PPC Technical Guidance Note 35

Anaerobic Digestion

Contents

SCHEDULE 1: Scope

1.1 This document aims to provide clear guidance on what SEPA considers to be best available technique (BAT) for the anaerobic digestion (AD) of waste. It is aimed at operators preparing applications and officers determining applications.

1.2 It lays out a variety of issues which will require consideration during the initial permitting of an anaerobic digestion facility. It is not the intention to apply this guidance to the consequential offsite storage of digestate, although elements may be regarded as best practice.

1.3 It is recognised that a number of anaerobic digestion facilities may fall under the Waste Management Licensing Regulations 1994 (as amended) and for those sites this guidance document should also be considered what SEPA regard as best practice.

1.4 In preparing this document SEPA has made extensive reference to a number of best available technique reference documents (BREF).

SCHEDULE 2: Background

2.1 AD is the biological treatment of biodegradable organic waste in the absence of oxygen, utilising microbial activity to break down the waste in a controlled environment. AD can lead to a more stable material with less odour, fewer weed seeds and a more predictable and readily available form of nitrogen. AD can also reduce certain bacteria by up to 90-99% depending on management, residence time and temperature. AD results in the generation of:

- fibre, (or digestate) which is nutrient rich and can potentially be used as a soil conditioner;
- liquor, which is nutrient rich and can potentially be used as a liquid fertiliser;
- biogas, which is rich in methane and can be used to generate heat and electricity.

2.2 The fibre and liquor generated are not generally separated as part of the AD process which produces a homogenised slurry-like liquid material with about 5% dry matter.

2.3 There is increasing interest in the use of biogas as an alternative to fossil fuels. SEPA supports the move to using more sustainable sources of energy and the recovery of energy from waste in line with the waste hierarchy.

SCHEDULE 3: Anaerobic digestion process

3.1 As described above anaerobic digestion is defined as the biological process during which organic material is decomposed by anaerobic micro organisms in the absence of dissolved oxygen (i.e. anaerobic conditions). Anaerobic micro organisms digest the input organic material which is converted through anaerobic degradation into a more stabilised form as in digestate, whilst also producing a high energy biogas consisting mainly of methane and carbon dioxide as well as by-products such as hydrogen sulphide. Biogas can be combusted for heat and power or used directly as a vehicle fuel.

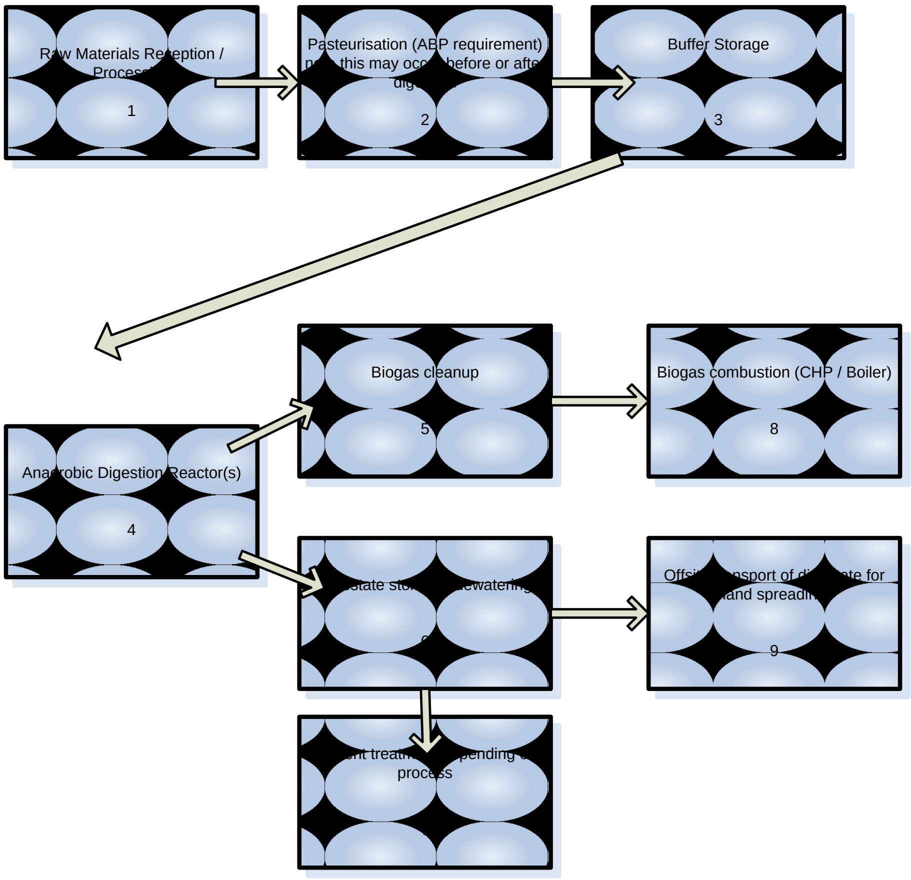
Factors affecting the success or failure of an anaerobic digestion process

