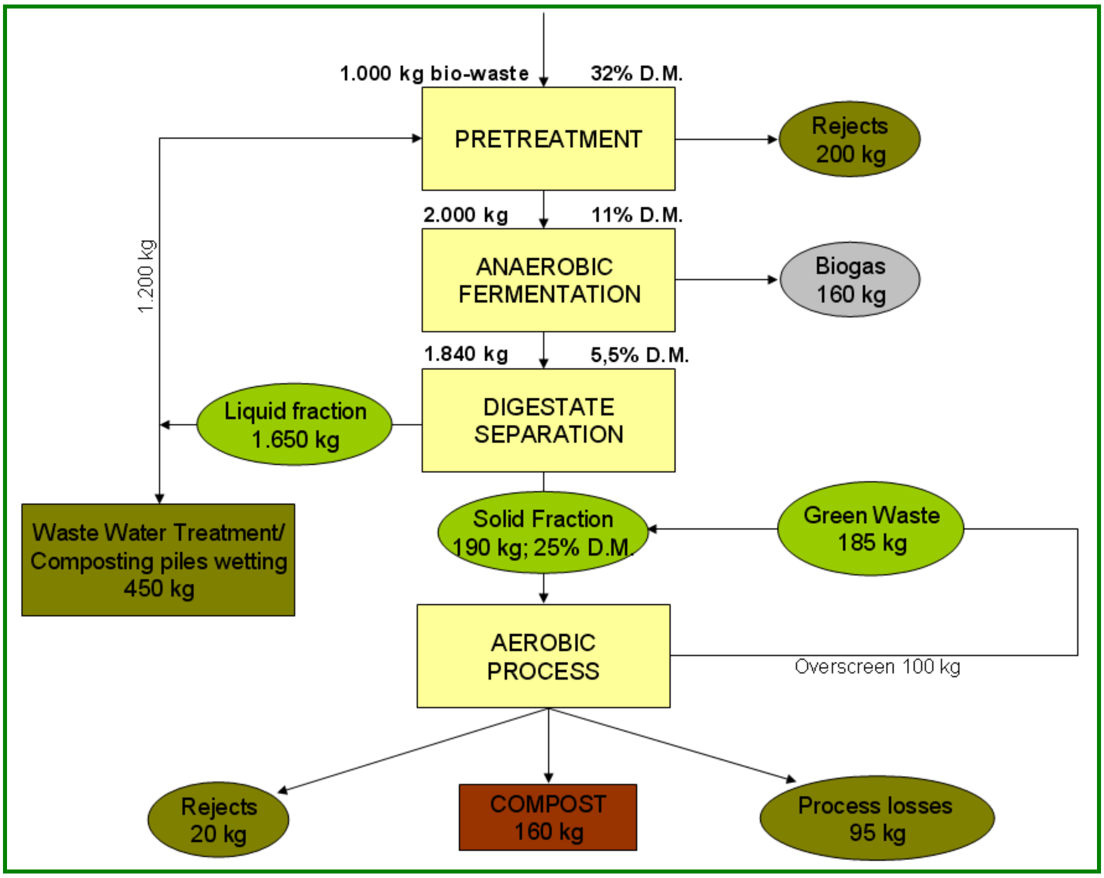



**Figure 12: Possible mass balance of a biowaste wet fermentation technology**

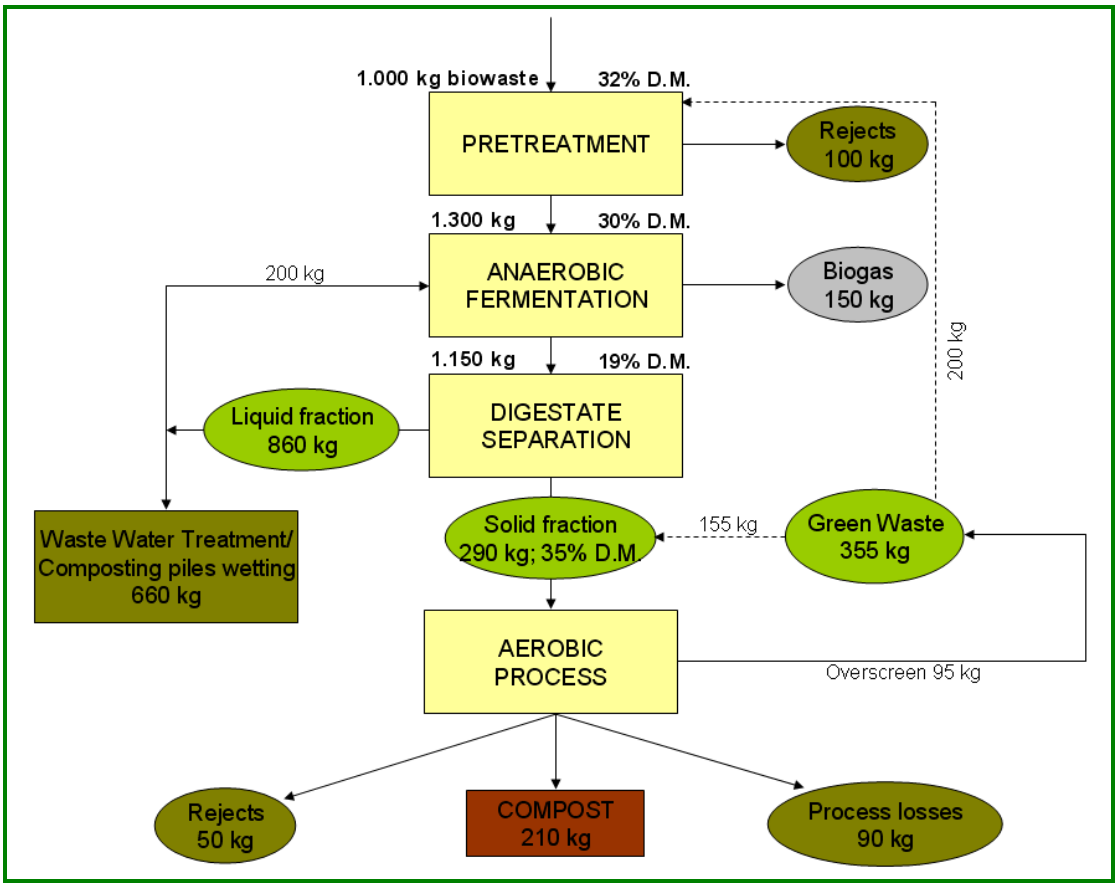



**Figure 13: Possible mass balance of a biowaste dry-continuous fermentation technology**

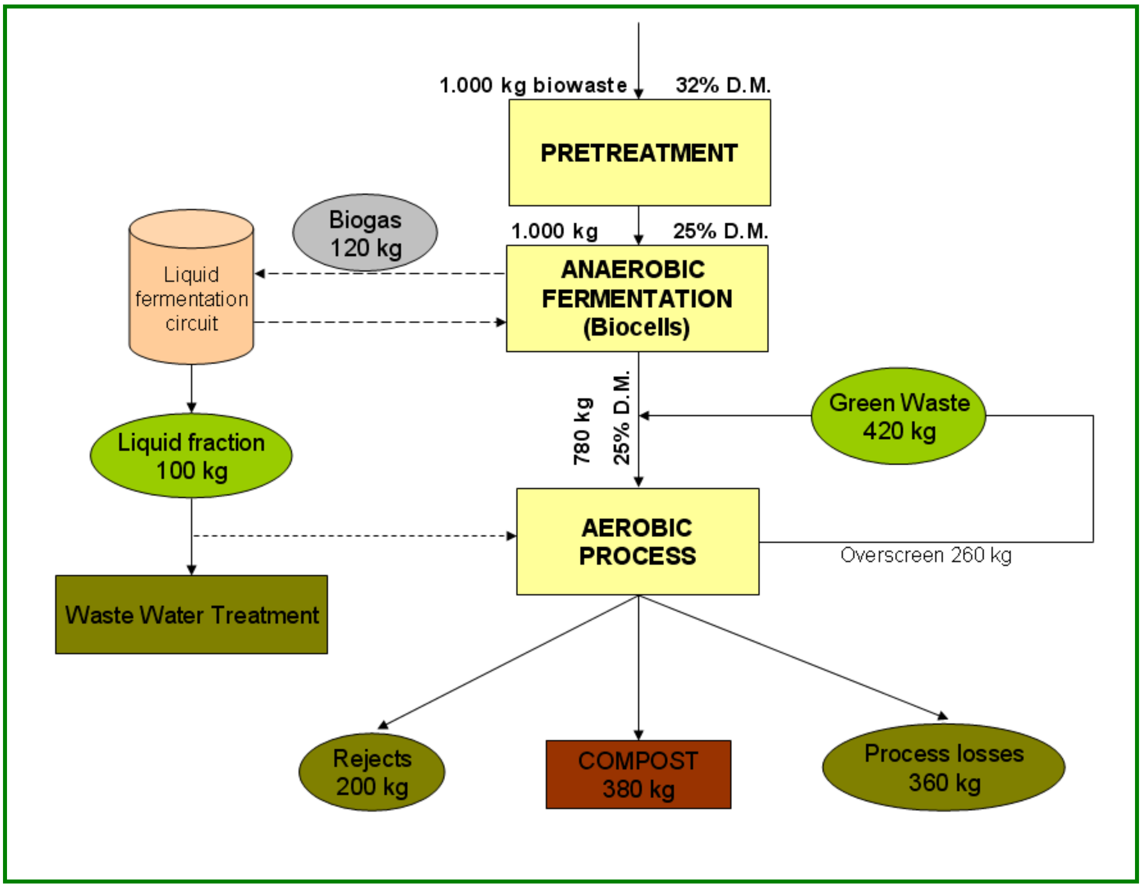



**Figure 14: Possible mass balance of a biowaste dry-batch fermentation technology**

# 4 Biogas - quality and use

The production of biogas and its composition depends on several aspects, ranging from biowaste composition to the technology features and performances. It is then useful to give a figure of the potential biogas production for some of the main biomasses (see Table 2).

