MWAN مــوان
المركز الوطني لإدارة النفايات
National Center for Waste Management

الضوابط والأدلة الفنية
للمعالجة البيولوجية للنفايات

Technical Guidelines
Biological Waste Treatment

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ACRONYMS

AD	Anaerobic Digestion
BAT	Best Available Technique
BT	Biological Treatment
CHP	Combined Heat and Power
C:N	Carbon-to-Nitrogen Ratio
CV	Calorific Value
EIA	Environmental Impact Assessment
EMS	Environmental Management System
IR	Implementing Regulations
IVC	In-vessel Composting
KSA	Kingdom of Saudi Arabia
MBT	Mechanical Biological Treatment
WML	Waste Management Law
MSW	Municipal Solid Waste
MWAN/The Centre	National Centre for Waste Management
NCEC	National Centre for Environmental Compliance
OAW	Open Air Windrow
PPE	Personal Protective Equipment
TG	Technical Guideline
VFA	Volatile Fatty Acids
WtE	Waste-to-Energy
WWTP	Wastewater Treatment Plant

DEFINITIONS

Aerobic Digestion	Aerobic digestion or composting of waste is the natural biological degradation process whereby microorganisms break down the waste into carbon dioxide, water, nitrates, and sulphates in the presence of oxygen to produce compost.
Anaerobic Digestion	Organic matter in the feedstock is broken down by micro-organisms in the absence of oxygen and is converted into digestate and biogas.
Biodegradable Waste	Any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard.
Biogas	Mixture of gases, primarily methane, carbon dioxide and small quantities of other gases, produced by anaerobic digestion.
Biological Waste Treatment	Treatment processes that utilise microorganisms to decompose waste, specifically organic waste, into either water, carbon dioxide and simple inorganics or into simpler organics such as aldehydes and acids.
Centre	The National Centre for Waste Management.
Channelled Emissions	Emissions of pollutants into the environment through any kind of duct, pipe, stack, etc. This also includes emissions from open-top biofilters.
Compost	Nutrient-rich material left following anaerobic digestion or composting
Diffuse Emissions	Non-channelled emissions (e.g., of dust, organic compounds, odour) which can result from 'area' sources (e.g., tanks) or 'point' sources (e.g., pipe flanges). This also includes emissions from open-air windrow composting.
Digestate	Nutrient-rich material left following anaerobic digestion
Digester	The tank in which anaerobic digestion takes place
Emission	The direct or indirect release of substances, vibrations, heat, or noise from individual or diffuse sources in the installation into the air, water, or land.
Feedstock	The material that is put into the treatment facility
Leachate	Solution obtained by leaching. The solution consists of liquid that, in passing through matter, extracts solutes, suspended solids or any other component of the material through which it has passed.
Storage	Storing the waste components or some of them temporarily for transfer or later use.
Treatment	It means the use of physical, biological, or chemical means, or a combination of these means, or others to bring about a change in the specifications of waste in order to reduce its volume or facilitate the processes of treating it when reusing or recycling, or extracting some products from it or to remove organic pollutants and others in order to reduce or utilize some of the waste components or eliminate the possibility of harm to humans or the environment.
Waste	All materials that are discarded or disposed of, and that directly or indirectly affect public health or the environment.

Waste Management	Organizing any activity or practice related to waste commencing from waste collection, transportation, sorting, storage, treatment, recycling, import, export, and safe disposal, including aftercare at waste disposal sites.

1 PURPOSE AND SCOPE

1.1 Purpose

This Technical Guideline (TG) sets out the information that will be used by the National Centre for Waste Management (the Centre) to regulate and licence biological waste treatment facilities in the Kingdom of Saudi Arabia (KSA).

Therefore, this document is intended to provide a guideline for those involved in design, construction, and operation of biological waste treatment facilities, to:

- Identify and determine all requirements for developing different biological waste treatment facilities according to the international best practices and latest available technologies;
- Provide practice guidance on how to treat biodegradable waste through different biological waste treatment technologies in an environmentally-sound manner;
- Identify the key technical and management parameters that influence the performance of the facility, minimise potential environmental impacts as well as health and safety risks for worker and the general public.

