Best Available Techniques (BAT) for (manure) co-digestion

Final report

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Abstract, chapter 4 and chapter 5 of the Flemish BAT study
"Beste Beschikbare Technieken (BBT)
voor (mest)covergistingsinstallaties"
http://www.emis.vito.be/bbt-voor-mestcovergistingsinstallaties

Study carried out by the Flemish Centre for Best Available Techniques (VITO) under assignment from the Flemish Government

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ABSTRACT

The BAT study (manure) co-digestion focuses on installations where manure and/or energy crops and/or organic waste streams are converted into biogas and digestate. The study selects and describes the BAT for this sector or group of similar activities.

(MANURE) CO-DIGESTION INSTALLATIONS
(Manure) co-digestion installations can be classified in several ways, for example depending on input streams, location, scale or processing capacity, operating temperature, dry matter content, the nutritional regime of the digester, the method of mixing the reactor contents and the number of digestion stages. In this BAT study, the analysis and BAT-selection is differentiated -if relevant- depending on the

- used input streams:
  - with or without co-digestion of manure;
  - with or without addition of animal by-products.
- location:
  - farm digesters (agricultural area);
  - industrial digesters (industrial area).
- scale of processing:
  - installation on a (very) limited scale and tied to a single company (small-scale digestion);
  - installation on a limited scale, not tied to one company;
  - large-scale installations, on such a scale that it actually concerns industrial companies.

PROCESS STEPS
The BAT study focuses on the process steps 'pre treatment', 'digestion', 'biogas treatment' and 'digestate treatment' in (manure) co-digestion installations.

OBJECTIVES OF THE BAT STUDY
One of the objectives of the BAT study is to describe the applied techniques and environmental aspects of (manure) co-digestion and to describe the state of art of (manure) co-digestion in Flanders (e.g. input streams, location and digestate treatment techniques). Furthermore, the study aims to select the BAT to reduce water and energy consumption, to prevent waste and to prevent nuisance from noise and vibration.
It is also the aim to select the BAT to reduce or prevent emissions to water and air (e.g. NH_3, CH_4, odour and dust), and to select the BAT to reduce explosion risks and to improve safety (e.g. storage H_2SO_4). The aim of the study is also to identify the applicable environmental regulations and where appropriate to formulate proposals to adapt or supplement the Flemish environmental legislation.

(MANURE) CO-DIGESTION INSTALLATIONS IN FLANDERS
The BAT study contains an inventory of (manure) co-digestion installations in Flanders (as of October 2010). In 27 of the 36 installations, manure is digested, in addition to energy crops and/or organic waste streams. These installations are often located in agricultural areas. In the remaining nine installations, only energy crops and/or organic waste streams (no manure) are used as input. These installations are often located in industrial areas.

APPLIED PROCESS
Each (manure) co-digestion installation in Flanders is unique. It is therefore difficult to describe a typical combination of techniques for the treatment of digestate. A first applicable step in the treatment of digestate is the separation of the digestate into a thick and a thin fraction. The thick fraction of the digestate can be further treated for example by post-digestion, drying, composting/biothermal drying, liming and/or

graining. Pasteurization / sterilization can be applied as well. Techniques that can be applied for further treatment of the liquid fraction of digestate are: biological treatment, liming, drying, evaporation, condensation, membrane filtration, nutrient recovery, ammonia stripping and/or constructed wetlands/lagoons.

ENVIRONMENTAL IMPACT OF (MANURE) CO-DIGESTION INSTALLATIONS

(Manure) co-digestion may be associated with odour. Storage, supply and treatment of input streams are the main sources of odour emissions. In addition, the treatment of the digestate (e.g. drying or separation) can cause odour emissions as well.
A number of process steps require energy, e.g. for the temperature control of the content of the digester, for mixing the reactor contents and for pumping materials. Depending on the applied digestate treatment technique(s), the energy requirement can significantly increase (e.g. drying of the digestate).
During the digestion process there is a potential risk of fire and explosion by the presence of methane gas (biogas).
Other environmental aspects which can occur in (manure) co-digestion installations are pollution of soil or water (e.g. in case of spill, overfill or leaching from storage), noise (e.g. transport movements), air emissions (e.g. biogas treatment) and waste (e.g. ferrous sludge or filter material, depending on the applied digestate treatment techniques).

ENVIRONMENTALLY FRIENDLY TECHNIQUES AND BAT

Chapter 4 provides an overview of the available environmentally friendly techniques for (manure) co-digestion installations based on literature, supplemented with practical information on the sector.
Chapter 5 evaluates the environmentally friendly techniques from Section 4 on their technical feasibility, environmental benefits and economic feasibility. This evaluation indicates whether the specified environmentally friendly techniques are BAT or not for (manure) co-digestion installations.
In the BAT study, more than 20 techniques are selected as BAT. The study contains many examples of measures to concretize these BAT. The BAT selection was carried out in close consultation with industry representatives and experts from the administrations, and is based on literature research and company information.

SOME EXAMPLES OF BAT

Most of the BAT for (manure) co-digestion installations are preventive and process-integrated measures. Some examples are: (1) prevent the use of water, e.g. by reintroducing spilled input- and output streams to the storage installation instead of cleaning them with water (2) limit the quantity and load of waste water / liquid wastes by using overfill protection on storage tanks for liquid materials, (3) avoid excessive use of energy by monitoring energy use of the most energy intensive processes, (4) use fresh and pure input material, (5) prevent noise nuisance at the source by choosing low noise installations during the design phase, (6) guarantee safety on the site and at the level of the (manure) co-digestion installation by implementation of a safety program, (7) run odour causing processes in a closed space under subnormal pressure
If preventive and process-integrated measures are insufficient to achieve acceptable levels of emissions, it is BAT to capture air emissions at source by (point) extraction and to implement appropriate (combinations of) end-of-pipe air treatment technique(s).

RECOMMENDATIONS FOR ENVIRONMENTAL LEGISLATION

We investigate how the BAT can be translated into environmental legislation, and we formulate suggestions to concretize and/or supplement the existing environmental regulations for (manure) co-digestion installations in Flanders.
On the one hand we formulate recommendations for adapting the list of establishments considered to be a nuisance of VLAREM I, e.g. for small-scale digestion, digestion of

energy crops and mono-digestion of animal by-products. On the other hand we formulate recommendations for sectoral environmental conditions in Chapter 5 of VLAREM II. The review of existing sectoral environmental conditions based on the BAT was performed for (manure) co-digestion installations licensed under section 9, section 28.3 and/or section 2 of VLAREM I.

RECOMMENDATIONS FOR ECO-INVESTMENT SUPPORT
We examine the way environmentally friendly techniques for (manure) co-digestion installations can be taken into account for eco-investment support in Flanders. (Manure) co-digestion installations or their components for which certificates for green power or combined heat and power are obtained, are not eligible for eco-investments. The majority of the (manure) co-digestion installations in Flanders are therefore de facto excluded from eco-investments. (Manure) co-digestion installations that use the biogas for production of heat (that do not generate electricity), may be eligible for eco-investments.
Possible future developments for (manure) co-digestion installations include biogas valorisation as heat, biogas valorisation by injection on the net and nutrient recovery. If these trends persist and depending on the legal framework, it should be examined whether the related techniques (e.g. heat networks, biogas cleanup, recycling nutrients) can become eligible for eco-investment support.

RECOMMENDATIONS FOR FURTHER RESEARCH
We identify a number of relevant items for (manure) co-digestion installations for which further research and technological development is desirable. We also describe a number of innovative technologies which can become BAT in the future.

CHAPTER 4 AVAILABLE ENVIRONMENTALLY-FRIENDLY TECHNIQUES

In this chapter we explain the various measures that can be implemented in (manure) co-digestion plants to prevent or limit environmental damage. The environmentally-friendly techniques are discussed per environmental discipline. The following items will be addressed while discussing the environmentally-friendly techniques:

- the description of the technique;
- the applicability of the technique;
- the environmental benefit of the technique;
- the financial aspects of the technique.

The information in this chapter forms the basis on which the BAT evaluation will take place in Chapter 5. It is not, therefore, the intention to make a judgement on whether or not certain techniques are BAT in this chapter (Chapter 4). In other words, the fact that a technique is discussed in this chapter does not mean that this technique is, by definition, a BAT.

4.1. Water

4.1.1. Introduction

No water is required for the actual digestion process. Water is used during the pretreatment stage (e.g. to produce a mixture with a suitable dry matter content that can be pumped), in certain air treatment installations (e.g. gas scrubber, biofilter) and secondary activities (e.g. cleaning storage recipients, transport vehicles, installations, sites and rooms).

4.1.2. Quantitative estimate

BREF Waste Treatments Industries (WT) mentions a total water consumption of 78 litres per ton of processed material (waste) for a plant that comprises separation and anaerobic digestion. 22 litres per ton of input is required for steam production. 56 litres of water per ton of input is used for making the additives read-to-use (polymer solution) (EIPPCB, 2005). Since steam production and polymer use occurs seldom or is not used in Flemish (manure) co-digestion plants (LT Eco, 2011) these figures probably cannot be extrapolated for (manure) co-digestion plants in Flanders.

Remarks
When the digestate is separated into thick and thin fractions using a centrifuge, polymers (usually powder polymers) are widely used in practice. This is not the case where a screw press is used. Water is required when powder polymers are used. The use of liquid polymer requires no water. The quantity of water that is required for producing a polymer solution may be limited in relation to the quantity of water that is required for, for instance, cleaning lorries (Vlaco, 2011f).

4.1.3. Environmentally-friendly techniques

→ *Prevent water consumption*

This technique has been selected as BAT in Chapter 5.

Description of the technique
As already mentioned in paragraph 4.1.1. water is primarily used during the hygienisation stage, in certain air treatment installations and in cleaning activities.

Examples of measures that can be used (insofar as current legal provisions are met) to prevent the use of water are:

- in an initial cleaning stage, prior to wet cleaning if necessary, make the greatest possible use of dry cleaning of storage recipients, installations, sites and rooms using brushes or scrapers for instance;
- clean up spilled solid input and output streams (with a shovel for instance) and put it back in the appropriate storage;
- remove spilled liquids competently.

  Remarks
  The 'Remove large waste by dry cleaning' technique has been selected as BAT for all livestock companies (Derden A. et al., 2006).

Technical feasibility
Dry cleaning may be found to be time-consuming but does not necessarily take more time than wet cleaning only. This measure is considered to be technically feasible for all (manure) co-digestion plants.

Environmental impact
Using these measures can limit water consumption as well as the burden from wastewater. It could also limit energy consumption (for heating).

Economic feasibility
The implementation of these environmentally-friendly techniques primarily requires a change in mentality, but does not include a direct and explicit cost increase or cost decrease. This measure is considered to be economically feasible for all (manure) co-digestion plants.

References

- Company details;
- Company visits, 2010 and 2011;
- Derden A. et al., 2006;
- EIPPCB, 2005.

→ ***Optimise water consumption***

This technique has been selected as BAT in Chapter 5.

Description of the technique
As already mentioned in paragraph 4.1.1. water is primarily used during the hygienisation stage, in certain air treatment installations and in cleaning activities.

The use of water in (manure) co-digestion plants can be optimised by making the greatest possible use of alternative water sources, such as

- process water, e.g.
  - cooling water (from motors for instance);
  - filtrate produced during the post-treatment of the digestate (e.g. membrane filtration);
  - condensed water produced during the treatment of biogas (e.g. dewatering) or with heat recovery;
- cleaning water;
- rinse water;
- non-polluted precipitation.

(see paragraph 4.2.3)

Remarks

- The 'Formulate a water balance plan' and 'Use alternative water sources' techniques have been selected as BAT for all livestock companies (Derden A. et al., 2006).
- The following techniques relating to the use of alternative water sources can be found on the LTL (limitative technology list, see http://www.agentschapondernemen.be/artikel/welke-investeringen-komen-aanmerking-incl-limitatieve-technologie%C3%ABnlijst):
  - provide an installation equipped for collecting, treating and using rainwater (LTL 1326[1]);
  - provide an installation equipped for the recycling of process, rinsing, cleaning and wastewater (derived from LTL 1327);
  - provide a water treatment installation equipped for recycling cleaning water for cleaning the transport vehicles (derived from LTL 1328).

Technical feasibility
The concrete interpretation of these measures should take place at company level. The availability and employability of alternative water sources can vary according to the specific situation. Hygiene requirements may be a limiting factor for the use of alternative water sources. There are, however, no indications that, generally speaking, these measures are not technically feasible.
The optimization of the cleaning activities is part of good business practise and is considered to be technically feasible for all (manure) co-digestion plants.

Environmental impact
The use of these measures can limit water consumption and the quantity of wastewater at the (manure) co-digestion plant. It could also limit energy consumption (for heating). There may be odour nuisance when recovering process water.

[1] The LTL list refers to the use of rainwater instead of precipitation.

Economic feasibility

The cost price of using alternative water sources depends on any water treatment that would have to be used. In addition, the necessary storage capacity needs to be provided. The optimization of the cleaning activities has a cost-saving effect (water and energy).

References

- Company visits, 2010 and 2011;
- Company details;
- Derden A. et al., 2006;
- LT Eco, 2011;
- LTL, 2010;
- VDI 3475,2010;
- VMM, 2011b.

4.2. Wastewater/liquid waste streams

4.2.1. Introduction

In principle, the actual digestion stage will not produce any wastewater or liquid waste streams. Wastewater or liquid waste streams can, however, be produced during the storage activities and in the digestate treatment and biogas treatment stages. Wastewater streams are also produced during secondary activities (cleaning process for instance).

Examples or wastewater or liquid waste streams that can be produced at the (manure) co-digestion plant:

- condensate produced during the post-treatment of the digestate (e.g. indirect drying, evaporation, membrane filtration);
- condensed water produced during the treatment of biogas (e.g. dewatering) or with heat recovery;
- distillate produced during the post-treatment of the digestate (e.g. evaporation);
- leachate produced during the post-treatment of the digestate (e.g. composting/biothermal drying);
- leachate (polluted precipitation) from the trench silos;
- polluted run-off water (polluted with manure) from hard surfaces;
- other polluted precipitation;
- domestic wastewater (e.g. toilets, showers, ...);
- cleaning water for vehicles and materials;
- cleaning water, manure storage;
- drain water from the air treatment installation (e.g. gas scrubber) on post-treatment of the digestate (e.g. drying and granulating (the solid fraction of) the digestate, composting/biothermal drying);
- cooling water (from motors for instance);
- sap losses from the trench silos;
- thin fraction of the digestate;
- effluent from the biological treatment (nitrification/denitrification);
- filtrate produced during the post-treatment of the digestate (e.g. membrane filtration);
- concentrates (produced during, for instance, membrane filtration, rich in salts and nitrogen);
- sludge from the WWTP.

4.2.2. Quantitative estimate

Quantity of wastewater/liquid waste streams

The average flow rate of wastewater produced in 5 Flemish (manure) co-digestion plants[2] that do not also digest manure amounts to 705.44 m^3/day. This is an average of 1,534 observations based on daily results from 2008, 2009 and 2010 (min = 16.00 m^3/day, max = 2,972.00 m^3/day and median = 600.50 m^3/day).
The quantity of condensed water that is produced during the treatment of biogas amounts to a maximum of 50 litres per day (= negligible quantity).

Composition of wastewater/liquid waste streams

BREF Waste Treatments Industries (WT) mentions the following concentrations in the raw wastewater for an installation that comprises the separation and anaerobic digestion of waste (EIPPCB, 2005):

- COD: 6,000-40,000 mg/l;
- BOD: 2.55-10,000 mg/l;
- N-total: 800-4,000 mg/l.

The degree to which these figures can be extrapolated for (manure) co-digestion plants in Flanders is not clear.

As far as the composition of specific wastewater streams, such as condensate for example, is concerned there is no data available for 2011.

The following discharge data relating to the composition of treated wastewater is available:

- daily results (2008 and/or 2009 and/or 2010) from 4 Flemish (manure) co-digestion plants that also digest manure and 4 Flemish installations that do not also digest manure (SOURCE LNE-AMI, confidential information).
- A summary of the discharge data for the installations that also digest manure is available for a number of parameters in Table 1. A summary of the discharge data for the installations that do not also digest manure is available for a number of parameters in Table 2. In the absence of sufficient background information no distinction is made according to the discharge situation.
- daily results (2008, 2009, and insofar as are available for 2010) and annual results (2008 and 2009) for 5 Flemish installations (4 surface water dischargers and 1 sewer discharger) that do not also digest manure (SOURCE: VMM, 2010c).
- A summary of the discharge data for a number of parameters can be found in Table 3 to Table 10. The available discharge data is classified in accordance with the discharge situation (discharge into surface water versus discharge into sewer).

  Remarks

  - Table 1 to Table 10 give an indication of the range of discharge concentrations for a number of parameters based on the <u>available information</u> and different sources (position as at 2010). This range of discharge concentrations should, however, be interpreted with the necessary caution because insufficient background data was available to establish a clear link between the measured discharge concentrations and the business-specific situation such as the origin of the wastewater used in processes, the (wastewater treatment) techniques used, whether or not the BAT was used, etc.

[2] The majority of the data is taken from two installations (768 and 717 respectively data; SOURCE: VMM, 2010c).

Table 1: Summary of the discharge data for the BOD, COD, FS, NO_2^-, NO_3^-, N-Kj, Ptot and Cl^- from 4 Flemish digestion plants that also digest manure (SOURCE: LNE-MI, 2011)

	parameter							
	BOD	COD	FS	NO_2^-	NO_3^-	N-Kj	Ptot	Cl^-
number of observations	6	7	7	3	4	7	6	6
minimum [mg/l]	3.00	31.00	2.10	0.02	0.28	2.70	0.73	54.90
maximum [mg/l]	38,670.00	88,570.00	711.00	0.33	9.64	1,230.00	611.00	1,143.00
average [mg/l]	6,538.80	13,009.57	170.60	0.13	2.89	200.26	116.61	413.27
median [mg/l]	5.90	140.00	14.00	0.04	0.81	9.40	12.50	186.85

Table 2: Summary of discharge data for the BOD, COD, FS, NO_2^-, NO_3^-, NH_4^+, N-Kj, Ptot and Cl^- parameters from 4 Flemish digestion plants that do not also digest manure (SOURCE: LNE-MI, 2011)

	parameter								
	BOD	COD	FS	NO_2^-	NO_3^-	NH_4^+	N-Kj	Ptot	Cl^-
number of observations	12	21	14	16	12	4	17	18	3
minimum [mg/l]	3.40	15.00	2.40	0.03	0.12	0.30	0.27	0.20	7.40
maximum [mg/l]	2,400.00	3,100.00	210.00	1.85	581.00	120.00	174.00	46.00	5,824.00
average [mg/l]	397.77	413.19	45.78	0.47	118.96	57.77	33.44	6.99	1,979.47
median [mg/l]	4.00	71.00	15.50	0.27	13.80	55.39	10.70	1.20	107.00

Remarks for Table 1 and Table 2:
Only a limited amount of measurement data is available for a number of additional parameters. This information is not included in Table 1 and Table 2.

