CHAPTER 4 ~ TECHNIQUES TO CONSIDER FOR THE DETERMINATION OF THE best available techniques RELEVANT TO BIOLOGICAL TREATMENTS

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# Techniques generally applicable to all biological treatments

## Waste pre-acceptance procedures

**Description**

Systems and procedures should be in place to ensure that wastes are subject to an appropriate technical appraisal. This is to ensure their suitability for the proposed treatment route prior to acceptance at the plant. Wastes should not be accepted at the site without sufficient capacity being available. These checks should be performed before the waste acceptance stage is reached, by competent personnel.

Waste should only be accepted at the facility if suitable for the relevant biological treatment. The plant operator should establish and maintain detailed written procedures for the pre-acceptance of wastes. These procedures should provide for the pre-acceptance and characterisation of waste types proposed to be accepted at the facility which must be amongst those listed in the installation permit (and any other non-statutory document that the site may have to comply with).

The procedure should contain the following items depending on the type of waste and installation:

1. Characterisation, which may, if appropriate to the nature and risk posed by the waste, involve sampling and testing or other type of assessment (e.g. visual assessment), particularly in the event that potential contamination may be present (e.g. in kerbside collected food wastes or waste collected at transfer stations/recycling centres).
2. Waste type according to the European Waste List or national waste code system.
3. General information (like contact details of the waste producer, description/origin of the waste, relevant information needed for planning waste handling) if applicable and practicable (it is not practicable to require this information from private residents delivering garden waste etc.).
4. Compliance with the authorised waste types as listed in the installation permit (and any other non-statutory document that the site may have to comply with) and with proposed treatment.
5. Indication of the foreseen loads and schedule of delivery when possible.
6. Internal audits to assess compliance with the pre-acceptance procedures with a record kept of any issues.
7. In case of risk of contamination for specific waste streams periodic verification of the initial characterisation may also be required.

The type of initial assessment required to characterise the waste and periodic verification will vary depending upon: the nature of the waste; the process to be used; the quality requirements of final output products produced and their intended use; and what is already known about the waste.

The initial assessment and periodic verification required shall be proportionate to the risk posed by the type and nature of the relevant waste. For example green waste from a landscaper is of a lower risk than mixed municipal waste and therefore will require a lesser degree of scrutiny at pre-acceptance.

The results of all assessments or analyses should be kept within the operator’s documentation system.

**Achieved environmental benefits**

These techniques help the operator to improve the knowledge of the waste input to be treated and to prevent negative environmental impacts (e.g. due to pollution transfer to the final output products), they also reduce the risk of accidents. However the extent of such characterisation will be dependent upon the type and nature of waste. It also ensures that unnecessary energy and resources are used trying to recover waste that has no end use and requires disposal.

**Cross-media effects**

Not identified at this stage

**Operational data**

Not identified at this stage

**Applicability**

Applicable to all biological treatments

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Example plants**

Not identified at this stage

**Reference literature**

EA 2013. Draft Sector guidance note ‘How to comply with your environmental permit. Additional technical guidance for: composting and aerobic treatment sector. LIT 8705, Report version 1.0’

## Waste acceptance procedures

**Description**

Verification at the receiving plant and compliance assessment needs to take place to confirm:

* the identity of the waste, including its description, identification of the source, compliance with the assigned EWC / relevant national code, and any visual or other form of assessment if appropriate; and
* the consistency with the pre-acceptance information and proposed treatment method.

Some acceptance techniques and procedures (after the pre-acceptance) applied to assess waste are given in the lists below, these include:

1. Waste is accepted at the facility from known customers or new customers subject to pre-acceptance procedures. The pre-acceptance criteria with each customer should be reviewed on a regular basis, at a frequency stated in the operator’s documentation system. Where possible contracts with clear acceptance criteria should be issued with waste suppliers. The contracts should identify the actions that will be taken in the event the criteria are exceeded and who has the responsibility for those actions.
2. A person with appropriate training shall be on site to receive the waste materials during opening hours.
3. The operator should have clear and unambiguous criteria for the rejection of wastes or any actions to be taken to remove or reduce physical contaminants or any other unsuitable content prior to processing, together with a written procedure for handling, tracking and reporting non-conformance. Non-conforming wastes should be stored separately to prevent cross-contamination of process waste inputs.
4. The operator should verify accompanying documents and compliance with acceptance criteria. Waste arriving at the facility is assessed against waste acceptance criteria (e.g. by visual inspection), weighed, documented and directed to the waste reception or intermediate waste storage area. The type, origin and quantity of feedstock arriving at the installation should be recorded at the weighbridge. The level of checking will depend on the risk associated with the waste stream.
5. The operator should have a clear procedure to ensure that accepted waste is unloaded in the right area depending on the following treatment procedures (pre-treatment such as unpacking, shredding, screening, blending, and sorting of specific feedstock types before feeding into the biological processing unit).
6. Unloading of putrescible wastes should be on an impermeable surface with sealed drainage.
7. If the inspection indicates that the wastes fail to meet the acceptance criteria, then such loads are stored in a dedicated area and dealt with appropriately. This may include returning to source, directing to an alternative destination, or processing to enable use on-site. In all cases the waste producer should be informed of the actions taken.
8. Contingency plans should be well understood by staff where there is plant failure and waste is required to be diverted.
9. Operators should have procedures in place to deal with handling and storage of rejected wastes.
10. Accepted wastes should be treated as quickly as possible in order to prevent/minimise uncontrolled emissions.
11. Input materials accepted for treatment shall be kept separate and shall not be cross contaminated by any other materials destined to or being treated in other process lines.

**Achieved environmental benefits**

These techniques prevent unsuitable wastes being accepted, which could otherwise lead to adverse reactions or uncontrolled emissions. These techniques therefore ensure that the accepted waste is suitable for the activity and prevent negative environmental impacts (e.g. due to pollution transfer to the final output products).Moreover, this minimises the time the vehicle delivering the waste is kept waiting.

**Cross-media effects**

Not identified at this stage

**Operational data**

Not identified at this stage

**Applicability**

Applicable to all biological treatments

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Example plants**

Not identified at this stage

**Reference literature**

EA 2013. Draft Sector guidance note ‘How to comply with your environmental permit. Additional technical guidance for: composting and aerobic treatment sector. LIT 8705, Report version 1.0’

## Storage & handling of incoming waste

**Description**

General techniques for storage and handling of incoming wastes include ensuring:

1. The storage area is appropriately sized and clearly identified to accommodate the expected volume of waste, including seasonal fluctuations, according to the daily capacity of the installation in a dedicated area for off-loading and inspections of accepted waste /feedstock, a dedicated area for unacceptable or rejected loads and any area allocated to pre-treatment.
2. The storage area for putrescible, non woody feedstock is designed to allow complete emptying and cleaning including drainage (when needed at this stage) to allow appropriate leachate and wash waters collection, transfer and discharge into gullies via a sump for use within the process, discharge into sewers where required, tankered to a WWTP or other authorised waste treatment plant or used on land where this is allowed.
3. The level of protection measures shall be proportional to the risk of surface and/or ground water pollution. All storage areas for putrescible, non woody feedstock have an impermeable surface with sealed drainage system, to prevent any spillage entering the storage systems or escaping off-site. The design should prevent the contamination of clean surface water.
4. Run off and leachate (dirty water) is collected via a sump, covered container, tank or lagoon (as appropriate to the type of leachate and run-off), which is clearly identifiable.
5. Waste is stored under appropriate conditions in a designated area to manage putrefaction, odour generation, the attraction of vermin and any other nuisance or objectionable condition. This can be achieved by ensuring that waste is processed quickly and waste storage is minimised.
6. Storage time is controlled and minimised to avoid putrefaction, leaching, odour generation, the attraction of vermin and any other nuisance or objectionable condition.
7. When enclosed buildings are used, fast acting doors are provided for access and egress by delivery and other vehicles. Buildings should be sized so offloading can be carried out within the building with the doors shut.
8. Storage areas should be capable of being easily cleaned.

*\* “impermeable surface*” means a surface or pavement constructed and maintained to a standard sufficient to prevent the transmission of liquids beyond the pavement surface.

**Achieved environmental benefits**

The appropriate and safe storage of wastes helps to reduce emissions and the risks of leakages along with reducing vermin.

**Cross-media effects**

Not identified at this stage

**Operational data**

Not identified at this stage

**Applicability**

Applicable to all biological treatments

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Example plants**

Not identified at this stage

**Reference literature**

EA 2013. Draft Sector guidance note ‘How to comply with your environmental permit. Additional technical guidance for: composting and aerobic treatment sector. LIT 8705, Report version 1.0’

## Traceability - waste in, product out

**Description**

It is best practise to establish a waste tracking system, which begins at the pre-acceptance stage. All records relating to pre-acceptance should be maintained at the facility for cross-reference and verification at the waste acceptance stage. Records pertaining to waste delivered to the facility should be subjected to document control and kept for a minimum of three years or longer if required by the installation permit.

Tracking and traceability is good practice for good operational control of the process and may be required to meet the requirements of quality assurance schemes for compost and digestate products.

Records

The auditing system should operate as a waste inventory/stock control system and include the following elements for waste coming in:

* date and time of arrival on-site
* quantity delivered
* name and address of the carrier
* waste designation and input code
* information of the producer or the previous holder (unique reference number)
* the outcome of the pre-acceptance and acceptance assessments, if available
* date of refusal, reason for refusal and intended treatment/disposal route for any waste unsuitable for biological treatment or arising on the facility
* a site plan
* identification of operators who recorded the relevant information

The auditing system should operate as a waste inventory/stock control system and include the following elements for outputs leaving the site:

* date and time of dispatch from the site
* quantity leaving the site
* name and address of the carrier
* waste designation and code (if the material is regarded as waste)
* information of the output destination.

**Achieved environmental benefits**

The system provides documentary evidence of the treatment given to a certain waste, detailing when the waste has entered the site, where it has come from, which other compounds has it been mixed with (if applicable), where and how stored and where and when it has been shipped. These techniques enable the waste treatment operator to:

* take advantage of any synergies between wastes
* prevent unwanted or unexpected reactions
* ensure that emissions are either prevented or reduced
* manage the throughput of incoming wastes / outputs

**Cross-media effects**

Not identified

**Operational data**

Computer databases or manual systems are required. Implementation of an effective system also requires additional administrative work. Traceability systems need to question what exactly has to be traced and when.

**Applicability**

Widely applied within the waste treatment (WT) sector. In the case of small waste treatment plants, the adaptation of some traceability systems (e.g. paper to computer based) may be difficult. The application of some of the techniques mentioned above may not be possible when installations operate on a continuous or semi-continuous basis. Some examples are when waste liquids from different batches are put together into the storage tank or mixed directly inside the digester, when solid wastes are put into the bunker and mixed with other waste or when the physico- chemical properties of the waste change. Traceability systems for small volumes or quantities are more difficult to apply, and estimate of volumes delivered into a specific process should be sufficient. As proposed, records can still be kept of what arrives on site even if it is more difficult to say exactly when it was mixed and/or processed.

**Economics**

Not identified at this stage

**Driving force for implementation**

* To help the operator manage the installation. It is commonly demanded of the waste producer by the regulatory body, to report that the waste is treated according to all relevant legislation and technical rules. This system helps as well to track how and when the treatment has been carried out.
* To provide information to facilitate process control and management (e.g. stock control).
* To contribute to quality assurance and product certification (eg certification of compost) if appropriate.
* To provide support when problems arise, enabling the location, immobilisation and, if appropriate, effective and selective removal or reprocessing of wastes/outputs.

**Example plants**

Commonly used in WT installations. It is fundamentally important for waste transfer installations.

**Reference literature**

EA 2013. Draft Sector guidance note ‘How to comply with your environmental permit. Additional technical guidance for: composting and aerobic treatment sector. LIT 8705, Report version 1.0’.

## Environmental management systems and quality management systems

**Description**

Environmental management systems

An effective, risk based and auditable management system should be in place to ensure that all appropriate process control, management techniques, maintenance, incident planning and pollution prevention procedures are delivered reliably and on an integrated basis. All relevant staff should be trained in these processes and be aware of how to record or, where required by the regulator, report incidents. The management system should be auditable.

Certified environmental management systems (EMSs) as well as non-certified systems should be accepted. The level of information and control should be proportionate to the scale of the operations and the risk each activity may have on process control and to the environment and human health.

Certification of EMS’s may include certification to a national standard, to the ISO 14001 standard or registration under EMAS (EC Eco Management and Audit Scheme) (OJ L114, 24/04/01). This certification and registration provide independent verification that the EMS conforms to an auditable standard. EMAS now incorporates ISO 14001 as the specification for the EMS element; overall EMAS has a number of other benefits over ISO14001 - including a greater focus on environmental performance, a greater emphasis on legal compliance, and a public environmental statement.

The management system should include information about the condition of the land before operations are started and how the land has been protected during the commissioning, operational life of the permit and site closure. When the installation permit is surrendered, the operator should be able to show that they have taken the necessary measures to avoid pollution risk resulting from their activities and the site has been returned to a satisfactory state.

Key elements of environmental management systems are described below.

Technical competence

Operators holding a permit for installations should be competent to deal with the environmental risks associated with their activities throughout the life of the installation permit.

Operators should ensure that staff are suitably trained and qualified for the management and operation of biological treatment facilities. Any facility undertaking a specified waste management activity under a permit should be operated by suitable technically competent management.

Training systems, covering the following items, should be in place for all relevant staff:

* Awareness of the regulatory implications of the installation permit and how this impacts on their work responsibilities and activities;
* Awareness of all potential environmental effects from operation under normal and abnormal or extreme circumstances (e.g. extreme weather, plant failure, emergency);
* Prevention of accidental emissions and action to be taken when accidental emissions occur;
* Able to deal with incidents effectively;
* Process and risk management procedures;
* Training for emergencies, including practice drills covering the different types of environmental incidents/accidents that may occur, to be prepared for proper course of action;
* Reporting and accountability procedures within the management structure of the facility.

The skills and competencies necessary for key positions should be documented and records of training needs and training received for these positions maintained.

The key positions in the organisation are responsible for contracting potential suppliers of waste inputs and purchasing machines, equipment and other materials. The people working within these positions should have adequate knowledge based on practical experience and proper training/ education.

The potential environmental risks posed by the work of contractors should be assessed and instructions provided to contractors about protecting the environment and risk procedures while working on site.

Where regulatory or industry standards or codes of practice for training exist they should be complied with.

Operations and maintenance

Effective operational and maintenance systems should be in use for all aspects of the process especially where failure could impact on the environment, in particular there should be:

* Documented procedures to control operations that may have an adverse impact on the environment;
* A defined procedure for identifying, reviewing and prioritising items of plant for which a preventative maintenance regime and/or periodic calibration or verification is necessary;
* Documented procedures for monitoring emissions or impacts, or to control and optimise the process so impacts are minimised;
* A preventative maintenance programme covering the whole plant, where failure of that plant could lead to impact on the environment, including regular inspection of major ‘non-productive’ items such as tanks, pipe work, retaining walls, bunds, ducts and filters;
* Essential equipment should be identified and spare items should be stocked when possible in order to allow operation to continue while the equipment is being repaired. Alternatively, specific arrangements with equipment suppliers or engineering companies could be made to ensure immediate response and equipment repair.

