**2.3 BAT conclusions for anaerobic treatment of source-separated bio-waste**

**2.3.1 Overview on Anaerobic Digestion process**

Anaerobic digestion (AD) is the microbiological decomposition of biomass (biogenic organic materials) with the absence of oxygen which can be observed in nature for instances in moors, marshes, inundated rice fields, badly aerated soils, eutrophic waters sediments, digestive tracts of animals (in particular cow’s rumen) or expired food in closed vessels. Also the deposition of organic waste at landfills under oxygen starvation leads to the uncontrolled decomposition processes.

The biogas technology makes use of these processes in which carbon from incoming organics is converted by the different micro-organisms under exclusion of air into biogas and a digestate richly in humus forming materials and nutrients. Biogas can be combusted in combined heat and power units (CHP) to generate electricity and heat. Biogas can also be upgraded to biomethane by enhancing the methane content to be injected into the natural gas grid or be used as a fuel for light and heavy duty vehicles. Biogas has a typical composition of 55 – 70 % methane, 30 – 45 % carbon dioxide and 200 – 4000 ppm hydrogen sulphide. The biogas yield and the proportion of methane to carbon dioxide will vary with the feedstock and the temperature of the system. The system needs to have a balanced feed to maximise methane production.

Currently, predominantly energy crops and liquid manure are used as feedstock for biogas production, which is not subject to this BREF. However, in principle, a great variety of organic compounds are suitable as feedstock for instance separately collected municipal organic waste, garden and park waste, fat separator contents, food leftovers from kitchen, hotels and restaurants, expired food from retail markets, agricultural by-products, animal by-products, industrial slurries and sewage sludge from municipal waste water treatment. One of the main limits on the anaerobic digestion process is its inability to degrade lignin (a major component of wood). This is in contrast with the process of aerobic biodegradation. Most types of biowastes legally have to be hygienisated to eradicating pathogens or reduce them to acceptably low, sanitary levels. This can be done by a pasteurisation (>70°C, 1h), thermophilic digestion (> 50°C) or a post composting step.

The characteristics of the feedstock have very important effects on the AD process and the biogas yield. A high quality feedstock will increase the quality of the digestate, which – if complying with national legislation - can be used as an organic fertilizer in agricultural either in liquid form (about 5-10 % dry matter) like manure, in semi-solid form (10 – 30 %) like peat or being further upgraded e.g. by composting, drying and/or pelletising in landscaping and horticulture as well as in private gardens. Digestate are commonly post-composted if the feedstock is mainly based on municpal biowaste. Digestate produced from industrial and agrucultural biowaste are commonly not composted but used direcly as liquid or separated solid digestate. The nutrients that were contained in the feedstock remain in the digestate. Only carbon, hydrogen and in marginal quantities nitrogen, sulphur and oxygen can leave the process during gas phase. Therefore, the used feedstocks determine directly the composition of the generated digestate. The relevant nutrients are predominantly nitrogen, phosphorus, potassium and the organic carbon content.

In order to improve the digestion process, materials, such as plastics, metals and oversized components are removed from the waste to be treated. Separation can be carried out under wet or dry conditions. Following this, a further process of size reduction is used to create a more homogenous material. The size reduction could be brought about by screw-cutting, milling, drumming, pulping or shredding machines.

The conversion of biomass to biogas and digestate is a complex biochemical process. Four phases can be distinguished as follows:

1. In the first step, the **hydrolysis**, polymers components of the feedstock (e.g. carbon hydrates, proteins, fat) are disassembled into lower molecular organic compounds (inter alia amino acids, sugar and fatty acids). The hydrolytic micro-organisms involve release hydrolytic enzymes, which decompose the material biochemically.

2. The produced intermediates are degraded during **acidogenesis** by acidogenic bacteria to lower fatty acids (acetic acids, propionic and butyric acid) as well as to carbon dioxide and hydrogen. Besides, also lactic acid and alcohols are produced, mostly in small quantities.

3. The intermediates subsequently are transformed during **acetogenesis** by acetogene bacteria to acetic acid, hydrogen and carbon dioxide.