Table 3: Summary of discharge data for the BOD, COD, FS, Ntot, NO_2^-, NO_3^-, NH_4^+, N-Kj, Ptot, o-PO_4, Cl^- and F^- from 4 Flemish digestion plants that discharge into surface water and that do not also digest manure (SOURCE: VMM, 2010c)

	parameter											
	BOD	COD	FS	Ntot	NO_2^-	NO_3^-	NH_4^+	N-Kj	Ptot	o-PO_4	Cl^-	F^-
number of observations	222	222	209	210	116	116	116	104	220	116	116	26
minimum [mg/l]	0.60	7.00	2.00	1.20	0.01	0.26	0.10	2.60	0.11	0.16	249.00	1.10
maximum [mg/l]	161.00	888.00	591.00	87.90	1.50	55.00	17.00	73.10	30.00	9.80	7,270.00	20.00
average [mg/l]	7.44	145.24	28.41	16.89	0.26	7.49	2.09	12.87	3.64	2.58	1,616.10	5.41
median [mg/l]	4.00	78.50	14.00	8.75	0.10	3.45	0.66	5.30	3.18	1.85	524.00	3.55

Table 4: Summary of discharge data for the BOD, COD, FS, Ntot, NO_2^-, NO_3^-, NH_4^+, N-Kj, Ptot, o-PO_4 en Cl^- from 1 Flemish digestion plant that discharges into the sewer and that does not also digest manure (SOURCE: VMM, 2010c)

	parameter										
	BOD	COD	FS	Ntot	NO_2^-	NO_3^-	NH_4^+	N-Kj	Ptot	o-PO_4	Cl^-
number of observations	36	36	36	35	10	10	10	9	36	10	10
minimum [mg/l]	0.65	3.50	3.50	1.10	0.05	0.26	0.50	2.60	0.22	0.16	563.00
maximum [mg/l]	1,570.00	11,820.00	10,000.00	103.50	1.63	0.52	16.00	20.40	295.00	19.00	824.00
average [mg/l]	94.73	735.71	585.82	20.60	0.46	0.31	3.52	8.78	18.23	2.54	661.20
median [mg/l]	8.45	85.00	23.50	13.20	0.23	0.26	1.01	5.40	2.75	0.64	625.00

Table 5: Summary of the discharge data for the Ag, Al, As, B, Ba, Cd and Co (total contents) parameters from 4 Flemish digestion plants that discharge into surface water and that do not also digest manure (SOURCE: VMM, 2010c)

	parameter						
	Ag	Al	As	B	Ba	Cd	Co
number of observations	141	23	141	26	23	141	26
minimum [mg/l]	0.00040	0.11000	0.00260	2.41000	0.01500	0.00030	0.00610
maximum [mg/l]	0.01270	11.31000	0.03200	10.17000	0.14100	0.00500	0.06960
average [mg/l]	0.00266	1.66183	0.01092	5.06000	0.06628	0.00086	0.01698
median [mg/l]	0.00040	0.79800	0.01000	4.33000	0.06100	0.00060	0.01190

Table 6: Summary of the discharge data for the Ag, As, and Cd (total contents) parameters from 1 Flemish digestion plant that discharges into surface water and that does not also digest manure (SOURCE: VMM, 2010c)

	parameter		
	Ag	As	Cd
number of observations	36	36	36
minimum [mg/l]	0.00040	0.00520	0.00030
maximum [mg/l]	0.01000	0.03500	0.00310
average [mg/l]	0.00733	0.01384	0.00087
median [mg/l]	0.01000	0.01500	0.00100

Table 7: Summary of the discharge data for the Cr6+ parameters and Cr, Cu, Fe, Hg, Mn and Mo total contents from 4 Flemish digestion plants that discharge into surface water and that do not also digest manure (SOURCE: VMM, 2010c)

	parameter						
	Cr6+	Cr	Cu	Fe	Hg	Mn	Mo
number of observations	4	141	141	26	99	23	26
minimum [mg/l]	0.01500	0.00270	0.00250	0.13500	0.00001	0.01020	0.19900
maximum [mg/l]	0.01500	0.02800	0.24200	5.65000	0.00060	0.52500	2.90000
average [mg/l]	0.01500	0.00722	0.02201	1.24877	0.00015	0.09837	0.72031
median [mg/l]	0.01500	0.00600	0.01500	0.49250	0.00010	0.06100	0.56150

Table 8: Summary of the discharge data for the Cr, Cu and Hg total contents parameters from 1 Flemish digestion plant that discharges into the sewer and that does not also digest manure (SOURCE: VMM, 2010c)

	parameter		
	Cr	Cu	Hg
number of observations	34	36	36
minimum [mg/l]	0.00270	0.01040	0.00001
maximum [mg/l]	0.01600	1.26900	0.00041
average [mg/l]	0.00821	0.08831	0.00014
median [mg/l]	0.01000	0.02000	0.00015

Table 9: Summary of the discharge data for the Ni, Pb, Se, Sn, V and Zn parameters from 4 Flemish digestion plants that discharge into surface water and that do not also digest manure (SOURCE: VMM, 2010c)

	parameter					
	Ni	Pb	Se	Sn	V	Zn
number of observations	141	141	23	26	23	141
minimum [mg/l]	0.00320	0.00230	0.00520	0.00870	0.00140	0.00630
maximum [mg/l]	0.41500	0.02400	0.01200	0.07330	0.01920	0.41100
average [mg/l]	0.05764	0.00861	0.00572	0.02825	0.00701	0.06924
median [mg/l]	0.01000	0.00230	0.00520	0.02565	0.00630	0.04200

Table 10: Summary of the discharge data for the Ni, Pb and Zn parameters from 1 Flemish digestion plant that discharges into the sewer and that does not also digest manure (SOURCE: VMM, 2010c)

	parameter		
	Ni	Pb	Zn
number of observations	36	36	36
minimum [mg/l]	0.00160	0.00230	0.02000
maximum [mg/l]	0.08300	0.08600	5.11200
average [mg/l]	0.03314	0.01155	0.31884
median [mg/l]	0.04000	0.01000	0.03750

Possible critical parameters for discharging wastewater from (manure) co-digestion plants according to the sector (Biogas-Vlaanderen, 2011; Biogas-Labo, 2011a and b) are:

- recalcitrant COD
  - origin: humic acids, for example;
    During the digestion process humines or humic acids are modified from plant components or are synthesised when they break down. These form complexes with metals as a result of which enzyme action and consequently biological breakdown becomes difficult. Humic acids have a complex structure and a high molecular mass. The COD content of humic acids is between 1,300,000 and 1,500,000 mg O_2/l. Humic acids also include fulvic acids and a phenolic fraction, the latter having a lower molecular mass and containing more oxygen atoms.
    Effluent from (manure) co-digestion can contain humines because manure, cow manure in particular, still contains plant matter. The presence of humic acids has a major influence on the COD content of the effluent that is produced. Its influence on the oxygen content of the surface water into which it is discharged is, however, negligible due to the recalcitrant nature of the humic acids.
    The recalcitrant COD issue has a role in both digestion plants that do and that do not also digest manure (Biogas-Labo, 2011b).
  - This problem can be avoided by proper control of the digestion process (e.g. determine the COD concentration in the input and output streams to be able to optimally adjust feeding the digester; optimise the input mix; optimizing the degree of reintroducing digestate into the digester, see paragraph 4.9.3)[3];
- nitrogen and phosphor compounds
  - this problem can be avoided subject to the use of good separation techniques to separate the digestate into a thick fraction and a thin fraction;
- heavy metals
  - origin: e.g. copper via pig feed;
  - this problem can be prevented by, for instance, using a good acceptance protocol (see paragraph 4.9.3)[4].

4.2.3. Environmentally-friendly techniques

→ ***Limit the quantity and burden of wastewater/liquid waste streams***

This technique has been selected as BAT in Chapter 5.

Description of the technique

As already mentioned in paragraph 4.2.1, wastewater or liquid waste streams can be produced during, amongst others, storage activities, digestate treatment, biogas treatment and cleaning activities. Examples of measures that can be used to limit the quantity and the burden of the wastewater/liquid waste streams are:

- keep hard surfaces clean (e.g. brush regularly);
- optimise cleaning activities (installations, transport material) (see paragraph 4.1.3);
- prevent groundwater infiltration at the storage facilities location;
- use bio-degradable detergents with a short emulsification period, that do not have a negative effect on the digestion process (in accordance with the Regulation on Detergents[5]);

[3] See the "Optimise the operation of the (manure) co-digestion plant" candidate BAT
[4] See the "Optimise the design of the (manure) co-digestion plant" and "Optimise the operation of the (manure) co-digestion plant" candidate BAT

- provide an installation equipped for collecting, treating and using
  - process water (derived from LTL 1327);
  - cleaning water (derived from LTL 1327 and 1328);
  - rinse water (derived from LTL 1327);
  - non-polluted precipitation (LTL 1326[6]).
- provide overflow protection on storage tanks for liquid streams;
- provide a suitable loading/unloading zone with suitable collection features in case of disasters;
- optimise storage of input streams, intermediate products and end products (see the 'Optimise storage of input streams, intermediate products and end products' candidate BAT).

  Remarks
  The 'Limit the sap losses' and 'Limit contamination of the run-off from the silage board' techniques have been selected as BAT for all livestock companies subject to a number of prior conditions (use of silage and/or use of a (new) silage board) (Derden A. et al., 2006).

Technical feasibility
Ensuring that the operating environment is hygienic as well as optimizing the cleaning activities and storage (see the 'Optimise the storage of input streams, intermediate products and end products' candidate BAT also) are part of good business practice. Limiting the quantity and burden of wastewater/liquid waste streams is considered to be technically feasible for all (manure) co-digestion plants.

Environmental impact
The use of these measures can limit the quantity of wastewater/liquid waste streams at the (manure) co-digestion plant. In addition, the water consumption and energy consumption can also be limited. Optimizing the storage can, moreover, limit the emissions to the air / odour nuisance. Clean hard surfaces and covered storage (e.g. input streams) also limit the risk of soil pollution.

Economic feasibility
Maintaining proper hygiene in the operating environment primarily requires an investment in time. The optimization of the cleaning activities has a cost-saving effect (water and energy). Optimizing the storage can increase the yield of the (manure) co-digestion plants.
This measure is considered to be economically feasible for all (manure) co-digestion plants.

References

- Company visits, 2010 and 2011;
- Company details;
- Derden A. et al., 2006;
- EIPPCB, 2005;
- LT Eco, 2011;
- LTL, 2010;
- VDI 3475,2010;
- VCM, 2011a;
- VLM, 2011b;
- VMM, 2011b.

[5] Regulation (EC) No. 648/2004 of the European Parliament and the Council of 31 March 2004 on Detergents (PB. 11/07/2006)
[6] The LTL list refers to the use of rainwater instead of precipitation.

→ ***Use, process, discharge or dispose of wastewater/liquid waste streams prudently***

This technique has been selected as BAT in Chapter 5.

Description of the technique
Depending the nature, source and burden of the wastewater/liquid waste streams, they can either be usefully used or jointly processed in the (manure) co-digestion plant, discharged or disposed of. The paragraphs below show what wastewater / which liquid waste streams are eligible for each of these options.

usefully used as process water (e.g. air scrubber, pasteurisation unit)
- condensed water produced during the treatment of biogas (e.g. dewatering) or with heat recovery;
- filtrate produced during the post-treatment of the digestate (e.g. membrane filtration);
- cooling water (from motors for instance);
- non-polluted precipitation.

usefully used as cleaning water (e.g. site, vehicles or machinery)
- process water
  - filtrate that is produced during the post treatment of the sanitised digestate (e.g. membrane filtration) on condition that this is hygienically responsible and in accordance with Regulation 1069/2009;
  - condensed water produced during the treatment of biogas (e.g. dewatering) or with heat recovery;
- non-polluted precipitation.

usefully used as fertiliser or soil improver (on condition that the VLAREA Regulations {Flemish Regulations on the Prevention and Management of Waste} and other relevant legislation such as Regulation 1069/2009 are complied with)
- drain water from the air treatment installation (e.g. gas scrubber) during post-treatment of the digestate (e.g. drying and granulating (the solid fraction of) the digestate, composting/biothermal drying) (collected separately and used as chemical fertiliser);
- condensate produced during the post-treatment of the digestate (e.g. indirect drying, evaporation, membrane filtration);
- distillate produced during the post-treatment of the digestate (e.g. evaporation).
- sap losses from trench silos, after digestion (together with the digestate);
- (thin fraction of the) digestate;
- concentrates.

co-processed in the (manure) co-digestion plant (after treatment if necessary)
- cleaning water, manure storage;
- polluted precipitation;
- cleaning water for vehicles and materials (oil separator);
- polluted run-off water (polluted with manure) from hard surfaces;
- sap losses from the trench silos.

  Remarks
  - BREF WT (EIPPCB, 2005) mentions that as much wastewater as possible must be reintroduced into the reactor with the aim of converting all dissolved organic matter into biogas.
  - A number of streams that are produced in (manure) co-digestion plants contain little or no convertible organic components. Some are troublesome (chemical air

scrubber drain water, cleaning water containing detergents) others are too pure (degree of dilution is too high resulting in loss of costly reactor volume) for co-processing in the (manure) co-digestion plant. A few examples of these type of streams are:

  - drain water from the air treatment installation (e.g. gas scrubber) on post-treatment of the digestate (e.g. drying and granulating (the solid fraction of) the digestate, composting/biothermal drying);
  - condensate produced during the post-treatment of the digestate (e.g. membrane filtration);
  - distillate produced during the post-treatment of the digestate (e.g. evaporation);
  - filtrate produced during the post-treatment of the digestate (e.g. membrane filtration);
  - leachate (polluted precipitation) from the trench silos;
  - leachate produced during the post-treatment of the digestate (e.g. composting/biothermal drying);
  - condensed water that is produced during the treatment of biogas (e.g. dewatering) or during heat recovery.

  If necessary, these streams can also be co-processed, together with the formed digestate (however, an expensive treatment of these types of streams) (LT Eco, 2011). However, the necessary caution is advised when co-processing non-sanitised materials (Vlaco 2011f).
- Industrial wastewater containing detergents and disinfectants must not be sent directly to the digester (if necessary, dilute or use after a delay, after a period in which the active ingredients can be broken down) (DLV, 2011b).

discharged (after treatment)

- condensed water produced during the treatment of biogas (e.g. dewatering) or with heat recovery;
- cleaning water for vehicles and materials (hydrocarbon separator, oil separator);
  Remarks
  The waste pipe from the vehicle wash and other transport material should be connected via a regularly maintained hydrocarbon separator with coalescing filter and sediment pit. The hydrocarbon separator should be at a sufficient distance from the vehicle wash so that emulsification can take place before the hydrocarbon separator.
- domestic wastewater (e.g. toilets, showers ...) (IWTU);
  Remarks
  Siting of the IWTU depends on the location of the establishment (outside area to be optimised individually).
- thin fraction of the digestate (biological treatment, membrane filtration, constructed wetlands).

  Remarks
  - Buffer basins, with a capacity of at least the permitted daily flow, should be installed to prevent, untreated or insufficiently treated wastewater entering the surface water and having a negative impact on its quality in the event of serious malfunction in the operation of the wastewater treatment plant or any disaster.
  - The treatment and/or discharge of wastewater is not an issue for pocket digesters. In 2011, any wastewater that was produced during pocket digestion was disposed of in its entirety to the digestion plant (DLV, 2011b).

transported for external treatment

- concentrates (rich in salts and nitrogen);
- digestate that does not comply with current legislation;
- sludge from the WWTP.

Remarks

- Non-polluted precipitation that cannot be used usefully, should be collected separately, be filtered and then removed with a delay. However, as this is a cross-sector subject, it is not considered in more detail in this BAT study.
- If connection to the sewer is possible, domestic wastewater should be transported to the sewer. This is also a cross-sector topic and is not considered further in this BAT study.
- The 'Collect wastewater containing manure particles and spread on the land' and 'Prevent the run-off of manure and/or manure liquors in external manure storage - optimise the manure storage' techniques have been selected as BAT for all livestock companies. The following techniques have been selected for livestock companies subject to prior conditions: 'Collect pressing juices and first-flush from the silage board and spread on the land', 'Discharge wastewater that does not contain manure particles into the sewer' and 'Use the thinned fraction of the run-off from the silage board and run-off of materials not polluted with manure to irrigate meadows or convey to the surface water after a delay' (Derden A. et al., 2006).

Technical feasibility

The type and quantity of wastewater/liquid waste streams play an important role in the choice of prudent use, processing and/or discharging. The content of the technique should be determined at company level. Generally speaking, this measure can be considered to be technically feasible for all (manure) co-digestion plants.

Environmental impact

Using these measures can limit emissions into water and the soil. If used usefully (process water or cleaning water) savings can be made on water consumption.

Economic feasibility

This measure is not explicitly cost-increasing or cost-reducing, unless wastewater treatment techniques have to be used (e.g. in case of discharge) or if streams have to be transported for external processing (e.g. concentrates). Generally speaking, this measure is considered to be economically feasible for all (manure) co-digestion plants.

For example:

The cost price for transportation and (sludge) incineration in 2010 was estimated to be 50-60 €/ton.

References

- Company visits, 2010 and 2011;
- Company details;
- Derden A. et al., 2006;
- DLV, 2011b;
- EIPPCB, 2005;
- LT Eco, 2011;
- LTL, 2010;
- OVAM, 2011a;
- VCM, 2011a;
- VDI 3475, 2010;
- Vlaco, 2011f;
- VLM, 2011b and c;
- VMM, 2011b and c.

4.3. Energy

4.3.1. Introduction

The most energy demanding process steps in (manure) co-digestion are:
- the pre-treatment of input streams (e.g. mixing, preparation, hygienisation);
- the actual digestion stage (e.g. heating the contents of the digester);
- post-treating the digestate (e.g. hygienisation, evaporation, drying).

In addition, the energy required for, for instance, driving the transport systems and utilities such as lighting and heating/cooling rooms.

Overall, however, it can be asserted that co-digestion produces energy. Co-digestion contributes to the production of green energy (via valorisation of the biogas that is produced).

4.3.2. Quantitative estimate

In 2010, the biogas that was produced by the (manure) co-digestion plant was valorised to the greatest possible extent in the production process (e.g. keeping the digester up to temperature) or for room heating.

In an actual Flemish company (relatively small installation) which, in addition to manure also digests energy crops and Organic Biological Waste (OBW) (capacity 20,000 tons/year) approximately 2,500,000 m³ biogas is produced. The biogas is valorised via a CHP plant:
- as heat:
  approximately 7,500 MW thermal capacity, good for approximately half of the heat used annually for drying digestate (approximately 10,000 tons), hygienisation, keeping the digester up to temperature and room heating.
- as electricity:
  approximately 5,500,000 kWh, of which approximately 160,000 kWh is used annually at the (manure) co-digestion plant.

  Remarks
  For a (manure) co-digestion plant with a larger processing capacity, it can be expected that the energy balance will be more favourable than in the example mentioned above (LT Eco, 2011).

BREF Waste Treatments Industries (WT) mentions a total energy consumption of 55 kWe per ton of processed material (waste) for a plant that comprises separation and anaerobic digestion. This energy can be generated (in part) via valorisation of the biogas that is produced. It is estimated that 1/3 of the valorised biogas is used to keep the digestion tank up to temperature (EIPPCB, 2005).
For a (manure) co-digestion plant in Flanders the heat consumption for the process is approximately 8 to 12% of the total heat production. In Flanders a biogas project can only be profitable if it achieves a high biogas output per m³ of digester. On a European scale, and certainly for waste digesters or wastewater digesters this can be much lower.

4.3.3. Environmentally-friendly techniques

→ ***Use input material that is as fresh as possible to maximise biogas production***

This technique has been selected as BAT in Chapter 5.

Description of the technique
There were practically no installations that only digest manure in Flanders in 2010. Adding energy crops and/or organic/biologic waste streams in manure (co-) digestion plants is intended to increase the biogas yield. It is therefore important to attract as many energy-rich input streams as possible (see the 'Optimise the operation of the (manure) co-digestion plant' candidate BAT also) to achieve a good biogas yield.

In addition, the quantity of biogas that is produced in a (manure) co-digestion plant can be maximised by using input material that is as fresh (energy-rich) as possible.
Sound production planning as well as good agreements with up-stream suppliers (e.g. farmers, suppliers of raw materials and additives, haulage companies) in relation to, amongst other things, the composition (e.g. minimum dry matter content[7]) and the quality (no chemical, physical and (micro) biological contamination) of the input streams and the timing of supply is essential here (see the 'Use input material that is as fresh as possible to maximise biogas production' candidate BAT also).
If input streams are to be stored locally before being introduced into the digestion plant, this storage should occur under optimal conditions and be for the shortest possible period (see the 'Optimise the storage of input streams, intermediate products and end products' candidate BAT also).

Technical feasibility
This measure is technically feasible for all (manure) co-digestion plants subject to sound planning, optimal storage (see the 'Optimise the storage of input streams, intermediate products and end products' candidate BAT also) and on condition that the necessary agreements are made with up-stream suppliers.

Environmental impact
Using input material that is as fresh as possible (energy-rich) allows the quantity of biogas that is produced to be maximised. For example, fresh semi-liquid pig manure straight from the pig pen can produce twice as much biogas in comparison with manure that is a couple of months old. In addition, odour nuisance can be limited, as well as emissions to the air (fewer uncontrolled losses of, amongst others, ammonia, methane and CO_2 during storage). In addition, the use of these measures can also limit the amount of waste.

Economic feasibility
If all input material has to be fresh, the number of transport movements may increase (with increasing costs). Practical experience has, after all, shown that companies that sell OBW to digestion plants are generally inclined to wait for a full load before they start transporting. And as far as energy crops are concerned the availability of fresh material is a function of the harvesting time (limited period).
Using these measures may therefore incur an increase in costs (transport), e.g. if a third-party is relied on for transporting the input material. Specifically in the case of introduced manure it can also be said that regular delivery of manure limits the manure storage costs for the livestock company and is therefore more likely to be cost-saving.

[7] To prevent rotting and for maximum valorisation of the energy content.

Generally speaking, this measure is considered to be technically feasible for all (manure) co-digestion plants.

References

- Company visits, 2010 and 2011;
- Company details;
- Elsen F. et al., 2009;
- Infomil, 2010;
- Lemmens B. et al., 2007;
- LT Eco, 2011;
- Melse R.W. et al., 2004;
- OVAM, 2011a;
- Vlaco, 2011b;
- VROM, 2005.

→ *Optimise processes to prevent or limit excessive energy consumption*

This technique has been selected as BAT in Chapter 5.

Description of the technique

Measures relating to process optimization that can be used in (manure) co-digestion plants to prevent energy consumption include:

- monitor the energy consumption by the most energy demanding processes;
- recover as much heat as possible, e.g.
  - use heat from sanitised digestate (70°C) in the drying installation;
  - use heat from the cooling water (e.g. from motors) to heat, for example, the digestion tank or the digestate dryer;
  - reuse the heat from the condensed water from the drying installation in the drying installation;
- good process monitoring, e.g.
  - do not dry the digestate longer than necessary;
- improve the energetic yield from the installations (derived from LTL-100011).

The quantity of energy (bought externally) can be further limited by, amongst other things, using the biogas formed in the (manure) co-digestion plant as efficiently as possible. The heat generated from the biogas can be usefully employed in the production process (e.g. heating the contents of the digester during the actual digestion stage or heating processes such as hygienisation, evaporation, drying during the post treatment of the digestate) or for room heating. Other (theoretical) options for the valorisation of the treated biogas are injection into the natural gas grid or use as transport fuel. Given that valorisation of the biogas falls outside of the scope of this BAT study, it will not be discussed in greater detail here.

Remarks

The 'Formulate an energy balance plan - carry out an energy audit' technique has been selected as BAT for all livestock companies (Derden A. et al., 2006).