Accidents-/incidents/non-conformance

1. There should be an incident management plan which:
   * identifies the likelihood and consequence of accidents and emergency;
   * identifies actions to prevent accidents and mitigate any consequences;
   * includes a continuous improvement process.
2. The incident management plan should consider and have procedures for dealing with events which effect the day to day operation of the facility e.g. risks and impact of flooding and fires;
3. There should be written procedures for handling, environmental non- compliances and / or complaints and implementation of appropriate actions;
4. There should be written procedures for investigating abnormal operational situations, including identifying suitable corrective action and follow up procedures;
5. Clear strategy for diverting waste and contingency for any down time or failure.

Quality management systems

Quality management systems play a fundamental part in good processing and quality of products and should be encouraged. Providing written procedures, monitoring of the process, recording and auditing that procedures have been followed and remain efficient, practical and effective are key to process control.

A list of quality management systems and external quality assurance schemes available in Europe can be found in the JRC’s technical proposals for end-of-waste criteria for composts and digestates (see <http://ftp.jrc.es/EURdoc/JRC87124.pdf)>. Some examples are listed in the table below. Examples of quality management systems implemented by the biological treatment sector in Europe are:

|  |  |
| --- | --- |
| **National/ EU** | **Name** |
| EU | QMS: ISO 9001 |
| EU | ECN-QAS |
| DE | RAL Gütezeichen/ Registrierung (German quality label for compost, digestate and sewage sludge compost) |
| NL | Keurcompost QAS |
| BE-Flanders | VLACO QAS |
| UK | BSI PAS 100 and PAS 110; Quality Protocols for Compost and Anaerobic Digestate |
| IE/ Ireland | Compost QAS |
| AT | ARGE Kompost and Biogas – Austria and KGVÖ based on the Austrian Standard ÖNORM S 2206 part 1 and part 2 and Technical Specification ONR 192206. |
| SE | Avfall Sverige Utvecklingssatsning, certification rules for compost and digestate. Avfall Sverige Utvecklingssatsning, certification rules for compost and digestate, SPCR 152 and SPCR 120 |
|  | <insert any additional quality assurance schemes> |

HAZOP and HACCP principles

Principles of HAZOP (Hazard and Operability Study) may be used to identify and evaluate problems that may represent risks to equipment, or prevent efficient operation. Principles of HACCP (Hazard Analysis and Critical Control Point) may be used to identify specific hazards and measures for their control to ensure the safety of products. These systems can be used as an integral part of environmental and quality management systems.

Energy Management Plans

The operator can undertake an energy management plan, which is an internal assessment of the energy and raw material consumption. Energy management plans consist of a procedure aimed at identifying the main energy requirements of an operation and ways to make the process more energy efficient or less energy consuming. However, when drawing energy plans, consideration must be given to the markets that the installation’s products are destined for. Measures to reduce energy consumption or improve energy efficiency should never be taken at the expense of the quality and fitness for purpose of the products (e.g. the production of a compost for use in a high value market such as the professional horticultural market will require additional maturation and, therefore, will be more demanding from an energy point of view than the production of compost intended for use in the agricultural market).

Energy management plans will enable the operator to follow a systematic approach in achieving continual improvement of energy performance, including energy efficiency, energy security, energy use and consumption. They will assist facilities in evaluating and prioritising the implementation of new energy-efficient technologies and it is helpful to promote energy management best practices and reinforce good energy management behaviours. These standard systems help the operators to reduce their energy consumption, and therefore their energy costs. The operator will also make positive contributions toward reducing depletion of energy resources and mitigating worldwide effects of energy use, such as global warming.

**Achieved environmental benefits**

An effective management system should be in place to ensure that all appropriate pollution prevention and control techniques are delivered reliably and on an integrated basis.

**Applicability**

The components described above can typically be applied to all IED installations. The scope (e.g. level of detail) and nature of the EMS (e.g. standardised or non-standardised) will generally be related to the nature, scale and complexity of the installation, and the range of environmental impacts it may have.

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Example plants**

Not identified at this stage

**Reference literature**

The Composting Association, 2005. The Composting Industry Code of Practice. http://www.organics-recycling.org.uk/dmdocuments/Composting\_Industry\_Code\_of\_Practice.pdf.

EA 2013. Draft Sector guidance note ‘How to comply with your environmental permit. Additional technical guidance for: composting and aerobic treatment sector. LIT 8705, Report version 1.0’

JRC-IPTS, 2014. End-of-waste criteria for biodegradable waste subjected to biological treatment compost & digestate): Technical proposals (see <http://ftp.jrc.es/EURdoc/JRC87124.pdf>).

## Resource and energy efficiency measures and measures to reduce raw materials consumption

**Description**

See ‘Energy management plans’ in section 1.5.

**Achieved environmental benefits**

Can contribute to a more efficient use of resources.

**Cross-media effects**

Not identified at this stage

**Operational data**

Not identified at this stage

**Applicability**

Not identified at this stage

**Economics**

**Driving force for implementation**

Not identified at this stage

**Example plants**

Not identified at this stage

**Reference literature**

Environmental Protection Agency, Wexford, Ireland (2009) Waste License Number WO249-0 1.for Acorn Recycling Limited

# Techniques specific to each biological treatment type

## Techniques specific to all composting systems

### Waste acceptance procedures

At composting sites each delivery of input material is normally visually inspected at an appropriate location and assessed against the stated acceptance criteria. Impurities (plastics, metals, glass etc.) are normally the most significant issue for composting as they can undermine the quality of the compost produced and its acceptance in the market place.

### Storage & handling of incoming waste

1. Some input woody materials (bulky bush and tree cuttings) are stored in a dedicated area for blending with other incoming biowastes and sludges. These must be stored in such a way to mitigate fugitive emissions and fires.
2. The design of the feedstock reception and storage area should be considered as an integral part of site planning and design. Adequate provision must be made for the acceptance of seasonal peak volumes of delivery such as those occurring during the spring and autumn seasons. In addition space needs to be made available for the storage of amendment material for use in blending feedstocks prior to shredding.
3. Depending on the feedstock type (C:N ratio, degradability…), the capacity for optimal residence time for feedstock material stored prior to processing is an important factor in a site's potential of odour generation. Untreated and not properly mixed material can increase the generation of odours. The separate storage of different waste types may be useful to create specified compost products (e.g. green waste compost, biowaste compost, bark compost, sludge compost…).

### Preparation of wastes for composting process

**Description**

Good preparation of feedstock for composting is essential. Key factors to be taken into account are:

* Sufficient porosity of the initial mix for composting. This can be provided by the structure of material such as shredded woody garden and park waste.
* A balanced C:N ratio to ensure a proper micro biological degradation and/or transformation. This can be achieved by mixing and blending low C:N with high C:N feedstocks at an appropriate rate (note that in some cases - e.g. winter months, typically characterised by high C:N feedstocks - it may be difficult for the operator to get hold of feedstocks with the desired C:N ratio).
* Optimal particle size, achieved by shredding the feedstocks, in order to create the ideal habitat for composting microbes and enhance biodegradation.
* Assessment and adjustment of a proper moisture content homogenously distributed in the entire material in order to create the appropriate environment to start the microbiological decomposition process.
* The mix is adapted to the specific process/technique applied.

Composting process additives (e.g. mineral-based or bio-based inoculants or activators), may be added at this stage of the process or at later stages to enhance the process, or ensure the necessary diversity of bacteria species to ensure consistency in plant operation. They should only be applied if they are intended to confer a benefit to the composting process or reduce emissions, without any significant adverse effects on compost characteristics.

**Achieved environmental benefits**

These procedures are fundamental to enable process optimisation and therefore minimisation of odour or other type of emissions.

**Cross-media effects**

Not identified at this stage

**Operational data**

Not identified at this stage

**Applicability**

Not identified at this stage

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Reference literature**

The Composting Association, 2007. An industry guide for the prevention and control of odours at biowaste processing facilities (available at <http://www.organics-recycling.org.uk/dmdocuments/Industry_guide_for_prevention_and_control_of_odours.pdf>).

### Process monitoring & control specific to composting

**Description**

Temperature must be monitored at an appropriate frequency during the intensive composting phase (for thermal hygienisation) as required by the regulator.

The temperature shall be recorded intermittently or continuously, as defined in the operator’s quality management system and likely to be at least once per working day during the entire hygienisation period.

1. In order to reduce the formation of odorous substances and ammonia it is recommended to avoid very high temperatures for prolonged periods of time after thermal hygienisation.
2. During the composting process the following activities and data must be recorded in the operational diary or equivalent record(s):

* Feedstock composition of the individual compost batches;
* Batch codes;
* Merging of compost batches;
* Location of compost batches;
* Temperature profile;
* Moisture assessment (when carried out – in indoor composting this is not always possible)
* Watering date and type of water used (well water, roof water; leachate water from intensive decomposition and tipping area; leachate water from maturation and compost storage area)
* Turning dates (if applicable);
* Forced aeration regime (if applicable);
* Intermediate screening (if applicable);
* The composting process duration.

Oxygen and/or CO2 monitoring

Oxygen and/or CO2 monitoring can provide a useful tool to operators, to demonstrate that aerobic conditions are maintained. Commercial probes can be used for this purpose. More sophisticated compost management softwares enabling integrated monitoring of oxygen, moisture, temperature, and carbon dioxide are also available for process control purposes and can assist the operator to understand more accurately the conditions actually occurring within the compost mass.

The importance of oxygen is its availability for the aerobic micro-organisms. Specifically, oxygen measurements tend to measure only the freely available oxygen in the composting mass and do not take into account the Oxygen Uptake Rate. At high activity rate the oxygen can be consumed as fast as it is available with little if any “free” oxygen left for measurements. This situation in itself does not necessarily indicate a stalled or oxygen-starved process or any risk of the system becoming anaerobic. It is therefore important that, when oxygen monitoring is carried out to aid process control, oxygen levels are not considered in isolation, but rather as a trend over time. Work has been done and guidance has been published in the UK to ensure that, when oxygen monitoring is undertaken, oxygen levels are monitored, recorded and interpreted correctly during composting and to outline the relation between oxygen pore space and dissolved oxygen (available to microbes). When oxygen levels are measured in composting systems, these measurements need to be corrected for errors introduced by condensation in the sample probe and connecting tube. The effect of temperature on the availability of oxygen for composting needs to be taken into consideration.

Examples of other indicators of adequate air supply

In the case of indoor composting systems, air supply can also be controlled by monitoring the temperature in the process air. This can be measured via temperature sensors within the inlet- and/or exhaust-air-pipes of forced aerated systems. The air flow rate will be regulated on the basis of the temperature values measured.

**Achieved environmental benefits**

Transparency, strengthen user confidence, quality control.

**Cross-media effects**

Not identified at this stage

**Operational data**

Not identified at this stage

**Applicability**

Not identified at this stage

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Reference literature**

Nick Sauer and Eric Crouch, 2013. Measuring oxygen in compost. BioCycle December 2013, Vol. 54, No. 12, p. 23 (see <http://www.biocycle.net/2013/12/17/measuring-oxygen-in-compost/>).

### Emissions to water

**Description**

All material for composting, compost and leachate should be stored so that pollution of the surface waters or ground waters can be minimised.

Any contaminated water that flows over the ground, through the soil, or enters surface water drains has the potential to pollute surface waters (e.g. streams, rivers, and lakes) or ground waters (e.g. aquifers, and perched water) in the vicinity of the site, if it is stored and used in a wrong way.

A distinction should be made between leachate seeping from compost piles and windrows and surface water from traffic surfaces and uncontaminated rainwater from buildings.

Dirty waters

Composting can create leachate as a result of high moisture levels in biowaste and putrescible waste and from natural precipitation seeping through active or curing compost piles. Run-off is water that has fallen onto the pile but has not percolated through it or has fallen onto the site surfaces. Wash water is water used to clean plant/equipment and surfaces.

Leachate has typically a high content of organic substances, which has to potential to cause eutrophication to surface water, groundwater, flora and can cause soil contamination. It has also a high potential to generate odour.

The site should have sufficient storage to collect dirty run off, leachate and wash water (dirty waters) from any impermeable paved areas of the site. Storage should be constructed according to construction design standards available. Underground tanks should be checked at regular intervals for integrity.

Dirty waters should be collected in an engineered system and collected via a sump, or lagoon or other appropriately sealed containment.

Note that dirty waters from waste containing animal by- products may be subject to additional control under the animal by-product regulations.

To comply with local, national and European water quality standards, dirty waters must be minimised, and collected. Then they are either reused within the composting process, disposed of properly for treatment in a waste water treatment plant, treated at another authorised waste treatment plant (e.g. AD plant) or applied to land when allowed by the relevant Competent Authority. Where possible and subject to the requirements of the animal by-product regulations, plant operators can use leachate to control the moisture of the composting process to reduce the cost of having it tankered offsite or disposed of via a sewer line connected to the local waste water treatment plant. When moisture adjustment is required in the composting process, dirty waters should be added to the composting process in preference to potable water for resource efficiency – provided these do not contain significant amount of contaminants that may compromise the quality of the compost produced.

Once collected, dirty water can be reused in the beginning of the composting process for wetting fresh feedstock materials in the facility’s mixing procedure, when moisture assessment warrants the adjustment, or later in the composting process if allowed by regulatory regime or any applicable quality assurance scheme. Dirty waters may become a potential source of odour or reintroduce pathogens into compost that has already met its time and temperature requirements for pathogen reduction under the ABP regulations or national regulations, so their re-use in the composting process must be carefully considered in order not to re-contaminate already sanitised composting material.

Treatment on-site of the leachate by approved means prior to discharge may also be present (e.g. via reed beds, aerated lagoons or on-site wastewater treatment plants).

Otherwise, dirty waters can be disposed off properly via an on-site sewer connection, pumped out of the tank and transported to a waste water treatment plant via a tanker truck treated at another authorised waste treatment plant (e.g. AD plant) or applied to land when allowed by the relevant Competent Authority. Emissions and odours are a risk in transport and should be managed.

Leachate can also be generated during the outdoor curing process. All curing pads should be graded so that leachate can be collected with the use of a catchment system to intercept and direct the liquid to a catch basin and underground storage tank or a storage lagoon.

Clean surface water

These are surface water from roofs or from areas of the site that are not being used in connection with storing and treating waste, and may be discharged directly to surface waters, or to groundwater by seepage through the soil via a soakaway. They are considered as ‘clean’ water. For new sites, clean surface waters should be collected and stored separately from ‘dirty water’ or leachate, to reduce the volume of dirty water to be treated.

Proper surface water management will be important to protect nearby water courses. The entire site should be graded and bunded or curbed to facilitate the collection and drainage of surface water to catch basins that direct this water to a storage lagoon for reuse in the composting process.

Surface water can be managed or used effectively on site in the following ways:

* Sprayed on working surfaces on the site for dust control;
* Moisture control at the start and during the active composting phase and curing stages;
* Surface water can also be stored in settling ponds to let the sediment settle to the bottom of the pond before being discharged to local water courses; and
* It can also be treated in constructed wetlands to reduce the polluting potential before discharge to local water courses.