Prior to its utilisation, the biogas produced is stored in gasholders which act as a buffer thus assuring the best working conditions for its further exploitation. Gasholders are usually dimensioned for holding the biogas produced in at least 4-5 hours. They can either be rigid or flexible, generally realised as “double” membrane technology. Rigid gasholders are usually settled alongside the fermenter, while flexible ones are placed on the roof of the reactors.

**Figure 15: Example of a rigid (top) and a flexible gasholder (below)**

The biogas produced can be utilized as

- renewable energy source in combined heat and power plants;
- vehicle fuel; or
- substitute of natural gas.

## *4.1 Biogas exploitation in combined Heat and Power plants*

In this case, a biogas pretreatment in necessary in order to:

- dewatering (by means of condensation in pipes or in a chiller)
- $H_2S$ removal (either biologically, with Sulphur oxidising micro-aerophilic bacteria, or chemically, flowing biogas through an oxidising mean)

Pretreated biogas is then fed to a combined heat and power engine able to recover:

- electricity (efficiency 38-40% of biogas LHV)
- heat (around 45% of biogas LHV)

In alternative, biogas can be used for district heating; in this case, heat recovery from biogas burning can reach 78-86% efficiency.

## 4.2 Biogas upgrading

The process of upgrading basically consists in enriching biogas in methane by means of $CO_2$ and trace elements removal, in order to obtain a final methane content between 96 and 99%, suitable to be used as biofuel for vehicles of grid injection. The process basically consists in the concentration of methane through carbon dioxide removal. Apart from methane and carbon dioxide, biogas can also contain

- water,
- hydrogen sulphide,
- nitrogen,
- oxygen,
- ammonia,
- siloxanes; and
- particles.

The main upgrading processes, all based on chemical and/or physical operations, and their performances, are:

**Table 7: Expected methane content according to the upgrading main technology**

| | Pressure Swing Adsorption | Water scrubbing | Organic physical scrubbing | Chemical scrubbing |
|---|---|---|---|---|
| Methane content in upgraded gas | > 96% | > 97% | > 96% | > 99% |

# 5 Digestate storage and treatment

Digestate is the relatively stable semi-solid or semi-liquid waste which can be submitted to the two main treatment and utilisation options:

1.) storage and direct application of digestate into soils
2.) mechanical separation:
    (a) dewatered solid digestate: drying with or without pelletising, aerobic treatment for compost production
    (b) liquids: recirculation in the plant (ingestate dilution, composting piles watering), direct application into soils, disposal

Digestate is generally stored in concrete tanks, which should be covered for capturing the residual biogas and in order to prevent uncontrolled fugitive methane emissions.

**Figure 16: Example of a uncovered (left) and covered (right) digestate storage tanks**

In case of direct application, digestate has to comply with the quality and use criteria of the *Biowaste Ordinance*.

Moreover, an additional refining section for removal physical impurities (glass, plastic, metals, etc) can be required as well.

## 5.1 *Compost production from dewatered or solid digestate*

The first step usually consists in the mechanical separation of digestate into a solid and a liquid fraction. Table xx lists the most common equipments indicating separation efficiencies.

**Table 8: Expected efficiency of solid-liquid separation according to the technology chosen**

| | Type of separator | Efficency of separation (%) | | |
|---|---|---|---|---|
| | | **Solids** | **N** | **P** |
| *Devices for coarse solids separation* | **Sieve** | 20-25 | 4-7 | 8-12 |
| | **Drum screen** | 28-40 | 8-15 | 30-42 |
| | **Helical** | 35-48 | 6-16 | 28-42 |
| *Devices for coarse and fine solids separation* | **Sedimentator** | 50-70 | 25-35 | 50-65 |
| | **Floater** | 70-90 | 30-40 | 70-90 |
| | **Centrifuge** | 55-65 | 20-26 | 73-87 |
| | **Belt press** | 50-70 | 20-35 | 60-80 |

**Table 9: Organic and inorganic N rates in digestate and the fractions deriving from solid/liquid separation**

| | | Digestate | Liquid phase | Solid phase |
|---|---|---|---|---|
| N organic | % of TKN | 30-40 | 30-40 | 30-40 |
| N-$NH_4^+$ | | 60-70 | 60-70 | 60-70 |

*TKN …. Total Kjeldahl Nitrogen*

Depending on digestate features and thickening system adopted the dry matter content of the solid fraction is usually between 20-40%, N concentration and *chemical oxygen demand* (COD) are comparable to total digestate. Still, the water soluble ammonium fraction is high (30 to 60 % of total N) and therefore caution just be put for proper application in order to minimise the risk of N leaching to the groundwater or emission of ammonia ($NH_3$) and nitrous oxide ($N_2O$).

Depending of fermentation temperatures (meso- or thermophile) concerns may still be there on insufficient pathogens reduction, especially at short hydraulic retention times in continuous digestion systems.