3.2 As anaerobic digestion is a biological process reliant on the symbiotic relationship of a number of different types of bacteria, a number of factors can affect the process including:

- temperature;
- pH value and redox potential;
- dry matter or water content;
- content of organic dry matter (loss on ignition);
- degradability as total content of organic acids or acetic acid equivalent and inhibitors;
- salt content;
- total content of nitrogen, phosphorus, potassium, magnesium (Mg) and sulphur;
- availability of plant nutrients (e.g. nitrate, ammonium, phosphorus pentoxide, potassium oxide, and Mg);
- granulation (maximum grain size), gross density;
- heavy metals (e.g. lead, cadmium, chromium, copper, nickel, zinc, mercury);
- concentrations of trace elements (particularly selenium and cobalt, but also molybdenum, tungsten and nickel);
- content of short - chain fatty acids, principally acetic acid, propionic acid, butyric acid, and isobutyric acid;
- carbon and nitrogen ratio.

3.3 In order to successfully manage the anaerobic digestion process the operator needs to understand and monitor the above parameters, making changes in the feed stock and micro nutrient dosing to maintain the biomass at an optimum level. Small deviations in any of the above can have large impacts on the microbiology, and under worst case scenario the biomass can be destroyed, or produce unwanted by-products (such as excessive foaming) which can give rise to increased pollution risk.

3.4 Below is a generic process flow diagram showing the different stages of the anaerobic digestion process.



3.5 However it should be noted that there are many different types of anaerobic digestion reactors, these include:

- anaerobic activated sludge process;
- anaerobic contact process;
- anaerobic expanded-bed reactor;
- anaerobic filter;
- anaerobic fluidised bed;
- anaerobic lagoon;
- anaerobic migrating blanket reactor;
- batch system anaerobic digester;
- continuous stirred-tank reactor (CSTR);
- dry anaerobic digestion plant;

- expanded granular sludge bed digestion (EGSB);
- hybrid reactor;
- Imhoff tank;
- internal circulation reactor (IC);
- one-stage anaerobic digester;
- plug-flow anaerobic digester;
- submerged media anaerobic reactor;
- sintex digester;
- two-stage anaerobic digester;
- upflow anaerobic sludge blanket digestion (UASB);
- upflow and down-flow anaerobic attached growth;

3.6 For the generic anaerobic digestion process likely emissions to the environment are summarised in the table below:

Stage of process	**Emissions**			
	Air	**Water**	**Land**	**Noise sources**
Reception and processing	Odour Dust Bioaerosol	Vehicles wash waters	N/A	Pumps, fan noise, shredding/ depackaging equipment, vehicle movements and reversing alarms.
Pasteurisation	Odour	N/A	N/A	Pumps
Buffer storage	Odour	N/A	N/A	Pumps
Anaerobic digestion	Odour in event of pressure relief valve operation.	N/A	N/A	Noise from pressure relief valves and motors driving mechanical stirrers.
Biogas cleanup	Refrigeration may involve F-gases[1]. Odour potential from collected condensate.	Production of condensate with a high pH, biochemical oxygen demand (BOD) and chemical oxygen demand	N/A	Pumps and fan noise.