Further considerations:

1. The appropriate dimensioning of the intermediate waste water tank(s) should take into account the site size and rainfall in order to hold dirty waters from all paved areas where compost or raw material is stored or treated in open, unroofed areas.
2. The impermeable area must cover the following areas of the composting plant:

* The tipping and intermediate feedstock storage area for all input materials with the possible exception of woody materials (tree and bush cut-tings), straw, or similar biologically non active, carbon rich, dry feedstock (if allowed by the regulatory regime) or finished compost;
* The storage area for non woody materials (food and kitchen waste, sludge, food processing waste, all materials with high water content and a high fermentability potential)
* The pre-processing area where feedstock are mixed, with the exception of the area where woody materials (tree and bush cuttings) only are shredded;
* The active decomposition area, irrespective of whether it is roofed or not
* The maturation area, irrespective of whether it is roofed or not; and
* The storage area for matured compost with the possible exception to be approved by the competent authority and taking into account at least:
* local precipitation
* ground and surface water protection
* coverage by water repellent fleece or roof

1. All storage and treatment areas must allow for the controlled drainage of all liquids to avoid water-logging at the windrow or feedstock base. This is achieved by constructing the composting pad on a gradient to avoid water stagnating. The minimum slope of the site is determined by the windrow height, annual precipitation, existence of roofing, the method of aeration and the presence of drain/aeration tubes.
2. A waste water management plan must ensure adequate treatment or reuse of the waste water.
3. Dirty waters need to be collected and treated according to the requirements of water protection principles i.e. to prevent pollution of ground and surface wasters due to its high biological oxygen demand, the nutrient content (above all phosphorus and nitrogen) and potential pathogenic microorganisms.
4. It must be distinguished between qualitative criteria for:

* Direct discharge into rivers
* Direct application to land
* Indirect or direct discharge to on-site or off-site waste water treatment plants

1. Quality management measures aimed at reducing the quantity and to manage dirty waters are:

* Including in the initial composting mixture feedstocks that provide a good structure and water holding capacity (e.g. shredded wood, bark, straw, oversize screenings, sawdust, leaves and compost at an appropriate rate);
* Adjusting the initial moisture content of the feedstock to adapt it as much as possible to the water holding capacity
* Assessing the need for water additions and ensuring correct adding of water as the composting process progresses and the total water holding capacity decreases.

**Achieved environmental benefits**

To minimise emissions to water from composting activities dirty water is captured and collected, so under normal operating conditions they will not penetrate into the soil and affect ground water or be carried away with surface water and pollute nearby water courses. It also enables efficient use of water.

**Cross-media effects**

Not identified at this stage

**Operational data**

Not identified at this stage

**Applicability**

Not identified at this stage

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Reference literature**

Composting and Anaerobic Digestion Association of Ireland (2011) Certificate in Compost Facility Operation Manual. Dundalk, Louth, Ireland.

Nick Sauer and Eric Crouch, 2013. Measuring oxygen in compost. BioCycle December 2013, Vol. 54, No. 12, p. 23 (see <http://www.biocycle.net/2013/12/17/measuring-oxygen-in-compost/>).

### Emissions to air

The main releases from aerobic treatment operations are:

* Odorous compounds
* Dust
* Ammonia
* Bioaerosols

Different types of waste streams may have different potential to generate emissions to air. For example, putrescible wastes (e.g. food wastes), generally characterised by high moisture contents and low C:N ratios, are more likely to generate odour and ammonia emissions than less putrescible wastes (e.g. green waste, especially woody fractions), which are less wet and are generally characterised by higher C:N ratios.

Proximity to residential, commercial and other industrial premises will determine the amount and type of environmental control that will be needed as well as the extent of environmental monitoring required.

#### Odour

**Description**

There are a number of good management practices that can be used in order to prevent the generation and subsequent release of odours off site. Many of these techniques are complementary. These are as follows:

1. Pre-acceptance and planning treatment process is first off, as per section 1.1.
2. It is essential that odorous wastes be identified at the site as quickly as possible upon delivery.
3. It is vital that aeration (via natural convection, mechanical turning and/or forced aeration) is supplied to ensure sufficient air is supplied to the composting material. During the most active composting stage at higher temperatures, there can be moisture loss and water may need to be replaced to ensure optimal conditions are maintained.
4. The operator may mix input materials in order to achieve a consistent and balanced C:N ratio in the batch. The accepted load is assessed to identify the processing requirements and any potential problems. Any moist or wet loads accepted are routinely blended with other woody or dry inputs or compost oversize material (compost screenings) upon discharge to reduce the possibility of anaerobic conditions developing and so causing an odour release.
5. An ‘Odour Management Plan’ should be prepared for each composting site to identify the appropriate measure to mitigate odours at the site. As part of the ‘Odour Management Plan’, the ‘complaints management’ in the case of single odour emission events should include:

* Name, address and telephone number of the complainant;
* Date, time of the complaint;
* Subject of the complaint;
* Operations carried out at the time of the complaint;
* Weather conditions (e.g. temperature, wind direction, rainfall);
* Operational measures due to the complaint;
* Communication with the complainant. There should follow an immediate reply to the complainant.

Composting process additives such as mineral-based or bio-based inoculants or activators, may be added to the process to enhance the process, on the provision they are intended to confer a benefit to the composting process or reduce emissions, without any significant adverse effects on compost characteristics.

**Achieved environmental benefits**

To minimise odour emissions to air from composting activities.

**Cross-media effects**

Not identified at this stage

**Operational data**

Not identified at this stage

**Applicability**

Not identified at this stage

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Reference literature**

Composting and Anaerobic Digestion Association of Ireland (2011) Certificate in Compost Facility Operation Manual. Dundalk, Louth, Ireland.

#### Dust and bioaerosols

**Description**

There are a number of good management practices, mainly related to outdoor activities which can be carried out at any type of plant, and that can be used in order to prevent the generation and subsequent release of bioaerosols and dust off site.

In plants which have active vehicle movements outside there should be a ‘dust management plan’ in place. Typically preventative measures in dry weather is water spraying on site roads and any other areas used by vehicles.

Other measures include:

1. Covering of skips to and from site and in storage.
2. Where dust creation is unavoidable, use of sprays, binders, stockpile management techniques, windbreaks etc. are employed based on risk assessment
3. Wheel and road cleaning (avoiding transfer of pollution to water and windblown particulate)
4. Regular housekeeping (e.g. keeping the site in order and clean)
5. Effective management of moisture, temperature and air supply
6. Appropriate consideration of weather conditions and wind direction

A plant should identify activities that could potentially generate bioaerosols. The following activities/events can generate dust and bioaerosols:

* Vehicle and equipment movements around the site
* Shredding of feedstock or bulking materials
* Formation and turning of compost piles and filling of vessels
* Forced aeration
* Screening of finished compost
* The spraying of leachate when it is reused in the composting process, depending on the method used for spraying (e.g. sprinklers)
* Strong wind

The following measures that can be used to help minimise or control dust and bioaerosols from the composting facility include:

1. Maintaining adequate moisture content throughout the composting process to avoid the input feedstocks, composting materials and finished compost drying out and potentially generating dusts when handled.
2. The formation or turning of windrows or piles should be avoided if possible on windy days. Screening and shredding should also be undertaken when wind speed is calm or wind direction is away from sensitive receptors.
3. Site surfaces such as roads and tracks should be regularly dampened down and/or swept to suppress dust and bioaerosols.
4. Plant and machinery should be well maintained to avoid generation of dust or particulates.
5. The use of enclosures for screens and hoppers can be useful in reducing dust dispersal.
6. Physical barriers such as mounds or walls or a tree boundary can reduce the amount of dust leaving a site.
7. Site construction & specific landscaping techniques can contain dusts that are generated.
8. The shredding, mixing, pile turning and/or screening within buildings allow control and treatment of dust / bioaerosol emissions. Batch irrigation should be undertaken when the parameters for moisture content fall below the critical limits.
9. For indoor composting, scrubbers and biofilters should be monitored to ensure optimum performance.
10. It is a good practice to have a wind sock to monitor wind direction on site and also to record weather data and to use weather monitoring data to help determine site activities. For example it is advisable not to turn when wind is blowing towards sensitive receptors.

**Achieved environmental benefits**

To minimise bioaerosols and dust emissions to air from composting activities.

**Cross-media effects**

Dust control means higher water consumption. Higher ventilation rate also means higher energy consumption.

**Operational data**

Not identified at this stage

**Applicability**

Not identified at this stage

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Reference literature**

Composting and Anaerobic Digestion Association of Ireland (2011) Certificate in Compost Facility Operation Manual. Dundalk, Louth, Ireland.

### Product preparation

Product preparation could involve but is not limited to:

1. screening to create one or more compost grades (in terms of particle size range) and/or remove any physical contaminants;
2. blending with other materials, composts, products, or additives; and/or
3. increase or reduction of moisture content.

A grade of compost may be used as more than one type of product and/or in more than one type of product.

Screening is a process stage that separates compost particles according to their size, in order to achieve one more separate grades of compost in terms of particle size range.

When drum screens are used, it should be noted that:

* When the material to be screened is wet (> 35% moisture content), this results into reduced screening capability, low screening yield, and high screen overflow.
* When the material to be screened is dry (< 35% moisture content), this results in good screening capability, good screening yield, but also significant dust and bioaerosols emissions possibly associated with microbe emissions as the moisture levels decrease (< 20%).

Screening should be managed in a way that uncontrolled emissions to air (e.g. odours and bioaerosols) are prevented or minimised.

Products should be prepared under appropriate conditions, for example, product should not be stored at the bottom of a slope where raw materials are accepted for composting or composted.

The compost should be stored so that batches with different quality specifications can be distinguished. Compost can be stored in bags or stockpiled subject to customer’s delivery and/or handling requirements.

**Achieved environmental benefits**

Not identified at this stage

**Cross-media effects**

Not identified at this stage

**Operational data**

Not identified at this stage

**Applicability**

Not identified at this stage

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Reference literature**

BSI PAS 100:2011 Specification for composted materials.

Waste Consult International and Gewitra, 2013. Determining Best Available Techniques for the Waste Treatments Industries in the Context of the Sevilla Process to Review the Best Available Techniques Reference Document (BREF) on Waste Treatments Industries. Treatment of Separately Collected Organic Waste (Composting and Digestion). Commissioned by German Federal Environment Agency.

The Composting Industry Code of Practice. <http://www.organics-recycling.org.uk/dmdocuments/Composting_Industry_Code_of_Practice.pdf>.

## Specific techniques to consider for outdoor composting

### Storage & handling of incoming waste

**Description**

See also section 2.1.2.

1. In the case of intermediate storage of source separated green waste and food waste from households (in countries where this is allowed outdoor), physical protection against wind drifting of light fractions (contaminants such as plastics) must be installed (fences, walls, fleece coverage) or light fractions are removed from the surface.
2. Storage time should be kept to a minimum

**Achieved environmental benefits**

Avoidance of uncontrolled littering. Low specific energy consumption

**Cross-media effects**

Improvement of product quality.

**Operational data**

Not identified at this stage

**Applicability**

Applicable to outdoor composting.

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Reference literature**

Not identified at this stage

### Preparation of wastes for composting process

**Description**

See also section 2.1.3.

1. Shredding of raw materials may cause dust, odours and bioaerosols to be emitted.
2. For sites with sensitive receptors nearby, reduction of dust, odours and bio-aerosols emissions can be achieved by spraying water or fogging onto the shredding process and considering actual wind direction and strength.

Achieved environmental benefits

Waste preparation is necessary to ensure the composting process is optimised and does not result in uncontrolled emissions.

**Cross-media effects**

Poor preparation of feedstock and prompt management usually results in poor quality and highly odorous material that has risk of pollution when used.

**Operational data**

Not identified at this stage

**Applicability**

Not identified at this stage

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Reference literature**

### Process monitoring & control specific to outdoor composting

**Description**

See also section 2.1.4 for monitoring applicable to all composting systems.

Moisture assessments

Moisture should be controlled during the entire composting process. This can be done by means of visual control combined with one of the following methods:

* a ‘squeeze or fist test’, which is the most commonly used by operators. It entails grasping and clenching the sample in a gloved hand for approximately ten seconds, then opening and assessing moisture content using table 1 below; this is a subjective test but is regarded as reliable when carried out by an experienced operator;
* a moisture monitoring device with read-out or connectivity to a data capture system;
* a more accurate drying in an oven method, which is followed by calculating the change of mass having weighed sample mass before and after ‘drying and cooling of the sample’.

Since results from squeeze test and moisture probe techniques are less accurate, when possible these should be verified at regular, stated intervals by comparison with quantitative results (% mass/mass) obtained using the drying in an oven method.

|  |  |  |
| --- | --- | --- |
| Table 1: Moisture assessment index | | |
| Index | Sample moisture behaviour | Interpretation |
| 1 | Water seeps out | Too wet |
| 2 | More than one droplet appears | Too wet |
| 3 | One droplet appears | OK |
| 4 | Compost particles remain packed together and no droplets appears | OK |
| 5 | Compost particles fall away from each other | Too dry |

**Achieved environmental benefits**

**Cross-media effects**

Transparency, strengthen user confidence, quality control.

**Operational data**

Not identified at this stage

**Applicability**

Not identified at this stage

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Reference literature**

The Composting Association, 2005. The Composting Industry Code of Practice. The Composting Association, 2005. The Composting Industry Code of Practice. http://www.organics-recycling.org.uk/dmdocuments/Composting\_Industry\_Code\_of\_Practice.pdf.

### Emissions to water

In case of heavy rainfalls and if the measures described in section 2.1.5 are insufficient the following can also be considered:

* In case of heavy rainfall or high precipitation areas, covering small triangle windrows with geo-textiles or composting under a roofed structure reduces the formation and the organic contamination of waste water and helps improve run-off management.

**Achieved environmental benefits**

Not identified at this stage

**Cross-media effects**

Not identified at this stage

**Operational data**

Not identified at this stage

**Applicability**

Not identified at this stage

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Reference literature**

Not identified at this stage

### Emissions to air

Potential emissions to air include:

* Odour
* Dust and particulate
* Bioaerosols
* Ammonia (depending on the input material and the quality of the treatment process)

In open/outdoor composting all of these are diffuse emissions inherently providing little or no options for direct regular monitoring of channelled emission components. Hence, end of pipe techniques for the abatement of emissions to air in outdoor composting are only applicable if negative aeration techniques with a biofilter are installed.

Therefore, besides quality and operational process management aiming at the minimisation of emissions to air, specifically in the case of odour, dust and bioaerosols the selection of a suitable location for outdoor composting plant is of utmost importance.

In this respect, it is not only the potential level of diffusely emitted compound, but the potential to cause intolerable impacts on the health or also the subjective wellbeing of potentially affected neighbourhood.

As an important element, the permitting procedure should include a diffusion modelling specifically for odour and dust/bioaerosols (e.g. for sited within the boundary for sensitive receptors), or national guidelines for site locations of composting facilities and distances to odour receptors.

* The local climate and topographic conditions;
* Prevailing historic wind direction
* Existence and location of potential sensitive receptors (permanent residents, permanent working places, public institutions, hospitals, schools, recreation areas, care homes etc.); and
* Typical and worst case events of emission under routine plant management conditions.

Based on the assessment results using standard methodologies approved by the regulatory body, the regulatory body approves the suitability of the foreseen location of the composting site and key management/operation requirements aimed at minimising the risk of unacceptable impacts stemming from emission events as included in the quality management manual as part of the permit.