This technical guideline is not a design manual or a standard for biological waste treatment facilities. Sound judgement and the appropriate technical expertise needs to be applied to ensure that, when designed, constructed, and operated, biological waste treatment facilities will comply with the principles set out in this TG as well as with any conditions of a licence issued by the Centre.

1.2 Scope

The provisions of the present Technical Guideline address all parties involved in the management of biological waste treatment facilities, namely:

- The National Centre for Waste Management (MWAN or the Centre);
- The Environmental Protection Competent Authorities or The National Centre of Environmental Compliance (NCEC);
- Design and Construction companies involved in biological waste treatment facility projects; and
- Biological waste treatment facility operators (Service Providers).

It covers aerobic and anaerobic digestion of non-hazardous organic fraction from municipal solid waste (MSW) streams (including residential waste, institutional and commercial waste), industrial waste streams, green waste, and agricultural waste.

This document does not address or apply to the biological treatment of water-based liquid waste.

2 LEGAL REQUIREMENTS

This Technical Guideline is developed in line with the requirements of the WML and the corresponding Implementing Regulations (IR), with a focus on the application of Best Available Techniques (BAT) considering the local economic, environmental, and social context of the Kingdom with a more step-by-step approach to provide guidance through the planning process.

For additional legal requirements on the design, construction, and operation of biological waste treatment facilities, however, users should consult both the WML and the IR. The main legal provisions on the design, construction and operation of biological waste treatment are highlighted below.