All this may lead to the conclusion that post-composting of digestate solid fraction which, owing to the reduction in putrescible organic compounds incurred during the anaerobic fermentation, can be performed in 4-6 weeks. The aims of the post-composting step are basically:

- the reduction of moisture content, thanks to heat production from aerobic oxidation of organic matter and subsequent evaporation of water in excess
- the reduction of free mineral N concentration, by a combined action of ammonia evaporation and its turning into an organic form due to microbial action
- the sanitisation, thanks to the production of biogenic heat and the increase of temperature over 55-60°C for several days
- the obtainment of a product suitable for wider markets than direct application on agricultural soil (horticulture, gardening, domestic applications, etc…).

As for digestate, a storage capacity for compost of at least 60-90 days shall be assured. This can be simply represented by a concrete floor upon which compost can be set in piles up to 3,5-4m high.

## 5.2 Information on end uses of digestate

Due to its high nutrition value for fertilisation, digestate is predominantly used in agriculture. The high level of soluble plant nutrients (N-P-K) makes it necessary to provide exact information to farmers in order to facilitate nutrient balance in good fertilisation practice. Salinity could also be elevated if food waste from restaurants and catering services is processed. Hence, declaration of *electrical conductivity* is also necessary, specifically if offered for the use in horticulture or agricultural fruit and vegetable production.

With the recommendations for proper application, it should be guaranteed that the utilisation follows best practice within the specified application area.

**Table 10: Obligatory parameters for compost and soil amendment from composting to be labelled as reported in the Biowaste Ordinance**

| Quality criteria | Parameter | Dimension |
|---|---|---|
| Soil improvement | Organic matter | [% DM] |
| | CaO | [% DM] |
| | C/N ratio | |
| Fertilising properties | Nitrogen (N) total | [% DM] |
| | Phosphorus ($P_20_5$) total | [% DM] |
| | Potassium ($K_2O$) total | [% DM.] |
| | Magnesium (MgO) total | [% DM] |
| | Sulfur (S) total | [% DM] |
| | Ammonium nitrogen ($NH_4$-N) | [mg/l] |
| | *Optional:* Nitrate nitrogen ($NO_3$-N) | [mg/l] |
| Material properties | Maximum particle size *if solid* | [mm] |
| | *Optional:* Bulk density *if solid* | [g/l FM] |
| | Dry matter | [% FM] |
| | *For horticulture / agricultural fruit and vegetable production*: Salinity / El. conductivity | [mS/m] |
| | pH value | |

Further important information to be provided for the user are:

- main groups of input materials used (biowaste, manure, sewage sludge, mixed municipal waste)
- statement of conformity with Biowaste Ordinance
- the recommended conditions of storage *(in case of solid digestate*);
- description of admissible application areas depending on the achieved quality pursuant to the *Biowaste Ordinance*
- recommended quantity for the proper use
- With the recommendations for proper application, based on the assessment report under art. 15 of the Biowaste Ordinance, it should be guaranteed that the utilisation follows best practice within the specified application area.

In addition further labelling requirements as laid down in the *Biowaste Ordinance* have to be respected.

# 6 General requirements for equipment and facilities for anaerobic digestion

The overall footprint of an anaerobic digestion facility can range between 0,3 and 1 $m^2$/ton biowaste treated/year. This accounts for all buildings and technical areas required for the process, in particular:

- reception/pre-processing hall, including pasteurisation unit if required
- anaerobic fermentation reactors
- mechanical post-treatment of digestate (e.g. dewatering)
- 4-6 weeks composting site in case of post-composting of the dewatered or solid digestate-
- Digestate storage (tanks, lagoons, silos, boxes or area under roof for dewatered solid digestate)
- Waste air cleaning in case of air sucked from closed halls for storing or pre-processing of organic feedstock (in most cases by means of biofilter)
- Liquid digestate depuration (biological or physical or thermal, i.e. evaporation, reverse osmosis, ultra-filtration, etc..) aimed at reducing N content and possibly salts, in order to be able to recirculate most of it at the front end of the process (fresh waste dilution)
- Offices/warehouses

## *6.1 Buildings*

A biowaste recovery facility must provide for enclosed areas for receiving and stocking high fermentable input waste (sludge, food waste etc.). Such structures (silos, covered windrows pools etc.) need to be designed according to the typology of incoming biomass and sized on a basis of a storage capacity of 2 days and a maximum of 5 days, in order to avoid uncontrolled decomposition and odour emissions.

Storage and tipping structures need to be easily accessible by trucks, with high-speed opening and closing doors.

Enclosed areas and structures must be provided for the management of pre-treatment phases whenever unpacked putrescible waste which can be a potential source of odours (i.e. food waste, market waste) are among the treated feedstocks. In other cases, pretreatment can be simply done under roof, in order to avoid bad interference by adverse climate conditions.

## *6.2 Impact management*

### 6.2.1 Odours

In order to secure the minimization of odour emissions and environmental nuisances, wherever there is a biological processing is taken place in enclosed buildings there must be air sucking and collection to a odour abatement unit (i.e. biofilter).

Thechnical and maintenance minimum criteria are the same as for biofilter systems applied in *composting* and *rchanical-bilogical treatment* (MBT) and aredescribed in the *“National Technical Requirements for Composting”*.