#### Odour

**Description**

Key criteria for controlling the formation and release (emission) of odorous substances in outdoor composting are:

* Type and mixture of the initial feedstock (structure, C:N ratio);
* Temperature profile;
* Moisture content;
* Maintaining the aerobic conditions.

One of the most important measures aimed at effectively reducing odour emissions is the *homogeneous mixing of different raw materials* which helps establish adequate free pore space, continuous air exchange and, if optimised moisture level is provided, rapid decomposition of the primary and easily degradable organic substances. The correct mixing of shredded ligneous bulking agents of the right particle size composition therefore has to be managed carefully, and considered to be an important pre-processing measure.

The *temperature regime* is another key factor influencing odours. In order to reduce the formation of odorous substances and ammonia it is recommended to avoid very high temperatures for prolonged periods of time after thermal hygienisation. High temperatures diminish the microbial diversity and thus slow down the decomposition process. Intermediate metabolite substances with high odour intensity are more likely to be generated. Intensified aeration or mechanical agitation, changing the heap diameter and watering can counter steer the effects of overheating. Optimised *water content at any stage of decomposition* is a pre-condition for proper odour management. Process water and condensates may constitute a significant source of odours. An excess of water as well as poor windrow construction may cause anaerobic conditions especially in the bottom of windrows. Therefore besides operating an effective watering system, sites also need to ensure continuous drainage of both process and surface waters.

Furthermore, the sufficient *supply of oxygen* to the microbial community must be guaranteed at all stages of composting. These are described in the following table.

|  |  |
| --- | --- |
| Table xx: Measures to prevent oxygen deficiency during composting **(Adapted from Bidlingmaier & Müsken, 1997[[1]](#footnote-1))** | |
| **Measures against  water surplus** | Reducing the water input:   * Choose dry feedstock with a high water retention capacity * Add high C:N input materials (chopped/shredded wood, bark, sawdust, dry compost etc.) * Optional in case of heavy rainfalls: Cover open triangle windrows with a geo-textile (drains off 80 to 90 % of rain water) * Shape windrow to shed water   Increase water release:   * Ensure initial ‘mix’ of materials is balanced and that porosity is maximised * Uncover the windrows on days with high evaporation potential |
| **Measures to improve structure** | * Mix additional bulking agents if required (shredded bush cuttings) * Increase bulking agents especially in the bottom of the heap, if required. Create a basic layer with structure forming shredded wood. * Use oversize when required to ‘open’ the feedstock texture.   Porosity is a key factor in the generation of odours. The density of the material should be optimised from the beginning by effective blending and mixing of feedstocks. This will enable adequate air flow throughput the pile. |
| **Windrow structure** | * Set up loose, well-structured windrows for the initial intensive degradation phase * The maximum height of a pile/windrow depends on   decomposition age (the more mature, the higher the piles can be)  structural stability of the whole mixture  installation of a forced aeration system (alternating positive [blowing] and/or negative [sucking])   * Through mechanical agitation (turning) new accessible surfaces are created and air exchange rates are increased. |

In *open windrow systems without forced aeration* operators need to ensure that there is sufficient and continuous air exchange reaching down to the central zone of the windrow. Those systems need to carefully balance windrow diameter, material composition (free air space, water content, and structural stability) and turning frequency.

In areas or seasons with very *high precipitation*, reduced water evaporation can lead to water logging, so when cost effective to do so, triangle windrows could be covered with hydrophobic geo-textiles or placed under roofing.

Natural aeration in open windrow systems is based on the *principle of natural convection* and do not require the waste air to be treated as long as the process is managed properly. However, during the preliminary decomposition stages, mechanical agitation can cause short term increased odour emissions. Therefore in open windrow systems the site specific conditions have to be considered together with the feedstock properties and daily process management operations.

Specific operational measures to reduce odour emissions from open windrow composting systems are:

* The immediate and efficient processing of delivered waste material with high potential of formation of odorous substances (e.g. food waste, fresh grass prunings);
* Mixing in well shredded and structured woody garden and park waste (maintaining sufficient storage /supply of bulking agents);
* Managing the decomposition process, e.g.
* Regular turning to avoid anaerobic zones forming in windrows;
* Limiting the size of the windrows; and
* Keeping the facility clean (regular cleaning of surfaces, equipment and all traffic routes etc.); and
* Turning the windrows only when there is an advantageous wind direction relative to the possible affected neighbourhood.

An important factor in open windrow composting is the *annual extent and seasonal distribution of precipitation*.

On sites with high rainfall, is it recommended to consider covering windrows (e.g. with a fleece/geo-textile) if no roofing is available. Smaller windrows risk exceeding the water capacity of the composting material, especially during late composting/maturation stages (at temperatures < 40/45 °C the evaporation rate is diminished). In this particular respect, due to their favourable surface area/volume ratio larger windrows (ca. > 1.20/1.50 m high) and table windrows are less vulnerable to water logging through precipitation.

Windrows with an inherently high water content run a greater risk of forming anaerobic zones (due to the pores filling with water, rather than allowing gasses to migrate) and of causing odour nuisance. Moreover wet materials handicap the final value-added stages of the composting process (sieving, segregation of impurities).

**Achieved environmental benefits**

Not identified at this stage

**Cross-media effects**

Not identified at this stage

**Operational data**

Not identified at this stage

**Applicability**

Not identified at this stage

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Reference literature**

Not identified at this stage

#### Dust and bioaerosols

**Description**

Assessing the risks to human health from exposure to bioaerosols is inherently problematic, due to the lack of dose-response relationships (Böhm *et al*., 1998[[2]](#footnote-2)). As such, “acceptable” maximum exposure levels or occupational exposure standards cannot be established. Therefore composting facility operators need to establish measures (both technical and operational) to minimise bioaerosol and dust formation.

[Note: Research on bioaerosols is currently being undertaken in the UK and associated results will be available in the near future. This will be discussed at the next meeting of the JRC biological sub-group]

Effective measures are:

1. Depending on the national requirement conduct an assessment for new facilities in order to consider an appropriate distance between the new facility and residential areas (or other sensitive receptors) Investigations have shown that in distances of 150 to 200 meters – depending on topography and dominant wind direction – natural background concentrations are attained (Amlinger et al. 2005[[3]](#footnote-3)). The UK has adopted 250m based on research and the precautionary principle – Wheeler et al.;
2. All materials handling areas and traffic routes need to be kept clean and moist (although water should not be allowed to build up and stagnate, as this will create an odour source);
3. In case of outdoor composting or outdoor maturation of material which has been composted in vessel systems the handling of this material may lead to increased bioaerosol emissions. In particular this may happen when the following sub-optimal decomposition conditions have occurred during composting:

* heterogeneous distribution of moisture, degradation and temperature respectively,
* excessive drying of the material due to excessive aeration; or
* ineffective mixing of the material

1. Maintaining appropriate levels of moisture in all composting materials:
2. In case of critical locations:

* Materials handling needs to take into account daily climatic conditions;
* When used, turning machines should be equipped with rubber aprons to reduce the emission of dusts.

[Note: Further discussions on bioaerosols and the approaches adopted by different countries to control bioaerosols will be discussed later in the year. Further text may be added based on the outcome of these discussions].

**Achieved environmental benefits**

Not identified at this stage

**Cross-media effects**

Not identified at this stage

**Operational data**

Not identified at this stage

**Applicability**

Not identified at this stage

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Reference literature**

IndusTox Consult, Dr Frans Jongeneelen, European Registered Toxicologist, Nijmegen - NL ; May 14th 2014.

#### Ammonia

**Description**

Feedstock management related measures to reduce emissions of ammonia (NH3):

1. N-rich materials, (sewage sludge, fermentation residues, specific industrial wastes, poultry manure, household organic wastes [especially when kitchen waste and grass clippings are > 30 to 40%]) must be blended homogenously with a sufficient amount of carbon-rich materials, to balance the C:N ratio. In this respect the carbon availability is also of specific importance: which can be achieved by a proper particle size distribution of the shredded material and fresh material. Within a low C:N ratio, the NH3 emissions increase as the composting temperature increases. A C:N-ratio of > 25 minimises NH3 formation, however, as the ratio increases (to above 35) the rate of composting will slow down, as N will be rate-limiting;
2. Water content: Ideally the moisture content of the waste mixture should not be above 65-70% (m/m) at the start of the composting process, and should be maintained to between 40 to 60% (m/m) during the following stages of the process, although a lower moisture content during the final stage of the process may be required to optimise the screening process.
3. Bulking/structural materials (these are required to maintain an adequate pore structure to allow air circulation): The ratio of structure-forming materials (shredded bush and tree cuttings, screen overflow, etc.) should – in dependence of C:N ratio and structural properties of the individual constituents be adjusted accordingly
4. Mature compost – in order to facilitate the efficient formation of humic substances (humification) and the incorporation of volatile carbon- and nitrogen compounds into more complex compounds: the addition of mature compost may be beneficial.

**Achieved environmental benefits**

Not identified at this stage

**Cross-media effects**

Not identified at this stage

**Operational data**

Not identified at this stage

**Applicability**

Not identified at this stage

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Reference literature**

Not identified at this stage

### Energy efficiency measures

Refer to 1.6

### Measures to reduce raw materials consumption

Refer to 1.6

## Specific techniques to consider for indoor composting

### Storage & handling of incoming waste

**Description**

Specific techniques for storage and handling of incoming waste are:

1. Storage of putrescible wastes should be carried out in an enclosed area.
2. Where the waste storage area is required to be in an enclosed building it should include a building ventilation system and an emission abatement system that maintains the building under negative air pressure in order to minimise fugitive odour and dust release from the building.
3. Fast acting doors should be provided for access and egress by delivery and other vehicles. Buildings should be sized so offloading can be carried out in the building with the doors shut.
4. Operators may wish to consider the use of air lock entrances for sites located in sensitive areas, when these are practicable.
5. The storage area for putrescible, non woody feedstock is designed to allow complete emptying and cleaning including drainage (when needed at this stage) to allow appropriate leachate and wash waters collection, transfer and discharge into gullies via a sump for use within the process, discharge into sewers where required, tankered to a WWTP or other authorised waste treatment plant or used on land where this is allowed.
6. All storage areas for putrescible, non woody feedstock must have an impermeable or paved surface with sealed contained drainage, to prevent any spillage entering the storage systems or escaping off-site.
7. When storage is enclosed, exhaust air is captured, and can be reused to aerate the composting piles, then discharged and treated, when this is required by regulatory body.

**Achieved environmental benefits**

Not identified at this stage

**Cross-media effects**

Not identified at this stage

**Operational data**

Not identified at this stage

**Applicability**

Not identified at this stage

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Reference literature**

Not identified at this stage

### Process monitoring & control specific to indoor composting

**Description**

Adequate plant design is essential for enclosed composting systems to work effectively.

Enclosed composting systems ensure that composting takes place in an enclosed environment, with accurate air flow and temperature control.

The temperature is generally recorded regularly against time with the use of electronic sensors used in conjunction with programmable logic controllers and/or computer hardware and software. Temperature should be measured in the composting material and, where possible, in the process air (which can be both inlet and exhaust air - inlet air is more relevant for the control of the process). Such measurements are not only important to control the process but also to ensure abatement systems’ optimal removal efficiencies. This should be taken into account when designing and commissioning the plant.

When animal by-products are treated, the installation is required to comply with the minimum requirements for the thermal hygienisation as specified in the animal by-product regulations and approved by the competent authority.

It is normally challenging to monitor moisture during the composting process inside an enclosed building or vessel, due to health and safety issues. Regular measurements of moisture content in the material inside closed systems is technically not feasible. Moisture can be assessed before loading the material into the enclosed composting reactor and amending and adjusting when it comes out of the indoor composting stage. Optimal moisture content inside the enclosed composting unit can be maintained based on the operator’s experience. In addition the assessment of the water balance can be determined if the initial moisture content is analyzed and the water loss is estimated by calculating the air flow rate and the water content of the exhaust air.

**Achieved environmental benefits**

**Cross-media effects**

**Operational data**

**Applicability**

**Economics**

**Driving force for implementation**

**Example plants**

### Emissions to air

End-of-pipe techniques to treat air emissions include the use of one or a combination of the following abatement systems: biofilter, wet scrubber (water or acid), activated carbon, bioscrubber and ozone treatment.

In addition, encapsulation with a semipermeable membrane covers *as a point of source abatement technique* can also be used to mitigate emissions to air.

#### Odour

**Description**

In addition to the techniques already described in section 2.1, the following operational procedures can be of importance to reduce odour emissions: closing gates and doors, maintaining building under negative pressure, and composting process optimisation. The negative pressure works however “against the gravity” – this must be taken into consideration as well as energy consumption and the efficiency of the aeration is concerned.

In addition, the following technologies are commonly used:

Encapsulation with semipermeable membrane covers

Encapsulated, positively aerated installations covered and sealed with semipermeable membrane covers are a common method of treating emissions, such as odours, ammonia, VOCs, dust and bioaerosols from an active composting heap. In opposition to the known end of pipe means these systems realize the emission abatement at the point of source. The cover is formed by a textile laminate with the membrane being the middle layer as the functional component. The emission retention is based on the combination of the phenomena that a liquid condensate layer is generated on the inner surface of the cover which acts as a kind of bio washer layer dissolving the majority of the gaseous substances and the semipermeable behaviour of the membrane.

The design of an installation in which a semipermeable membrane cover is used, has to be tuned so that the cover is sealed to the installation interfaces to facilitate a slight backpressure and to ensure the exhaust air passage through the membrane.

End of pipe techniques

Biofilters are the most common type of abatement techniques used in indoor composting systems. They are often combined with a wet scrubber (which tend to be mainly water scrubbers) to improve removal efficiencies. In general, the type of technique used will be partly dependent on the type of input materials processed at the facility, which in turn will affect the composition of the exhaust air to be treated and, hence, the type and combination of abatement treatments required.

*Biofilters*

Biofilters are the most common method of treating odours from a composting facility. Biofilters are based on the principal that microorganisms break down or consume some of the compounds within an odorous gas. Biofilters are also effective in removing volatile organic compounds, organic acids, sulfides and aldehydes. A biofilter consist of a bed, typically called the biofilter media, and is usually made up of woodchips, root woods and mature compost. However, the bed can also be made from wood chips alone, bark, soil, peat, or other suitable media. The process air collected from the composting system is forced through the biofilter bed from the bottom. The odorous compounds in the gas are then absorbed into a moist biofilm that surrounds the filter media. Within the biofilm is a diverse microbial community which then consumes the nutrients from the passing air flow as a food source, in effect breaking down the odour or nutrients within the process air or gases. Carbon dioxide, water, inorganic compounds and small amounts of odorous compounds are then released from the biofilter as by-products of the treatment process (Chiumenti et al., 2005[[4]](#footnote-4)).

When it is properly designed and maintained, a biofilter’s ecosystem is remarkably robust in its ability to remove pollutants and odours across a wide range of compounds and concentrations. In terms of odour treatment, all composting process air from in-vessel and aerated static pile systems can be forced through a biofilter to treat residual odours. Biofiltration has been accepted in Europe and North America as the “best available technology” (BAT) for odour treatment at enclosed composting facilities. Removal efficiencies will depend on a number of issues, including how well the biofilter is designed, operated and maintained, and also the load of odorous compounds in the exhaust inlet air. When operated and maintained properly, they are 90-95% effective in removing odorous compounds from the composting process air. Further abatement may be necessary if the residual odorous compounds are still considerable and likely to cause nuisance. The used filter-material can be used as input material in the composting plant again.