4. In the last phase, the **methanogenesis**, methane and carbon dioxide are formed, by archaea.

There are a number of different techniques used to effect digestion. They are usually distinguished on the basis of the operating temperature (thermophilic plants operate at around 55 °C and mesophilic ones at around 40 °C and the percentage of dry matter in the feedstock (e.g. dry systems with 15 – 40 % dry matter, wet systems with 10 - 25 % dry matter). Generally speaking, the higher the temperature, the faster the process, but the thermophilic process may be harder to control and will need more biogas for heating to keep them at the required temperature. The currently most common technologies are listed in Table 2.5. Moisture content is very important for the choice of the technology. Therefore, kitchen waste and other putrescible wastes, which may be too wet and lacking in structure for aerobic digestion, can provide an excellent feedstock for AD. Liquids are often added to the AD processes (either water or recycled effluent) to maintain a high moisture content.

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| Technique | Description | Input |
| Wet digestion | Solid biowaste is slurried with the process water to provide a diluted feedstock for feeding into the digester. Liquid biowaste can be used directly.  | The technique can be used for municipal, industrial, commercial and agricultural biowaste as well as animal manure and energy crops. |
| Dry continuous digestion | The digestior is continuously fed with a material with 15 – 40 % dry matter through batch loading. In both mixed and plug flow variants, the heat balance is favourable for thermophilic digestion. | The technique can be used for municipal, industrial, commercial and agricultural biowaste. |
| Dry batch digestion | A batch is inoculated with digestate from another reactor and left to digest naturally. Leachate is recirculated to maintain moisture content and to redistribute methane bacteria throughout the vessel. | The technique is commonly used for municipal biowaste but seldom also for industrial, commercial and agricultural biowaste. |

Table 2.5: Anaerobic digestion technologies

**2.3.2 General environmental performance**

In order to improve the general environmental performance of AD, BAT is to use the techniques given below, in addition to BAT

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| --- | --- | --- |
| Techniques | Description | Applicability |
|  | Choice of feedstock | The characteristics of the feedstock have very important effects on the AD process. A high quality feedstock or special mixtures can lead to higher biogas yield, because of better nutrient and micronutrient supply.The choice of feedstock is also important for the quality of the digestate and its possiblilty to be used as organic fertilizer  | Applicable for AD |
|  | Loading rate, retention time,  | Loading rate and retention time can have a significant effect on the biogas yield. The higher the organic load and the longer time it stays in the digestor the higher the biogas yield which relates conversely to the invest of the plant. | Applicable for AD with low biogas yield, but also can be achieved with general process improvements and monitoring |
|  | [Other] |  |  |

* + 1. **Monitoring**

A suitable monitoring system, both manual and instrumental, is essential to ensure stable reactor operation and to minimise operational difficulties (e.g. foaming). Common key factors to be monitored during the AD process are temperature, pH value, digestor feeding (e.g. organic loading rate), organic acids and ammonia concentrations, gas production, composition (e.g. H2S concentrations) and pressure. The digestate is analysed on all parameters relevant for the use as fertiliser e.g. nutrients, heavy metals, contaminants.

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| --- | --- | --- |
| **Techniques** | **Description** | **Applicability** |
| a | Biogas production, composition and pressure, pH value, organic acids and ammonia concentration | The biogas yield, composition and pressure are a direct measurement of the microbiological activity. If the biogas yield is decreasing, the process is already disturbed, so that measurements of pH value, organic acids and ammonia are important to monitor the process and to detect a disturbed process conditions more early. | Applicable for AD |
| b | Measurement of temperature  | Constant temperature is very important for the microbiological milieu and has direct influence on biogas production. | Applicable for AD |
| d | [Other] |  |  |

* + 1. **Emissions to air, odour**

The AD process itself is enclosed and air emissions and odour are unlikely to occur except during transfer to and from the digester as well as separation and pretreatment of biowaste as well as open tanks and digestate conditioning. However emissions related to the delivery of waste and mechanical treatment may cause emissions of odours and dust as well as the post composting of the digestate may cause a significant odour problem if not properly treated.

The principal gaseous emission (methane) is a desired product of the AD process, which used as renewable energy source reduces green house gas emissions. However, fugitive emissions of biogas are possible from pressure relief valves, poorly sealed water traps or condensate handling. This can result in a range of hazards, including the risk of fire or explosion, as well as toxicity from contaminant gases such as H2S and mercaptans (generating odour). Nitrogen gases also are possible.

In order to prevent or reduce diffuse emissions of methane to air from anaerobic digestion, BAT is to use the techniques given below.