### 6.2.2 Other gaseus emissions

Depending on the total *Hydraulic Retention Time* (HRT) and the subsequent level of stabilisation after leaving the final fermenter digestate storage tanks shall be covered in order to prevent fugitive methane emissions. Exhaust air can be fed to biogas cleaning systems and further exploitation.

### 6.2.3 Wastewater

The facility must provide for a waterproof floor in all the operating areas (tipping, storage, pre-treatment, curing, post-treatment).

Wastewater should preferably recycled into the process, especially for biowaste pre-processing or in post-composting if this is installed..

### 6.2.4 Process Leachate

Leachate must be collected in a storage tank properly dimensioned; due to its easily degradable organic content, it can be fed to the fermenter or mixed to the biowaste during the pre-processing.

### 6.2.5 Liquid fraction from anaerobic digestion after partly dewatering of liquid digestate

This fraction, which can represent the main output from anaerobic digestion phase (typical range 40-100% of biowaste treated) can be either:

- Recycled in the post-composting step (exploiting the evaporation power of composting processes during the active rotting phase at temperatures above 50 °C)
- Recycled in the digester (or to the primary digester, in case of multi-stage technologies (possibly after a depuration step in order to reduce N content)
- Disposed to an own or an external WWTP, above all in order to reduce N-$NH_3$, BOD, COD, $Cl^-$ and $Na^+$

### 6.2.6 Rainfall

Rainfall on outdoor transit areas (excluding curing) should have a separation of the “first rain” (usually 5 mm) and the “second rain”.

First rain can be recycled in the process, both during pretreatment and curing phase, second rain can be discharged in groundwater or dikes.

For the calculation of first water rain need a proposed formula is:

$$C = (S \times P) / (1000)$$

*where*

*C = Storage needed (cubic meters)*

*S = Surface area (square meters)*

*P = First rain (mm) = 5*

### 6.2.7 Requirements for ***Health*** protection of workers

In order to prevent biological risk due to airborne pathogens (bioaerosols) and dust, workers involved in waste movement, shredding and screening must be provided with proper masks and machines with enclosed working cabins.

The biological process must secure the hygienisation of the biomass (see Chapter 2.3.2).

# 7 Feedstock list for Anaerobic Digestion

| Designation of waste material | | Further specifications also specifically with respect to AD | EWC Code | Corresponding EWC waste type |
|---|---|---|---|---|
| (a) | (b) | (c) | (d) | (e) |
| **1** | **Waste for biological treatment fro*m exclusively vegetable origi*n (NO animal by-products or meat)** | | | |
| **1.1** | **Organic vegetable waste from garden & parks and other greens** | | | |
| 1.1.01 | Source separated vegetable, fruit & garden waste | From separate collection from households, shops, restaurants – without meat | n.s. | n.s. |
| 1.1.02 | Grass cuttings, hay, leaves | Only green leaves during vegetation period | 20 02 01 | Compostable waste |
| 1.1.03 | Leaves, windfalls | | 20 02 01 | Compostable waste |
| 1.1.08 | Cemetery waste – source separated | Grass mowings only | 20 02 01 | Biodegradable waste |
| **1.2** | **Vegetable waste, from the preparation and consumption of food, luxury/convenience food & beverages** | | | |
| 1.2.01 | Cereals, fruit & vegetables | | 02 01 03 | Waste from vegetable tissue |
| 1.2.02 | Tea leaves, coffee grounds | | 02 01 03 | Waste from vegetable tissue |
| 1.2.03 | wastes from the baking and confectionery industry | from vegetable origin only; including Dough, yeast | 02 06 01 | Materials not suitable for consumption or processing |
| | | | 02 06 02 | wastes from preserving agents |
| | | | 02 06 03 | sludges from on-site effluent treatment |
| 1.2.04 | Residues from spices and herbs | | 02 01 03 | Waste from vegetable tissue |
| 1.2.05 | Former foodstuff of vegetable origin | From shops, wholsalers, of vegetable origin only | 02 03 04 | Materials not suitable for consumption or processing |
| 1.2.06 | Vegetable food waste | Of vegetable origin only (plant tissue) Source separated from central as well as household kitchens as well as catering services | 20 01 08 | Biodegradable kitchen and canteen waste |
| 1.2.07 | Used vegetable cooking oil | Cooking oil, Oil - vegetable, Vegetable oil, Vegetable oil and water | 20 01 25 | Edible oil and fat |
| 1.2.08 | Vegetable market waste | Of Vegetable and fruit origin only | 20 03 02 | Waste from markets |
| **1.3** | **Organic residues from commercial, agricultural and industrial production, processing and marketing of agricultural and forestry products – purely of vegetable origin** | | | |
| 1.3.01 | Harvest residues, hay and silage | | 02 01 03 | Plant-tissue waste |
| 1.3.03 | Grain/Cereal dust, spelt | | 02 01 03 | Plant-tissue waste |
| 1.3.04 | Straw | | 02 01 03 | Plant-tissue waste |
| 1.3.06 | Tobacco waste | | 02 03 04 | Materials not suitable for consumption or processing |
| 1.3.07 | Beet root chips, tails | | 02 03 04 | Materials not suitable for consumption or processing |
| 1.3.08 | Residues from canned and deep freeze food processing | | 02 03 04 | Materials not suitable for consumption or processing |
| 1.3.09 | Residues from fruit juice and jam production | | 02 03 04 | Materials not suitable for consumption or processing |
| 1.3.10 | Residues from starch production | | 02 03 04 | Materials not suitable for consumption or processing |