The design of the biofilter is essential to ensure that the process air is adequately / homogeneously fed into the biofilter. The objective is to reduce preferential circuit to take place into the system and ensure efficiency over time. The biofilter would be designed and constructed regarding the flow rate to be treated (ventilation system) and their variabilities over time (process composition, air flow variations on specific equipment / area).

Biofilter management

A biofilter is a microbial system that requires active management. Failure to carry out a management plan will result in poor and inadequate performance, and can in some cases cause offensive odours to be generated by the biofilter itself. Other modes of failure for poorly designed or maintained biofilters include:

* + Channelling (fissure flow which bypasses most of the biofilter)
  + Compaction / blockage (resulting in high resistance to flow)
  + Drying out (ineffective and in extreme cases may catch fire)

Management of a biofilter would include: moisture and temperature management, performance monitoring (including back-pressure), establishment of a maintenance schedule and the use of standard operating procedures (SOPs).

#### *Activated carbons / carbon filters*

#### Carbon adsorption has numerous applications in removing pollutants from air streams. Different types of carbon can be utilised: there are standard untreated grades, catalytically enhanced materials or chemically impregnated types.

The carbon can be tested on a regular basis and samples sent off to a lab for absorption testing, this then gives an indication of the remaining life of the carbon and dictates the frequency of additional samples and estimates when the media needs replacing. In addition to this you can have the standard inlet and outlet performance testing.

#### *Ozone Treatment (not generally applicable, few plants in UK identified)*

Ozone (O3) consists of three oxygen atoms. When ozone comes in contact with an odorous air stream, it oxidises the volatile compounds in the odour air stream and reduces the odour compounds and it loses an atom and become oxygen (O2). In practical terms, the system operates by passing oxygen through a chamber with two electrodes emitting an electrical charge to form ozone, which is then passed into a chamber of odorous air stream from the compost site where it attacks the odorous compounds and neutralises the odour (Jacobs et al., 2007)6.

**Achieved environmental benefits**

Odour complaints are the most common issue for composting plants. Management of odour is critical. Once odours are managed effectively the plant has significantly improved environmental benefits.

**Cross-media effects**

**Operational data**

**Applicability**

**Economics**

**Driving force for implementation**

**Example plants**

**Reference literature**

Cré-Composting and Anaerobic Digestion Association of Ireland (2011) Certificate in Compost Facility Operation Manual. Dundalk, Louth, Ireland.

#### Bioaerosols and dust

**Description**

Whilst containing part of the composting process, indoor and encapsulated systems may still emit airborne microorganisms, especially if some operational activities are carried out outdoors (for example, the bulk movement of organic materials or the maturation of compost in piles/windrows). At enclosed facilities dusts are usually generated from the screening of the final product. Some facilities enclose the screening to reduce dust emissions.

**Achieved environmental benefits**

As indoor facilities are contained, the impact on neighbours is minimal when the air treatment systems are working correctly.

#### Ammonia

High nitrogen content wastes (e.g. sewage sludge/ food waste) can generate a lot of ammonia. This is managed by treating air with acid scrubbers.

#### Scrubbers

Because ammonia has an inhibiting effect on biofilters, a combination of wet scrubbing first followed by treatment in a biofilter may work best. The air stream lead into the biofilter can be monitored for ammonia to ensure that the stripping of ammonium is working correctly. Also a certain amount of dust emissions can be reduced by the use of a wet scrubber system. Scrubbers can have a higher capital and operating cost, but require less space. Scrubbers come in many variations – re-circulating and single pass scrubbing solutions, acidic or alkaline scrubbing solutions, oxidising scrubbing solutions or packed column, plate or spray towers (Jacobs et al., 2007[[5]](#footnote-5)). Air from the composting process is collected and passed through a large cylinder/ tower and is washed in a mist of water or absorbent liquid. The liquid absorbs some of the odour compounds and the liquid is transferred to a tank or to a waste water treatment plant.

Composting facilities are using mostly a biofilter and if necessary in conjunction with a wet scrubbers (= mainly using water, although sometimes acid or alkaline scrubbers can also be used. For ammonia, an acid scrubber is an effective system to limit competition between H2S and NH3 on the biofilter and ensure that the biofilter would treat efficiently H2S) - for the treatment of odours from the composting process. This combination of odour treatment techniques has proven to be over 95% effective in removing odorous compounds from composting process air. Further abatement may be necessary if the residual odorous compounds are likely to cause nuisance.

### Energy efficiency measures and measures to reduce raw materials consumption

The operator can undertake an internal assessment of the energy and raw material consumption (see also general applicable chapter 1.6). The main energy consumption in an indoor plant is from aeration fans and diesel used in loaders.

(Example) An indoor composting plant has the ability to control the composting process to provide the optimal conditions for composting e.g. aeration fans. As part of the process an indoor facility has the ability to re-use leachate (prior to pasteurisation) in the composting process. This reduces the volume of water used.

**Achieved environmental benefits**

**Cross-media effects**

The negative pressure works “against the gravity” – the energy consumption is much higher as in the case of positive pressure. This must be taken into consideration.

**Operational data**

Not identified at this stage

**Applicability**

Not identified at this stage

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Example plants**

Not identified at this stage

## Specific techniques to consider for anaerobic digestion (AD)

The typical process stages of an AD plant with the principal functions of each step are listed below:

* Feedstock acceptance and storage to:
* Formally accept waste
* Provide adequate capacity for the feedstock
* Prevent fugitive emissions
* Blend feedstocks and balance loading into the plant
* Pre-treatment of feedstock prior to digestion to:
* Remove unwanted materials and contaminants
* Physically and chemically prepare the feedstock for digestion
* Pasteurisation:
* To meet the requirements of Animal By-Products (ABP) Regulations (where necessary)
* Digestion processes:
* To stabilise the feedstock and produce the required outputs
* Biogas storage and utilisation:
* To prepare, store and utilise the biogas output
* Digestate storage and utilisation:
* To prepare, store and utilise the digestate output

### Waste acceptance procedures

**Description**

The degree of flexibility associated with anaerobic digestion (AD) is claimed to be an important advantage of the method, since several types of wastes can be accepted for treatment, ranging from wet to dry and from source-separated to mixed waste. The suitability of the method for very wet materials, for instance, has been addressed as an important feature in those scenarios where source separated food waste cannot be mixed up with enough quantities of bulking agents such as garden and park waste from municipal districts for a proper composting process.

Although AD is a flexible waste treatment technology, the AD design has to be matched to the inputs. Significant changes in inputs should be addressed through a management of change process to ensure the design of the AD is fit to deal with the wastes.

Nevertheless, the quality of the input material is an important parameter at AD plants as well, so that acceptance protocols with clear acceptance criteria are required. Permissible feedstock is defined by the authorities and should also be described in the installation permit. When possible, input materials should be visually inspected on arrival. The operator may also wish to take backup samples of input materials which can be analysed at a later date to trace back any contaminated and unsuitable input material present, if required. More information about this chapter is to be found in the general part for pre-acceptance and acceptance procedure for biological treatment section 1.1.and 1.2.

**Achieved environmental benefits**

The intention of AD is to recover nutrients (digestate) and energy (biogas) in a safe, environmentally friendly and sustainable way according to the waste hierarchy (recycling) rather than disposing biowaste.

**Cross-media effects**

The use of any feedstock in AD needs to be decided on a case-by-case basis not to disturb the biological process and - if the digestate is used as organic fertiliser - to be in line with limit values such as for heavy metals or organic pollutants specified for organic fertilisers and soil improvers in European and national legislation, as well as in voluntary product specifications indicated in section 1.5, on environmental management systems and quality management systems.

**Operational data**

**Applicability**

The applicability of AD depends on the characteristics of the feedstock, which have very important effects on the AD process and their control. It is essential to ensure the environmental requirements needed for the maintenance of a healthy population of bacteria. Choice and quality of each single feedstock is important for minimising contaminants and potentially toxic materials (e.g. heavy metals) in order to use the digestate as organic fertiliser. Furthermore the possibility to deliver the produced electricity, heat and gas for the energy demand in the area e.g. in the local net is important for its applicability.

**Economics**

The main area of concern within AD is guaranteeing long term performance of a plant, which is of course key to its economic feasibility. This risk can be reduced by securing the feedstock for a long period of time and in case of seasonal fluctuation, by flexibility of the chosen technology. Depending on the chosen technology, AD plants can provide a wide flexibility to process different kinds of waste streams.

Used feedstock with its effects on the biogas yield can have a direct impact on the economics. The first objective of AD plants is to treat wastes and other feed materials but the energy production becomes more and more important for its economics.

**Driving force for implementation**

The acceptance of unsuitable input material should be avoided and is often regulated against, even if higher gate fees are possible and can have severe implications for the environment as well as the profitability of the plant:

* Non-biodegradable contaminants can cause severe damage to the process (destabilizing the process organisms), and inert material (like sand, glass etc.) can impact on the operational function of mechanical devices (pumps, pipes etc.), causing increased maintenance and downtime and/or to the possible market and application of the digestate;
* biogas production is largely affected by the quality and composition of the input material;
* gate fees for the treatment of biodegradable waste streams.

**Example plants**

AD is a common treatment for biowaste and mixed or separated household waste in Europe.

### Storage & handling of incoming waste

**Description**

Liquid and solid materials should be stored appropriately to its environmental risk. There can be many differences between the storage of different feedstock (vegetal, animal, etc.). The requirements are mainly described in section 1.3.: Requirements for AD may be:

* Liquid and semi-liquid waste should be stored in vessels, closed tanks, silos, bunkers etc. provided with secondary containment if necessary, usually in the form of an engineered bund. It should be ensured that the materials of construction for the primary containment, transfer components and secondary containment are suitable for the stored input materials (e.g. corrosion resistant, acid resistant, and resistant for temperature impacts).
* Solid waste input materials should be stored on paved and/or impermeable surface with self-contained drainage to prevent contamination of clean surface water and any loss off-site.
* Putrescible material should be received in an enclosed building with a building ventilation and odour abatement system that maintains the building under negative air pressure in order to minimise. Such wastes should be processed as soon as possible in order to reduce odour generation through biodegradation.
* Operators should consider the use of air lock entrances for sites located in sensitive areas.
* Storage areas should be capable of being easily cleaned.

**Achieved environmental benefits**

The storage of the incoming materials according to the principles described above is an important aspect to minimise emissions (e.g. odour), to prevent risks of on and off-site pollution of soils and water bodies by waste leakage or catastrophic failure of plant and to optimise the quality of the used input material.

**Cross-media effects**

**Operational data**

**Applicability**

**Economics**

**Driving force for implementation**

Well-designed storage helps with the management of the waste material, avoids odour pollution and vermin problems. Sufficient storage volume ensures the reliability of feedstock. It also prevents the operator having to tackle future costly actions to address pollution of soil and/or groundwater caused by leaks and spills.

**Example plants**

AD is a common treatment for biowaste and mixed or separated household waste in Europe.

**Reference literature**

UK EA: How to comply with your environmental permit. Additional guidance for: Anaerobic Digestion. LIT 8737, Report version 1.0 and November 2013

### Preparation of wastes for AD process

**Description**

In order to improve the digestion process, pre-treatment under wet or dry conditions (screening, unpacking, pulping, shredding, mixing, adjusting the material’s moisture, settling of heavy materials, floating of light materials and other pre-treatments) aims to remove non-biodegradable or unsuitable material and contaminants, such as plastics, metals, grit and oversized components and wood in wet digestion from the waste. The final goal of the treatment is to produce an optimum substrate input mixture for the subsequent AD process as well as the downstream located machinery.

**Achieved environmental benefits**

The pre-treatment is important to optimise the following process.

**Cross-media effects**

During the pre-treatment it is important to limit the risk on emissions (e.g. odour) and maximize the recovery rate of the digestible organics to the AD process.

**Operational data**

**Applicability**

**Economics**

An effective and efficient pre-treatment stage is necessary to ensure a stable operation whilst maintaining the life of the equipment e.g. removal of material such as plastics, metals, grit and oversized components from the waste. This can cause failures of the downstream located machinery or process. Removing solids will also minimize downtime for desilting the tank, maintaining an effective working volume in the tank. This can also be combined with additional removal steps at the back end or at other stages of the process, if required to achieve the desired end product quality.

In some cases, where the AD step is less sensitive to impurities (normally dry digestion processes), removal of physical contaminants can also be done after the AD processes although in wet AD systems contamination removal prior to digestion is recommended to avoid build-up of contaminants over time. Economic viability is improved the less digestible organics are lost to the AD process by removing it unintentionally with the impurities (due to less biogas production, higher disposal costs).

**Driving force for implementation**

An optimum feedstock mixture ensures the efficiency of the process treatment, the best possible biogas production and helps to maintain a stable process. The feedstock should be treated as fast as possible, to reduce the storage times, to avoid emissions to air and to reduce the leachate generation. The treatment time also depends on the containment and abatement system.

**Example plants**

AD is a common treatment for biowaste and mixed or separated household waste in Europe.

### Process monitoring & control specific to AD

**Description**

Apart from the composition of the waste being digested, the operational and environmental conditions of digestion have a significant influence on the specific bacterial colonies that are favoured during AD. Suboptimal conditions result in suppressed rates of biogas production. Optimal conditions are different for hydrolysis and methane formation. Shock-loading of feed-material can lead to changes in the digestion conditions within a short period of time and have extremely detrimental effects on the desired microbial population.

A suitable monitoring system, both manual and instrumental, is essential to ensure stable reactor operation and to minimise operational difficulties, such as foaming, which may lead to odour and aesthetic problems. It should also provide sufficient early warning of system failures which may lead to loss of containment and potentially explosions.

Process monitoring and control will also maintain efficient biogas production, and a sanitised and stable digestate, which – if complying with national legislation and voluntary product specifications – can be used as an organic fertiliser in liquid or solid form or can be post-composted or post-treated like separation, drying (see chapter 2.4.8 product presentation).

Post-composting is common in some countries of Europe, especially in Germany, Netherlands and Belgium for separately collected household biowaste. In UK and Sweden the digestate is usually spread directly without post-composting. Liquid application is usual in Germany and Belgium for waste from industrial and commercial waste (catering waste, food processing, and overlaid food from retail markets, etc.)

Depending on the feedstock, the chosen AD system and use of the digestate (fertilisation, landfilling, and incineration), the control parameters can be very different. Possible key factors to be monitored of the digestion process itself, having better control to optimize the process or to shorten the time of recovery after a problem has occurred can include:

* Alkalinity and pH
* Temperature and temperature distribution
* Hydraulic loading rate
* Organic loading rate
* Total solids and volatile solids (VS) fractions in the inlet and outlet
* Concentration of volatile fatty acids (VFA)
* Ammonia, calculated ammonia concentration
* C:N ratio and other nutrient and key feedstock data
* Gas production and composition
* Gas pressure
* Gas H2S concentrations
* Liquid and foam levels

Monitoring of these parameters may require sampling of digester feed, substrate within the digester, digestate and biogas at key points in the process. Periodic digester capacity testing should also be undertaken. The system design should allow this. Regular laboratory testing will be required to analyse samples and the operator should consider provision for on-site laboratory facilities at large scale AD facilities.