Technical feasibility

Optimizing the production processes is considered to be good business practice and is technically feasible for all (manure) co-digestion plants. As far as is known, the biogas created in the Flemish (manure) co-digestion plants is valorised to the greatest possible extent. Limitation of the energy cost is an important stimulus for this.

Environmental impact
This measure allows the optimization of energy consumption in the (manure) co-digestion plants. The amount of energy that has to be bought-in externally can, moreover, be limited if the biogas that is created is valorised internally.

Economic feasibility
This measure is considered to be economically feasible for all (manure) co-digestion plants.

References
- Company visits, 2010 and 2011;
- Company details;
- Derden A. et al., 2006;
- Infomil, 2010;
- LTL, 2010;
- VDI 3475, 2010;
- Vlaco, 2011b;
- www.senternovem.nl.

4.4. Waste streams / secondary streams

4.4.1. Introduction

In addition to the (processed) digestate which can be used in agriculture, the following solid waste streams / secondary streams may be produced, directly linked to the activities in a (manure) co-digestion plant:
- unprocessed/rejected input streams (e.g. OBW); here it is important to provide a procedure for removing these input streams that do not meet the acceptance requirements (see the 'Optimise the operation of the (manure) co-digestion plant' candidate BAT also);
- non-conformant digestate;
- sediment fractions (e.g. sand and coarse material) from the digestion plant;
- adsorption and filter material.

  Remarks
  - Examples of liquid waste streams that could be produced at the (manure) co-digestion plant can be found in paragraph 4.2.1.
  - There must be separate sampling for non-conformant digestate and sediment from a digestion tank (sediment fractions) when emptying the tank.

In addition, general, solid waste streams could be produced, e.g. non-recyclable waste, plastic and paper and cardboard. Furthermore, waste streams could be produced during valorisation of the biogas (e.g. used oil at the CHP plant) or during the treatment of polluted precipitation such as sludge from the oil separator. Given that these waste streams are not directly linked to the (manure) co-digestion activities that have been studied, the environmentally-friendly techniques linked to them, such as collect waste separately, dispose of used oil through a recognised processor or collect sludge from the oil separator and dispose of it through a recognised processor are not discussed in further detail in this paragraph.

4.4.2. Quantitative estimate

Unpacking or not unpacking foodstuffs, for instance, has a significant impact on the amount of packaging waste that is produced at the (manure) co-digestion plant. In Flanders the unpacking activities are generally carried out externally (e.g. by foodstuff companies themselves or by an intermediary) certainly if it involves agriculture related (manure) co-digestion plants (located in agricultural areas).

As far as is known, no quantitative information is available about the amount of various waste streams / secondary streams that are produced during (manure) co-digestion.

4.4.3. Environmentally-friendly techniques

→ ***Use manure, energy crops and/or OBW that is as fresh and pure as possible to limit the amount of unprocessed or un-processable input streams***

This technique has been selected as BAT in Chapter 5.

Description of the technique
In order to limit the amount of unprocessed or un-processable input streams you should use manure, energy crops and/or OBW that is as fresh and pure as possible. Sound production planning as well as good agreements with up-stream suppliers (e.g. farmers, suppliers of raw materials and additives, haulage companies) in relation to, amongst other things, the composition (e.g. minimum dry matter content[8]) and the quality (no chemical, physical or (micro) biological contamination) of the input streams and the timing of supply is essential here (see the 'Use input material that is as fresh as possible to maximise biogas production' candidate BAT also).

Remarks
- Verge cuttings can be pretreated to remove physical contaminants (e.g. litter, sand) first (= pure material). As a result of this it many no longer be as 'fresh' but it will have a better digestion capacity as a result of being cleaned.
- Practical experience has shown that there are a number of technical problems if verge cuttings are added as input in 100% OBW digesters. These problems can occur at the input of the material into the (manure) co-digestion plant or while it is being operated. An example is the occurrence of blockages in the installation as a result of the digestate having a thicker viscosity and layer formation occurring in the digester (ODE Vlaanderen, 2011b; Vlaco, 2011f; www.graskracht.be).

If input streams are to be stored locally before being introduced into the digestion plant, this storage should occur under optimal conditions and be for the shortest possible period (see the 'Optimise the storage of input streams, intermediate products and end products' candidate BAT also).

Technical feasibility
Using input that is as fresh as possible falls under the good business practice measure. Impurities such as sediment fractions (e.g. soil and sand) enter the business activity through the supplied input streams. A sound acceptance protocol is therefore in order (see the 'Optimise the operation of the (manure) co-digestion plant' candidate BAT also).

[8] To prevent rotting and for maximum valorisation of the energy content.

This measure is technically feasible for all (manure) co-digestion plants subject to sound planning, optimal storage and on condition that the necessary agreements are made with up-stream suppliers.

Environmental impact
The amount of waste can be limited by using manure, energy crops and/or OBW that is as fresh as possible. Odour nuisance can also be limited. In addition, the quantity of biogas that is created will be increased if fresh input material is used.

Economic feasibility
If all input material has to be fresh, the number of transport movements may increase (with increasing costs). Practical experience has, after all, shown that companies that sell OBW to digestion plants are generally inclined to wait for a full load before they start transporting. The use of this measure could, therefore, also entail a cost increase (transport). Generally speaking, this measure is considered to be technically feasible for all (manure) co-digestion plants.

References
- Company visits, 2010 and 2011;
- Company details;
- Infomil, 2010;
- Melse R.W. et al., 2004;
- ODE Vlaanderen, 2011b;
- Vlaco, 2011b and f;
- VROM, 2005;
- www.graskracht.be;
- www.ows.be.

→ ***Dispose of the sediment fraction from the digester in a suitable manner***

This technique has been selected as BAT in Chapter 5.

Description of the technique
The sediment fraction from the digester is also known as ash residue. The following options for disposal are used in practice in Flanders:
- spreading on the land, on condition that the relevant regulations from VLARE(M)A (incl. analyses) and other relevant legislation e.g. Regulation 1069/2009 are complied with, and possibly mixed with other streams (e.g. manure or digestate);
- stirring into the digestate (dilution) and disposing of it together with the raw digestate or, if necessary, further post treatment;
- removal to composting (on condition that the VLAREA standards are met);
- incineration.

  Remarks
  The 'Minimise waste streams and dispose of in accordance with the most appropriate options' technique has been selected as BAT for all livestock companies (Derden A. et al., 2006).

Technical feasibility
In practice there is a real risk that the sediment fraction does not meet some parameters of the VLAREA regulations and other relevant legislation (e.g. Regulation 1069/2009) (e.g. exceeding limits due to higher levels or concentrations of specific substances). This measure is, per se, technically feasible for all (manure) co-digestion

plants. The concrete interpretation of this technique, amongst other things, depends on the composition of the sediment fraction.

Environmental impact
Disposing of the sediment fraction from the digester in a suitable manner avoids the waste entering the environment (e.g. surface water, soil) in an uncontrolled manner.

Economic feasibility
The cost price of this measure depends on the concrete interpretation. Some examples of cost prices (2011, incl. VAT and any transport costs) are:

- removal for composting: approximately 40 €/ton;
- incineration: approximately 150 €/ton.

There are, however, no indications that this measure is not economically feasible for all (manure) co-digestion plants.

References

- Company visits, 2010 and 2011;
- Company details;
- Derden A., et al., 2006;
- DLV, 2011a and b;
- Vlaco, 2011a and f.

→ ***Reuse adsorption and filter material to the greatest possible extent and/or dispose of via external parties***

This technique has been selected as BAT in Chapter 5.

Description of the technique
Adsorption and filter material are produced during, amongst others:

- separation of the thick and thin fractions of the digestate using straw filters and microfilters;
- further treatment of the thin fraction of the digestate using membrane filtration (e.g. microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) or reverse osmosis (RO);
- desulphurisation of the biogas by adsorption (e.g. activated carbon filter, ferrous materials) or a bioscrubber;
- removal of NH_3 from the biogas using a biological filter;
- removal of CO_2 from the biogas by absorption in polyethylene glycol.

In many cases, adsorption and filter material can be reused a number of times. To this end, the material has to be regenerated in many cases. This can take place both internally (e.g. aeration of activated carbon filter) and externally (via the supplier). If the material can no longer be used in the production process, it should be disposed of via a recognised processor (the supplier if necessary).

> *Remarks*
> The 'Minimise waste streams and dispose of in accordance with the most appropriate options' technique has been selected as BAT for all livestock companies (Derden A. et al., 2006).

Technical feasibility
This measure is technically feasible for all (manure) co-digestion plants that treat digestate and/or biogas. As pocket digesters do not usually treat the digestate and/or biogas, this technique is less relevant for this category of digestion plant.

With external regeneration and/or disposal of the adsorption and filter material, sound agreements should be made with down-stream suppliers.

Environmental impact
Reusing adsorption and filter material to the greatest possible extent and/or disposing of it via external parties can prevent these waste streams entering the environment in an uncontrolled manner.

Economic feasibility
Regeneration and/or external disposal of adsorption and filter material also incurs certain costs. On the other hand, reuse can limit the use of fresh material which saves costs. Generally speaking, this measure is considered to be economically feasible for all (manure) co-digestion plants.

References
- Company visits, 2010 and 2011;
- Company details;
- Vlaco, 2011b.

4.5. Air/odour/dust

4.5.1. Introduction

In addition to the greenhouse gas methane, dust, odour components (e.g. low molecular weight amines and organic acids), ammonia, hydrogen sulphide, sodium oxide and bio-aerosols (pathogens) may be produced at a (manure) co-digestion plant.

Air emissions, odour nuisance and dust emissions can occur at the following process steps in (manure) co-digestion plants:
- supply, storage, pre-treatment and mixing the input streams (manure, energy crops and OBW) (odour components, dust and H_2 amongst others);
- introducing the input streams into the digester (actual digestion process) (odour components and dust amongst others);
- treatment (e.g. drying) of the digestate (emissions of dust and NH_3 and odour amongst others);
- storage of the (dried) digestate as fertiliser (emissions of NH_3, N_2O, CH_4 and dust, and odour components amongst others);
- ...

In addition, emissions are also produced during incineration of the biogas (e.g. dust, soot, TOC, NO_x and CO). Given that valorisation (burning) of the biogas falls outside of the scope of this BAT study, these emissions will not be discussed further.

Air emissions are also produced when using the digestate as fertiliser. This activity also falls outside of the scope of this BAT study and consequently it is not considered in detail.

4.5.2. Quantitative estimate

As far as is known, no quantitative information is available about the air emissions produced during (manure) co-digestion.

4.5.3. Environmentally-friendly techniques

→ ***Prevent air emissions, odour nuisance and/or dust emissions as far as possible by using source-oriented and/or process-oriented measures***

This technique has been selected as BAT in Chapter 5.

Description of the technique
The following measures, amongst others, can be used to limit the nuisance from odour, dust and/or other air emissions:

- make agreements with the up-stream suppliers on the use of closed lorries;
- use manure, energy crops and/or OBW that are as fresh as possible (see the 'Use input material that is as fresh as possible to maximise biogas production' candidate BAT also);
- optimise unloading and loading activities:
  - unload and load solid input and output materials in a closed shed under negative pressure, equipped with (point) extraction of the air to a suitable (combination of) end-of-pipe air treatment technique(s) (see the 'Perform odour-producing processes in an enclosed area under negative pressure' and 'Capture air emissions at source and using (point) extraction and use end-of-pipe air treatment techniques' candidate BAT);
  - provide a spillage pit at the unloading and loading locations;
  - unload liquid input streams from the lorry's vacuum tank via a closed system with quick-release couplings and correctly functioning connection and shut-off systems or an equivalent alternative;
- construct and empty trench silos (e.g. for maize storage) according to good practice;
- limit the storage duration of input and output streams;
- optimise the storage of input streams, intermediate products and end products (see the 'Optimise the storage of input streams, intermediate products and end products' candidate BAT also);
- avoid diffuse air emissions;
- keep doors, windows and gates closed where possible;
- use quick-close gates;
- perform all odour or dust producing processes (e.g. separating and drying digestate) in an enclosed area that is always under negative pressure (even when the gates are open);
- roof-over and confine digestion operations to the maximum extent;
- capture air emissions at the source using (point) extraction;
- extract and treat air effectively using a suitable (combination of) e-o-p air treatment technique(s) (see the 'Perform odour-producing processes in an enclosed area under negative pressure' candidate BAT also);
- optimise the air management at the site of the processes and in the areas (monitor and adjust); in practice this proves to be an important measure for preventing odour nuisance, amongst other things;
- optimise the feed of input streams into the digester:
  - mix input streams with a high DM content (e.g. grass) with liquid input steams (e.g. manure) so that they can be cross-pumped to the digester;

  - introduce solid input streams via a screw press through the wall of the digester, below manure level;
  - apply one or more of the following measures if input streams are introduced into the digester via an opening in the digester:
    - provide a skirt (system of flaps) on the inside of the digester that reaches to the level of the material that is to be digested;
    - perform this activity in a closed storage and transshipping area under negative pressure equipped with (point) extraction of the air to a suitable (combination of) air treatment technique(s) (see the 'Perform odour-producing processes in an enclosed area under negative pressure' and 'Capture air emissions at source and using (point) extraction and use end-of-pipe air treatment techniques' candidate BAT also);
  - introduce input streams though a suction installation at the bottom of the digester;
- optimise the treatment of biogas (see the 'Optimise biogas treatment' candidate BAT also);
- optimise the treatment of digestate (see the 'Optimise digestate treatment' candidate BAT also).

Remarks

- LTL also mentions a technology relating to the tank infrastructure for biogas (LTL-100068). As far as is known, the biogas that is produced in (manure) co-digestion plants in Flanders has not yet been used as transport fuel.
- Examples of more general measures that can implement these techniques are:
  - Store Oil (CHP plant), heating oil and diesel above a leak tray.
  - Provide drip trays for oil, antifreeze and detergents.
  - Store waste oil in bunded tanks.
  - Place a leak tray under the CHP plant.
  - Use dual-wall oil tanks equipped with overflow protection and leak detection.

  As these measures are cross-sector they are not elaborated further in this BAT study.

Technical feasibility

Generally speaking, preventing air emissions, odour nuisance and/or dust emissions by using source-oriented and/or process-oriented measures is technically feasible for all (manure) co-digestion plants on condition that the operation and the functioning of the air treatment systems are properly monitored and agreements are made with down-stream suppliers. The concrete interpretation of this measure should be at company level. The aim is to prevent odour nuisance in the vicinity (e.g. private individuals in the nearest residential area). A number of measures are generally applicable. Other measures are only relevant for companies that use digestate and/or biogas treatment (e.g. 'Optimise biogas treatment' and 'Optimise digestate treatment'). As pocket digesters do not usually treat the digestate and/or biogas, such measures are less relevant for this category of digestion plant.

Environmental impact

Using these measures limits or avoids emissions into the air (e.g. methane, nitrous oxide and ammonia) as well as nuisance from odour and dust.

Economic feasibility
The primary requirement for the majority of these measures is effort in relation to planning and mentality. Generally speaking, this measure is considered to be economically feasible for all (manure) co-digestion plants.

References
- Company visits, 2010 and 2011;
- Company details;
- EIPPCB, 2005;
- FEBEM, 2011a;
- Infomil, 2010;
- LTL, 2010;
- VDI 3475, 2010;
- Vlaco, 2011f;
- VMM, 2011a;
- VROM, 2005;
- Zwart K.B. et al., 2006.

→ ***Monitor odour emissions accurately***

This technique has been selected as BAT in Chapter 5.

Description of the technique
The accurate monitoring of odour emissions comprises, amongst other things, regularly monitoring the odour limiting measures with the aim of preventing odour nuisance in the vicinity (e.g. private individuals in the nearest residential area). A few examples are:
- maintaining a log relating to monitoring and maintaining the odour limiting measures (e.g. 1x/day, 1x/week, 1x/week) and possible problems/complaints and the measures taken in relation to odour nuisance;
  Remarks
  Examples of accurate monitoring of odour emissions are logging the pH of, for example, (an) acid scrubber(s) and measuring the temperature of, for example, (a) biofilter(s).
- engage a recognised EIR expert in the air discipline in the event of problems with odour nuisance;
  Remarks
  Amongst other things, this expert compiles a checklist of possible problems and remedial measures.
- list the measures for combating odour nuisance (e.g. based on an external expert's checklist).
  Remarks
  The operator maintains a log of problems that have been detected and the measures that have been taken.

Accurately monitoring the odour limiting measures can prevent these techniques not being used or not being used correctly in practice.

Technical feasibility
Accurately monitoring odour emissions is considered to be technically feasible for all (manure) co-digestion plants.

Environmental impact
The advantage of accurately monitoring odour emissions is that serious odour problems can be avoided. In addition, communication with nearby residents can be optimised by indicating that real progress is being made in limiting/preventing odour nuisance.

Economic feasibility
Maintaining a log does not involve any significant costs. Engaging a recognised EIR expert in the air discipline does involve certain costs. Generally speaking, accurately monitoring odour emissions is considered to be technically feasible for all (manure) co-digestion plants.

References
- Company visits, 2010 and 2011;
- Company details;
- DLV, 2011b;
- LNE-AMV, 2011b;
- VCM and Biogas-E, 2010;
- Vlaco, 2011f;
- VMM, 2011c;
- Wiels and partners, 2010.

→ ***Optimise the storage of input streams, intermediate products and end products***

This technique has been selected as BAT in Chapter 5.

Description of the technique
Manure, energy crops and/or OBW that are as fresh as possible should be used (see the 'Use input material that is as fresh as possible to maximise biogas production' candidate BAT also). If streams are to be stored locally this storage should be under optimal conditions. The aim is to prevent odour nuisance in the vicinity (e.g. private individuals in the nearest residential area).

Some examples of good business practices for (manure) co-digestion plants in relation to storage are, for:
- solid streams (e.g. solid manure, thick fraction of the digestate[9], dried digestate and digestate granules):
  - covered trench silos;
  - covered basins;
  - closed containers;
  - enclosed silos;
  - closed sheds (in containers or Big Bags if necessary).
- semi-solid input streams (e.g. energy crops, OBW):
  - liquid-proof storage plate (e.g. acid-resistant concrete), with a raised edge or equivalent provision and roofing (bunding);
  - in (closed) silos.
- liquid streams (e.g. liquid (mixed) manure, liquid OBW, liquid category 3 material, raw digestate, thin fraction of the digestate):

[9] In practice, the thick fraction of the digestate may be a liquid stream (VLM 2011b).

- indoors;
- closed (intermediate) storage (e.g. closed packaging, closed buffers, silos with vapour recovery);
- covered, leak-proof receptacles;
- water-tight storage installations (e.g. water-tight basins, (manure) cellars or (manure) bags);
- storage tanks with overflow protection.

Odour producing streams (estimated to be 90% of the input streams) should be stored in an enclosed area under negative pressure, equipped with (point) extraction to conduct the air to a suitable (combination of) end-of-pipe air treatment technique(s) (see the 'Perform odour-producing processes in an enclosed area under negative pressure' and 'Capture air emissions at source using (point) extraction and use end-of-pipe air treatment techniques' candidate BAT also).
In addition, groundwater infiltration at the storage facilities should be prevented and the storage facilities that are outdoors (e.g. energy crops and OBW) should be covered (e.g. plastic sheets). Furthermore, the storage silos set up outdoors (for liquid OBW) should be vented to the air treatment installation.

Points to note in relation to optimal storage include:

- Prevent the formation of a floating layer (e.g. manure).
- Limit uncontrolled storage (e.g. verge cuttings, maximum 5 days; 3 days in the case of a Vlaco certificate).
- Use specific silage additives (energy crops and/or OBW).
  For example, provide homofermentative lactic acid bacteria for forming acetic acid in the silage instead of lactic acid. Additives with homo and fermentative lactic acid bacteria work both during the acidification of the silage and during the limitation of the fermentation during removal of silage. More complex additives (e.g. with enzymes and yeasts) act on the cell walls (partial breakdown), so that faster acidification of the silage occurs when silaging grass.
  - Acetic acid is needed in silage for digestion because it is a direct food source for the methanogenesis.
  - Biogas production losses of at least 10-15% can be expected in controlled storage (silaging). The addition of an additive of homofermentative lactic acid bacteria to the silage of verge cuttings will have almost no effect on this loss.
- Mixing OBW with other streams (e.g. verge cuttings).
  The biogas production loss (10-15%) with silaging can be almost totally compensated by mixing the verge cuttings with a co-stream such as milk slurry or fruit pulp before silaging (Elsen F et al.; 2009).
- Covering the silage can prevent losses in the dry matter.
- Storing manure (incl. pig manure) in manure cellars for an initial storage period that is too long is detrimental to later digestion because digestion has already occurred during the storage; this results in loss of some of the potential gas production.
- The dryer the products to be digested, the more energy can be generated; energy crops that are stored outdoors should be covered (e.g. with plastic) to prevent rehydration by rain, for instance.

Technical feasibility
Optimizing storage is technically feasible for all (manure) co-digestion plants.

Environmental impact
Optimizing the storage of input streams, intermediate products and end products can prevent odour nuisance and limit the amount of waste. Moreover, optimizing the storage of input streams can maximise the quantity of biogas produced.

Economic feasibility
Optimizing the storage is considered to be economically feasible for all (manure) co-digestion plants.

References
- Company visits, 2010 and 2011;
- Company details;
- Elsen F. et al., 2009;
- Ghekiere G. and Vandenbulcke J., 2011;
- Infomil, 2010;
- Lemmens B. et al., 2007;
- Melse R.W. et al., 2004;
- OVAM, 2011a and b;
- Vlaco, 2011a;
- VLM, 2011b and c;
- VMM, 2011a;
- VROM, 2005.