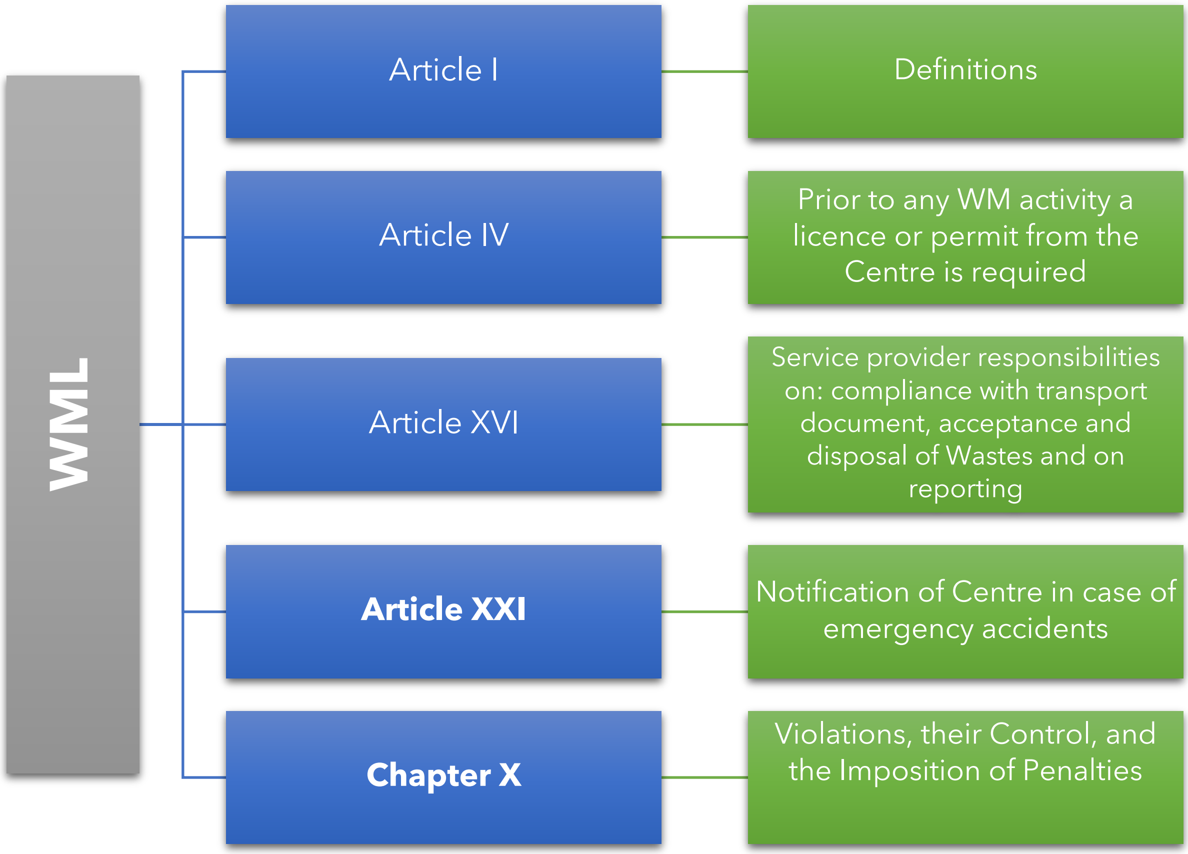

Figure 2-1: Relevant Legal Provisions in WML

The terms used in this guidance document have the same meanings as in the Waste Management Law. Specifically, the term treatment, according to the WML, has the meaning of bringing about a change in the specifications of waste. These changes occur in order :

- To reduce the volume of waste; or
- To facilitate the processes of treating it when reusing or recycling, or extracting some products from it; or
- To remove organic pollutants; or
- To reduce or utilize some of the waste components; or
- To eliminate the possibility of harm to humans or the environment.