| Designation of waste material | | Further specifications also specifically with respect to AD | EWC Code | Corresponding EWC waste type |
|---|---|---|---|---|
| (a) | (b) | (c) | (d) | (e) |
| 1.3.11 | Vinasse, molasse residues | | 02 03 04 | Materials not suitable for consumption or processing |
| 1.3.12 | Feed and feed residues not fit for use | Of vegetable origin only | 02 01 03 | Plant-tissue waste |
| ~~1.3.13~~ | ~~Residues from tea and coffee production~~ | - | ~~02 03 04~~ | ~~Materials not suitable for consumption or processing~~ |
| 1.3.14 | Marc, press-cake | E.g. from oil mills, breweries, only materials which have not been treated with organic extraction agents | 02 03 01 | Sludge from washing, cleaning, peeling, centrifuging and segregation processes |
| 1.3.15 | Crushed grain or process residues | | 02 01 03 | Plant-tissue waste |
| 1.3.16 | Fruit, cereal and potato draff | From breweries and distilleries | 02 03 01 | Sludge from washing, cleaning, peeling, centrifuging and segregation processes |
| 1.3.17 | Uncontaminated sludge or residues of press filters from separately collected process water of the food, beverage, tobacco and animal feed industry | From vegetable, fruit and plant tissue processing only | 02 03 01 | Sludge from washing, cleaning, peeling, centrifuging and segregation processes |
| 1.3.18 | Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa) | | 02 07 01 | Wastes from washing, cleaning and mechanical reduction of raw materials |
| | | | 02 07 02 | Wastes from spirits distillation |
| | | | 02 07 04 | Materials unsuitable for consumption or processing |
| 1.3.19 | Spoilt seeds | | 02 01 03 | Plant-tissue waste |
| 1.3.23 | Distillation residues from production of rape seed oil methyl ester | | 02 03 04 | Materials unsuitable for consumption or processing |
| | | | | |
| **1.4** | **Other Organic residues – pure vegetable origin** | | | |
| 1.4.01 | Sub-aqua plants; sea weed | Incl. Algae and industrial derivates of alge (e.g. alginate). | 02 01 03 | Plant-tissue waste |
| 1.4.02 | Micelles from antibiotics production, | may not not contain antibiotics | 07 05 14 | solid wastes other than those mentioned in 07 05 13 |
| 1.4.07 | Cooking oil and fats, grease trap residues of vegetable origin | | 20 01 25 | Edible oil and fat |
| 1.4.11 | Liquor/leachate from a composting process | From vegetable waste treatment only; only for material from same plant and derived from materials on positive list | 19 05 99 | liquor/leachate from a Composting process |
| **1.5** | **Digestion residues from anaerobic digestion of waste materials – pure vegetable origin** | | | |
| 1.5.02 | Liquor from anaerobic treatment of materials in 1.1, 1.2, 1.3 and 1.4 | | 19 06 03 | Liquor from anaerobic treatment of municipal waste |
| 1.5.03 | Liquor from anaerobic treatment of vegetable waste | from vegetable waste processing only | 19 06 05 | Liquor from anaerobic treatment of animal and vegetable waste |
| **2** | **Waste for biological treatment with parts of animal origin** | | | |
| **2.1** | **Animal waste, especially waste from the preparation of foodstuffs** | | | |