→ ***Perform odour-producing processes in an enclosed area under negative pressure***

This technique has been selected as BAT in Chapter 5.

Description of the technique
This measure entails all odour producing processes (which also includes the processes that produce dust and ammonia emissions) being carried out in an enclosed space (e.g. shed) under negative pressure. This room should be under negative pressure at all times (even when the doors are open). The aim is to prevent odour nuisance in the vicinity (e.g. private individuals in the nearest residential area).

Examples of processes to which this measure applies are:
- supply, storage, pre-treatment and mixing of input streams (see the 'Optimise the storage of input streams, intermediate products and end products' candidate BAT also); an estimated 90% of the input streams are odour producing materials;
- introducing the input streams into the digester (actual digestion process);
- treating the digestate (separation, drying, composting/biothermal drying, granulating) (see the 'Optimise digestate treatment' candidate BAT also);
- treating the biogas (see the 'Optimise biogas treatment' candidate BAT also).

Remarks
In a subsequent step the air extracted by (point) extraction should be conducted to a suitable (combination of) end-of-pipe air treatment technique(s) (see the 'Capture air emissions at the source using (point) extraction and use a suitable (combination of) end-of-pipe air treatment technique(s)' candidate BAT also).

Technical feasibility
Performing odour producing processes in enclosed areas under negative pressure is technically feasible for all (manure) co-digestion plants.

Environmental impact
Using this measure can limit odour nuisance.

Economic feasibility
Performing odour-producing processes in an enclosed area under negative pressure is considered to be economically feasible for all (manure) co-digestion plants.

References
- Company visits, 2010 and 2011;
- Company details;
- Infomil, 2010;
- VMM, 2011a;
- VROM, 2005.

→ ***Capture air emissions at the source using (point) extraction and employ a (suitable combination of) end-of-pipe air treatment technique(s)***

This technique has been selected as BAT on a case by case basis in Chapter 5.

Description of the technique
This measure is applicable if source-oriented and/or process-oriented measures are insufficient to prevent odour nuisance.
Odour containing air can come from, for instance:
- supply and storage shed for input material (e.g. OBW);
- storage silos for animal by-products: escaping air;
- digester: penetrating air between 2 layers of the digester roof;
- post treatment of the digestate: air that is released during separation and drying, for instance;
- ...

This measure also applies if digestate treatment techniques are used which produce dust emissions.
Dust containing air is produced, for example:
- at the drying installation;
- during evaporation of the digestate;
- during granulation of the digestate.
- ...

From 01/01/2012 general dust standards of 20 mg/Nm³ (from a mass flow >200g/h) and 150 mg/Nm³ (from a mass flow ≤ 200 g/h) apply (VLAREM II, Appendix 4.4.2.1).

An installation with a manure drying or equivalent technique must comply with the following sector emission limit value for ammonia (in accordance with VLAREM II, Article 5.28.3.5.2): 10 mg/Nm³ (for a mass flow of 5 kg/hour and hour or more).

<u>Ammonia</u> containing air is produced, for example, during:
- storage of manure;
- drying of the digestate;
- storage of the digestate.

Remarks
In addition, there are exhaust gases from the biogas motors which cause emissions to the air. Given that valorisation of the biogas falls outside of the scope of this BAT study, this will not be discussed further.

Examples of (combinations of) end-of-pipe air treatment techniques that are (could be) used in Flemish (manure) co-digestion plants (position as at October 2010) are listed in the paragraph below (SOURCES: company-specific information; www.emis.vito.be/LUSS; Derden A. and Huybrechts D., 2011).

- chemical scrubber (incl. odour, ammonia and dust)
    - general, theoretical removal performances:
        - odour: >99%;
        - ammonia: >99%;
        - dust: 70-95%;
    - acid scrubber:
        - odour: 30->99%;
        - ammonia: 75->99%;
    - alkaline scrubber:
        - odour: 90-95%;
    - alkaline oxidative scrubber:
        - odour: 75-95%;
    - field data:
        - A chemical scrubber is used in at least one Flemish (manure) co-digestion plant that also digests manure (position as at October 2010).
        - Concrete field data about the removal performances for odour, ammonia and dust from a properly functioning chemical scrubber in a (manure) co-digestion plant in Flanders is not available as far as is known.
- biological scrubber (incl. odour, ammonia and dust)
    - theoretical removal performances
        - odour: 40-80%;
        - ammonia: 70%-95%;
        - dust: 90%;
    - field data:
        - A biological scrubber is used in at least one Flemish installation that does not also digest manure (position as at October 2010).
        - Concrete field data about the removal performances for odour, ammonia and dust from a properly functioning biological scrubber in a (manure) co-digestion plant in Flanders is not available as far as is known.
- multistage scrubber (incl. odour, ammonia and dust)
    - theoretical removal performances:
        - odour: 70-85%;
        - ammonia: 70-85%;
        - dust: 90%;
    - field data:
        - A two-stage chemical scrubber is used in at least one Flemish (manure) co-digestion plant that also digests manure (position as at October 2010).
        - The combination of an acid, alkaline and biological scrubber would also have been used in Flemish (manure) co-digestion plants in 2010.
        - Multistage chemical scrubbers are also used in 100% of OBW digestion plants (no information available on actual removal performances).

          Remarks
          The investment cost for a two-stage chemical scrubber was € 76,000 in a specific case (2008); the annual operating cost for additives for the chemical scrubber is estimated to be approximately € 6,000 (2010).

- biofilter (incl. odour and ammonia)
  - theoretical removal performances
    - odour: 75-95%;
    - ammonia: 48-90%;
  - field data:
    - This technique is used in at least two Flemish (manure) co-digestion plants that also digest manure and 3 plants that do not also digest manure (position as at October 2010).
    - Concrete field data about the removal performances for odour, ammonia and dust from a properly functioning biofilter in a (manure) co-digestion plant in Flanders is not available as far as is known.
    - High removal performances can often be achieved for high incoming odour concentrations. The treated air can never be totally odour free because a biofilter emits its own specific odour (200-1,000 ou_E/m^3) (Huybrechts D. and Vrancken K., 2005; VITO, 2011b).
- biotrickling filter (incl. odour and ammonia)
  - theoretical removal performances:
    - odour: 45-90%;
    - ammonia: 50-95%;
  - field data:
    - As far as is known, biotrickling filters are not used in Flemish (manure) co-digestion plants.
- combined scrubber (= one (or more) scrubber(s) in combination with a biofilter) (incl. odour, ammonia and dust)
  - theoretical removal performances:
    - odour: 85%;
    - ammonia: 70-95%;
    - dust: 90-95%;
  - field data:
    - The combination of an acid scrubber and a biofilter is used in at least three Flemish (manure) co-digestion plants that also digest manure and in one plant that does not also digest manure (position as at October 2010).
      Concrete field data on the removal performances for odour and ammonia, from a properly functioning combination of an acid scrubber and a biofilter is available for only one of these plants.
      - treated flow: >35,000 m^3/h;
      - average, residual concentration: 1,658 ou_E/m^3 (1,216-2,260 OU_E/m^3);
      - average residual odour emission: 16,437 ou_E/s;
      - average input concentration NH_3: 80 ppm;
      - total ammonia removal efficiency: 88% (75% by the chemical scrubber (to 20 ppm) and then 50% by the biofilter (to 10 ppm));
      - outgoing ammonia concentration: 7.6 mg/Nm^3 (< sector norm 10 mg/Nm^3).

      As far as removal performances for dust are concerned, no field data is available.
    - In practice, odour removal using a combined scrubber (100% OBW digester) would, however, appear to be limited, namely 40% (60% for VOC).
    - A two-stage chemical scrubber (acid + alkaline) in combination with a biofilter is used in at least one Flemish (manure) co-digestion plant that also digests manure (position as at October 2010).
    - A two-stage chemical (acid) scrubber in combination with four biofilters is used in at least one Flemish plant that does not also digest manure (position as at October 2010).

- activated carbon filter (incl. odour and ammonia)
  - theoretical removal performances:
    - odour: 80-95%;
    - ammonia: 99%;
  - field data:
    - The combination of a chemical (acid) scrubber and an activated carbon filter is used in at least one Flemish (manure) co-digestion plant that also digests manure and in one that does not also digest manure (position as at October 2010).
    - Concrete field data about the removal performances for odour and ammonia by a properly functioning activated carbon filter in a (manure) co-digestion plant in Flanders is not available as far as is known.
- cyclone (dust)
  - theoretical removal performances:
    - The residual emissions for dust (>10 µm) for a cyclone are 100 mg/Nm^3 (removal performance of 90%[10]).
  - field data:
    - According to the sector, a cyclone is used in Flanders to treat the extracted dry air, in combination with a flash dryer as a digestate treatment technique. In a flash dryer the product that is to be dried is dosed into a heated airflow that streams at high speed through the flash dryer in an upward direction. The use of this type of dryer imposes significant demands on the separation of the dried product after drying. This separation is usually done using cyclones (www.aspas.nl).
      As far as is known, no field data is available on the removal performances or the residual emissions for dust in this specific case.
- fabric or sleeve filter (dust)
  - theoretical removal performances:
    - odour: >99%;
    - The residual emissions with a fabric filter depend on the fabrics used, but concentrations <20 mg/Nm^3 are still achievable (www.emis.vito.be/LUSS);
  - field data:
    - As far as is known, fabric filters are not used in Flemish (manure) co-digestion plants.
- water scrubber (dust)
  - general, theoretical removal performances:
    - dust: 90%;
  - field data:
    - A water scrubber is used in Flemish (manure) co-digestion plants usually, it is assumed, as a pre-treatment technique (dust removal), before further treating the airflow, e.g. biofilter or activated carbon filter. A water filter is often built in as a pre-treatment step in a chemical scrubber.
      As far as is known, no field data is available on the removal performances or the residual emissions for dust in these types of applications. As a precondition for using an activated carbon filter, the dust concentration in the ingoing air should be limited to, for example, 3-5 mg/Nm^3 (www.emis.vito.be/LUSS).
- afterburner (incl. odour, VOC)
  - theoretical removal performances:
    - VOC: 98-99.9%.
    - Residual concentration of VOC: <1-20 mg/Nm^3 is achievable at a minimum final oxygen content greater than 3 vol%.

[10] Depending on the specific configuration and operating conditions. In principle, values are based on thirty-minute average values. SOURCE: www.infomil.nl and www.emis.vito.be/LUSS.

- field data:
    - As far as is known, there is only 1 digestion plant in Flanders that uses an afterburner, preceded by an acid scrubber as an end-of-pipe air treatment technique. Specifically, it involves a regenerative thermal oxidiser with 3 beds and the use of heat recovery.
    Air from the digestate hall (14,000 m³/h, containing odour, NH_3, H_2S and H_2), the digestion hall (14,000 m³/h, containing odour, NH_3, H_2S en H_2) and the hall containing the sludge dryer (14,000 m³/h containing odour, NH_3, HCs and VOC) has the dust removed and is treated using a dust remover (carousel) and an acid scrubber. This airflow (42,000 m³/h), together with the air from the buffer tanks in the biological stage (1,500 m³/h), dry air from the sludge dryer (2,000 m³/h) and flue gases from the CHP plant (11,000-14,000 m³/h) is then treated in the afterburner.
    There is no information available on the odour component load of the ingoing airflow. There is measurement data available relating to the measured odour concentrations after the burner (1.138 ou_E/m³ with a range of 1.009-1.283 ou_E/m³) and the residual emissions from the afterburner (12,044 ou_E/s). The calculated emission concentrations for the 98th percentile are below 0.5 ou_E/m³ (the zero effect level is 1-1.5 ou_E/m³ as the 98th percentile).
    Likewise, there is no information available about the dust concentration in the air before the afterburner. The following dust concentration is found in the treated airflow after the afterburner: 1.6-5.4 mg/Nm³.
    The investment cost for the afterburner (excl. acid scrubber and piping) is approximately € 1,100,000 (excl. VAT, 2009). The annual maintenance costs for the afterburner are estimated to be approximately € 35,000. The cost price for emission measurements amounts to 800 €/analysis; the annual cost price for this is estimated to be approximately € 10,000. Personnel costs in relation to this technique are negligible. Natural gas is used as an auxiliary substance in the afterburner. If the cost price of the natural gas is taken into account, then the annual operating cost for the afterburner is more than € 175,000 (2010).
    The motivation for implementing this combination of end-of-pipe air treatment techniques is, on the one hand, a proactive company policy in relation to odour emissions and, on the other hand, the current zero tolerance (residential area at 180 metres).

Points for attention in relation to end-of-pipe air treatment techniques include:

- practical experience has shown that the effective removal percentages are generally lower than the above mentioned removal percentages including in relation to the odour aspect;
- installations for limiting ammonia emissions in agricultural areas (linked to animal husbandry) must comply with the requirements in relation to design, operation, inspection and maintenance as stated in the list of low ammonia emission livestock house systems[11] (B.S. dated 08/07/2011);
- dimension the end-of-pipe air treatment technique of sufficient size as a function of the quantity of air that is to be treated;
- optimise the procedure for starting/stopping the air treatment installation, so that the air treatment techniques are operational as required;
- accurately monitor the functioning of the end-of-pipe air treatment technique, maintain and monitor it optimally and optimise it, e.g.

[11] A Ministerial decision to change Appendix 1 to the Ministerial Decision of 19 March 2004 containing the specification of the list of low ammonia emission livestock house systems implementing Article 1.1.2 and Article 5.9.2.1b of the Decision by the Flemish Government of 1 June 1995 containing general and sectoral regulations in relation to environmental hygiene.

- measure the effective air emissions (and determine the effective removal performances);
- equip the acid scrubber with automatic and continuous pH measurement and automatic acid dosing;
- install a pressure gauge between the chemical scrubber and the biobed to be able to monitor pressure build-up in the biobed and take timely action if the pressure builds up too quickly;
- keep the biofilter or the biobed sufficiently moist (check the moisture content);
- prevent collapses (open spaces where air can escape) and repair if necessary;
- monitor the air treatment technique regularly (e.g. 1x/day, 1x/month) and maintain properly paying attention to the following points:
  - perform the six-monthly analysis of the drain water in accordance with the sampling protocol;
  - have the annual inspection of the maintenance carried out by a recognised EIR expert in accordance with the maintenance instructions;
  - maintain a log of the maintenance activities and inspections.

Remarks

- 'Extract livestock building air and treat with a gas scrubber' has been selected as BAT for mechanically ventilated new-build livestock buildings for animal categories for which low ammonia emission livestock building systems have not yet been included in Appendix I to the Ministerial Decision of 19/03/2004 (now superseded by the Ministerial Decision of 31/05/2011, B.S. 08/07/2011) (Derden A. et al., 2006), if additional emission sources have to be tackled in addition to the emission from the livestock building (e.g. manure treatment by drying)
- The (theoretically) achievable performance from e-o-p air treatment techniques does not present the full picture per se. After all, removal performances are closely related to the initial load (type and concentration of odour components) in the air that is to be treated. In practice, the degree of limiting the odour nuisance is important. In addition, the monitoring, inspection and maintenance of the technique(s) used are important.

  For example:

  BREF Waste Treatments Industries (WT) indicate that odour emissions of 500-1,000 GE/m³ are achievable with a combination of biofilter and scrubber if the incoming air from the anaerobic digestion plant contains more than 30 mg/Nm³. The degree to which these figures can be extrapolated for (manure) co-digestion plants in Flanders is not clear.
- The use of certain e-o-p air treatment techniques may produce secondary (unpleasant) odours, e.g. with acid scrubbers as a result of the addition of H_2SO_4.
- Diluting the air or increasing the air inlet can provide a solution to odour problems in certain circumstances. However, this method is contrary to the VLAREM principles (VMM, 2011a).
- In practice, the extracted (odour containing) air is used as combustion air in, for example, CHP plant motors instead of being conducted to an end-of-pipe air treatment installation (FEBEM, 2011a).

The Air Treatment Techniques Guide, or LUSS (Lemmens B. et al., 2004) includes a technical description of the available air treatment techniques (can be viewed at http://www.emis.vito.be/luss/techniekbladen).

Technical feasibility

Which end-of-pipe air treatment technique(s) should be used in a specific case of odour and/or dust nuisance should be determined as a function of the specific situation. The aim is to prevent nuisance from odour and dust in the vicinity (e.g. private individuals in the nearest residential area) and to prevent/limit emissions into the air. In general, end-of-pipe air treatment is considered to be technically feasible for all (manure) co-digestion plants, provided that certain preconditions in regard to the technique(s) involved are met.
For more information about the preconditions for the various air treatment techniques please see the LUSS technique sheets (www.emis.vito.be/LUSS).

Environmental impact

Using and optimizing (monitoring, inspecting and maintaining) end-of-pipe air treatment techniques avoids or limits emissions into the air and odour and/or dust nuisance. The removal performances of the various components depend on the technique or combination of techniques that are used.

Economic feasibility

The use and optimization (monitoring, inspecting and maintaining) of end-of-pipe air treatment techniques involves additional costs for the (manure) co-digestion plant. In addition to investment costs (e.g. technology and piping) there are also operating costs (e.g. labour, energy, chemicals). The effective cost price for this measure is determined by the following, amongst others:

- the (combination of) technique(s) used;
- the flow that is to be treated (dimensioning);
- the input concentration of the component(s).

Air treatment will probably be seen as more economically feasible for large digestion plants in comparison with small (manure) co-digestion plants (e.g. pocket digesters) because of the advantage of scale. The economic feasibility of this measure depends on the specific situation.

References

- Company visits, 2010 and 2011;
- Company details;
- Biogas-Flanders, 2011;
- Derden A. et al., 2006;
- Derden A. and Huybrechts D., 2011;
- DLV, 2011b;
- EIPPCB, 2005;
- Huybrechts D. and Vrancken K., 2005;
- Infomil, 2010;
- LNE-AMV, 2011b;
- LT Eco, 2011;
- ODE Vlaanderen, 2011a;
- VDI 3475, 2010;
- Vlaco, 2011f;
- VMM, 2011a, b and c;
- VROM, 2005;
- www.aspas.nl;
- www.emis.vito.be/LUSS;
- www.infomil.nl.

4.6. Noise/vibrations

4.6.1. Introduction

Noise and vibration can be caused by the following, for example:
- transport activities;
- fans;
- pumps;
- agitators;
- aerators;
- motors (e.g. CHP plant);
- thin/thick fraction separation installation;
- flare installation
- ...

In addition, transport activities (loading and unloading) could also produce noise nuisance.

Furthermore, the CHP plant is also a significant source of noise. Given that valorisation (combustion) of the biogas falls outside of the scope of this BAT study, this noise source will not be discussed further.

4.6.2. Quantitative estimate

There is little or no quantitative data available for noise and vibrations in (manure) co-digestion plants.

4.6.3. Environmentally-friendly techniques

→ ***Tackle noise nuisance at the source, at the design, selection, operations and maintenance levels***

This technique has been selected as BAT in Chapter 5.

Description of the technique
Amongst other things, the following measures can be used to limit the nuisance from noise and vibrations where processes take place:
- select low-noise installations in the design phase (e.g. fans, pumps, agitators, aerators);
- set up noise sources (e.g. centrifuges, pumps, hopper with shredding system, agitators, motors, drying installation) in an enclosed space, with soundproof walls and doors if necessary;
- position pumps and mixers inside the installation/digester wherever possible;
- fit soundproof casings to installations (e.g. suppressors, pumps) that may produce noise nuisance and position them inside the engineering room;
- mount motors on cork or rubber feet (silent blocks);
- use sound-insulating hatches at suction openings;
- fit silencers to exhausts;
- keep doors, windows and gates closed where possible;

- use quick-close doors; in practice this is done using, for instance, a flexible, folding curtain;
- operate fans as little as possible (e.g. by using a computer-controlled climate control system).

Technical feasibility
There are various examples of (manure) co-digestion plants using one or more of the above mentioned measures in Flanders. Generally speaking, this measure is considered to be technically feasible for all (manure) co-digestion plants.

Environmental impact
The use of this measure can limit nuisance from noise and vibrations as a result of business operations.

Economic feasibility
Tackling noise and vibration nuisance at the source is considered to be economically feasible for all (manure) co-digestion plants.

References
- Company visits, 2010 and 2011;
- Company details;
- DLV, 2011b;
- EIPPCB, 2005;
- VDI 3475.

→ ***Limit noise nuisance produced by vehicles***

This technique has been selected as BAT in Chapter 5.

Description of the technique
Noise nuisance produced by vehicles can be limited by using, amongst other things, the following measures:
- lay down the mobility aspects in consultation with the municipal authority;
- make agreements with up-stream and down-stream suppliers to limit the number of transport movements;

  For example:
  combine the supply of input streams and the removal of digestate;
  Remarks
  It is not always possible to combine the supply of input streams and the removal of digestate for hygiene reasons (clean/dirty). Lorries delivering animal by-products and then wanting to transport sanitised material must be cleaned and disinfected first. For many lorries this requires tank cleaning (usually an external activity). And in the case of OBW too, plant pathogens and/or weed seeds must not transfer from supply to end product.
- respect agreements that have been made in relation to the transport times for supply and removal of the raw materials and end products (see, for example, the stipulations in VLAREM II, Article 5.2.1.6.§4: the supply and removal of raw materials and end products must not take place between 19:00 hours and 07:00 hours and on Sundays and Public Holidays);
- do not leave the engines of lorries and agricultural vehicles running unnecessarily.