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| --- | --- | --- |
| **Techniques** | **Description** | **Applicability** |
|  | Covered liquid digestate storage | Methane and ammonia emissions can occur during open digestate storage as long as the digestate is not sufficient stabilized.  | Applicable for digestate storage. |
|  | controlled post-composting | If the digestate should be post-composted it is important to have a adequate aerobisation that uncontrolled anaerobic processes in windrows are avoided. | Applicable for digestate from municipal biowaste |
|  | Leak-control  | AD plants can be controlled on leakage with IR camera to be able to fix it and also increase the biogas yield. | Applicable for AD with low biogas yield |
| d | Removal of sulphur | In order to prevent or reduce sulphur emissions to air when using biogas from AD as a fuel in gas engines, gas turbines or boilers, chemical and biological precipitation of sulphur inside of the digestor by air injection or use of metal-ions. Alternatively or additionally the produced biogas can be cleaned from sulphur and siloxane with activated carbon filtration | Applicable biogas with high sulphur concentrations |
| e | [Other] |  |  |

The BAT-associated emission (e.g. NOX, SOX, CO, H2S, VOC) levels for the engine combustion of biogas should be regulated in the directive on the limitation of emissions of certain pollutants into the air from medium combustion plants.

**2.3.5 Emissions to water**

The advantages associated with biogas production from biowaste include the production of digestate that commonly can be used as a fertiliser. In this way in AD plants waste water can be generally avoided, although in some cases a surplus of wastewater has to be treated in internal or external treatment plants. The emission species will be similar to those from aerobic systems.

In order to reduce water consumption of AD plants, BAT is to use the techniques given below.

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| **Techniques** | **Description** | **Applicability** |
|  | Recirculation, inoculation | Digestate has to be circulated to maintain the microbiological population in the digestor to the extent that no inhibiting effects (e.g. NH3) may occur. Good digestate and water management reduces the amount of waste water. | Applicable for biological treatment |
|  | Application of solid and/or liquid digestate as fertiliser  | In order to prevent or reduce emissions to water from anaerobic digestion plants, digestate is a valuable nutrient-rich fertiliser which should be applied for the nutrient demand of the plants, if all legal requirements are fulfilled. | Applicable for AD |
|  | [Other] |  |  |

**2.3.6 Energy efficiency**

The energy sources which are used during the normal operation of the installation, is electricity, fuel and heat, which could be generated on-site. This electricity could be generated at the installation itself by the combustion of biogas in CHP. Up to one third of the produced heat is needed to heat the digester itself, since the process requires warm conditions. The choice to install CHP or produce biomethane, which also can be used as fuel for light and heavy duty vehicles, is economically subsidy driven.

In order to increase the energy efficiency and to reduce the emissions to air of anaerobic digestion of biodegradable waste and associated activities, BAT is to use all the techniques given below.

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| **Techniques** | **Description** | **Applicability** |
|  | Using biogas as energy source | Using biogas from AD as in energy conversion apparatus, e.g. gas engines, gas turbines, boilers, vehicles is generally applied. | Applicable for AD |
|  | Biogas maximisation | Maximise the production of biogas. This technique needs to consider the effect on the digestate and biogas quality. | Applicable when the biogas yield is very low |
|  | Using heat for external use | Excess heat which is produced in CHP which can also be used for external heat users e.g. buildings, stables drying processes. | Applicable for AD |
|  | Flaring biogas | If engines do not run, biogas which cannot be stored or used elsewhere should be flared by a gas torch not to led methane in the atmosphere. | Applicable for this OTNOC |
|  | Biofilter | After die discontinuous anaerobic digestion, the garages have to be flushed with air before opening. This air should be cleaned in a biofilter. | Applicable if air streams are collected |
|  | Upgrading biogas | Biogas can also be upgraded to biomethane by enhancing the methane content to be injected into the natural gas grid or be used as a fuel for light and heavy duty vehicles. | Applicable for AD without external heat use |
|  | Use of Additives | For the optimization of the process and increasing the biogas yield, additives like trace elements and enzymes can be used in certain cases to offer nutrients for the micro-organisms. | Applicable for AD |
|  | [Other] |  |  |