1 Fluorinated gases (F-gases) used in refrigeration and air-conditioning equipment (including heat pumps).

		(COD) loading.		
Digestate storage and dewatering	Odour.	Ammonia, BOD, COD and suspended solids. Generation of odorous sludges	Sludges generated should be accredited to PAS 110 and spread in accordance with the PEPFAA Code and nitrate vulnerable zone regulations. Where the material does not meet PAS 110 it is regarded as a waste and should be spread under a waste management exemption where the requirements are met.	Pumps, fans, blowing equipment and compressed air.
Biogas combustion	Combustion gases e.g. nitrogen oxides, sulphur oxides and carbon monoxide. Potential for hydrogen sulphide emissions in the case of incomplete combustion.	N/A	Potential deposition of combustion gases on designated habitats should be assessed.	Fans and combustion equipment.

SCHEDULE 4: Permitting and licensing considerations

4.1 SEPA regard the following as BAT in relation to the processing of waste using anaerobic digestion. As such any application submitted should demonstrate how the site achieves the stated requirements or justify any departure from BAT.

Waste acceptance and biomass performance

4.2 In order to ensure that the feed to an anaerobic digestion plant is as stable and homogenous as possible (to encourage stable gas and digestate production and avoid shock loading) operators should establish site specific waste acceptance criteria for each waste stream accepted onto site, along with appropriate waste validation procedures.

4.3 Validation monitoring should be carried out of every load for new waste streams for the first month of acceptance thereafter being relaxed to once every three months. If the process producing the waste stream changes then it may be appropriate to reassess the material on a more regular basis until satisfied that the material which is being received is consistent.

4.4 Operators should undertake frequent monitoring of the key microbial parameters identified in Schedule 3 above. The results should be continually and routinely assessed to monitor the performance of the digester.

Process buildings

4.5 All process buildings (including those handling raw materials, pasteurisation, maturation, etc) should be air tight, and be held under negative pressure with a minimum of three air changes per hour, vented to abatement. Assessments should be carried out annually demonstrating the integrity of the building and effectiveness of negative pressure e.g. smoke testing.

4.6 All process buildings should have impermeable, kerbed flooring laid to a fall and directed to a foul drainage system so as to prevent ponding. The internal drainage system should be designed to be readily accessible for cleaning.

4.7 The process building dealing with waste acceptance should be fitted with an airlock system.

4.8 Where airlock facilities are not feasible air curtain arrangements would be considered BAT for the control of fugitive odour emissions during access and egress. Such systems should be installed on all entry points to buildings requiring negative pressure.

4.9 All vehicle entry points to process buildings should be via fast acting roller shutter doors which open and close on a pressure switch. All doors associated with process buildings should be connected to an alarm system which alerts operators in the event of doors being left open.

4.10 Hoppers and storage bins used to store incoming wastes should be fitted with lids. These lids should be interlocked to the door entry system to prevent access to the relevant building when these hoppers and storage bins are open.

4.11 Wastes should be stored no longer than 24hrs from initial acceptance onsite prior to introduction into the anaerobic digestion reactor(s) unless held in process tanks connected to abatement.