| Designation of waste material | | Further specifications also specifically with respect to AD | EWC Code | Corresponding EWC waste type |
|---|---|---|---|---|
| (a) | (b) | (c) | (d) | (e) |
| 2.1.01 | Food waste from private households and similar institutions | Source separated catering waste only; Cat. 3 catering waste, ABPR 1069/2008/EC art.10 lit. p | 20 01 08 | biodegradable kitchen and canteen waste |
| 2.1.02 | Food waste from central kitchens and catering services with animal residues | Cat. 3 catering waste, ABPR 1069/2008/EC art.10 lit. p | 20 01 08 | biodegradable kitchen and canteen waste |
| 2.1.03 | Former foodstuffs of animal origin | Cat. 3 material, ABPR 1069/2008/EC art.10 lit. f | 20 02 02 | Animal tissue waste |
| | | | 02 03 04 | Materials unsuitable for consumption or processing |
| **2.2** | **Organic residues from commercial, agricultural and industrial production, processing and marketing of agricultural and forestry products – <u>with parts of animal origin</u>** | | | |
| 2.2.01 | Sludge from food and feeding stuff processing with parts of animal origin | | 02 02 03 | Materials unsuitable for consumption or processing (?) |
| 2.2.02 | Press-filter, extraction and oil seed residues from the food and fodder industry with parts of animal origin | | 02 02 03 | Materials unsuitable for consumption or processing (?) |
| 2.2.03 | Spoilt feeding stuff of animal origin from fodder producing industry | Cat. 3 material, ABPR 1069/2008/EC art.10 lit. g | 02 02 03 | Materials unsuitable for consumption or processing (?) |
| 2.2.04 | Residues from, hair, wool, feathers | Cat. 3 material, ABPR 1069/2008/EC art.10 ; no horn or hoof residues. | 02 02 02 | Animal tissue waste |
| 2.2.06 | Paunch waste | Cat. 2 Material ABPR 1069/2008/EC art. 9 (a) [digestive tract content separated from digestive tract] | 02 02 02 | Animal tissue waste |
| 2.2.07 | Solid and liquid manure | Cat. 2 Material ABPR 1069/2008/EC art. 9 (a) | 02 01 06 | Animal faeces, urine and manure |
| 2.2.08 | Wastes from the preparation and processing of meat, fish and other food of animal origin | Cat. 3 material, ABPR 1069/2008/EC art.10 | 02 02 02 | Animal tissue waste |
| | | | 02 02 03 | Material unsuitable for consumption or processing |
| 2.2.09 | Wastes from the dairy industry | Cat. 3 material, ABPR 1069/2008/EC art.10 Raw milk: lit. h; Other milk based products; colostrum | 02 05 01 | Materials unsuitable for consumption or processing |
| | | | 02 05 02 | sludges from on-site effluent treatment |
| 2.2.10 | Wastes from the baking and confectionery industry | Cat. 3 material, ABPR 1069/2008/EC art.10 lit. f | 02 06 01 | Materials unsuitable for consumption or processing |

# 8 Glossary – basic definitions

| | |
|---|---|
| **ABP / ABPR** | Animal By-Products / Regulation. ABP as defined by the Animal By-Products Regulation (EC) no. 1774/2002. The regulation is being amended between 2007 and 2009. The new regulation will be published between September und December 2009. |
| **Anaerobic digestion (AD)** | Fermentation process of organic feedstocks under anaerobic conditions with the objective to produce a methane-rich gas as renewable energy resource, liquid or solid digestion residues (digestate) can be used as organic soil amendment. Solid digestate can be composted together with structure material or other organic feedstocks and used like compost. |
| **Biodegradable materials** | materials capable of undergoing biologically mediated decomposition |
| **Biogas plant** | a facility where bio-waste, agricultural residues and animal by-products and/or energy crops are processed under anaerobic conditions with the aim to produce biogas and digestate |
| **Biogas** | Combustible energy rich gaseous mixture of methane and carbon dioxide and other trace gases like hydrogen sulphide, ammonia and steam produced in anaerobic digestion process |
| **Biowaste** | Traditionally: Source-segregated biodegradable waste of an organic or putrescible character. It is used in line with the term *'organic waste'* which represents the source separated fraction of municipal waste collected from households and similar premises.<br>In the context of this report it does not include *'former foodstuff' from retail premises which include meat or is in contact with raw meat.*<br>Definition of draft revised Waste Framework Directive: 'biodegradable garden and park organic waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants' |
| **Compost** | is defined as humified solid particulate material that is the result of composting, which has been sanitised and stabilised, and which confers beneficial effects when it is added to soil, used as growing media constituent, or used in another way in conjunction with plants Note: post-composted digestate materials are defined as compost |
| **Digestate** | product of anaerobic digestion of biodegradable materials, including bio-waste, agricultural residues and animal by-products. It can be presented in whole or separated in a liquid and solid digestate. Digestate can be post composted or dried and further upgraded to pellets or granulates. |
| **Dry digestion** | anaerobic digestion with dry matter content over 20 % in the digester |
| **Food waste** | For this report we use the term food waste synonym to organic kitchen waste or catering waste from domestic origin and restaurants. It does not include former food stuff from commercial sources as defined by the EU Animal By-Product Regulation. |
| **Garden and Park waste (Green waste)** | Vegetation waste from gardens, parks, landscape maintenance including tree cuttings, branches, grass, leaves, prunings, old plants and flowers. |
| **Garden waste** | Vegetation waste from private gardens |
| **Heavy metals** | Even if chemically not fully correct we use heavy metals for the potential toxic elements Cd, Cr, Cu, Hg, Ni, Pb and Zn |
| **Hydraulic retention time (HRT)** | average time that material stays in the digester vessel, determined by the loading rate and operational digester capacity Note: The hydraulic retention time can be calculated by dividing the digester working volume by the rate of flow of input materials into the digester: HRT [days] = digester volume [m3] / influent flow rate [m3 per day] |
| **Ingestate** | biowaste introduced in the first anaerobic digester after mechanical pre-treatment operations. |
| **Liquid digestate:** | Digestate from wet digestion or the liquid fraction of material by separating the whole digestate Note: Less than 15 % of its mass should be dry matter in order that |