**4.3 Techniques to consider for anaerobic treatment of source-separated bio-waste**

**4.3.1 Process improvement**

|  |  |  |
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| **Techniques** | **Description** | **Applicability** |
| a | Choice of feedstock | The characteristics of the feedstock have very important effects on the AD process. A high quality feedstock or special mixtures can lead to higher biogas yield, because of better nutrient and micronutrient supply.The choice of feedstock is also important for the quality of the digestate and its possiblilty to be used as organic fertilizer  | Applicable for AD |
| b | Loading rate, retention time,  | Loading rate and retention time can have a significant effect on the biogas yield. The higher the organic load and the longer time it stays in the digestor the higher the biogas yield which relates conversely to the invest of the plant. | Applicable for AD with low biogas yield, but also can be achieved with general process improvements and monitoring |
|  | Recirculation, inoculation | Digestate has to be circulated to maintain the microbiological population in the digestor to the extent that no inhibiting effects (e.g. NH3) may occur. Good digestate and water management reduces the amount of waste water. | Applicable for biological treatment |
| d | Use of Additives | For the optimization of the process and increasing the biogas yield, additives like trace elements and enzymes can be used in certain cases to offer nutrients for the micro-organisms. | Applicable for AD |
| e | [Other] |  |  |

**4.3.2 Process monitoring and control**

|  |  |  |
| --- | --- | --- |
| **Techniques** | **Description** | **Applicability** |
| a | Biogas production, composition and pressure, pH value, organic acids and ammonia concentration | The biogas yield, composition and pressure are a direct measurement of the microbiological activity. If the biogas yield is decreasing, the process is already disturbed, so that measurements of pH value, organic acids and ammonia are important to monitor the process and to detect a disturbed process conditions more early. | Applicable for AD |
| b | Measurement of temperature  | Constant temperature is very important for the microbiological milieu and has direct influence on biogas production. | Applicable for AD |
| c | [Other] |  |  |

**4.3.3 Good practice management techniques**

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| --- | --- | --- |
| **Techniques** | **Description** | **Applicability** |
|  | Covered liquid digestate storage | Methane and ammonia emissions can occur during open digestate storage as long as the digestate is not sufficient stabilized.  | Applicable for digestate storage. |
|  | Controlled post-composting | If the digestate should be post-composted it is important to have a adequate aerobisation that uncontrolled anaerobic processes in the windrow are avoided | Applicable digestate from municipal biowaste |
|  | Leak-control  | AD plants can be controlled on leakage with IR camera to be able to fix it and also increase the biogas yield. | Applicable for AD |
|  | Removal of sulphur | In order to prevent or reduce sulphur emissions to air when using biogas from AD as a fuel in gas engines, gas turbines or boilers, chemical and biological precipitation of sulphur inside of the digestor by air injection or use of metal-ions. Alternatively or additionally the produced biogas can be cleaned from sulphur and siloxane with activated carbon filtration | Applicable biogas with high sulphur concentrations |
|  | [Other] |  |  |

**4.3.4 Increase energy efficiency**

|  |  |  |
| --- | --- | --- |
| **Techniques** | **Description** | **Applicability** |
|  | Biogas maximisation | Maximise the production of biogas. This technique needs to consider the effect on the digestate and biogas quality. | Applicable when the biogas yield is very low |
|  | Increasing the energy efficiency of CHP | Modern combined heat and power units (CHP) have higher efficiency levels. The efficiency of AD plants can be increase with modern techniques. | Applicable for AD |
|  | Using heat for external use | Excess heat which is produced in CHP which can also be used for external heat users e.g. buildings, stables drying processes. | Applicable for AD |
|  | Upgrading biogas | Biogas can also be upgraded to biomethane by enhancing the methane content to be injected into the natural gas grid or be used as a fuel for light and heavy duty vehicles. | Applicable for AD without external heat use |
|  | Leak-control  | AD plants can be controlled on leakage with IR camera. | Applicable for AD with low biogas yield |
|  | [Other] |  |  |

* + 1. **Material product presentation**

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| --- | --- | --- |
| **Techniques** | **Description** | **Applicability** |
| a | Application of solid and/or liquid digestate as fertiliser  | In order to prevent or reduce emissions to water from anaerobic digestion plants, digestate is a valuable nutrient-rich fertiliser which should only be applied for the nutrient demand of the plants, if all legal requirements are fulfilled. | Applicable for AD |
| b | Upgrading liquid digestate | To establish new markets and reducing the costs for storage, transportation and application, also the liquid digestate can be upgraded e.g. by drying, pelletizing, granulating, stripping, steam evaporation, filtration (e.g. reverse osmosis) etc.  | Applicable for AD without sufficient agricultural area for application |
| c | [Other] |  |  |