Odour abatement and bio-aerosols

4.12 All odorous areas should be vented to appropriate abatement. Odour abatement systems should be designed to a minimum of 95% destruction efficiency or sufficient to meet $1.5OU_E/m^3$ (or $1.0OU_E/m^3$ for a hypersensitive population) standard at the site boundary. Demonstration of meeting the $1.5OU_E/m^3$ standard should be provided within the application via full ADMS and AERMOD dispersion modelling. Further information on this subject is available within SEPA's 2010 odour guidance document. In addition it is considered best practice that applicants prepare and submit a method statement regarding how they intend to undertake the modelling in line with SEPAs guidance prior to actually conducting the modelling.

4.13 Validation of the abatement plant performance should be carried out annually via extractive odour monitoring.

4.14 In addition performance indicators (such as biofilter pressure differential, liquor pH etc, scrubber liquor ph,redox and flow) should be established relevant to the abatement technology to monitor performance against design criteria.

4.15 All liquid and slurried waste storage, buffer and digestate tanks should be connected to abatement to control breathing losses.

4.16 A site specific bio-aerosol risk assessment should be undertaken and accompany any application for those plants with sensitive receptors (work place and dwellings) within 250m from the site boundary. This should include background and operational monitoring where appropriate.

Containment

4.17 For all newly constructed sites it is BAT for all tanks containing liquids whose spillage could be harmful to the environment to be bunded. This shall include:

- liquid and slurried waste storage;
- buffer tanks;
- reactors;
- chemical and oil storage (including micro nutrients);
- digestate storage.

For new sites it is insufficient to be reliant on double skinned tanks as the sole containment.

4.18 Bunds should:

- be impermeable and resistant to the stored materials;
- have no outlet and drain to a blind collection point;
- have pipe work routed within bunded areas with no penetration of contained surfaces;
- be designed to catch leaks from tanks and fittings;
- have a capacity greater than 110% of the largest tank or 25% of the total tankage, whichever is the larger;
- be subject to visual inspection and any contents pumped out or otherwise removed under manual control after checking for contamination;
- where not frequently inspected, be fitted with a high level probe and an alarm, as appropriate;
- where possible, have tanker connection points within the bund, otherwise provide adequate containment; and
- be subject to programmed engineering inspection.

4.19 It is generally considered that tanks for newly constructed sites should be above ground; however there may be site specific reasons requiring underground or partially submerged tanks such as spatial constraints. Where this is the case the applicant should make a detailed BAT justification providing details as to the mitigation measures and design considerations to be installed for all subsurface pipe work and vessels such that an equivalent level of environmental protection is afforded. This should include as a minimum secondary containment and inspection and maintenance regimes pressure testing, leak detection etc.

- bunds should be designed and constructed in accordance with CIRIA 164.

Modelling and impact assessment

4.20 As part of the application an H1 impact assessment (carried out in accordance with the 2003 version available on SEPA's website) should be produced of emissions to air with full dispersion modelling where required

4.21 All stack and flare heights shall be justified using D1 or dispersion modelling. No stack height shall be lower than the calculated D1 value without significant site specific justification

Hierarchy of biogas use

4.22 Notwithstanding the requirements to operate in accordance with a heat and power plan in compliance with SEPA's thermal treatment guidance, SEPA's hierarchy for biogas combustion is as follows:

- injection into the national gas network – (this is an evolving technique);
- combustion within engines generating both heat and power (CHP);
- combustion within boilers – usually acceptable as a standby arrangement only owing to reduction in efficiency;

- flaring – acceptable under emergency situations and during controlled startup and shutdown periods only.

Biogas combustion

4.23 Desulphurisation plant should be provided to reduce Hydrogen Sulphide (H_2S) concentration within biogas prior to combustion by a minimum of 90%. Desulphurisation is required to reduce the potential for incomplete combustion of H_2S rich gas and subsequent odour In addition biogas engine suppliers will set a maximum inlet H_2S concentration owing to corrosion concerns. For most anaerobic digestion facilities it is unlikely that this concentration would be achieved without abatement.

4.24 Desulphurisation plant should be fitted with appropriate continuous monitoring for performance (e.g. liquor flow, pH) which should be fitted with alarms in the event of deviation from set parameters.