Technical feasibility
Limiting noise nuisance from vehicles is technically feasible for all (manure) co-digestion plants, on condition that the necessary agreements are made with up-stream (e.g. farmers, suppliers of raw materials and additives, haulage companies) and down-stream (e.g. farmers, haulage companies) partners.

Environmental impact
The use of this measure can limit nuisance from noise and vibrations produced by vehicles.

Economic feasibility
Limiting noise nuisance produced by vehicles carries no implicit cost increase or cost reduction but in most cases does require a certain change in mentality. This measure is considered to be economically feasible for all (manure) co-digestion plants.

References
- Company visits, 2010 and 2011;
- Company details;
- VDI 3475;
- Vlaco, 2011b;
- www.senternovem.nl.

→ ***Use noise barriers or green barriers***

This technique has been selected as BAT on a case by case basis in Chapter 5.

Description of the technique
In addition to limiting nuisance from noise and vibrations, the visual nuisance to neighbours can be limited by noise barriers. If the noise barriers comprise or include plants this is known as green barriers.

> *Remarks*
> Embankments (e.g. mounds of earth) can also serve as noise or green barriers.

Technical feasibility
This technique is primarily relevant to (manure) co-digestion plants that are located in agricultural (valuable) areas. This technique (probably) does not apply to industrial digestion plants.
The use of noise barriers or green barriers is considered to be technically feasible for all (manure) co-digestion plants that are situated in agricultural (valuable) areas.

Environmental impact
The use of noise barriers or green barriers can limit nuisance from noise and vibrations. Moreover, noise barriers or green barriers limit the possible visual nuisance caused by the (manure) co-digestion plant.

Economic feasibility
The use of noise barriers or green barriers has been stipulated in legislation (VLAREM II Article 5.2.1.5.§5) but is usually further specified in the particular environmental conditions. This measure is considered to be economically feasible for all (manure) co-digestion plants.

References
- Company visits, 2010 and 2011;
- Company details;
- EIPPCB, 2005.

4.7. Chemicals

4.7.1. Introduction

BREF Waste Treatments Industries (WT) mentions a number of quantities of additives (see below) that are used in an installation that comprises separation and anaerobic digestion of waste (EIPPCB, 2005). The degree to which these figures can be extrapolated for (manure) co-digestion plants in Flanders is not clear.

The following chemicals could be used at a (manure) co-digestion plant (Company visits, 2010 and 2011; DLV, 2011b):
- lorry disinfectants (recognised biodegradable products with a short emulsification time (see the list of the Federal Agency for the Safety of the Food Chain), which must not have a negative effect on the digestion process);
- sulphuric acid[12] (chemical scrubber);
- NaOH (alkaline scrubber);
- Hypochlorite (NaOCl) (cleaning agent and disinfectant);
- $FeCl_3$ (biogas desulphurisation catalyst) (3 kg/ton input according to BREF WT);
- polymers (60 g/ton input according to BREF WT);
- anti-foam agents (e.g. polyalkylene glycol solution: 50 g/ton input according to BREF WT).

4.7.2. Quantitative estimate

There is little or no quantitative data available for the use of chemicals in (manure) co-digestion plants.

4.7.3. Environmentally-friendly techniques

The techniques relating to the use of chemicals generally have an impact on multiple environmental compartments. The candidate BAT for limiting the use of chemicals has therefore also been included in paragraph 4.9.3.

4.8. Soil

4.8.1. Introduction

Emissions to the soil in (manure) co-digestion plants can occur at, amongst others, the following process steps (Company visits, 2010 and 2011; DLV, 2011b):
- storage of the input streams (manure, energy crops and OBW);
- the actual processing (e.g. in case of foaming);
- storage of the digestate;
- storage of chemicals for the air treatment installation (e.g. H_2SO_4 for the chemical scrubber).

In addition, there is a possible risk of soil contamination from the valorisation (combustion) of the biogas (mineral oils, e.g. for the CHP plant). As these activities fall outside of the scope of this BAT study, these risks of soil contamination are not discussed further.

[12] The Seveso regulations apply in the case of large quantities.

4.8.2. Quantitative estimate

As far as is known, there is no quantitative data available on the risk of soil contamination.

4.8.3. Environmentally-friendly techniques

The techniques relating to limiting the risk of soil contamination generally have an impact on multiple environmental compartments. The techniques for preventing soil contamination have therefore also been included in paragraph 4.9.3.

4.9. Other

4.9.1. Introduction

Paragraphs 4.1 to 4.8 contain environmental measures that are reasonably directly linked to one or more environmental compartments. In addition, a number of more general measures apply to (manure) co-digestion plants in relation to the design of the installation, the business operations, hygiene and safety. These are covered in more detail in the next paragraph.

4.9.2. Quantitative estimate

The more general environmental measures relating to the design of the installation, maintenance, the business operations, etc. can contribute to improving the environmental performance of (manure) co-digestion plants. The environmental benefit is, however, difficult to quantify in the sense of, for instance, emission reductions or driving down energy consumption.

4.9.3. Environmentally-friendly techniques

→ ***Optimise the design of the (manure) co-digestion plant***

This technique has been selected as BAT in Chapter 5.

Description of the technique
Well-considered design of the (manure) co-digestion plant can, amongst other things, include the following measures:

- provide an environmental management system;
  Environmental management includes all the measures taken in an attempt to prevent or counteract the undesirable effects of human activities or actions on the external environment (i.e. the surrounding area). The best way for businesses to address environmental risks is through preventive or proactive environmental management. Here, attention is paid to formulating an environmental policy, planning a strategy or an environmental programme, drawing up procedures, defining tasks and responsibilities, communicating, specifying a system for internal control, a procedure for dealing with anomalies, disasters and complaints (e.g. an emergency plan and complaints procedure). Applying a measuring and management

programme can also be viewed as part of the environmental management system. Care for the environment is inextricably linked to (occupational) safety. Constant attention to tidiness and order in a company will, for example, not only reduce the risk of (occupational) accidents, but it will also prevent emissions to the environment from occurring.

- optimise the location, construction and housing of (certain components of) the digestion plant whilst, amongst other things, adhering to distance rules (e.g. VLAREM) and construction regulations (e.g. VLAREM, ATEX[13]);
- provide a monitoring system so that the quantity (venturi flume) and quality (standards) of the discharged wastewater can be determined (e.g. for (manure) co-digestion plants that post-treat the digestate into a dischargeable effluent);
- provide sampling points at the storage sites for various liquid streams, so that samples can be taken in a safe and representative manner;
- provide observation wells and a drainage system to prevent soil and ground water contamination;

  Remarks

  The actual design of the observation wells and drainage system should be determined at company level (amongst other things, depending on the number and size of the storage sites).
- lay down the preconditions for the digestion plant in advance;
  - maximum annual processing capacity [x tons per year].
  - whether or not a mix of input streams is to be used
    - The mix of input streams used (type and quantity) has a direct effect on, amongst other things
      - the operating processes (operating temperature, design, etc.);
      - the techniques required for biogas treatment and digestate treatment;
    - single stage versus multistage systems;
    - whether or not to use post-digestion;
  - input manure:
    - measuring protocol and sampling procedure for supplied streams, for example, should be determined in consultation with the VLM (in accordance with the measurement protocol within the scope of the nutrient balance);
  - input of animal by-products (incl. manure):
    - animal by-products (incl. manure) must only be digested if the installation has been authorised in accordance with Regulation 1069/2009 (previously 1774/2002) for determining the health regulations in relation to animal by-products not intended for human consumption. A hygienisation step is mandatory depending on the specific product.
- enclosed design for process components of the (manure) co-digestion plant in which biogas is present, incl.
  - initial storage;
  - digester;
  - biogas storage;
  - post-storage;

[13] ATEX is the French name "ATmosphère EXplosible" and is used synonymously for two European Directives in the field of explosive hazard under atmospheric conditions. From 1 July 2003, organizations in the EU where there is an explosive hazard must comply with the new ATEX 137 Directive (Directive 1999/92/EC). Another Directive is the ATEX 95 Directive (Directive 94/9/EC). This Directive is especially for the equipment that is used in locations where there is an explosive hazard.

  - post-treatment (e.g. manure separation, evaporation);
  - biogas treatment;
  - pipes;
  - control;
- design (components of) installations with materials that are resistant to (corrosion from) biogas;
  - concrete can be eroded by acidic components;
- use energy-efficient installations or components, e.g.
  - make the greatest possible use of natural lighting;
  - optimise the artificial lighting;
- use frequency controlled mixers, feed pumps, centrifuges, etc.;
- provide sufficient storage capacity;
- provide water-tight, quick-release couplings for the transfer of liquid streams (e.g. between lorry and a closed storage cellar) or an equivalent alternative;
- provide a dual-valve system for transferring liquid streams so that the supply/removal takes place via a single, closed circuit (e.g. storage cellar - supply hose - lorry);
- blow the manure hose empty using high-pressure after unloading;
- provide the necessary hard surfaces, incl.
  - all surfaces that are driven over;
  - unloading sites for manure and other input streams;
  - storage sites for the solid streams such as green fodders and energy crops (liquid-tight storage site, e.g. acid-resistant concrete);
- take measures (incl. storage) to capture the run-off from the hard surfaces and convey it to the (manure) co-digestion plant;
- take measures (e.g. first-flush system) to prevent sap losses at the trench silos;
- provide water-tight floors at all locations where seepage of N or P can be expected;
- provide capture (for lye, run-off for example) at the storage sites;
- prevent streams (e.g. manure) entering the environment in the event of disaster (e.g. provide leak trays);
- provide a physical barrier between the various operations sections, particularly the dirty/input section and the clean/output section;
- limit the size of the dirty zones as far as possible by suitable operating processes and optimizing vehicle movements;
- provide emergency facilities to keep the most critical components of the digestion plant working in the event of power failure (e.g. air pump for desulphurisation, flare installation);
- provide a collection tank as a buffer in case of unwanted foaming in the digestion tank(s);
- design the input and output of the digester as far as possible away from each other to prevent the efflux of incompletely digested material (in the event of sub-optimal mixing);
- optimise mixing in the digester to prevent floating and sediment layers, to prevent the creation of foam layers and to achieve a uniform output stream (homogeneous end product);
- in the design stage too, pay attention to good environmental communication with all parties involved (e.g. nearby residents, municipal authority, advisory bodies, the press);

- store sulphuric acid[14] in dual-wall or bunded, above-ground tanks (relevant in case of a chemical scrubber being used as e-o-p air treatment technique);
- provide overflow protection on the storage and buffer tanks;
- provide a suitable loading/unloading zone with suitable collection features in case of disasters.

  Remarks
  - BREF WT (EIPPCB, 2005) reports using thermophilic digestion to improve pathogen destruction, biogas production and residence time.
  - The 'Provide sufficient manure storage capacity' and 'Optimise the design of the ventilation system in mechanically ventilated livestock houses' techniques have been selected as BAT for all livestock companies. 'Optimise livestock houses and/or manure storage sites within the company premises' has been selected as BAT for all new livestock houses and/or manure storage sites in livestock companies. (Derden A., et al., 2006)

Technical feasibility
A well-considered design of the (manure) co-digestion plant is one of the fundamental conditions for receiving a permit and is also considered to be state of the art. This measure is considered to be technically feasible for all (manure) co-digestion plants.

Environmental impact
This measure can contribute to improved environmental performance of (manure) co-digestion plants in the field of, amongst others, energy and water consumption, production of waste, emissions of odour/dust to the air and the water, noise/vibrations, the use of chemicals and emissions into the soil.

Economic feasibility
As this measure is considered to be state of the art, it is also considered to be economically feasible for all (manure) co-digestion plants.

References

- Company visits, 2010 and 2011;
- Company details;
- Biesemans P. et al., 2011;
- Biogas-E, 2010b;
- Derden A. et al., 2006;
- DLV, 2011b;
- EIPPCB, 2005;
- FEBEM, 2011a;
- Infomil, 2010;
- KULeuven, 2010a;
- LNE-AMV, 2011a;
- LT Eco, 2011;
- LTL, 2010;
- OVAM, 2011a and b;
- Polders C. et al., 2011;
- Röring Energie-Anlagen, 2010;
- VCM and Biogas-E, 2007;
- Vlaco, 2011b;
- VLM, 2011b and c;
- VMM, 2011c;

[14] The Seveso regulations apply in the case of large quantities.

- VROM, 2005 and 2010;
- Wiels and partners, 2010;
- www.senternovem.nl.

→ *Optimally maintain (manure) co-digestion plants*

This technique has been selected as BAT in Chapter 5.

Description of the technique
The following environmental measure relating to maintenance, amongst others, applies to (manure) co-digestion plants:
- maintenance of (parts of the) (manure) co-digestion plant should be carried out by a professional, in combination with regular inspection (e.g. 1x/day, 1x/week, 1x/month) and be monitored by the manager;
- enter into a maintenance contract with the supplier of the digestion plant, which contains stipulations in connection with the maximum time within which any breakdown must be resolved.

Technical feasibility
Sound maintenance of the (manure) co-digestion plant is a component of good business practice and an environmental management system[15] and is also considered to be state of the art. This measure is considered to be technically feasible for all (manure) co-digestion plants.

Environmental impact
This measure can contribute to improved environmental performance of (manure) co-digestion plants in the field of, amongst others, energy and water consumption, production of waste, emissions of odour/dust to the air and the water, noise/vibrations, the use of chemicals and emissions into the soil.

Economic feasibility
Proper maintenance of the (manure) co-digestion plant mainly requires time and labour and requires a positive attitude in regard to environmental awareness. This measure is not directly paired with costs and is considered to be economically feasible for all (manure) co-digestion plants.

References
- Company visits, 2010 and 2011;
- Company details;
- Infomil, 2010;
- VMM, 2011c.

→ *Optimise the operation of the (manure) co-digestion plant*

This technique has been selected as BAT in Chapter 5.

Description of the technique
Well-considered optimization of the (manure) co-digestion plant can, amongst other things, include the following measures:
- use good business practices in relation to operations;

[15] See the 'Optimise the design of the (manure) co-digestion plant' candidate BAT

- use an environmental management system[16];
- internal compliance with the stipulated conditions and processes by an individual with technical responsibility for the (manure) co-digestion plant;
- unload and load with the necessary care and in accordance with the internal procedures
- determine concentrations of a number of parameters (e.g. COD, N-total, P-total, Cl^- and TOC) in input and output streams (e.g. digestate and wastewater) to use optimal feeding of the digester and to achieve good methane production;
- make agreements with up-stream suppliers/haulage companies to ensure a sufficient quantity of input streams to allow continuous operation of the (manure) co-digestion plant; this must not, however, be at the expense of the quality of the streams that are supplied;
- harmonise supply with the (manure) co-digestion plant's processing capacity;
- optimise the moisture content of the input streams (mix) to prevent leaching-out;
- optimise the residence time of the material in the digester;
- thoroughly evaluate (any changes in) the input streams in advance:
  - at least one analysis of P_2O_5 and N should be carried out when manure, energy crops and OBW is delivered from new establishments or suppliers;
  - co-digestion with energy crops and/or OBW (in addition to manure) is widely used in practice to increase biogas production;
    Remarks
    - manure contains little organic matter, is low-fat and poorly degradable;
    - the input for the digester must be selected such that stable digestion is achieved. Factors having a significant role in this are the C/N ratio, the C availability and the presence of toxic substances;
    - the COD content of the input streams is a measure of the energy content (1 kg COD ≈ 0.35 Nm³ CH_4 ≈ 3.5 kWh ≈ 12.56 mJ); a couple of examples:
      - 1 kg sugar ≈ 1.0-1.4 kg COD;
      - 1 kg protein ≈ 1.2-1.7 kg COD;
      - 1 kg fat ≈ 2.0-2.8 kg COD;
      - 1 kg alcohol ≈ 2.0-2.3 kg COD;
- use a good acceptance protocol in practice (incl. HACCP and risk analysis principles) and provide a procedure for handling the removal of input streams that do not meet the acceptance criteria:
  - take the necessary samples and carry out the necessary analyses (have them carried out);
  - take account of current legislation (incl. no-dilution principle for waste matter);
  - attract pure input streams;
    Remarks
    The contamination aspect (chemical, physical, microbiological) plays a major role in the acceptance of input streams.
  - attract the right combination of energy streams:
    - attract as many energy-rich streams as possible;
      Remarks
      Sometimes, streams have to be accepted to control by dry matter content (e.g. mix in more maize if the dry-matter content becomes too low as a

[16] See the 'Optimise the design of the (manure) co-digestion plant' candidate BAT

result of large quantities of (liquid) energy-rich streams). For streams that produce less biogas in the normal digestion period, you can opt to return the thick fraction to the digester in the event of dewatering.
    - use streams that are difficult to digest or streams with a limited biogas yield (e.g. manure) in an optimal mix with steams that digest well and streams with a higher biogas yield;
  - refuse streams that cannot be used;
  - information about the source of input streams is crucial within the scope of traceability;
- ensure good quality of input streams from own company (e.g. manure and energy crops for pocket digesters);
- list suppliers and recipients of raw materials and products to/from the (manure) co-digestion plants respectively (for traceability reasons);
- optimise the input mix with a view to maximum energy yield;
- mix input streams thoroughly;
- do not add organic waste streams at the post-digestion installation;
- accurately monitor the digestion process (temperature, residence time, etc.) and adjust if necessary;
- use automatic control of the system, e.g. to keep the temperature in the digester up to level;
- avoid foaming by, for example:
  - controlling the digestion processes based on the organic matter content of the (mix of) input streams;
  - mixing the content of the digester thoroughly (the top layer in particular);
  - provide spraying systems in the digesters;
  - administer optimal doses of environmentally friendly foam suppressants;
- have modifications to (parts of the) (manure) co-digestion plant carried out by a professional;
- limit the manure surface area in the digester to prevent/limit the formation of a floating layer; the manure surface area is determined by the shape of the digester (rectangular or circular);
- ensure that the quantity of digestate that is removed from the digester is commensurate with the quantity of input material supplied;
- provide sufficient post-storage for the digestate;
- do not transport or mix digestate that has come directly from the digestion plant with other animal fertilisers because of the risk of secondary digestion and biogas production during transport and storage;
- check the water seal and overpressure valve at the biogas storage regularly and top up with water as additional protection to prevent penetration through the water seal; a minimum check of 1x/week (2x/week during hot periods) is recommended;
- use process control based on a (simple) balance;
- only use detergent that is permitted by the FAVV and which does not have a negative effect on the digestion process to clean lorries;
- always report any disasters to the competent authorities.

Remarks

Additional examples of measures that can interpret these techniques are:

- emit combustion gases in a controlled manner;
- lead outlet gases from the biogas motor(s) over the drying installation.

As valorisation of the biogas falls outside of the scope of this BAT study, this measure will not be discussed further in this BAT study.

Technical feasibility
Practical experience has shown that the dimensioning of the techniques in a (manure) co-digestion plant is not simple. Choice between over-dimensioning (and simple monitoring of the processes) and correct dimensioning (combined with very accurate process monitoring) appears to be a difficult exercise.
Generally speaking, optimizing the operating process of the (manure) co-digestion plant is usually considered to be the state of the art. This measure is technically feasible for all (manure) co-digestion plants.

Environmental impact
This measure can contribute to improved environmental performance of (manure) co-digestion plants in the field of, amongst others, energy and water consumption, production of waste, emissions of odour/dust to the air and the water, noise/vibrations, the use of chemicals and emissions into the soil.

Economic feasibility
As far as is known, no concrete data is available for the cost price of optimizing the operating process of the (manure) co-digestion plant. As this measure is considered to be state of the art, it is also considered to be economically feasible for all (manure) co-digestion plants.

References
- Company visits, 2010 and 2011;
- Company details;
- Biogas-E, 2010a and b;
- Devriendt N. et al., 2004;
- DLV, 2011b;
- EIPPCB, 2005;
- Infomil, 2010;
- Howest, 2010a;
- KULeuven, 2010a;
- Lemmens B. et al., 2006;
- Röring Energie-Anlagen, 2010;
- VCM, 2011b;
- Vlaco, 2011b;
- VROM, 2010;
- www.senternovem.nl.

→ ***Optimise digestate treatment***

This technique has been selected as BAT in Chapter 5.

Description of the technique
Digestate can be used directly on the land (provided that current manure legislation is complied with). In practice, digestate generally undergoes further treatment so that it can be marketed and to limit transport costs.

No judgements are made within the framework of this BAT on whether or not the digestate should be treated and the choice of treatment technique(s). The strategy to be followed depends on the company-specific situation (e.g. available input streams, desired marketing route(s), heat available via biogas valorisation).

Remarks
The sector indicates that, in practice the 'biological treatment into dischargeable effluent' is being forsaken more and more (Biogas-Vlaanderen, 2011; UGent, 2011a).