Some other techniques specific to AD may include:

1. Recycling digestate to the digester (inoculation) to maintain the microbiological population in the digester (possible with an ammonia stripping stage) and to establish the right rheology and water content of the feed.
2. Optimal mixing of substrate inside the digesters

The health of the biology in the digester, which will enable running the digesters under optimal biological conditions, is key to ensure optimal biogas production and plant performance. Provided the biology is healthy, an appropriate retention time - depending on the applied techniques and process parameters - will enable more biodegradation and will consequently increase the total biogas production as well as the stability of the digestate, which in turn is likely to result in lower odour emissions. However, it should be noted that once the retention time has achieved the plant’s maximum gas yield, the yield will start decrease and finally cease, regardless of the retention time. As well, it is important for post-composting that the digestate or mixture with fresh untreated material has enough degradable organic matter for sufficient heating and evaporation of water during the composting process.

In addition, longer retention times, mesophilic or thermophilic temperatures in the digestion process and the post composting step in nearly all cases will cause a reduction or even elimination of pathogenic bacteria and weed seeds. For specific biowaste sanitation under thermophilic condition with a minimum retention time is required for the use of the digestate or compost as organic fertiliser under European and national regulation as well as voluntary specification. Alternatively, a batch pasteurisation treatment step before, between or after AD has to be included which enables eradication of human and animal pathogens in line with the requirements of the animal by-products regulations for category 3 material. In the case of energy recovery of digestate neither sanitation nor pasteurisation treatment is necessary.

**Achieved environmental benefits**

The techniques described above increase the efficiency of AD and allow better use of the products.

**Cross-media effects**

The achieved benefits of higher retention times have to be balanced against lower possible loading rate, which reduces the throughput, or enlarges the size of the digester. Both increases the economic cost per tonne treated.

**Operational data**

In all circumstances, it is necessary to control and monitor relevant parameters in the feedstock, digester and digestate at regular intervals in order to ensure a good operational mode of the installation. Monitoring includes logging, checking and acting upon the data at frequent intervals, influenced by the rate of change in the process.

An increase in the biogas production relating to the amount of feed is typically correlated with an increased stability of the produced digestate having been better digested microbiologically if the feedstock is not changed. As well, there is correlation between hygienic status and biogas production because the higher amount of methane forming microorganism displace pathogenic bacteria. These are indirect effects on the quality of the digestate.

**Applicability**

**Economics**

Specific investment costs are generally higher than for aerobic treatment especially outdoor composting. Therefore the decision between anaerobic and aerobic is partly driven by the subsidies available for renewable energy in most member state but also depend on the energy content of the feedstock. The decision depends also on the consideration of location (neighbourhood population), emission level, independent energy production, flexibility, etc.

The higher the organic load the higher the gas potential, however, the longer the retention time the less material can be processed. If there is a gate fee for the waste, this will impact on the economy of the plant. All parameters need to be optimised in conjunction with each other.

**Driving force for implementation**

Better management of the process and compliance with the requirements of the Landfill Directive as well as the Renewable Energy Directive.

**Example plants**

AD is a common treatment for biowaste and mixed or separated household waste in Europe.

**Reference literature**

2006 Waste Treatment BREF, UK EA: How to comply with your environmental permit. Additional guidance for: Anaerobic Digestion. LIT 8737, Report version 1.0 and November 2013

### Emissions to water

**Description**

During the closed AD process itself, there is no excess water; however during storage, pre- and post-treatment and side-activities (like cleaning or condensate from biogas) this can be important. Water from surfaces can be collected and used in the AD process or according to chapter 2.1.4 for composting plants.

Some specific techniques to AD may include:

1. Having a close integration between waste management and water management. This would be helpful for further developments and for management to make improvements and gather data.
2. Using in the process as much as possible alternative sources of water e.g. condensed water, rinsing water, rainwater, etc.
3. Applying liquid digestate (e.g. whole digestate or separated liquid fraction) as organic fertiliser in order to prevent or reduce the generation of wastewaters
4. When liquid digestate is dewatered and the produced liquid phase cannot be completely recirculated to the process or applied on land, wastewater is generated and depending on wastewater treatment plant, on-site treatment of wastewater is necessary before being discharged

**Achieved environmental benefits**

The use of alternative water sources can be useful in reducing the total water consumption of the plant, such as the use of liquid feedstock to mix with solids to achieve required dry matter (dm) loading. The more water can be recirculated into the process, the more excess water can be reduced. The recirculation into the process is limited by potential contents of impurities (heavy metals, salts etc.)

Also the use of digestate as organic fertiliser depend on its quality and have to be in line with national and European requirements as well as voluntary product specifications in accordance to possible pollutants and available nutrients. Otherwise the energetically recovery of the digestate is possible alternative. Digestate that is used as organic fertiliser is no wastewater but a valuable product. The application of digestate closes nutrient cycles and substitutes inorganic fertiliser. A sufficient storage capacity for the digestate during the time it cannot be applied on land (e.g. during the winter) should be guaranteed.

**Cross-media effects**

By reusing some alternative water sources, odour can be a problem. Also the costs for making this water sources available, have to be taken into account (e.g. water treatment).

**Operational data**

**Applicability**

**Economics**

The substitution of fertiliser reducing the generation of waste water by applying liquid and solid digestate can improve the economics of the treatment costs of the AD plants.

**Driving force for implementation**

**Example plants**

AD is a common treatment for biowaste and mixed or separated household waste in Europe.

**Reference literature**

The BAT study (manure) co-digestion (VITO), 2006 Waste Treatment BREF

### Emissions to air

**Description**

Purpose of the technical digestion of putrescible matter is also to avoid odour in nature, open storage or landfills (e.g. from uncontrolled digestion of biowaste, manure and other animal by-products). The AD process itself is enclosed but air emissions and odour can occur during handling of incoming waste input material, transfer to and from the digester as well as open storage, separation, pre-treatment and mixing of biowaste e.g. with digestate as well as from open reactors or tanks and digestate conditioning and post-treatment. The principal gaseous emission (methane) is a desired product of the AD process, which, used as renewable energy source, maximises the profit and reduces greenhouse gas emissions.

However, fugitive emissions of biogas can arise from pressure relief valves, poorly sealed water traps or condensate handling. This can result in a range of hazards, including the risk of fire or explosion, as well as toxicity from contaminant gases such as H2S. H2S, Nitrogen compounds and mercaptans present in biogas can be extremely odorous as well.

Process monitoring and control is the main preventative action on reducing emissions to air as well as producing a stable digestate, however, some specific techniques to AD may include:

1. Having a closed storage with gas collection or exhaust air treatment for insufficiently stabilised liquid digestate to minimize methane and ammonia emissions.
2. Avoiding emissions from uncontrolled anaerobic processes during pre-treatment or digester feeding by treatment within a few days and/or connecting to exhaust air treatment
3. Avoiding emissions from uncontrolled anaerobic processes during post-composting by an adequate aeration step. Implementing a leak control e.g. with IR camera, identifying significant fugitive emissions to air. Undertaking maintenance activities for fixing any detected leaks of methane, e.g. replacing valve.
4. If exhaust air is collected, odours and other emissions can be controlled and reduced according to chapter 2.3.3 describing emissions from indoor composting plants.

Biogas from the digester is dehumidified can be cleaned to remove siloxanes and hydrogen sulphide before it is used as fuel by either an external user or for internal use. Biogas can be combusted in gas boilers to produce heat/steam or directly in CHP - gas engines (combusted in combined heat and power units) to generate electricity at the same time. Biogas can also be upgraded to biomethane by enhancing the methane content to be injected into the natural gas grid or be used as a fuel for light and heavy duty vehicles. For the reliable motor operation sulphur and siloxane concentration should be below the technical demand of specific engine. But also in order to reduce emissions after its combustion, biogas can be cleaned with following techniques:

1. Reducing hydrogen sulphide emissions by scrubbing biogas adding metal salts into the digester or internal or external biological oxidation by a controlled addition of oxygen.
2. Cleaning the produced biogas of sulphur and if necessary also of siloxane with activated carbon filtration.
3. Equipping those plants with additional biogas storage and/or alternative biogas consumer (e.g. oversized CHP, boiler, emergency flare).

Note that when flaring any biogas that cannot be used on-site or upgraded to natural gas quality, the outlet temperature of the flue-gas should be at least 850°C and the residence time 0.3 sec. For lower temperatures the destruction of pollutants during flaring has to be demonstrated with monitoring. If the flare installation is only in place for the purpose of flaring gases during periodical maintenance and in case of a technical failure of the installation, and if under normal conditions these gasses are appropriately processed, also open Flares are allowed.

**Achieved environmental benefits**

Hydrogen sulphide emissions to air can be significantly reduced by chemical and biological precipitation of sulphur inside of the digester by controlled air injection or use of metal-ions. Alternatively or additionally the produced biogas can be cleaned of sulphur by external biological desulphurisation units and of sulphur and siloxane with activated carbon filtration. Removal of H2S contributes also to lower SOx emissions once the biogas is combusted in the engine. If engines do not run, biogas which cannot be stored or used energetically elsewhere should be flared by a gas torch and not just released to atmosphere.

**Cross-media effects**

The use of additives like metal salts or oxygen into the digester should also be dependent on the specific AD process in each plant.

**Operational data**

**Applicability**

Cleaning of biogas (except dewatering and removal of solids) before CHP is not always necessary to reach emission levels. Most of emission levels are typically met by motor adjustments alone. Desulphurisation especially is carried out to prevent corrosion of the motors using the biogas.

**Economics**

Biological desulphurisation is the cheapest possibility to reduce hydrogen sulphide emissions but also chemical precipitation and even activated carbon is used to prevent motor damage. Flaring of biogas should be avoided but most member states demand for biogas plants without an additional biogas storage or consuming unit (e.g. oversized CHP or gas boiler) to prevent direct methane emissions into the atmosphere.

The cost of a leak detection survey and associated repairs can be partially offset by savings from reduced biogas losses to the air. Monetary savings may dependent upon the compensation or price for biomethane or electricity from biogas in each member state.

**Driving force for implementation**

**Example plants**

AD is a common treatment for biowaste and mixed or separated household waste in Europe.

**Reference literature**

Waste Consult International and Gewitra, 2013. Determining BEST Available Techniques for the Waste Treatments Industries in the Context of the Seville Process to Review the Best Available Technique Reference Document (BREF) on Waste Treatments Industries. Treatment of Separately Collected Organic Waste (Composting and digestion). Commissioned by Federal Environment Agency, 2006 Waste Treatment BREF

### Measures of energy efficiency and reduction of raw material consumption

**Description**

Some issues to consider are:

1. Maximising the production of biogas and methane content per tonne of volatile solids delivered.
2. Installing biogas engines with higher electrical conversion efficiencies (36% - 40%).
3. Using CHP - excess heat for external heat users e.g. buildings, stables drying processes to increase the overall conversion (electrical and thermal) efficiency up to 65 – 85 %.
4. Upgrading biogas to biomethane by enhancing the methane content to be injected into the natural gas grid or be used as a fuel for light and heavy duty vehicles.
5. Using additives (like trace elements and enzymes) for optimising the biogas process and increasing the biogas yield It may have an effect on the composition and stabilisation of digestate and compost.
6. Management of feedstock to minimise clean water demand.
7. Not undersizing the engine.

**Achieved environmental benefits**

Considered techniques may increase the energy efficiency of AD processes. Wide ranges in energy production of different plants depend basically on the used material. Feedstock with high energy content or specific mixtures of different materials can lead to higher biogas yield, because of better nutrients and micronutrients supplying and/or more easily degradable organic matter fractions. The biogas engine should be designed for consuming the higher amount for biogas and does not have to be flared.

**Cross-media effects**

The increase of the energy efficiency and energetic use is substitution of fossil energy carriers and a direct reduction of raw materials if using

1. Electricity directly for the operational demand on the plant
2. The self produced heat in CHP e.g. for social buildings
3. Upgraded biomethane as fuel for waste collecting vehicles

The application of the digestate as fertiliser should not be affected by the use of additives in the process. The use of additives needs to be in line with European and national legislation as well as voluntary product specifications.

**Operational data**

**Applicability**

**Economics**

The use of self- produced energy reduces external costs for energy supply, especially relevant with increasing energy costs. The objective for operators is to become energy independent and if possible to provide financial contributions that help increase the economic viability of the plant.

**Driving force for implementation**

Increasing the energy efficiency is an important economical parameter.

**Example plants**

AD is a common treatment for biowaste and mixed or separated household waste in Europe.

**Reference literature**

Waste Consult International and Gewitra, 2013. Determining BEST Available Techniques for the Waste Treatments Industries in the Context of the Sevilla Process to Review the Best Available Technique Reference Document (BREF) on Waste Treatments Industries. Treatment of Separately Collected Organic Waste (Composting and digestion). Comissioned by Federal Environment Agency, 2006 Waste Treatment BREF

### Product preparation and storage

Description

To establish new markets and reducing the cost for storage, transportation and application, the liquid digestate can be upgraded e.g. by dewatering, composting, drying, pelletizing, granulating, stripping, steam evaporation, filtration (e.g. ultrafiltration or reverse osmosis) etc. Furthermore, if impurities have not been efficiently removed upfront, they must be removed from the digestate/product after the AD step. The choice for the upgrading process highly depends on marked demands and the location of the plant. They are not absolutely necessary if the market has been established for non-upgraded digestate and suitable storage capacities have been constructed.

**Achieved environmental benefits**

Upgraded e.g. dried digestate is physically stabilised and will have reduced emissions to air during open storage, transportation and application. These conditioned products can be more easily stored during the winter where no nutrient demand exists in agriculture or they can be sold to new markets like garden centres, home improvement store and retail markets which guarantee the use as fertiliser.

The application of digestate (liquid, solid, composted, upgraded) as an organic fertiliser - according to national and European legislation as well as voluntary product specifications - generally reduce the use of inorganic fertiliser. This can avoid long distance transportation. The production of nitrogen for use as an inorganic fertiliser is very energy consuming. Critical levels of uranium and cadmium in the inorganic phosphorus is well known.

**Cross-media effects**

**Operational data**

**Applicability**

Upgrading digestate is normally done in regions with high production of organic fertilisers like manure and where long-term storage and/or long-distance transportation are necessary e.g. for plants located inside of cities without sufficient agricultural area for the digestate application.

**Economics**

The cost effectiveness of these techniques strongly depends on local conditions. With the reduction of storage, transport and application costs (after upgrading digestate) and the increased possibility of selling digestate products, cost-reduction is possible but often only provided if the plant receives energy subsidies e.g. in Germany usually viable only with a special compensation for the use of the heat from AD plants.

**Driving force for implementation**

**Example plants**

Many plants in Europe separate, compost or dry the produced digestate. Pelletizing, stripping, steam evaporation and reverse osmosis is seldom used in pilot plants.

**Reference literature**

## Techniques to consider for mechanical biological treatment (MBT)

**Description**

Mechanical-biological waste treatment (MBT technology) is a material-specific process that corresponds to a succession of mechanical and biological steps applied to mixed municipal waste, C&I waste and bulky waste. The core elements of MBT are mechanical or physical separation technologies and the biological treatment of biodegradable waste components unless they are diverted to matter recycling (e.g. paper).