4.25 Flares should meet the NER standard which specifies a combustion temperature in the range of 1000 to 1100^oC and a retention time of 0.3s.

4.26 For new flare systems it is BAT to continuously monitor the combustion temperature of flares with an alarm system in the event of a drop in temperature below 1000 ^oC.

4.27 Flares and flame arrestors should be designed to cope with wet gas. On this subject BS5098 and API537 should be consulted.

4.28 As part of the design process consideration should be given to the impact of power failure on the ability to safely combust biogas and prevent a pressure relief event.

Biogas engines

4.29 It would be expected that an applicant would justify the levels of emission and abatement on a site specific basis. Where there is a structured argument put forward for achieving a different emission standard including all aspects including cost, efficiency, availability of technology, site specific impact at receptors etc SEPA would make a decision on BAT in the round. The following should be regarded as indicative BAT emission limits for the combustion of biogas within gas engines:

Pollutant	**ELV (at normal temp, pressure and 5%O2)** **New and replacement plant** **New is regarded as any plant installed post issue date of this guidance document**	**ELV (at normal temp, pressure and 5% oxygen)** **Existing plant**	**Extractive monitoring requirements** **All plant**	**Continuous monitoring** **Requirements for all plant**
NOx	250 mg/m^3	500 mg/m^3	Minimum annually with option to reduce dependant on risk and consistent compliance.	No
CO	1000 mg/m^3	1400 mg/m^3	Minimum annually with option to reduce dependant on risk and consistent compliance.	Yes- to continually monitor combustion efficiency.
SO_2	300 mg/m^3	300 mg/m^3	Minimum annually with option to reduce dependant on risk and consistent compliance.	No
VOC (including methane)	1000mg/m^3	1000mg/m^3	Minimum annually with option to reduce dependant on risk and consistent compliance	No
NMVOC	75mg/m^3	75mg/m^3	Minimum annually with option to reduce dependant on risk and consistent compliance	No
H_2S	5ppm at outlet and specify maximum concentration which can be combusted at inlet dependant on risk identified via modelling.	5ppm at outlet and specify maximum concentration which can be combusted at inlet dependant on risk identified via modelling.	Minimum annually with option to reduce dependant on risk and consistent compliance.	Yes to monitor inlet concentrations to CHP

Biogas boiler

4.30 For biogas boiler combustion it would be expected that an applicant should justify the levels of emission and abatement on a site specific basis. Where there is a structured argument put forward for achieving a different emission standard including all aspects including cost, efficiency, availability of technology, site specific impact at receptors etc SEPA would make a decision on BAT. The following should be regarded as indicative BAT emission limits:

Pollutant	**ELV (at Normal Temp, Pressure and 3%O2)** **All Plant**	**Extractive Monitoring Requirements** **All Plant**	**Continuous Monitoring Requirement** **All Plant**
NOx	100mg/m^3	Minimum annually with option to reduce dependant on risk and consistent compliance.	No
CO	10mg/m^3	Minimum annually with option to reduce dependant on risk and consistent compliance.	Yes- to continually monitor combustion efficiency.
SO_2	35mg/m^3	Minimum annually with option to reduce dependant on risk and consistent compliance.	May be provided but not a BAT requirement.
H_2S	5ppm at outlet and specify maximum concentration (max concentration modelled) which can be combusted at inlet dependant on risk identified via modelling.	Minimum annually with option to reduce dependant on risk and consistent compliance.	Yes to monitor inlet concentrations

Monitoring requirements

4.31 All extractive monitoring should be carried out by appropriately qualified sampling staff with analysis undertaken by appropriately certified laboratories e.g. UKAS and MCERTS.

4.32 All monitoring should be carried out in accordance with methodologies specified within the latest version of the Environment Agency's M2 document.