Once the choice of digestate treatment technique(s) has been made, the aim should be optimal business processes relating to digestate treatment, for example:

- use good business practices in relation to operations[17];
- if polymers are used to optimise the separation of the digestate into a thick and thin fraction, avoid polymers based on mineral oil (due to the environmental standards for soil and water);
- use energy-efficient installations or components[18];
- monitor the energy consumption of the most energy demanding process steps[19];
- improve the energetic yield of the installation[20];
- reuse the heat from the condensed water from the drying installation in the drying process[21];
- set up the drying installation in a separate, enclosed space;
- do not dry the digestate longer than necessary[22];
- provide continuous temperature monitoring (e.g. using thermometers, heat cameras or infrared detectors) at the drying installation, incl. for
    - incoming drying air (e.g. preheated outside air);
    - outgoing drying air;
    - end product;
- make provisions for excessive temperatures at the drying installation, e.g.
    - stop the feed of input;
    - stop the supply of combustion gases;
    - provide a sprinkler system that starts automatically and immediately in the event of alarmingly high temperatures;
- earth metal parts of the drying installation to prevent electrostatic charging;
- design mechanical transport systems for drying installations in such a way that the product is not heated as a result of friction;
- provide a spark separator between the motor and the drying installation;
- fit inspection apertures in the drying installation for regular visual inspection;
- fit fire-resistant insulation to the drying installation;
- limit the storage period for output streams[23];
- limit the drying temperature (digestate post-treatment) (e.g. in practice the aim is to keep this temperature below 90°C);
- use intensive automation[24];
- store digestate optimally[25];

[17] see the 'Optimise the operation of the (manure) co-digestion plant' candidate BAT
[18] see the 'Optimise the design of the (manure) co-digestion plant' candidate BAT
[19] see the 'Optimise processes to prevent or limit excessive energy consumption' candidate BAT
[20] see the 'Optimise processes to prevent or limit excessive energy consumption' candidate BAT
[21] see the 'Optimise processes to prevent or limit excessive energy consumption' candidate BAT
[22] see the 'Optimise processes to prevent or limit excessive energy consumption' candidate BAT
[23] see the 'Prevent air emissions, odour nuisance and/or dust emissions as far as possible by using source-oriented and/or process-oriented measures' candidate BAT
[24] Derived from LTL-1215 "Installation with intensive automation for the biothermal drying (composting) of manure".
[25] see the 'Optimise the storage of input streams, intermediate products and end products' candidate BAT

    - solid streams (e.g. solid fraction of the digestate, dried digestate and digestate granules):
        - covered trench silos;
        - covered basins;
        - enclosed sheds;
    - liquid streams (e.g. thin fraction of the digestate):
        - enclosed (interim) storage (e.g. enclosed buffers);
        - water-tight storage installations (e.g. water-tight basins);
        - fit overflow protection to storage tanks;
- combine the removal of digestate with the supply of input streams to limit the number of transport movements[26];

  Remarks

  It is not always possible to combine the supply of input streams and the removal of digestate for hygiene reasons (clean/dirty). Lorries delivering animal by-products and then wanting to transport sanitised material must be cleaned and disinfected first. For many lorries this requires tank cleaning (usually an external activity). And in the case of OBW too, plant pathogens and/or weed seeds must not transfer from supply to end product.
- provide an installation for recycling process water[27]; e.g. for filtrate that is produced during the post treatment of the digestate (e.g. membrane filtration)[28], on condition that this is hygienically responsible and in accordance with Regulation 1069/2009.

  Remarks

  Practical experience has shown that (manure) co-digesters change the digestate treatment techniques used over the course of time due to, for instance, changes in the field of marketing possibilities in neighbouring countries (e.g. France).

The techniques below can be used for separating the digestate into a thick and thin fraction:
- centrifuge[29];
- screw compression filter[30] or screw press;
- decanter;
- drum separator;
- dung scraper;
- (band) sieve;
- microfilter;
- sedimentation installation.

The separation process can be optimised by adding polymers or solid materials.

Remarks

If polymers are used to optimise the separation of the digestate into a thick and thin fraction, avoid polymers based on mineral oil (due to the environmental standards for soil and water).

The thick fraction of the digestate can be further treated by, for example:
- secondary digestion;
- drying (belt dryer, paddle dryer or fluidised-bed dryer);

[26] see the 'Limit noise nuisance produced by vehicles' candidate BAT
[27] see the 'Limit the quantity and burden of wastewater/liquid waste streams' candidate BAT
[28] see the 'Optimise water consumption' candidate BAT
[29] According to the sector this is a very efficient but expensive separation technique.
[30] According to the sector a less efficient (10-15% less compared to a centrifuge) but cheaper separation technique.

Remarks
- Drying the digestate can involve odour and dust nuisance. That is why this air is usually extracted and treated using (a combination of) end-of-pipe (e-o-p) air treatment techniques (see the 'Capture air emissions at the source using (point) extraction and use a (suitable combination of) end-of-pipe air treatment technique(s)' candidate BAT also).
- In 2011 a number of (manure) co-digestion plants had already burned down in Flanders, during which the fire started at the drying installations[31]. This is why further optimization of drying techniques was investigated in 2011. Some points for attention in this regard are: avoid plastic conveyor belts, avoid moving parts, and prevent overheating. There is also further optimization to be achieved by improving heat recovery, e.g. by using enclosed, insulated housings with doors that close air-tight on the drying system. Regular inspection and maintenance of the drying system is very important. This is why good accessibility and the availability of (standard) components is also a point for attention.

- composting/biothermal drying;
- centrifuging;
- thickening;
- liming;
- granulating;

  Remarks
  According to RWZ-RIZA (2006) an increasing market value can be expected for the manure granules as a replacement for expensive artificial fertiliser (because of the continually increasing raw material prices for phosphate).

Possible treatment techniques for the further treatment of the thin fraction are:
- biological/aerobic wastewater treatment (e.g. MBR);
- liming;
- drying;
- evaporation;
- membrane filtration (e.g. microfiltration (MF), ultrafiltration (UF), nanofiltration (NF) or reverse osmosis (RO);
- nutrient recovery (e.g. production of ammonium sulphate or struvite production);
- stripping;
- constructed wetlands/lagoons.

Hygienisation can be used to destroy pathogens. In this process the digestate is kept at a specific temperature for a specific time (e.g. at 70°C for 1 h[32]). Hygienisation can be used on the raw digestate and on the thick and the thick fraction of the digestate after separation also. The hygienisation step can be optimised by ensuring that, for example, there are sufficient small parts, a homogeneous mixture and correct processing (temperature).

Technical feasibility
Thanks to the years of experience in manure processing techniques Flanders is one of the leaders in digestate treatment. It can also be assumed that optimizing these techniques receives a great deal of attention within the sector. Nonetheless, digestate treatment is seen as one of the biggest sticking points for developing the sector. Much

[31] see the 'Guarantee safety on the company site and at the (manure) co-digestion plant' candidate BAT
[32] A Danish monitoring programme demonstrated that a digestate treatment lasting 8 hours at 53.5°C would have the same effect as a treatment of 1 hour at 70°C (www.biogasbranchen.dk). However, this does not mean that this alternative method should be used without further discussion. After all, there must be compliance with Regulation 1069/2009 and alternatives to the 'min 1h 70°C' must be validated by the competent body.

experience has been gained, but many (manure) co-digestion plants do not work optimally.
Optimization of the digestate treatment can, generally speaking, be considered to be technically feasible for all (manure) co-digestion plants that treat digestate. As pocket digesters do not usually treat the digestate, this technique is less relevant for this category of digestion plant.

Environmental impact
Generally speaking, it can be stated that optimizing the digestate treatment, can limit the amount of waste (non-conformant digestate).

Depending on the specific digestate treatment technique(s), optimization of the digestate treatment can limit energy consumption, prevent odour nuisance and limit nuisance from noise/vibrations. As is the case for the supply of input streams too, there could also be a mobility issue during removal of the digestate, in particular in large (manure) co-digestion plants in agricultural areas (number of transport movements and road infrastructure that is not suitable for heavy lorries). In addition, the application of this measure can also prevent the use of water, the use of chemicals as well as contamination of the soil or water.

Economic feasibility
In addition to the requirements (legislation) to be able to market the digestate, limiting the costs for transport or utilities (energy) are important motivators for optimizing the digestate treatment. Digestate treatment will be probably be seen as more economically feasible for large digestion plants in comparison with small (manure) co-digestion plants because of the advantage of scale. Optimizing the digestate treatment is generally a requirement to guarantee the operational security and returns from the plant and is considered to be economically feasible for all (manure) co-digestion plants.

References

- Company visits, 2010 and 2011;
- Company details;
- Biogas-E, 2010c;
- DLV, 2011a;
- FEBEM, 2010;
- KBC, 2011b;
- Meus B. et al., 2009;
- LNE-AMV, 2010a;
- LT Eco, 2011;
- ODE, 2010b;
- VCM, 2010a and 2011;
- Vlaco, 2009;
- VLM, 2009 and 2011;
- VMM, 2010a;
- www.biogas-e.be;
- www.biogas-vlaanderen.be;
- www.vcm-mestverwerking.be

→ *Optimise biogas treatment*

This technique has been selected as BAT in Chapter 5.

Description of the technique

Biogas that is produced should be treated before it is able to be valorised. Treatment means that components such as H_2S, NH_3, CO_2 and H_2O are removed from the biogas.

Remarks

Using specific biogas treatment techniques (e.g. injecting air above the biogas storage) means that some of the methane can be valorised and therefore kept out of the environment (Vlaco, 2011b).

No judgements are made within the framework of this BAT on whether or not the biogas should be treated and the choice of treatment technique(s). The strategy that is to be followed depends on the method of valorising the biogas (the topic falls outside of the scope of the BAT study).
Company-specific situation (e.g. available input streams, desired marketing route(s), heat available via biogas valorisation).

Once the choice of biogas treatment technique(s) has been made, the aim should be optimal business processes relating to biogas treatment, for example:

- provide an installation for recycling process water[33]; e.g. for condensed water that is produced during treatment of the biogas (e.g. dewatering) or with heat recovery[34];
- reuse adsorption and filter material to the greatest possible extent[35];
- prevent the formation of aerosols (containing S);
- implement an enclosed installation for treating the biogas[36];
- design (components of) installations with materials that are resistant to (corrosion from) biogas[37];
- provide emergency provisions to keep the air pump for desulphurisation of biogas working in the event of power failure[38];
- store sulphuric acid[39] in dual-wall or bunded, above-ground tanks[40].

The following techniques can be used for desulphurisation (removal of H_2S) of biogas, for example:

- chemical precipitation (e.g. adding $FeCl_3$);
  - this technique is used in at least one Flemish (manure) co-digestion plant that also digests manure, in combination with condensation (see below) (position as at October 2010);
- biological treatment (with aeration in/outside of the digester);
  - this technique (air injection) is used in at least four Flemish (manure) co-digestion plants that also digest manure; in one plant this is done in combination with an activated carbon filter (position as at October 2010);

[33] see the 'Limit the quantity and burden of wastewater/liquid waste streams' candidate BAT
[34] see the 'Optimise water consumption' candidate BAT and 'Use, process, discharge or dispose of wastewater/liquid waste streams prudently' candidate BAT
[35] see the 'Reuse adsorption and filter material to the greatest possible extent and/or dispose of via external parties' candidate BAT
[36] See the 'Optimise the design of the (manure) co-digestion plant' candidate BAT
[37] See the 'Optimise the design of the (manure) co-digestion plant' candidate BAT
[38] See the 'Optimise the design of the (manure) co-digestion plant' candidate BAT
[39] The Seveso regulations apply in the case of large quantities.
[40] The Seveso regulations apply in the case of large quantities.

    - air injection is also used in at least one plant in Flanders that does not also digest manure, in combination with cooling (see below) (position as at October 2010);
- gas scrubber (addition of H_2SO_4);
- adsorption (e.g. activated carbon filter, ferrous materials, such as swarf);
- bioscrubber, biofilter, etc.

NH_3 can be removed by using, for instance:
- a gas scrubber;
- a biological filter.

CO_2 can be removed from the biogas using the following techniques, for example:
- adsorption in water;
- adsorption in polyethylene glycol;
- molecular sieving;
- membrane filtration;
- adsorption and regeneration by pressure variation (VPSA);
- cryogenic reprocessing.

The following techniques can be used to remove water (H_2O):
- drying;
- condensation;
    - condensation is used in at least one Flemish (manure) co-digestion plant that also digests manure, in combination with chemical precipitation (see above) (position as at October 2010);
    - this technique is used in at least one Flemish plant that does not also digest manure, in combination with cooling and filtration (position as at October 2010);
- cooling
    - this technique is used in at least three Flemish plants that do not also digest manure; once in combination with air injection (see above), and once in combination with condensation and filtration (see above) (position as at October 2010).

Technical feasibility
There are no indications that optimization of the biogas treatment is not technically feasible for all (manure) co-digestion plants that treat biogas. As pocket digesters do not usually treat biogas, this technique is less relevant for this category of digestion plant.

Environmental impact
Optimization of the biogas treatment can lead to fewer emissions of air/odour/dust. And emissions to the water and soil can be limited also. In addition, the use of water, energy and chemicals, as well as the quantity of wastewater and waste can be limited.

Economic feasibility
Biogas treatment will be probably be seen as more economically feasible for large digestion plants in comparison with small (manure) co-digestion plants (e.g. in agricultural areas) because of the advantage of scale. Optimizing biogas treatment can be considered to be economically feasible for all (manure) co-digestion plants that treat biogas.

References
- Company visits, 2010 and 2011;
- Company visits;
- Company details;
- Biogas-E, 2010a, b and c;

- Devriendt N. et al., 2004;
- Goovaerts L. et al., 2008;
- Infomil, 2010;
- ODE, 2010b;
- VDI 3475, 2010;
- VMM, 2011c;
- www.biogas-e.be;
- www.biogas-vlaanderen.be;
- www.vcm-mestverwerking.be.

→ ***Pay attention to hygiene on the company site***

This technique has been selected as BAT in Chapter 5.

Description of the technique
Hygiene at the company site can include the following environmental measures, amongst others:

- keep hard surfaces clean by cleaning them regularly;
- take the necessary actions in relation to pest control, whether or not in cooperation with a pest control company; nuisance could be caused by rodents (e.g. rats, mice), birds (e.g. gulls), insects, etc.;
- provide a vehicle wash with high-pressure cleaning system or alternative cleaning infrastructure to clean the lorries that leave the site;
- provide an arch system with nozzles to disinfect the lorries that leave the site;
- avoid contact with the reactor contents and digestate as far as possible;
- use good personal hygiene after contact with the reactor contents and digestate (e.g. wash hands);
- prevent reinfection of sanitised material (e.g. via lorries, bulldozers, conveyor belts, pumps and pipelines);
- limit the size of the dirty zones as far as possible by suitable operating processes and optimizing vehicle movements.

  Remarks
  The 'Avoid soiling the floor where possible' and 'Regular inspection and cleaning of pipes and fans in mechanically ventilated livestock houses' techniques have been selected as BAT for all livestock companies (Derden A. et al., 2006).

Technical feasibility
Paying attention to hygiene on the company site is part of good business practice and is considered to be technically feasible for all (manure) co-digestion plants.

Environmental impact
Paying attention to hygiene on the company site can limit the use of water and chemicals for cleaning activities. And the quantity of wastewater produced and its burden can be limited.

Economic feasibility
Paying attention to hygiene on the company site mainly requires time and labour and requires a positive attitude in regard to environmental awareness. This measure is not directly paired with costs and is considered to be economically feasible for all (manure) co-digestion plants.

References

- Company visits, 2010 and 2011;
- Company details;
- Derden A. et al., 2006;
- KULeuven, 2010a;
- Lemmens B. et al., 2007;
- OVAM, 2011a.

→ ***Guarantee safety on the company site and at the (manure) co-digestion plant***

This technique has been selected as BAT in Chapter 5.

Description of the technique

The safety risks on the company site and at the (manure) co-digestion plant can be managed by using, amongst other things, the following environmental measures:

- use an environmental management system[41];
- take all necessary measures to prevent serious accidents and to limit their consequences for humans and the environment;
- draw up a safety plan in consultation with the local fire brigade, before taking the installation into use;
- within one year of taking into use, draw up a memorandum (by an SR expert) which demonstrates that the installation complies with the normal safety criteria in accordance with the safety study;
- formulate an internal emergency plan in consultation with the local fire brigade and in accordance with their guidelines;
- check the proper functioning of all safety provisions in accordance with a laid down programme;
- place the management and running of a (manure) co-digestion plant in the hands of a responsible individual with the necessary technical expertise (training, knowledge of possible dangers, safety, hazardous gases regulations (e.g. H_2S, CO, CO_2 and CH_4, etc.);
- only store input streams in suitable storage facilities (e.g. closed tank) to prevent or limit unwanted chemical reactions (e.g. formation of H_2S);
- apply the correct pictograms (lettering) to tankers in relation to the content being transported (in addition to the necessary transport documents), so that the fire brigade is correctly informed of the substances involved in the event of a disaster;
- avoid biogas (methane) leaks (e.g. in the biogas production unit or from the biogas storage);
- provide good ventilation to prevent asphyxiation and explosive hazard;
- take measures in relation to fire prevention, emergency situations and fire-fighting, incl.
    - prohibitions (e.g. smoking and fire prohibition);
    - fire-resistant materials;
    - emergency lighting;
    - emergency exits;
    - fire-fighting resources (extinguishers, rainwater, ...);
- provide lightening protection;

[41] See the 'Optimise the design of the (manure) co-digestion plant' candidate BAT

- provide an emergency procedure;
- only admit authorised persons to the company site (e.g. fence the site);
- lock access to the site outside of working hours;
- fit a flame extinguisher to biogas pipes;
- protect free-standing reservoirs against collision and sharp objects (e.g. install fencing);
- exclude ignition sources from the vicinity of biogas storage installations as far as possible; sparks can be avoided by, for instance:
    - using spark-free electrical equipment;
    - using suitable tools (no steel);
    - excluding mobile phones;
    - preventing static electricity;
- optimise the biogas storage (above the digester or elsewhere):
    - provide continuous level measuring or pressure measuring of the biogas;
    - provide underpressure protection at the biogas storage;
    - provide overpressure protection at the biogas storage with an overpressure valve (with a water seal or equivalent technology), and for installations with a total annual capacity >5,000 tons input follow this with, for instance,
        - a blow-off installation: the excess biogas is blown-off via a blow-off installation;
        - an emergency burner: the excess gas is burned in, for example, a gas burner (two or more CHP plants so that the operational security is guaranteed);
        - a (enclosed) flare: the excess biogas is burned-off via a flare installation;

          Remarks
            - according to VROM (2005) an overpressure safety system with flare is:
                - economically feasible for larger plants;
                - not economically feasible for smaller plants
                - there is no obligation in Germany for installations with a biogas production of <50 m^3/h (CHP plant with a capacity of <100 kW).
        - a second motor;
        - a steam boiler.

          Remarks
            - Overpressure can occur if the gas receptacle is fully filled and there is no possibility of using all of the biogas in the gas motor. If the gas motor breaks down for example, the production of biogas continues for a while, even if the digester is stopped.
            - An overpressure safety device is activated automatically and continues to work until an acceptable pressure level is reached.
            - An overpressure valve with water seal blows-off the biogas when a specific pressure is reached. The disadvantage here is that methane is then emitted into the air. When a flare is used the surplus biogas is burned so that no biogas enters the air.
            - For pocket digesters (total annual capacity ≤5,000 tons input) a water seal and an overpressure valve should be an adequate measure in regard to safety.
            - Over-dimensioning the motor(s) is often cheaper than providing an additional measure (e.g. flare).

- optimise the treatment of biogas (see the 'Optimise biogas treatment' candidate BAT also);
- optimise the location and operating processes of the drying installation (see the 'Optimise digestate treatment' candidate BAT also);
- provide automatic reporting/alarm if the power supply fails, and along with it the measuring and control equipment;
- provide emergency coolers to disperse excess heat.

Technical feasibility
Guaranteeing safety on the company site and at the (manure) co-digestion plant is part of good business practice and is considered to be technically feasible for all (manure) co-digestion plants.

Environmental impact
Using this measure avoids the risk of disasters and emissions into the water, the air and the soil.

Economic feasibility
As far as is known, no concrete data is available for guaranteeing safety on the company site and at the (manure) co-digestion plant. As this measure is considered to be state of the art, it is also considered to be economically feasible for all (manure) co-digestion plants.

References

- Company visits, 2010 and 2011;
- Company details;
- EIPPCB, 2005;
- Infomil, 2010;
- KULeuven, 2010b;
- LNE-AMV, 2011b;
- ODE, 2010a;
- OVAM, 2011a;
- VDI 3475, 2010;
- VROM, 2005 and 2010;
- www.senternovem.nl;
- www.seveso.be.

CHAPTER 5 SELECTION OF BEST AVAILABLE TECHNIQUES

In this chapter we will evaluate the environmentally-friendly techniques from Chapter 4 in regard to their technical feasibility, the environmental impact and their economic feasibility and we will indicate whether or not the environmentally-friendly techniques mentioned can be considered BAT for the (manure) co-digestion plants.

The BAT selected in this chapter are considered to be BAT for the (manure) co-digestion plants, feasible for an average company. This does not mean that every business in this sector can apply every technique designated as BAT without further thought. The business-specific circumstances must always be taken into account.

The BAT selection in this chapter must not be seen as a stand-alone fact, but must be viewed within the overall framework of the study. This means that both the description of the environmentally-friendly techniques in Chapter 4 and the translation of the BAT selection into recommendations and interpretation of environmental legislation in Chapter 6 should be taken into account.

5.1. Evaluation of available environmentally-friendly techniques

In Table 11 the available environmentally-friendly techniques from Chapter 4 are tested against a number of criteria. This environmental criteria analysis makes it possible to decide whether a technique can be considered a Best Available Technique (BAT). The criteria not only relate to the environmental compartments (waste, wastewater, energy, waste/secondary streams, air/odour/dust, noise/vibrations, chemicals and soil) but the technical feasibility and the economic aspects are also considered. This makes it possible to perform an integrated evaluation in accordance with the definition of BAT (see Chapter 1).