The process is a combination of various mechanical and biological treatments, and the aim is to produce recyclables, compost, compost like output (CLO), stabilate, liquid and/or solid digestate, biogas, light and heavy rejects, Refuse Derived Fuel (RDF)/Solid Recovery Fuel (SRF).

The objectives and the process design of mechanical-biological waste treatment can vary a lot depending on the location of the plant, on waste flows, on the national regulation and on the economic situation. That is why the mass balance of the MBT plants can show rather different combinations and proportions of outputs that will meet various final outlets or disposals.

Depending on specific conditions, technical choices and output material use, mechanical treatments can take place at different stages, thus an MBT plant can be equipped with mechanical pre-treatments and/or post-treatments and refining.

Three main purposes of treatment of the organic fraction that lead to different types of MBT plants can be distinguished:

1. The first purpose : reduce or minimise the biodegradability of the organic fraction of MSW before landfilling in order to shorten or minimise the biogas and leachate production of this fraction after landfilling
2. The second purpose : optimise the extraction of the organic fraction of MSW before composting or AD and composting and minimise physical impurities content in the final product in order to use it as a compost that complies with the national regulations or specifications
3. The third purpose : optimise the energetic potential of MSW and integrate the raw organic fraction in the production of RDF/SRF

### Techniques to improve the knowledge of the waste IN

Please refer to the common section as it is not specific to MBT

#### Waste pre-acceptance procedure

#### In cases where the purpose of the treatment would be to produce compost, the waste pre-acceptance procedure specific to MBT should ensure that a systematic selective collection of hazardous household waste (batteries, paint pots, medicine, solvents, etc.) in MSW feedstock have been set up in order to guarantee the final quality and safety of the compost.

The quality control of the different feedstocks to be treated could be performed by sampling and characterization dedicated campaigns that follow a national sampling and characterisation method (for instance with Modecom method in France) or guide previously established for domestic or commercial mixed solid waste characterisation.

The results of these quality controls will help to identify the eventual presence of domestic or industrial hazardous waste in some feedstocks and to improve the selective collection of hazardous waste in the concerned municipality or industrial producer before acceptance of the corresponding waste feedstock. The eventual feedstock showing a significant level of contamination will definitively be banned.

#### Preparation of waste

**Description**

Adequate process descriptions of the activities and the abatement and control equipment for all of the activities should be provided. This should include:

1. diagrams of the main plant items where they have environmental relevance, for example storage, tanks, treatment and abatement plant design etc.
2. equipment inventory, detailing plant type and design parameters, for example, efficiencies, tolerances and expected emissions
3. demonstrating infrastructure and equipment is made of materials suitable for each unit operation for example to cope with any corrosive atmospheres that may be encountered
4. waste types to be subjected to the process
5. control system philosophy and how the control system incorporates environmental monitoring information
6. process flow diagrams (schematics)
7. venting and emergency relief provisions
8. summary of operating and maintenance procedures
9. a description of how protection is provided during commissioning and abnormal operating conditions such as, unexpected reactions, unexpected releases, start-up, momentary stoppages and shut-down for as long as is necessary to ensure compliance with release limits in permits.

Additionally, for some applications, it may be appropriate to supply pipe and instrumentation diagrams for systems containing potentially polluting substances, for example composting, AD and air management including abatement systems. For each treatment process, the objectives for physical/chemical/biological treatment should be clearly defined. There must be a defined end-point to the process so that the treatment can be monitored and controlled. The suitable inputs to the process must be defined, and the design must take into account the likely variables expected within the waste stream.

Operators should develop a transparent operational manual within the management system alongside a structured maintenance programme to automate and optimise processes throughout the MBTfacility.

In order to track and control the process of change, there should be a written procedure for proposal, consideration and approval of changes to technical developments, procedural or quality changes.

**Pre-treatment of bulky waste**

Sorting activities may be carried out in order to prepare bulky waste for further mechanical treatment to minimise physical impurities which may interrupt further treatment steps.

**Achieved environmental benefits**

Not identified at this stage

**Cross-media effects**

Not identified at this stage

**Operational data**

Not identified at this stage

**Applicability**

Not identified at this stage

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Example plants**

Not identified at this stage

**Reference literature**

Environment Agency U.K., 2013. How to comply with your environmental permit. Additional technical guidance for: Mechanical Biological Treatment Sector

### Mechanical Treatment and thermal treatments used for before and/or after -biological treatments

**Description**

The mechanical and thermal treatments to be applied to the waste stream will depend on the purpose of the process. There are usually implemented before (pre-treatments) or after (post treatments) the biological treatment, but they can also take place between two biological treatments (e.g. pressing of the digestate before composting).

They can also sometimes be connected to one another to achieve an objective (e.g. 1: screening and shredding and upstream reintroduction of solid biowaste; e.g. 2: shredding and screening/ separation of flows for packaged food biowaste).

Mechanical and thermal processing prepares waste for subsequent treatment. The degree of processing is determined mainly by the application for the high-calorific coarse fraction and the biological treatment process for the fine fraction.

The most common mechanical treatments are listed in Table XY

|  |
| --- |
| Pre-sorting of bulky refuse |
| Pre-shredding |
| Rotating drum |
| Screening/Sieving |
| Separation of ferrous metals |
| Separation of non-ferrous metals |
| Aeraulic separation |
| Ballistic separation |
| Densimetric water separation |
| Hygienisation |
| Manual sorting |
| Optical separation |
| Granulation |
| Drying |
| Mechanical dehydration |
| Homogenisation/mixing |
| Pulping |
| Pellet manufacturing |
| Baling |
| Wet mechanical sorting technologies |
| Sorting coarse and fine fractions |
| Processing the high-calorific fraction |
| Ejection of impurities and recyclables using sensors |
| Pressing |

**Functions of mechanical treatment and thermal treatments:**

* bag openers
* ejecting and/or processing of impurities
* screening out a fine fraction with a high level of degradable organic components for biological treatment
* sorting, shredding or customising high-calorific waste fractions for energy recovery ejecting heavy fractions
* separating groups of materials for recycling (e.g. metals)
* breaking down and homogenising waste components for biological treatment
* customising high-calorific output material

**1/ Separate the putrescible organic fraction** for biological treatment from other fractions in the treatable waste by:

* screening: single or multi-mesh trommel screens, shaking screens, trampoline screens, star screens;
* aeraulic separation: blowing and/or sucking and separation of light fractions;
* ballistic separation: single or multi-level ballistic separators, high-speed conveyor belts, ballistic conveyors (using rebound effect);
* dry densimetric separation *via* densimetric tables or by wet process: water bath, flotation/sedimentation channels;
* manual sorting which can be used at different stages of the process line: pre-sorting, positive or negative sorting, etc.;
* optical sorting (under development, for RHW fractions);
* pulping with water: this is a densimetric separation preceded by a more energetic agitation/stirring step;
* pressure screen separation: piston pump, extrusion screw;
* magnetic separation of ferrous metals (overband, magnetic pulleys) and non-ferrous metals (eddy currents);
* Etc.

**2/ Reduce grain size** of the organic fraction to apply treatment; this requires:

* High-speed shredding with or without screens,
* Slow shredding with or without screens,
* hammer mills,
* blade mills,
* chippers,
* …

**3/ Pre-degrade** using**:**

* rotating drums with variable retention time and rotation speeds depending on dimensions (length, diameter) and applied waste flow,
* aerobic silo

**4/ Homogenise** a heterogeneous organic fraction/mix two or more organic fractions using:

* continuous screw mixers,
* batch screw or chain mixers
* mixing drums
* paired conveyor belts
* self-turning mixers (see composting)
* specific tools mounted on a moving platform (oblique screws, bucket wheel excavators, etc.),

**5/** Mechanically **dehydrate** the organic fraction by using:

* screw presses,
* draining tables,
* centrifuges,
* belt filter or filter press,,
* …

**6/ Hygienise /dry** an organic fraction before or after biological treatment using:

* batch digester in batches at 70°C for 1 hour,
* autoclaving at 120°C under 3 bars for 20 minutes,
* various thermal dryers: direct or indirect, drum, conveyor belt, rotating, etc.…

**7/ Compact the elements to reduce fine fraction (dust, etc.) and increase the density of the organic fraction using granulators/dies to produce granules and corks.**

**8/ Increase biodegradability by:**

* adding active microorganisms,
* thermal treatment,
* ultrasonic treatment,

The organic fraction obtained by these different treatments can then be biologically treated by composting, or by anaerobic digestion followed by composting (also called aerobic maturation).

The other generated fractions can be subjected to material reprocessing, energy recovery or disposal in non-hazardous landfills.

Depending on the intended final destination for the organic fraction (production of compost for use in agriculture or stabilised waste for burying in a waste storage installation), the process line combining different mechanical pre- and post-treatment tools and one or more biological treatment tool(s) will have a different design.

**Sorting coarse and fine fractions**

The sorting of high-calorific coarse waste fractions and the fine fraction destined for biological treatment is largely performed using screening (drum, vibrating and star screens) with screen cuts between 40 mm and 150 mm. Air-classifiers are occasionally used as well. A few plants also utilise ballistic separators.

**Separating FE and NF metals**

Magnets remove ferrous metals; non-ferrous (NF) metals are extracted using eddy current separation systems.

**Processing the high-calorific fraction**

The resulting high-calorific fraction must undergo additional processing prior to energy recovery, if necessary, depending on the customer’s specifications. Apart from additional shredding, other steps include further removal of metals and other impurities, such as rocks or other inert, non-combustible materials.

**Ejection of impurities and recyclables using sensors**

A few plants also utilise sensor-based sorting technologies (optical NIR sensors) or X-Ray sorting systems in order to remove PVC, for instance, from the high-calorific fraction. The PVC's high chlorine level would lower fuel quality. A few sensor-based sorting solutions remove paper and wood from the fine fraction.

**Wet mechanical sorting technologies**

Wet digestion plants use pulpers after the dry mechanical stage to homogenise substrate and better bring it into suspension through defibration. The pulper can eject both non-digestible floating solids and inert suspended solids, but this step may also be performed in other stages (e.g. the grit chamber). The pulper is followed by other wet sorting stages to remove floating and suspended solids (the grit chamber). Hydrocyclones are also used for this purpose.

The objective is to remove impurities, such as leftover metal, glass, sand, rocks and gravel, through sedimentation and plastic through a floating action to the aqueous phase. The degradable organic fraction that is left will be sent for anaerobic biological treatment.

**For MBT installations whose purpose is to produce compost**

The different mechanical pre-treatment purposes linked to the biological treatment of RHW often have the common goal of mechanically separating the different categories of waste by generally classifying them (via a rotating drum described hereafter as "drumming") and/or granulometric fractioning (shredding and/or screening) and by sorting, as fully as possible, waste materials that can be recycled (primarily ferrous and non-ferrous metals) or that can constitute an alternative fuel (plastic film and packaging, cardboard and other fuels).

The biodegradable organic fraction of the RHW is therefore extracted with a more or less significant capture rate and a variable level of residual physical impurities then treated biologically either by anaerobic process followed by aerobic maturation or directly through composting.

One or several mechanical refinement phases occur during or at the end of composting to produce compost recycled in agriculture.

An efficient preparatory mechanical sorting which has to handle, from a flow of RHW, the sorting of different fractions that can be recovery:

* for the material (ferrous and non-ferrous elements, unsoiled cartons, unsoiled plastic bottles, glass, etc.),
* to produce energy through a dry process (plastics and similar materials and cardboard),
* biologically (non -synthetic organic material that can lead to the production of green energy through anaerobic digestion and/or standardised aerobic composting;

Use of rotating drums for organic fraction pre-treatment before extraction (purpose of compost production: MBT composting and MBT/AD/composting)

When the main objective is to produce a clean organic fraction that can be digested or composted and lead to an agricultural use compliant compost, MSW are frequently introduced directly from the reception pit, or just after a primary coarse screening for large capacity plants, in one or several large rotating drums ( 3 to 4 meters diameter and 30 to 60 meters long) with a slow speed rotation (1 turn per minute) , an on board forced air ventilation equipment and where water content of MSW is adjusted to +/- 50%. During this 2 to 4 days stage of pre-treatment, the putrescible fraction of MSW is subjected to both mechanical and biological treatments that lead to a classification/ important size reduction of paper and cardboard fractions and to the production of a fine cellulosic pulp easy to extract and separate from other MSW components and physical impurities.

Just after the exit of the rotating drum, the pre-treated fraction is sent to a refining line that generally incorporates a rotating screen followed by one or several ballistic separators and subsequently by an 8 to 10 mm mesh trampoline screen.

This very fine s and clean organic fraction is subsequently structured with the reject material from composting green waste and/or wooden pallets and composted in accordance with the various procedures described in the chapter related to composting.

Some other MBT installations that aim to produce compost, with or without rotating drums, generate a product with a coarser particle size distribution (PSD) that does not necessitate structuring material before the composting step; in this case, a final performant refining step eliminates the inert waste.

In the absence of a rotating drum, MSW is directly sifted througha coarse mesh (80 to 120 mm) in a trommel screen fitted with blades to rip open bags without actually shredding the waste. The passing organic fraction is then usually composted without structuring materials through the different processes mentioned in the following paragraphs. The resulting compost that is generally produced in lower quantities is refined by sophisticated devices including rotating or vibrating screens ballistic separators and/or densimetric tables in order to improve its quality.

For MBT /AD/composting installations, anaerobic digestion (dry or wet process) is applied to the organic fraction(s) generated by mechanical pre-treatment.

The glass content and other physical impurities remaining in the organic fraction(s) for anaerobic digestion can be controlled and limited in order to:

* prevent any accumulation of glass at the bottom of the digester and/or floating debris at the surface facilitate possible and unobstructed pressing of the digestate before its aerobic maturation or composting.

**Achieved environmental benefits**

The preparation of MSW by a rotating drum helps to reduce the volume of materials to be treated and facilitates the separation of the organic fraction from the other compounds present.

The sorting of recyclable materials (ferrous and non-ferrous metals, possibly bottles or plastic film, etc.) derived from MSW allows their orientation towards a material recovery segment and improvement of the facility's diversion rate.

One or several fractions of the refuse from the preparation chain characterised by high net calorific value (NCV), (essentially comprised of plastic materials) can be used as alternative fuel (to replace fossil-origin fuel) in energy recovery facilities or in industrial processes (i.e., cement or power plants).

The production of good quality compost helps to generate an organic-calcium improvement that can partly replace fossil deposits (lime quarries) and useful for the organic maintenance of cultivated soils.

The inclusion of organic matter to poor subsoils such as those where quarrying has taken place, makes the use of CLO a beneficial material to manufacture top soils from in order to enhance the landscape and assist in its subsequent regeneration

In the case of a “MBT and AD plant”, the recovery of biogas allows the generation of energy (electrical, thermal, fuel) as an alternative for fossil fuels.

Pre-treatment that includes a drum allows reuse of the process water.

**Cross-media effects**

Energy consumption varies mostly as a function of the treatment strategy and in particular the choice of the equipment and the complexity of the mechanical pre-treatment chain.

The MBT and AD plant presents specific consumption of reagents linked to the biogas treatment.