| | |
|---|---|
| | the sample is suitable for laboratory tests as a liquid material. It should contain sufficient moisture to be pumpable. |
| **MS** | Member States of the European Union |
| **MSW** | Municipal solid waste |
| **OFBMW** | Organic fraction of biodegradable municipal waste. As defined by the National Strategy for Biodegradable Waste this comprises mainly food and garden waste from the household and commercial sector |
| **Palable** | suitable to be transported by wheel loader, characterised by a solids content usually above 20% in the fresh matter. |
| **Pre-processing** | Methods of starage and intermediate stabilisation such as an anaerobic fermentation (ensiling) step prior to systematic aerobic composting. It uses in most cases specific inoculants |
| **Pumpable** | liquid to semi liquid, suitable to be pumped in a pipeline, characterised by a solids content usually below 20%. |
| **QM (quality management)** | Management required for the entire process of compost production. It starts from the receipt control of delivered feedstock materials and ends with final product storage and dispatch of compost to the customer. QM systems comprise a traceable documentation system to be checked by external QSO or the competent authority if it is part of the licensing and compost related legislation. |
| **Residual waste** | This is waste collected from households, commerce, and industry, which has not been separated at source. |
| **Sanitisation** | reduction of human, animal and plant pathogens to acceptable levels as a result of the hygienisation process |
| **Semi-dry digestion** | anaerobic digestion with dry matter content between 10and 20% in the digester |
| **Solid digestate** | digestate from a dry digestion or the solid or fibrous fraction of material by separating the coarse fibres from whole digestate Note: At least 15 % of its mass should be dry matter in order that the sample is suitable for laboratory tests as a solid material. |
| **Wet digestion** | anaerobic digestion with dry matter content of the substrate ≤ 10 % in the digester |

# 9 Acronyms and annotation

| | |
|---|---|
| % (m/m) | mass related percentage |
| % (v/v) | volume related percentage |
| °C | Celsius/centigrade |
| a | year (*L.*) annum |
| ABP | Animal By-Products |
| ABPR | Animal By-Products Regulation (European Commission Nº 1774/2002) |
| ACP | Agricultural Composting Plants |
| AD | Anaerobic Digestion |
| AgrC | Agricultural Composting |
| ASP | Application Service Provider |
| BAT | Best Available Technique |
| BGBl | Bundesgesetzblatt → Federal Law Gazette (FLG) |
| BOD | Biological Oxygen Demand |
| BSE | Bovine Spongiform Encephalopathy |
| C | Carbon |
| ca. | about, approximately, (*L.*) *circa* |
| CaO | Calcium Oxide |
| Cat. | Category, in the context of an catogry of animal by-products as defined by the EU Animal By-Products Regulation |
| Cd | Cadmium |
| CEN | *Comité Européen de Normalisation* (*F.*) (Belgium) - European Committee for Standardization |
| $CH_4$ | methane |
| $CO_2$ | carbon dioxide |
| COD | Chemical Oxygen Demand |
| COM | [European] Commission |
| Cr | Chromium |
| Cu | Copper, (*L.*) *cuprum* |
| DM | dry matter |
| DM | Dry Matter |
| e.g. | for example, (*L.*) *exempli gratia* |
| EC | European Communities |
| ECCP | European Climate Change Programme |
| equ | equivalent |
| et al. | and others, (*L.*) *et alii* |
| etc. | and so on, in similar respects, *(L.) et cetera* |
| EU | European Union |
| EWC | European Waste Catalogue |
| f.m. | fresh matter |
| FLG | Federal law gazette |
| G&P | Garden and Park [waste ; compost] |
| GHG | Greenhouse Gas |
| GWC | Green waste compost |
| h | hour(s) |
| $H_2S$ | Hydrogen sulphide |
| ha | hectare |
| HACCP | Hazard Analysis Critical Control Point |
| Hg | Mercury, (*L* ) *hydrargyrum* |
| HRT | Hydraulic Retention Time |

| | |
|---|---|
| i.e. | that is [to say], *(L.) id est* |
| IPCC | Intergovernmental Panel on Climate Change (United Nations) |
| K | Potassium, *(L.) kalium* |
| kg | kilo |
| LCA | Life Cycle Assessment |
| LHV | Low Heating Value |
| $m^2$ | square metre |
| $m^3$ | cubic metre |
| MBT | Mechanical Biological Treatment |
| Mg | Magnesium |
| MS | Municipal Solid Waste |
| MS | Member State(s) [of the European Union] |
| MSW | Municipal Solid Waste |
| N | Nitrogen |
| n.a. | not available |
| $N_20$ | nitrous oxide |
| Ni | Nickel |
| OC | Organic Carbon |
| OL | Organic Load Rate |
| OM | Organic Matter |
| P | Phosphorus |
| Pb | Lead, (*L.*) *plumbum* |
| pH | Quantitative unit of measure of acidity or alkalinity, (*L. pondus Hydrogen*i) |
| QAS | Quality Assurance System |
| QM | Quality Management |
| SOM | Soil Organic Matter |
| t | tonne (metric 1,000 kgs) / ton (imperial) |
| t/a | tonnes per annum |
| TKN | Total Kjeldahl Nitrogen |
| VFA | Volatile Fatty Acids |
| VOC | Volatile Organic Compounds |
| VS | volatile solids |
| WFD | Waste Framework Directive |
| WWTP | Waste Water Treatment Plant |
| Zn | Zinc |