Pressure relief systems

4.33 As part of any application, modelling should be conducted of any pressure relief valve systems at a credible H_2S concentration to assess the odour and human health impact of any such event. As a minimum this assessment should take the form of "puff modelling" the methodology of which should be agreed with SEPA. Assessment should be made of the impact against the environmental assessment levels contained within horizontal guidance note H1 and the guideline odour thresholds contained within SEPA's odour guidance.

4.34 Any application should contain an assessment of the feasibility of reducing pressure from these vents and abating the emission. In making any assessment as to the feasibility of abating pressure vent emissions the applicant must consider the risks associated with explosion and flammability. In agreeing to abatement operations staff should seek advice from the Health and Safety Executive as part of the statutory consultation process.

4.35 Any application should contain a probabilistic risk assessment of the likelihood of a pressure relief event along with a hazard and operability (HAZOP) study reviewing options to reduce the risk to as low as is reasonably practicable.

Biogas pressure monitoring

4.36 The AD plant should have continuous biogas pressure monitoring with an alarm mechanism. Any application should specify the maximum pressure above which there should be no feed to the AD reactor which should be interlocked.

Heat and power plan

4.37 Any application should include a heat and power plan compliant with SEPA's thermal treatment of waste guidelines demonstrating compliance with the minimum quality index (QI) values along with an implementation plan.

Digestate and effluent

4.38 It is BAT, where feasible to do so (dependent on waste types accepted), to produce digestates to the PAS 110 standard.

4.39 Effluent should used for recirculation into the Activity, used as PAS 110 standard liquid fertiliser or discharged to sewer and water environment in compliance with a relevant trade and SEPA permissions. For operators discharging effluent directly to the water environment it is BAT to treat effluent to reduce BOD, COD, suspended solids, ammonia and pH. Site specific limits would be determined as part of any application and it would be anticipated that modelling would be submitted to justify the emission.

Maintenance and incident prevention

4.40 A list, or register, of plant infrastructure integral to preventing or limiting pollution to the environment must be submitted with the application. This list should include, amongst other things, details of planned preventative maintenance which will be undertaken on the identified plant, and what critical spares will be kept on site.

4.41 An incident prevention and mitigation plan should be developed and submitted with the application. This plan should set out the actions to be taken and measures required to prevent incidents and where an incident occurs the appropriate mitigation action to be taken. As a minimum the plan should consider the following scenarios:

- not being able to receive waste into the allocated reception building i.e. alternative storage or refusal of loads;
- any leaks being detected within liquid or gas pipelines;
- emptying, filling and seeding of any tanks associated with the anaerobic digestion process for both routine maintenance and non routine purposes;
- any overflow situation from parts of the plant associated with the anaerobic digestion process i.e. high level alarms, interlocks and actions to be taken;
- failure of a flare to operate;
- failure or unavailability of an environmentally critical plant;
- operation of a pressure relief valve.

4.42 Where any tank associated with the anaerobic digestion process requires to be emptied it is BAT for this to be carried out using tankers fitted with activated carbon filters or back vented to appropriate onsite abatement.

Surface water

4.43 The operator should have a clear diagrammatic record of the routing of all installation drains, subsurface pipe work, sumps and storage vessels including the type and broad location of the receiving environment.

4.44 The operator should identify the potential risk to the environment from drainage systems and should devise an inspection and maintenance programme having regard to the nature and volume of waste waters, groundwater vulnerability and proximity of drainage systems to surface waters.

4.45 The operator should ensure that all operational areas are equipped with an impervious surface, spill containment kerbs, sealed construction joints, and connected to a sealed drainage system or such alternative requirements as approved by the regulator. The condition of the impervious surface should be checked regularly and the results of inspections and intended maintenance arising should be recorded.

4.46 It is preferable that sustainable urban drainage system techniques should be used for the drainage of open storage areas. In the event that these techniques cannot be employed then oil and grit interceptors will be required.

4.47 All sumps should be impermeable and resistant to stored materials.