**Operational data**

It must be possible to establish every month the plant's input rate as well as biogas and compost production rate in order to efficiently monitor the performance level of the facility and improve it.

To do so, the facility's design must allow for the regular performance of operating assessments of the various aspects of the process including in particular that of the mechanical preparation equipment so as to rapidly identify any operating deviation linked to one or several tools and especially to optimise on a daily basis the quality and quantity of recoverable material (compost, biogas, recyclables) and as applicable, RDF.

The strict management of the different compost batches and the performance of regular analysis on each batch are necessary to secure their market authorisation.

**Applicability**

The correct design and the correct construction of mechanical treatment plants allowing the separation of the organic fraction of MSW will secure the production of compost and possibly of biogas in quantities and qualities compliant with the initial project as well as outlets for the two main products.

Numerous municipalities have already invested in the selective collection of hazardous for household waste (batteries, solvents, medications, etc...) and in the updating of standards old sorting-composting facilities or in the creation of new facilities with an efficient refinement system to guarantee the compliance of the compost with agronomic recovery standards.

However, with respect to the compost, it is important to constantly improve its quality for it to be not only compliant with current standards but to allow it to also comply in future with a more demanding quality level. This improvement of the quality level of MSW compost must be jointly based on an improvement of the selective collection of plastic and glass package and on the optimisation of the techniques used to separate physical impurities.

The overall environmental assessment of a facility comprising one or several aspects of mechanical treatment plants must be assessed individually in such a way as to offset as much as possible the negative environmental impacts (energy consumption, emissions of pollutants into the atmosphere, into water or into the soil) linked to the treatment process through savings of raw materials (recyclables, mineral fertilisers, non-renewable organic matter The unit must provide an "additional" environmental touch compared to the initial organisation of the local management of household waste without pre-treatment.

In this perspective, the overall balance of the facility and the production rate of recoverable compost and biogas become extremely important

**Economics**

The optimisation of the compost production rate per tonne of treated RHW and the minimisation of the refuse rate generated help to minimise the operating costs of an MBT composting or MBT and AD/ and- or composting plant.

The residual disposal costs have a strong impact on the overall economic balance of the facility. The confinement level of the facility as well as the integration of an anaerobic digestion facility also generate additional investment and operating costs.

**Driving force for implementation**

The European regulatory context is driven by the fierce determination of political authorities to raise the recycling rate of domestic waste and in particular the quantities of organic waste recovered.

**Example plants**

**Reference literature**

Environment Agency U.K., 2013. How to comply with your environmental permit. Additional technical guidance for: Mechanical Biological Treatment Sector

Waste Consult & gewitra, 2013. Determination of the Best Available Techniques for Waste Treatment Industries within the Sevilla Process to Review the Reference Document on Best Available Techniques for the Waste Treatment Industries. Technical Document: Mechanical-Biological Treatment of residual waste.

Survey conducted by FNADE and financed by ADEME. Waste Treatment BREF, Biological treatment section, 22 November 2013

### Biological Treatment

**Description**

A biological treatment with efficient mesophilic or thermophilic anaerobic digestion and aerobic maturation where applicable of the digestate or plain composting of the fine organic fraction isolated starting from the mechanical pre-treatment:

* As appropriate, an efficient mechanical post-treatment of the compost produced in such a way as to produce a product compliant with the agricultural use;
* As appropriate, the production of alternative fuel with high NCV;
* For the aerobic process, refer to section 2.1 to 2.3 where applicable.
* For the AD element, refer to section 2.4.

#### Drying of digestate

The output from partial-stream digestion plants is mixed with untreated feedstock entering composting, thereby also providing the necessary moisture for decomposition. Excess moisture is discharged in warm, water-saturated exhaust air.

Full-stream digestion plants require separate drying stages, especially when performing wet digestion. First, mechanical dehydration takes place using decanters or centrifuges and auger presses, for instance. Flocculants can assist the dehydration process. If necessary, and it often is, this phase is followed by thermal drying in band or drum dryers heated with waste heat from the CHP plant and biogas. Drum dryers are more energy-efficient, but faults (e.g. blockages) are harder to resolve. In addition, a lengthy cool-down phase is needed before work can take place on a drum dryer. By contrast, band dryers can be worked on almost without any waiting.

**Achieved environmental benefits**

Not identified at this stage

**Cross-media effects**

Not identified at this stage

**Operational data**

Not identified at this stage

**Applicability**

Not identified at this stage

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Example plants**

Not identified at this stage

**Reference literature**

Environment Agency U.K., 2013. How to comply with your environmental permit. Additional technical guidance for: Mechanical Biological Treatment Sector

Waste Consult & gewitra, 2013. Determination of the Best Available Techniques for Waste Treatment Industries within the Sevilla Process to Review the Reference Document on Best Available Techniques for the Waste Treatment Industries. Technical Document: Mechanical-Biological Treatment of residual waste.

Survey conducted by FNADE and financed by ADEME. Waste Treatment BREF, Biological treatment section, 22 November 2013

#### Process monitoring & control

* For the aerobic process, refer to section 2.3.2 where applicable.
* For the AD element, refer to section 2.4.4.

### Emissions to water

**Description**

**Leachate**

The amount of excess wastewater is related to the type of biological treatment. Aerobic MBT plants normally run without generating wastewater with biodrying strategy, but for the other strategies there are some excess water (for the composting, excessed water is recycled; percolate water is utilised in the composting stage. Partial-stream dry digestion plants can also operate on a largely wastewater-free basis. Water leaving the fermenter in digestate is used to make up the water deficit in the subsequent composting phase.

Anaerobic MBT plants generate wastewater. The quantity of wastewater produced by dry digestion installations is less important than the one produced by Wet digestion plants.

Where possible, industrial water or, processed water is used to minimise MBT plants' fresh water consumption.

Unless a plant is wastewater-free, wastewater that is not recirculated is treated prior to discharge. This step typically takes place in landfill leachate treatment units or the wastewater is sent to the local sewage sludge treatment plant through the sewer network. Wastewater treatment is thus not typically part of the mechanical-biological treatment plant itself. Requirements for discharge before mixing may necessitate pre-treatment before wastewater is discharged into the sewer network. According to the applicable national provisions

Generating excess wastewater shall be minimised as a matter of principle. To this end, it makes sense to:

* use or recirculate wastewater, preferably fully, to make up the water deficit during encapsulated intensive decomposition at aerobic plants. This practice is contingent on compliance with occupational safety rules and on corrosive damage being kept to a reasonable level through technical steps and by selecting suitable materials.
* recirculate wastewater as much as possible in anaerobic plants. Salinity and the accumulation of pollutants can limit the ability to recirculate water, meaning that process water treatment or removal of wastewater may generally be needed in this instance.

Where wastewater is treated directly at the plant itself, the following techniques and combinations thereof are options:

* ultra filtration / reverse osmosis
* activated carbon adsorption
* biological treatment (generally in combination with another technique)

The following general principles should be applied in sequence to control emissions to water:

* water use should be minimised and wastewater reused or recycled
* contamination risk of process or surface water should be minimised
* wherever possible, closed loop cooling systems should be used and procedures in place to ensure blow down is minimised
* where any potentially harmful materials are used measures should be taken to prevent them entering the water circuit

Consideration should be given to the use of filtration/osmosis or other techniques which allow the effluent water to be cleaned if discharge is to be to controlled waters.

Where effluent is treated off-site at a sewage treatment works the above factors still apply. In particular, it should be demonstrated that:

* action plans are appropriate to prevent direct discharge of the waste-waters in the event of sewer bypass, (via storm/emergency overflows or at intermediate sewage pumping stations) for example, knowing when bypass is occurring, rescheduling activities such as cleaning or even shutting down when bypass is occurring.
* a suitable monitoring programme is in place for emissions to sewer.

The operator should conduct daily visual checks on the effluent management system and maintain a log where applicable.

The operator should have in place procedures to ensure that the effluent specification is suitable for the on-site effluent treatment system or discharge criteria. Measures should be in place to isolate effluent where samples indicate a breach of specification. Incidents of this nature should be recorded in the effluent log.

For subsurface structures:

* establish and record the routing of all MBT facility drains and subsurface pipe work
* engineer systems to minimise leakages from pipes and ensure swift detection if they do occur, particularly where polluting substances are involved
* provide secondary containment and/or leakage detection for sub-surface pipe work, sumps and storage vessels
* establish an inspection and maintenance programme for all subsurface structures, e.g. pressure tests, leak tests, material thickness checks.

All sumps should:

* be impermeable and resistant to stored materials
* be subject to regular visual inspection and any contents pumped out or otherwise removed after checking for contamination
* where not frequently inspected, be fitted with a high level probe and alarm, as appropriate
* be subject to programmed engineering inspection (normally visual, but extending to water testing where structural integrity is in doubt).

Surface water (to reflect chapter on composting process 2.1.4)

For surfacing:

* design appropriate surfacing and containment or drainage facilities for all operational areas, taking into consideration collection capacities, surface thicknesses, strength/reinforcement, falls, materials of construction, permeability, , and inspection and maintenance procedures
* have an inspection and maintenance programme for impervious surfaces and containment facilities
* unless the risk is negligible, have improvement plans in place where operational areas have not been equipped with:
* an impermeable surface
* spill containment kerbs
* sealed construction joints
* connection to a sealed drainage system

All above-ground tanks containing liquids should be bunded. Bunds should:

* be impermeable and resistant to the stored materials
* have no outlet (that is, no drains or taps) and drain to a blind collection point
* have pipe work routed within bunded areas with no penetration of contained surfaces
* be designed to catch leaks from tanks or fittings
* be subject to regular visual inspection and any contents pumped out or otherwise removed under manual control after checking for contamination
* where not frequently inspected, be fitted with a high-level probe and an alarm, as appropriate
* where possible, locate tanker connection points within the bund, otherwise provide adequate containment
* be subject to programmed engineering inspection (normally visual, but extending to water testing where structural integrity is in doubt) be designed, constructed and maintained to meet with the specifications outlined in the European or national regulations.

Note: the above seems to take into account only percolate/process water (to elaborate)

**Achieved environmental benefits**

Not identified at this stage

**Cross-media effects**

Not identified at this stage

**Operational data**

Not identified at this stage

**Applicability**

Not identified at this stage

**Economics**

Not identified at this stage

**Driving force for implementation**

Not identified at this stage

**Example plants**

**Reference literature**

Environment Agency U.K., 2013. How to comply with your environmental permit. Additional technical guidance for: Mechanical Biological Treatment Sector

Waste Consult & gewitra, 2013. Determination of the Best Available Techniques for Waste Treatment Industries within the Sevilla Process to Review the Reference Document on Best Available Techniques for the Waste Treatment Industries. Technical Document: Mechanical-Biological Treatment of residual waste.

Austria and Italian Ministries introduced parameters for emissions into the air/water like particulate matters, dust

### Emissions to air

For the aerobic process, refer to section 2.15, 2.2.5, 2.3.3 and 2.4.6.where necessary and applicable

### Waste gas management and treatment

Provided that the intensive decomposition and digestion take place in encapsulated areas, the following exhaust gas treatment techniques or combinations thereof may be included when determining BATs based on cross media effects.

* electronic filters
* fabric filters
* acidic scrubbers
* biofilters
* regenerative thermal oxidisers
* external waste incineration at a waste-to-energy plant or a power plant running on secondary fuel

**Acidic scrubber**

The main function of an acidic scrubber is to remove nitrogen compounds that would lead to the release of nitrogen oxide (NOx) and nitrous oxide (N2O) from waste gas. Any ammonium nitrogen in the waste gas stream is transferred into the scrubbing liquid (generally diluted sulphuric acid). In addition, the scrubbing process captures dust and humidifies dry waste gas from mechanical treatment before it enters the biofilter.

**Biofilter**

In the biofilter, the waste gas flows extensively through a bundle of organic material (often root wood) whose surface is teeming with microorganisms.

Biofilter functionality “is based upon the degradable organic substances and odours from the waste air being dissolved in a liquid phase (generally water), thereby allowing microorganisms to foster biologically oxidative degradation. Conditions must be put in place to facilitate microorganism growth in order to achieve the necessary degradation efficiency (from the BREF for large-scale shredders). In particular, these conditions include having consistent and suitable temperature and moisture conditions, a suitable pH level and adequate surface area contamination for degradation, i.e. not too large (degradable material per m² and hour).

**Regenerative thermal oxidisers**

Regenerative thermal oxidisation (RTO) is a flameless oxidation technique that involves a heated bed ofceramic material. The function of an RTO is to reduce greenhouse gas emissions (e.g. methane) and to dispose of other organic substances that have an impact on the environment and human health.

Non-catalytic regenerative thermal oxidisers can essentially be broken down into the following systems:

* RTO systems with a combustion chamber (largely three chamber systems)
* RTO systems without a combustion chamber (largely one chamber systems)

RTO systems consist of an oxidation zone and heat exchange elements before and after the oxidation zone. Crude gas is preheated to the oxidation temperature of ca. 800°C to 1,000°C in the upstream heat exchange element.

The RTO can source some of its operating energy and temperature from the oxidation of organic waste gas components, apart from in the start-up phase.

**Waste gas combustion**

It is also possible to send the waste gas to an incineration plant for waste or secondary fuel where it is used as supply air). The emissions of those incineration plants are subject to the national regulations.

Where CHP plants involving biogas engines are used, routine servicing of the engine is also required to maintain combustion efficiency. As well as the annual monitoring required, additional monitoring of NOx and CO should also be undertaken periodically and the engine(s) re-tuned to ensure the energy recovery plant remains within the permitted emission limits.

Records should be kept by the operator of all monitoring undertaken and the monitoring results, maintenance undertaken, periods of operation of the auxiliary flare and releases of biogas from pressure release valves.

Biogas storage and combustion should be appropriately sized to deal with the quantity of biogas generated from a stabilised AD process. Biogas should not be routinely flared to atmosphere and allowances made for potential grid injection.

The main chemical constituents of the emissions should be identified. This will allow the appropriate abatement technology to be selected to clean incidental emissions.

Emphasis should be placed on the prevention of the production and displacement of pollutants. Abatement can be readily overloaded and become ineffective. Abatement techniques should not be used as an inline process tool as part of the treatment process.

Correctly operate and maintain the abatement equipment, including the handling and disposal of spent scrubber medium or spent carbon.

Vent and chimney heights should be assessed for dispersion capability and an assessment made of the fate of the substances emitted to the environment.

The operator should justify whether or not abatement is required, assessing the impact of the emissions.

**Noise and vibration**

Describe the main sources of noise and vibration; the nearest noise sensitive locations and relevant environmental surveys which have been undertaken; and the proposed techniques and measures for the control of noise.

The operator should employ basic good practice measures for the control of noise, including adequate maintenance of any parts of plant or equipment whose deterioration may give rise to increases in noise (for example, bearings, air handling plant, the building fabric, and specific noise attenuation kit associated with plant or machinery).

The operator should employ such other noise control techniques necessary to ensure the noise from the facility does not give rise to reasonable cause for annoyance, in the view of the regulator.

Noise surveys, measurements, investigations (e.g. on sound power levels of individual items of plant) or modelling may be necessary for either new or for existing facilities, depending upon the potential for noise problems. Where appropriate, the operator should have a noise management plan as part of its management system.

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