Notes on the contents of the criteria in Table 11:

→ ***Technical feasibility***

proven: indicates whether the technique has proven its worth in industrial practice:
- "-": not proven;
- "+": proven.

safety: indicates whether, upon correct implementation of suitable safety measures, the technique results in an increase in the risk of fire, explosion and occupational accidents in general:
- "-": increased risk;
- "0": no increased risk;
- "+": decreased risk.

quality: indicates whether the technique affects the quality of the end product:
"-": reduced quality;
"0": no effect on quality;
"+": increased quality.

overall: estimates the overall technical feasibility of the technique:
"+": if all of the above are "+" or "0";
"-": if at least one of the above is "-".

→ ***Environmental benefit***

water consumption: recycling of wastewater and limitation of the total water consumption;
wastewater: the introduction of pollutants into the water as a result of operating the establishment;
energy: energy savings, employ environmentally-friendly energy sources and reuse energy;
waste streams / secondary streams: identifying and managing waste streams;
air/odour/dust: the introduction of pollutants into the atmosphere as a result of operating the establishment;
noise/vibrations: sources of nuisance for noise and vibrations;
chemicals: influence on the use of chemicals and the quantity;
soil: the introduction of pollutants into the soil and the groundwater as a result of operating the establishment;
overall: estimated effect on the environment as a whole.

For each technique a qualitative assessment is provided for each of the above criteria, where:
"-": negative effect;
"0": no/negligible impact;
"+": positive effect;
"+/-": sometimes a positive effect, sometimes a negative effect.

→ ***Economic feasibility***

"+": the technique has a cost-saving effect;
"0": the technique has a negligible effect on the costs;
"-": the technique results in increased costs; the additional costs are deemed to be bearable for the sector (i.e. for an average company) and are reasonable compared to the environmental benefits achieved;
"--": the technique results in increased costs; the additional costs are not deemed to be bearable for the sector (i.e. for an average company) or are not reasonable compared to the environmental benefits achieved.

Finally, the last column states whether the technique under consideration can be viewed as best available technique (BAT: yes or BAT: no). If this depends greatly on the establishment under consideration and/or local conditions, the assessment BAT: is given on a case-by-case basis.

The process followed for the BAT selection is schematically depicted in Figure 1.

First of all, it is established whether the technique (called "candidate BAT") is technically feasible, taking into account the quality of the product and safety (step 1).
If the technique is technically feasible, the effects on the various environmental compartments are established (step 2). By performing an analysis of the effects on the various environmental compartments, an overall environmental assessment can be given. To determine the latter, the following elements are taken into account:

- If one or more environmental score is positive and none are negative, the overall effect is always positive;
- If there are both positive and negative scores, the overall environmental effect depends on the following elements:
  - the shift from a less controllable to a more controllable compartment (from air to waste for example);
  - a relatively larger reduction in one compartment compared to an increase in the other compartment;
  - the desirability of reduction based on the policy; also derived from the environmental quality targets for water, air, … ("distance-to-target approach" for instance).

If the overall environmental effect is positive, it is established whether the technique leads to additional costs, whether these costs are reasonable in comparison with the environmental benefits achieved and are bearable for an average business from the sector (step 3).
Candidate BAT that cannot be mutually combined (because combining them is not possible or not useful) are individually compared, and only the best is retained as a candidate BAT (step 4).
Finally, it is determined whether the technique under consideration can be selected as a best available technique (BAT) (step 5). A technique is BAT if it is technically feasible, presents environmental benefits (generally speaking), is economically feasible (assessment "-" or higher) and if there are no "better" candidate BAT. If this depends greatly on the establishment under consideration and/or local conditions, preconditions can be attached to the BAT selection.

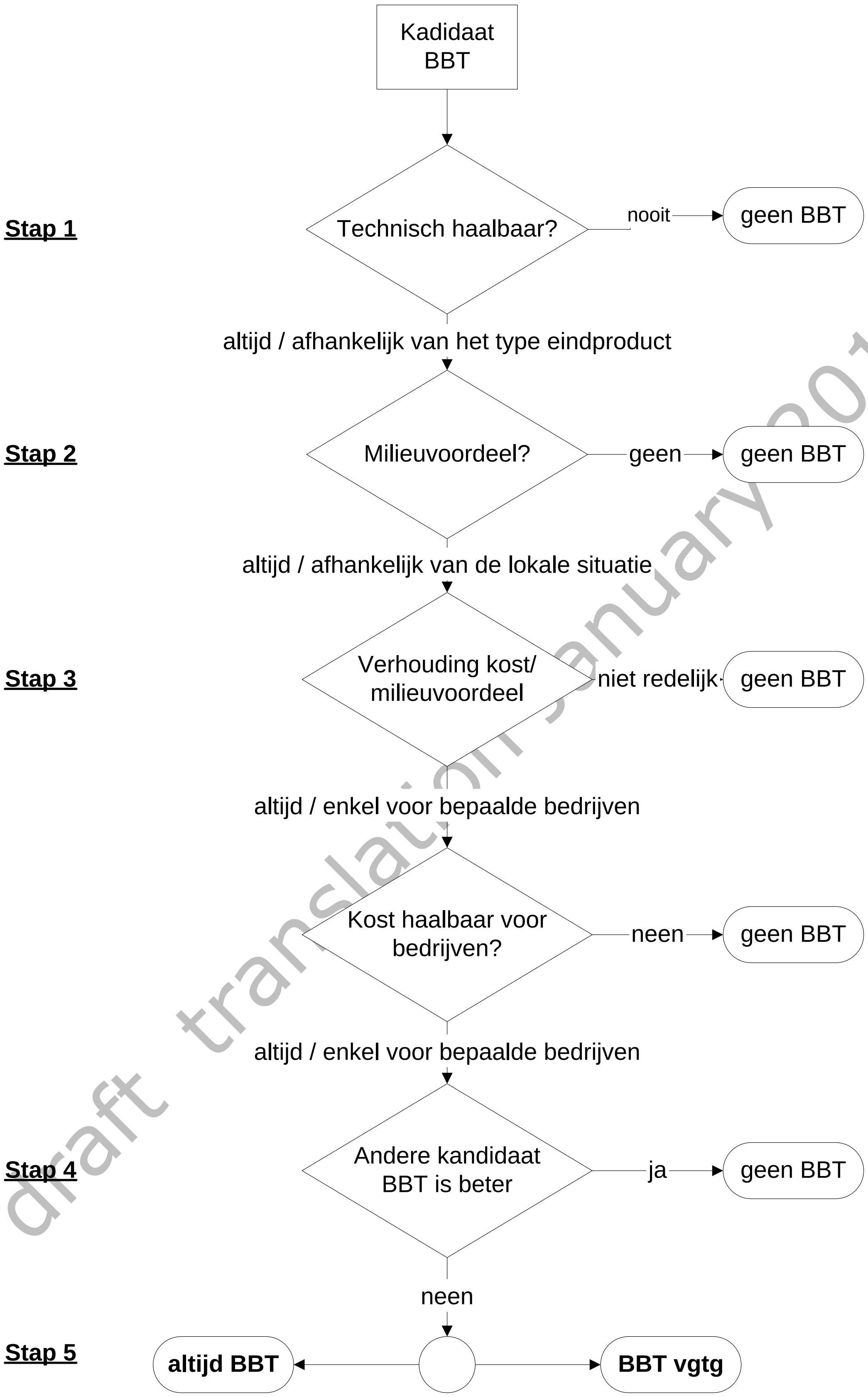

Figure 1: Selection of BAT based on scores for various criteria

Evaluation of available environmentally-friendly techniques and selection of BAT is summarised in Table 11.

Important comments regarding the use of Table 11:
When using the following table, the following points for attention should always be taken into account:

- Among other things, the assessment of the various criteria is based on:
  - experience of operators using this technique;
  - BAT selections performed in other (foreign) comparable studies;
  - recommendations provided by the supervisory committee;
  - judgements made by the authors

  Where required, additional explanations are provided in footnotes. For the meaning of the criteria and the scores, please refer to paragraph 5.1.
- The assessment of the criteria can be considered indicative and is not necessarily applicable in each individual case. This by no means implies that the assessment releases an operator from its responsibility, for example, to investigate whether the technique is technically feasible in its specific situation, does not pose any safety risks, does not cause any unacceptable environmental damage or results in excessive costs. The assessment of a technique also assumes that suitable safety/environmental protection measures are always implemented.
- The table must not be seen as a stand-alone fact, but must be viewed within the overall framework of the study. This means that both the description of the environmentally-friendly techniques in Chapter 4 and the translation of the table into recommendations and interpretation of environmental legislation in Chapter 6 should be taken into account.
- The table presents a general assessment of whether the environmentally-friendly techniques stated can be considered BAT for the (manure) co-digestion plants. This does not mean that every business in this sector can apply every technique designated as BAT without further thought. The business-specific circumstances must always be taken into account.

5.2. Evaluation of the available environmentally-friendly techniques

The candidate BAT is entered at a general level in Table 11. The concrete interpretation of this candidate BAT (see the examples in Chapter 4 also) can be found in paragraph 5.3.

Table 11: Evaluation of available environmentally-friendly techniques and selection of BAT

Technique - Water	Concrete interpretation can be found in paragraph	Technical feasibility				Environmental benefit										BAT
		Proven	Safety	Quality	Overall	Water	Wastewater	Energy	Waste streams / secondary streams	Air/odour/dust	Noise/vibrations	Chemicals	Soil	Overall	Economic feasibility	
Prevent water consumption	5.3.1 (1.)	+[42]	+	+	+	+	+	0/+	0	0	0	0	0	+	0	Yes
Optimise water consumption	5.3.1 (2.)	+[43]	+	+	+	+	+	0/+	0	0	0	0	0	+	-/0	Yes

[42] Current legal provisions should be complied with at all times.
[43] Hygiene requirements may be a limiting factor for the use of alternative water sources.

Technique - Wastewater/liquid waste streams	Concrete interpretation can be found in paragraph	Technical feasibility				Environmental benefit									Economic feasibility	BAT
		Proven	Safety	Quality	Overall	Water	Wastewater	Energy	Waste streams /	Air/odour/dust	Noise/vibrations	Chemicals	Soil	Overall		
Limit the quantity and burden of wastewater/liquid waste streams	5.3.1 (3.)	+	0	0	+	+	+	+	0	0/+[44]	0	0	0/+[45]	+	0/+	Yes
Use, process, discharge or dispose of wastewater/liquid waste streams prudently	5.3.1 (4.)	+[46]	0	0	+	+	+	0	0	0	0	0	+	+	-[47]/0	Yes

[44] In the case of covered storage (e.g. input streams).
[45] In the case of clean hard surfaces and covered storage (e.g. input streams).
[46] The concrete interpretation of this measure should be at company level.
[47] If wastewater treatment techniques have to be used (e.g. in case of discharge) or if streams have to be transported for external processing (e.g. concentrates).

Technique - Energy	Concrete interpretation can be found in paragraph	Technical feasibility				Environmental benefit									Economic feasibility	BAT
		Proven	Safety	Quality	Overall	Water	Wastewater	Energy	Waste / streams	Air/odour/dust	Noise/vibrations	Chemicals	Soil	Overall		
Use input material that is as fresh as possible to maximise biogas production	5.3.1 (5.)	+[48]	0	+	+	0	0	+	+	+	0	0	0	+	0	Yes
Optimise processes to prevent or limit excessive energy consumption	5.3.1 (6.)	+	0	0	+	0	0	+	0	0	0	0	0	+	-	Yes

[48] Subject to sound planning, optimal storage (see the 'Optimise the storage of input streams, intermediate products and end products' candidate BAT) and on condition that the necessary agreements are made with down-stream suppliers.

Technique - Waste streams / secondary streams	Concrete interpretation can be found in paragraph	Technical feasibility				Environmental benefit									Economic feasibility	BAT
		Proven	Safety	Quality	Overall	Water	Wastewater	Energy	Waste / streams	Air/odour/dust	Noise/vibrations	Chemicals	Soil	Overall		
Use manure, energy crops and/or OBW that is as fresh and pure as possible to limit the amount of unprocessed or un-processable input streams	5.3.1 (7.)	+[49]	0	+	+	0	0	+	+	+	0	0	0	+	0	Yes
Dispose of the sediment fraction from the digester in a suitable manner	5.3.1 (8.)	+	0	0	+	0	+	0	+	0	0	0	+	+	-	Yes
Reuse adsorption and filter material to the greatest possible extent and/or dispose of via external parties	5.3.1 (22.)	+[50]	0	0	+	0	+	0	+	0	0	0	+	+	-[51]/0	Yes[52]

[49] Subject to sound planning, optimal storage (see the 'Optimise the storage of input streams, intermediate products and end products' candidate BAT) and on condition that the necessary agreements are made with up-stream suppliers.

[50] This measure is technically feasible for all (manure) co-digestion plants that treat digestate and/or biogas. As pocket digesters do not usually treat the digestate and/or biogas, this technique is less relevant for this category of digestion plant. With external regeneration and/or disposal of the adsorption and filter material, sound agreements should be made with down-stream suppliers.

[51] Costs for regeneration and/or disposal of adsorption and filtration material.

[52] BAT for all (manure) co-digestion plants that treat digestate and/or biogas.

Technique - Air/odour/dust	Concrete interpretation can be found in paragraph	Technical feasibility				Environmental benefit									Economic feasibility	BAT
		Proven	Safety	Quality	Overall	Water	Wastewater	Energy	Waste streams	Air/odour/dust	Noise/vibrations	Chemicals	Soil	Overall		
Prevent air emissions, odour nuisance and/or dust emissions as far as possible by using source-oriented and/or process-oriented measures	5.3.1 (9.)	+[53]	0	0	+	0	0	0	0	+	0	0	0	+	-/0[54]	Yes
Monitor odour emissions accurately	5.3.1 (10.)	+	0	0	+	0	0	0	0	+	0	0	0	+	-[55]/0	Yes
Optimise the storage of input streams, intermediate products and end products	5.3.1 (11.)	+	0	+	+	0	0	+	+	+	0	0	0	+	-	Yes
Perform odour-producing processes in an enclosed area under negative pressure	5.3.1 (12.)	+	0	0	+	0	0	0	0	+	0	0	0	+	-	Yes
Capture air emissions at the source using (point) extraction and use a suitable (combination of) end-of-pipe air treatment technique(s)																
odour	5.3.5 (24.)	+	0	0	+	0	0	0	0	+	0	0	0	+	-[56]	Case by case[57]

[53] The concrete interpretation of this measure should be at company level. A number of measures are only relevant for companies that use digestate and/or biogas treatment (e.g. 'Optimise biogas treatment' and 'Optimise digestate treatment'). As pocket digesters do not usually treat the digestate and/or biogas, such measures are less relevant for this category of digestion plant.
[54] The primary requirement for the majority of these measures is effort in relation to planning and mentality.
[55] Engaging a recognised EIR expert in the air discipline involves certain costs.
[56] Air treatment will probably be seen as more economically feasible for large digestion plants in comparison with small (manure) co-digestion plants (e.g. pocket digesters) because of the advantage of scale.
[57] BAT if source-oriented and/or process-oriented measures are insufficient to prevent odour nuisance, depending on the local situation.

Technique - Air/odour/dust	Concrete interpretation can be found in paragraph	Technical feasibility				Environmental benefit									Economic feasibility	BAT
		Proven	Safety	Quality	Overall	Water	Wastewater	Energy	Waste streams /	Air/odour/dust	Noise/vibrations	Chemicals	Soil	Overall		
dust	5.3.5 (24.)	+	0	0	+	0	0	0	0	+	0	0	0	+	-[58]	Case by case [59]
ammonia	5.3.5 (24.)	+	0	0	+	0	0	0	0	+	0	0	0	+	-[60]	Case by case [61]

[58] See footnote 90
[59] BAT if digestate treatment techniques are used (e.g. drying, evaporation and granulation) where dust emissions are produced.
[60] See footnote 90
[61] BAT if source-oriented and/or process-oriented measures are not sufficient to achieve an emission level <10 mg/Nm^3 (current VLAREM standard).

Technique - Noise/vibrations	Concrete interpretation can be found in paragraph	Technical feasibility				Environmental benefit									Economic feasibility	BAT
		Proven	Safety	Quality	Overall	Water	Wastewater	Energy	Waste / streams	Air/odour/dust	Noise/vibrations	Chemicals	Soil	Overall		
Tackle noise nuisance at the source, at the design, selection, operations and maintenance levels	5.3.1 (13.)	+	0	0	+	0	0	0	0	0	+	0	0	+	0	Yes
Limit noise nuisance produced by vehicles	5.3.1 (14.)	+	0	0	+	0	0	0	0	0	+	0	0	+	0	Yes
Use noise barriers or green barriers	5.3.2 (20.)	+	0	0	+	0	0	0	0	0	+	0	0	+	-	Case by case[62]

[62] BAT in the case of noise nuisance and/or visual nuisance (possibly more relevant for (manure) co-digestion plants located in an agricultural (valuable) area).

Technique - Other	Concrete interpretation can be found in paragraph	Technical feasibility				Environmental benefit									Economic feasibility	BAT
		Proven	Safety	Quality	Overall	Water	Wastewater	Energy	Waste streams	Air/odour/dust	Noise/vibrations	Chemicals	Soil	Overall		
Optimise the design of the (manure) co-digestion plant	5.3.1 (15.)	+	+	+	+	+	+	+	+	+	+	+	+	+	-	Yes
Optimally maintain (manure) co-digestion plants	5.3.1 (16.)	+	+	+	+	+	+	+	+	+	+	+	+	+	0	Yes
Optimise the operation of the (manure) co-digestion plant	5.3.1 (17.)	+	+	+	+	+	+	+	+	+	+	+	+	+	0	Yes
Optimise digestate treatment	5.3.3 (21.)	+[63]	0	+	+	+	+	+	+	+	+	+	+	+	0/+	Yes[64]
Optimise biogas treatment	5.3.4 (23.)	+[65]	+	+	+	+	+	+	+	+	+	+	+	+	0/+	Yes[66]
Pay attention to hygiene on the company site	5.3.1 (18.)	+	0	+	+	+	+	0	0	0	0	+	0	+	0	Yes
Guarantee safety on the company site and at the (manure) co-digestion plant	5.3.1 (19.)	+	+	0	+	0	+	0	0	+	0	0	+	+	0	Yes

[63] This technique is less relevant for pocket digesters, as this category of digester does not usually employ digestate treatment.
[64] BAT for all (manure) co-digestion plants that treat digestate.
[65] This technique is less relevant for pocket digesters, as this category of digester does not usually employ biogas treatment.
[66] BAT for all (manure) co-digestion plants that treat biogas.

5.3. BAT conclusions

The candidate BAT is entered at a general level in Table 11. The concrete interpretation of this BAT can be found in the paragraphs below. In a number of cases a summary is given of a number of measures that are technically feasible to interpret the BAT. The techniques that are optimal in a specific case should be viewed on a case by case basis.

The conclusions below can be formulated for the (manure) co-digestion plants based on Table 11. The BAT (19 techniques) that apply to all (manure) co-digestion plants are listed in paragraph 5.3.1. Additional BAT (5 techniques) for specific situations or (manure) co-digestion plants can be found in paragraphs 5.3.2 to 5.3.5.

5.3.1. General BAT

The following 19 techniques have been selected as BAT for all (manure) co-digestion plants that fall within the scope of this BAT study.

→ ***1. Prevent water consumption***

This BAT can be interpreted as follows (insofar as current legislation can be complied with):

- in an initial cleaning stage, prior to wet cleaning if necessary, make the greatest possible use of dry cleaning of storage recipients, installations, sites and rooms using brushes or scrapers for instance;
- clean up spilled solid input and output streams (with a shovel for instance) and put it back in the appropriate storage;
- remove spilled liquids competently.

→ ***2. Optimise water consumption***

This BAT can be interpreted by, for example, making the greatest possible use of alternative sources of water, such as

- process water, e.g.
  - cooling water (from motors for instance);
  - filtrate produced during the post-treatment of the digestate (e.g. membrane filtration);
  - condensed water produced during the treatment of biogas (e.g. dewatering) or with heat recovery;
- cleaning water;
- rinse water;
- non-polluted precipitation.

→ ***3. Limit the quantity and burden of wastewater/liquid waste streams***

This BAT can be interpreted, for example, as follows;

- keep hard surfaces clean (e.g. brush regularly);
- optimise cleaning activities (installations, transport material) (see paragraph 4.1.3);
- prevent groundwater infiltration at the storage facilities location;
- use bio-degradable detergents with a short emulsification period, that do not have a negative effect on the digestion process;
- provide an installation equipped for collecting, treating and using
  - process water;
  - cleaning water;
  - rinse water;
  - non-polluted precipitation;
- provide overflow protection on storage tanks for liquid streams;
- optimise the storage of input streams, intermediate products and end products.

→ ***4. Use, process, discharge or dispose of wastewater/liquid waste streams prudently***

Depending on the nature, origin and burden of the wastewater, wastewater/liquid waste streams can usefully be used as:

- process water (e.g. condensed water or non-polluted precipitation);
- cleaning water (e.g. filtrate or condensed water);
- as fertiliser or soil improver (on condition that the VLAREA (M)A Regulations and other relevant legislation such as Regulation 1069/2009 are complied with) (e.g. drain water from the air treatment installation or sap losses from trench silos).

If useful use is not possible, wastewater/liquid waste streams can be jointly processed in the (manure) co-digestion plant. This is case for, for example: run-off water from hard surfaces that is contaminated (with manure) and sap losses from the trench silos.

If the aforementioned options (useful use and joint processing in the (manure) co-digestion plant) are not possible then, for example, the following streams can be discharged (after treatment): condensed water, water for cleaning vehicles and material and the thin fraction of the digestate.

All wastewater/liquid waste streams that cannot be usefully used, that cannot be jointly processed in the (manure) co-digestion plant or that cannot be discharged (e.g. concentrates or digestate that do not comply with current legislation) should be transported for external processing.

→ ***5. Use input material that is as fresh as possible to maximise biogas production***

Sound production planning as well as good agreements with up-stream suppliers (e.g. farmers, suppliers of raw materials and additives, haulage companies) in relation to, amongst other things, the composition (e.g. minimum dry matter content) and the quality (no chemical, physical and (micro) biological contamination) of the input streams and the timing of supply is essential here.
If input streams are to be stored locally before being introduced into the digestion plant, this storage should occur under optimal conditions and be for the shortest possible period.

→ ***6. Optimise processes to prevent or limit excessive energy consumption***

This BAT can be concretely interpreted as follows:
- monitor the energy consumption of the most energy demanding process steps;
- recover as much heat as possible, e.g. from sanitised digestate, cooling water or condensed water;
- do not dry the digestate longer than necessary;
- improve the energetic yield of the installations.

→ ***7. Use manure, energy crops and/or OBW that is as fresh and pure as possible to limit the amount of unprocessed or un-processable input streams***

Sound production planning as well as good agreements with up-stream suppliers (e.g. farmers, suppliers of raw materials and additives, haulage companies) in relation to, amongst other things, the composition (e.g. minimum dry matter content) and the quality (no chemical, physical and (micro) biological contamination) of the input streams and the timing of supply is essential here.
If input streams are to be stored locally before being introduced into the digestion plant, this storage should occur under optimal conditions and be for the shortest possible period.

→ ***8. Dispose of the sediment fraction from the digester in a suitable manner***

This BAT can be concretely interpreted as follows for the sediment fraction from the digester:
- spreading on the land, on condition that the relevant regulations from VLARE(M)A (incl. analyses) and other relevant legislation e.g. Regulation 1069/2009 are complied with, and possibly mixed with other streams (e.g. manure or digestate);
- stirring into the digestate (dilution) and disposing of it together with the raw digestate or, if necessary, further post treatment;
- transporting for composting;
- incineration.

→ ***9. Prevent air emissions, odour nuisance and/or dust emissions as far as possible by using source-oriented and/or process-oriented measures***

This BAT can be concretely interpreted as follows:
- make agreements with the up-stream suppliers on the use of closed lorries;
- use manure, energy crops and/or OBW that is as fresh as possible;
- optimise unloading and loading activities:
    - unload and load solid input and output materials in a closed shed under negative pressure with (point) extraction of the air to a suitable (combination of) end-of-pipe air treatment technique(s), see the 'Capture air emissions at the source using (point) extraction and use a suitable (combination of) end-of-pipe air treatment technique(s)' candidate BAT also;
    - provide a spillage pit at the unloading and loading locations;
    - unload liquid input streams from the lorry's vacuum tank via a closed system with quick-release couplings and correctly functioning connection and shut-off systems or an equivalent alternative;
- construct and empty trench silos according to good practice;
- limit the storage duration of input and output streams;

- optimise the storage of input streams, intermediate products and output streams;
- avoid diffuse air emissions;
- keep doors, windows and gates closed where possible;
- use quick-close gates;
- perform all odour or dust producing processes (e.g. drying digestate) in an enclosed space that is always under negative pressure (even when the gates are open) and from which the air can be extracted and treated using a suitable (combination of) e-o-p air treatment technique(s);
- optimise the air management at the processes and in the rooms (monitor and adjust);
- optimise the feed of input streams into the digester;
- optimise the treatment of biogas;
- optimise the treatment of digestate.

→ *10. Monitor odour emissions accurately*

This BAT includes, amongst other things:
- maintaining a log relating to monitoring and maintaining the odour limiting measures (e.g. 1x/day, 1x/week, 1x/week) and possible problems/complaints and the measures taken in relation to odour nuisance;
- engaging a recognised air expert in the event of problems with odour nuisance;
- listing the measures for combating odour nuisance (e.g. based on an external EIR expert in the air discipline's checklist, log).

→ *11. Optimise the storage of input streams, intermediate products and end products*

If streams are to be stored locally, then this BAT can be interpreted as follows:
- solid streams (e.g. solid manure, thick fraction of the digestate, dried digestate and digestate granules):
  - covered trench silos;
  - covered basins;
  - closed containers;
  - enclosed silos;
  - closed sheds (in containers or Big Bags if necessary).
- semi-solid input streams (e.g. energy crops, OBW):
  - liquid-proof storage plate (e.g. acid-resistant concrete), with a raised edge or equivalent provision and roofing (bunding);
  - in (closed) silos.
- liquid streams (e.g. liquid (mixed) manure, liquid OBW, liquid category 3 material, raw digestate, thin fraction of the digestate):
  - indoors;
  - closed (intermediate) storage (e.g. closed packaging, closed buffers, silos with vapour recovery);
  - covered, leak-proof receptacles;
  - water-tight storage installations (e.g. water-tight basins, (manure) cellars or (manure) bags);
  - storage tanks with overflow protection.

Odour producing streams (estimated to be 90% of the input streams) should be stored in an enclosed area under negative pressure, equipped with (point) extraction to conduct the air to a suitable (combination of) end-of-pipe air

treatment technique(s) (see the 'Perform odour-producing processes in an enclosed area under negative pressure' and 'Capture air emissions at source using (point) extraction and use end-of-pipe air treatment techniques' candidate BAT also).
In addition, groundwater infiltration at the storage facilities should be prevented and the storage facilities that are outdoors (e.g. energy crops and OBW) should be covered (e.g. plastic sheets).

→ ***12. Perform odour-producing processes in an enclosed area under negative pressure***

Examples of processes to which this BAT applies are:
- drying the digestate;
- compositing/biothermally drying the digestate.

→ ***13. Tackle noise nuisance at the source, at the design, selection, operations and maintenance levels***

This BAT can be interpreted as follows:
- select low-noise installations in the design phase (e.g. fans, pumps, agitators, aerators);
- set up noise sources (e.g. centrifuges, pumps, hopper with shredding system, agitators, motors, drying installation) in an enclosed space, with soundproof walls and doors if necessary;
- fit soundproof casings to installations (e.g. suppressors, pumps) that may produce noise nuisance and position them inside the engineering room;
- mount motors on cork or rubber feet (silent blocks);
- use sound-insulating hatches at suction openings;
- fit silencers to exhausts;
- keep doors, windows and gates closed where possible;
- use quick-close gates;
- operate fans as little as possible (e.g. by using a computer-controlled climate control system).

→ ***14. Limit noise nuisance produced by vehicles***

This BAT can be interpreted as follows:
- lay down the mobility aspects in consultation with the municipal authority;
- make agreements with up-stream and down-stream suppliers to limit the number of transport movements, e.g. combine the supply of input streams and the removal of digestate;
- respect agreements that have been made in relation to the transport times for supply and removal of the raw materials and end products;
- do not leave the engines of lorries and agricultural vehicles running unnecessarily.

→ *15. Optimise the design of the (manure) co-digestion plant*

This BAT can be interpreted follows:

- provide an environmental management system;
- optimise the location, construction and housing of (certain components of) the digestion plant whilst, amongst other things, adhering to distance rules (e.g. VLAREM) and construction regulations (e.g. VLAREM, ATEX);
- provide a monitoring system so that the quantity (venturi flume) and quality (standards) of the discharged wastewater can be determined (e.g. for (manure) co-digestion plants that post-treat the digestate into a dischargeable effluent);
- provide sampling points at the storage sites for various liquid streams, so that samples can be taken in a safe and representative manner;
- provide observation wells and a drainage system to prevent soil and ground water contamination;
- lay down the preconditions for the digestion plant in advance;
- enclosed design for process components of the (manure) co-digestion plant in which biogas is present;
- design (components of) installations with materials that are resistant to (corrosion from) biogas;
- use energy-efficient installations or components;
- use frequency controlled mixers, feed pumps, centrifuges, etc.;
- provide sufficient storage capacity;
- provide water-tight, quick-release couplings for the transfer of liquid streams (e.g. between lorry and a closed storage cellar) or an equivalent alternative;
- provide a dual-valve system for transferring liquid streams so that the supply/removal takes place via a single, closed circuit (e.g. storage cellar - supply hose - lorry);
- blow the manure hose empty using high-pressure after unloading;
- provide the necessary hard surfaces;
- take measures (incl. storage) to capture the run-off from the hard surfaces and convey it to the (manure) co-digestion plant;
- take measures (e.g. first-flush system) to prevent sap losses at the trench silos;
- provide water-tight floors at all locations where seepage of N or P can be expected;
- provide capture (for lye, run-off for example) at the storage sites;
- prevent streams (e.g. manure) entering the environment in the event of disaster (e.g. provide leak trays);
- provide a physical barrier between the various operations sections, particularly the dirty/input section and the clean/output section;
- limit the size of the dirty zones as far as possible by suitable operating processes and optimizing vehicle movements;
- provide emergency facilities to keep the most critical components of the digestion plant working in the event of power failure (e.g. air pump for desulphurisation, flare installation);
- provide a collection tank as a buffer in case of unwanted foaming in the digestion tank(s);
- design the input and output of the digester as far as possible away from each other to prevent the efflux of incompletely digested material (in the event of sub-optimal mixing);

- optimise mixing in the digester to prevent floating and sediment layers, to prevent the creation of foam layers and to achieve a uniform output stream (homogeneous end product);
- in the design stage too, pay attention to good environmental communication with all parties involved (e.g. nearby residents, municipal authority, advisory bodies, the press);
- store sulphuric acid in dual-wall or bunded, above-ground tanks (relevant in case of a chemical scrubber being used as e-o-p air treatment technique);
- provide overflow protection on the storage and buffer tanks;
- provide a suitable loading/unloading zone with suitable collection features in case of disasters.

→ *16. Optimally maintain (manure) co-digestion plants*

The following environmental measures, amongst others, can provide an interpretation of this BAT:

- maintenance of (parts of the) (manure) co-digestion plant should be carried out by a professional, in combination with regular inspection (e.g. 1x/day, 1x/week, 1x/month) and be monitored by the manager;
- enter into a maintenance contract with the supplier of the digestion plant, which contains stipulations in connection with the maximum time within which any breakdown must be resolved.

→ *17. Optimise the operation of the (manure) co-digestion plant*

This BAT can contain the following measures, amongst others:

- use good business practices in relation to operations;
- use an environmental management system;
- internal compliance with the stipulated conditions and processes by an individual with technical responsibility for the (manure) co-digestion plant;
- unload and load with the necessary care and in accordance with the internal procedures
- determine concentrations of a number of parameters (e.g. COD, N-total, P-total, Cl^- and TOC) in input and output streams (e.g. digestate and wastewater) to use optimal feeding of the digester and to achieve good methane production;
- make agreements with up-stream suppliers/haulage companies to ensure a sufficient quantity of input streams to allow continuous operation of the (manure) co-digestion plant; this must not, however, be at the expense of the quality of the streams that are supplied;
- harmonise supply with the (manure) co-digestion plant's processing capacity;
- optimise the moisture content of the input streams (mix) to prevent leaching-out;
- maximise the residence time of the material in the digester;
- thoroughly evaluate (any changes in) the input streams in advance;
  - at least one analysis of P_2O_5 and N should be carried out when manure, energy crops and OBW is delivered from new establishments or suppliers;
  - co-digestion with energy crops and/or OBW (in addition to manure) is widely used in practice to increase biogas production;
- use a good acceptance protocol in practice and provide a procedure for handling the removal of input streams that do not meet the acceptance criteria;

- ensure good quality of input streams from own company (e.g. manure and energy crops for pocket digesters);
- list suppliers and recipients of raw materials and products to/from the (manure) co-digestion plants respectively (for traceability reasons);
- optimise the storage of input streams, intermediate products and end products;
- optimise the input mix with a view to maximum energy yield;
- mix input streams thoroughly;
- do not add organic waste streams at the post-digestion installation;
- accurately monitor the digestion process (temperature, residence time, etc.) and adjust if necessary;
- use automatic control of the system, e.g. to keep the temperature in the digester up to level;
- prevent foaming;
- have modifications to (parts of the) (manure) co-digestion plant carried out by a professional;
- limit the manure surface area in the digester to prevent/limit the formation of a floating layer; the manure surface area is determined by the shape of the digester (rectangular or circular);
- ensure that the quantity of digestate that is removed from the digester is commensurate with the quantity of input material supplied;
- provide sufficient post-storage for the digestate;
- do not transport or mix digestate that has come directly from the digestion plant with other animal fertilisers;
- check the water seal and overpressure valve at the biogas storage regularly and top up with water as additional protection to prevent penetration through the water seal; a minimum check of 1x/week (2x/week during hot periods) is recommended;
- use process control based on a (simple) balance
- only use detergent that is permitted by the FAVV to clean lorries;
- always report any disasters to the competent authorities.

→ ***18. Pay attention to hygiene on the company site***

Hygiene at the company site can include the following environmental measures, amongst others:

- keep hard surfaces clean by cleaning them regularly;
- take the necessary actions in relation to pest control, whether or not in cooperation with a pest control company; nuisance could be caused by rodents (e.g. rats, mice), birds (e.g. gulls), insects, etc.
- provide a vehicle wash with high-pressure cleaning system or alternative cleaning infrastructure to clean the lorries that leave the site;
- provide an arch system with nozzles to disinfect the lorries that leave the site;
- avoid contact with the reactor contents and digestate as far as possible;
- use good personal hygiene after contact with the reactor contents and digestate (e.g. wash hands);
- prevent reinfection of sanitised material (e.g. via lorries, bulldozers, conveyor belts, pumps and pipelines);
- limit the size of the dirty zones as far as possible by suitable operating processes and optimizing vehicle movements.

→ ***19. Guarantee safety on the company site and at the (manure) co-digestion plant***

The concrete interpretation of this BAT can be as follows, amongst others things:

- take all necessary measures to prevent serious accidents and to limit their consequences for humans and the environment;
- draw up a safety plan in consultation with the local fire brigade, before taking the installation into use;
- within one year of taking into use, draw up a memorandum (by a recognised SR expert) which demonstrates that the installation complies with the normal safety criteria in accordance with the safety study;
- formulate an internal emergency plan in consultation with the local fire brigade and in accordance with their guidelines;
- check the proper functioning of all safety provisions in accordance with a laid down programme;
- place the management and running of a (manure) co-digestion plant in the hands of a responsible individual with the necessary technical expertise (training, knowledge of possible dangers, safety, hazardous gases regulations (e.g. H_2S, CO, CO_2 and CH_4, etc.);
- only store input streams in suitable storage facilities (e.g. closed tank) to prevent or limit unwanted chemical reactions (e.g. formation of H_2S);
- apply the correct pictograms (lettering) to tankers in relation to the content being transported (in addition to the necessary transport documents), so that the fire brigade is correctly informed of the substances involved in the event of a disaster;
- avoid biogas (methane) leaks (e.g. in the biogas production unit or from the biogas storage);
- provide good ventilation to prevent asphyxiation and explosive hazard;
- take measures in relation to fire prevention, emergency situations and fire-fighting.
- provide lightening protection;
- provide an emergency procedure;
- only admit authorised persons to the company site (e.g. fence the site);
- lock access to the site outside of working hours;
- fit a flame extinguisher to biogas pipes;
- protect free-standing reservoirs against collision and sharp objects (e.g. install fencing);
- exclude ignition sources from the vicinity of biogas storage installations as far as possible;
- optimise the biogas storage (above the digester or elsewhere);
- optimise the treatment of biogas (see the 'Optimise biogas treatment' candidate BAT also);
- optimise the location and operating processes of the drying installation (see the 'Optimise digestate treatment' candidate BAT also);
- provide automatic reporting/alarm if the power supply fails, and along with it the measuring and control equipment;
- provide emergency coolers to disperse excess heat.

5.3.2. BAT in the event of noise nuisance and/or visual nuisance

The following measure is an additional BAT in the event of noise nuisance and/or visual nuisance:

→ ***20. Use noise barriers or green barriers***

Embankments (e.g. mounds of earth) can also serve as noise or green barriers. This measure is probably more relevant to (manure) co-digestion plants that are located in agricultural (valuable) areas.

5.3.3. BAT for (manure) co-digestion plants that use digestate treatment

No judgements are made within the framework of this BAT study on whether or not the digestate should be treated and the choice of treatment technique(s). The strategy to be followed depends on the company-specific situation (e.g. available input streams, desired marketing route(s), heat available via biogas valorisation).

Pocket digesters do not usually treat digestate. The BAT below is of less relevance to this category of digestion plant.

Once the digestate treatment technique(s) has (have) been selected, the following techniques are additional BAT:

→ ***21. Optimise digestate treatment***

This BAT can be interpreted as follows:
- use good business practices in relation to operations;
- if polymers are used to optimise the separation of the digestate into a thick and thin fraction, avoid polymers based on mineral oil (due to the environmental standards for soil and water).
- use energy-efficient installations or components;
- monitor the energy consumption of the most energy demanding process steps;
- improve the energetic yield of the installation;
- reuse the heat from the condensed water from the drying installation in the drying process;
- set up the drying installation in a separate, enclosed space;
- do not dry the digestate longer than necessary;
- provide continuous temperature monitoring (e.g. using thermometers, heat cameras or infrared detectors) at the drying installation;
- make provisions for excessive temperatures at the drying installation;
- earth metal parts of the drying installation to prevent electrostatic charging;
- design mechanical transport systems for drying installations in such a way that the product is not heated as a result of friction;
- provide a spark separator between the motor and the drying installation;
- fit inspection apertures in the drying installation for regular visual inspection;
- fit fire-resistant insulation to the drying installation;
- limit the storage period for the output streams;

- store digestate optimally:
  - solid streams (e.g. solid fraction of the digestate, dried digestate and digestate granules):
    - covered trench silos;
    - covered basins;
    - enclosed sheds;
  - liquid streams (e.g. thin fraction of the digestate):
    - enclosed (interim) storage (e.g. enclosed buffers);
    - water-tight storage installations (e.g. water-tight basins);
    - fit overflow protection to storage tanks;
- limit the drying temperature (digestate post-treatment) (e.g. in practice the aim is to keep this temperature below 90°C);
- use intensive automation;
- combine the removal of digestate with the supply of input streams to limit the number of transport movements;
- provide an installation for recycling process water; e.g. for filtrate that is produced during the post treatment of the digestate (e.g. membrane filtration), on condition that this is hygienically responsible and in accordance with Regulation 1069/2009.

→ ***22. Reuse adsorption and filter material to the greatest possible extent and/or dispose of via external parties***

In many cases, adsorption and filter material can be reused a number of times. To this end, the material has to be regenerated in many cases. This can take place both internally (e.g. aeration of activated carbon filter) and externally (via the supplier). If the material can no longer be used in the production process, it should be disposed of via a recognised processor (the supplier if necessary).

5.3.4. BAT for (manure) co-digestion plants that use biogas treatment

No judgements are made within the framework of this BAT study on whether or not the biogas should be treated and the choice of treatment technique(s). The strategy that is to be followed depends on the method of valorising the biogas (the topic falls outside of the scope of the BAT study).

Pocket digesters do not usually treat biogas. The BAT below is of less relevance to this category of digestion plant.

Once the biogas treatment technique(s) has (have) been selected, the following techniques are additional BAT:

→ ***23. Optimise biogas treatment***

This BAT can be interpreted as follows:

- use condensed water produced during the treatment of biogas (e.g. dewatering) or during heat recovery as cleaning water (e.g. site, vehicles or machines);
- provide an installation for recycling process water;
- reuse adsorption and filter material to the greatest possible extent;
- prevent the formation of aerosols (containing S);
- implement an enclosed installation for treating the biogas;

- design (components of) installations with materials that are resistant to (corrosion from) biogas;
- provide emergency provisions to keep the air pump for desulphurisation of the biogas working in the event of power failure;
- store sulphuric acid in dual-wall or bunded, above-ground tanks.

→ ***22. Reuse adsorption and filter material to the greatest possible extent and/or dispose of via external parties***

In many cases, adsorption and filter material can be reused a number of times. To this end, the material has to be regenerated in many cases. This can take place both internally (e.g. aeration of activated carbon filter) and externally (via the supplier). If the material can no longer be used in the production process, it should be disposed of via a recognised processor (the supplier if necessary).

5.3.5. End-of-pipe air treatment techniques

Subject to specific preconditions, the following technique is additional BAT:

→ ***24. Capture air emissions at the source using (point) extraction and use a suitable (combination of) end-of-pipe air treatment technique(s)***

This BAT can be interpreted as follows:

- use odour treatment techniques if source-oriented and/or process-oriented measures are insufficient to prevent odour nuisance;
- use dust removal techniques if digestate treatment techniques are used (e.g. drying, evaporation and granulation) where dust emissions are produced;
- use ammonia reduction techniques if source-oriented and/or process-oriented measures are not sufficient to achieve an emission level <10 mg/Nm³ (at a mass flow of 5 kg/h or more) (current VLAREM standard).

Points for attention in relation to end-of-pipe air treatment techniques include:
- installations for limiting ammonia emissions in agricultural areas (linked to animal husbandry) must comply with the requirements in relation to design, operation, inspection and maintenance as stated in the list of low ammonia emission livestock house systems (B.S. dated 08/07/2011);
- dimension the end-of-pipe air treatment technique of sufficient size as a function of the quantity of air that is to be treated;
- optimise the procedure for starting/stopping the air treatment installation, so that the air treatment techniques are operational as required;
- optimally maintain and monitor the functioning of the end-of-pipe air treatment technique and optimise it.

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