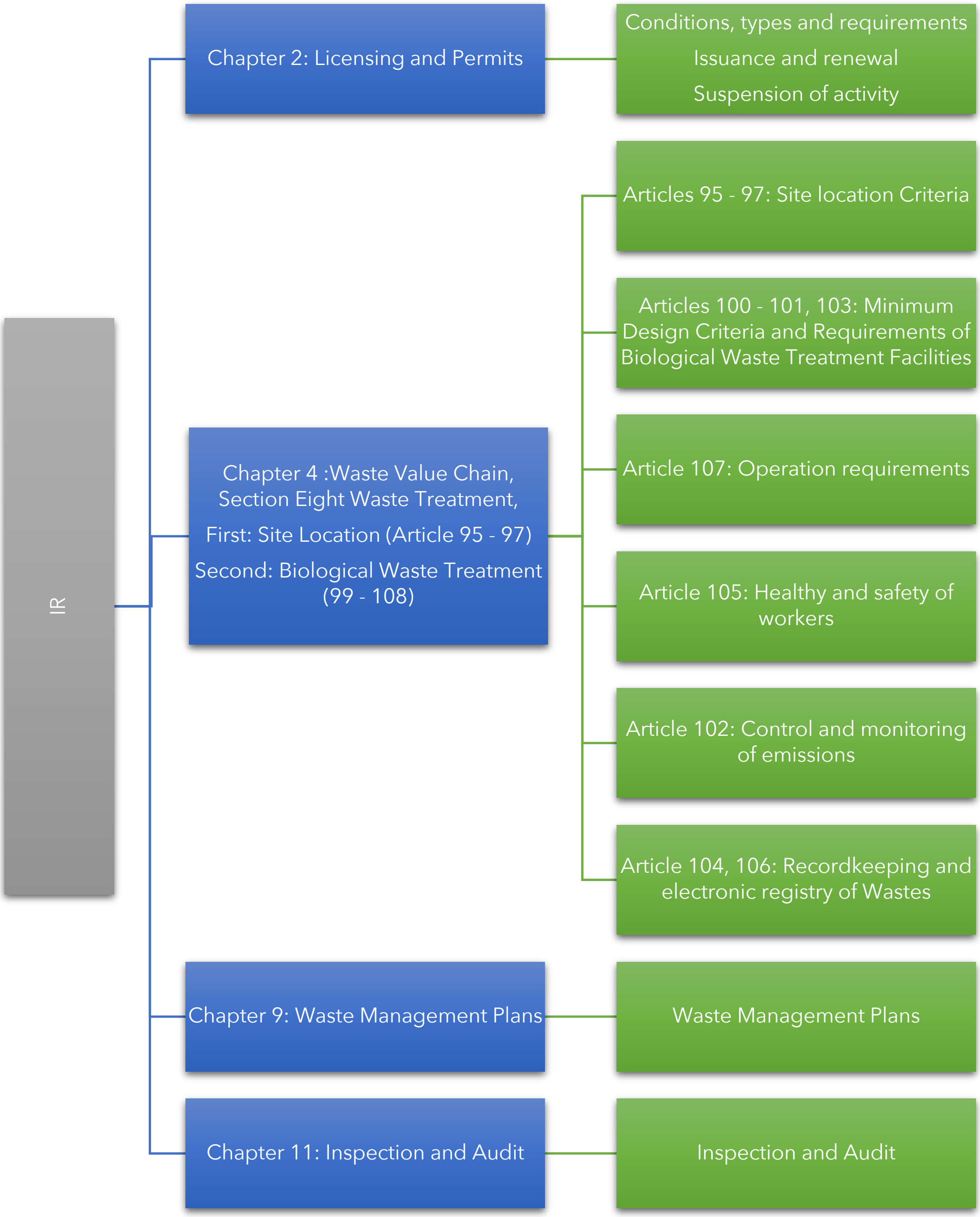

Figure 2-2: Relevant Legal Provisions in IR

3 ROLES AND RESPONSIBILITIES

The main organisations with responsibilities in Biological Treatment of waste as defined in Section 1, include but not limited to: the Ministry of Environment, Water and Agriculture, the Centre, design, and construction companies involved in biological treatment projects and Waste Service Providers (hereby only for treatment facilities).

The key roles and responsibilities of the parties involved are detailed as follows:

	Roles and Responsibilities
The Centre	▪ Issuing licence for Biological Waste Treatment in accordance with the controls determined by law and Regulations. ▪ Monitoring the compliance of Service Providers with the provisions of the Law and the Regulations, the rules and instructions issued thereunder, as well as their licence terms and conditions via the inspectors, who are appointed by a decision of the Minister.
NCEC	▪ Issuing an environmental permit for the construction and operation of a Biological Waste Treatment in accordance with the controls determined by law and Regulations, upon the submission and approval of the Environmental Impact Assessment. ▪ Monitoring the compliance of Service Providers in terms of environmental factors (such as emissions) as per the provisions of the Law and the Regulations, the rules and instructions issued thereunder, as well as their licence terms and conditions via the inspectors, who are appointed by a decision of the Minister.
Design and Construction Companies	Compliance with the provisions of the Law and the Regulations, the rules and instructions issued thereunder, as well as the terms and conditions of the construction and environmental permits, as well as any other pertaining permits.
Waste Treatment Service Providers / Operators	▪ Verify the authenticity of the waste transportation manifest details and ensure that they fall within the licence issued for the Biological Waste Treatment Facility competency. ▪ Submit periodic reports to the Centre, as per the controls stipulated by the Regulation.

Roles and Responsibilities

- Maintain an adequate and up to date record of its operations and provide this on a regular basis to the Centre.
- Provide adequate training to designated staff to ensure the highest level of skills and qualifications.
- Ensure proper and safe management of by-products and residues resulting from the biological treatment processes of waste, according to the applicable regulations and instructions by the Centre.
- Install a monitoring system in the biological waste treatment facility to monitor environmental factors (such as emissions) impacted by the technology used. The Operator is required to bear the cost.
- Be responsible for the maintenance, supervision, monitoring according to the relevant License and/or other Licenses or Permits required by the Law, the Regulations and the relevant technical controls the Centre issues.
- Report to the Centre notifications within a maximum of 24 hours from the finding of any negative ecological effects revealed by the self-monitoring.
- Provide financial guarantees to guarantee the fulfilment of their obligations.

4 OVERVIEW OF BIOLOGICAL TREATMENT OF WASTE

4.1 Context

Food waste represents approximately 60 % of the total municipal solid waste generated in KSA in and garden waste from landscaping activities accounts for approximately 10 %. In addition, food waste and other streams of organic waste are also generated from agriculture, food processing, distribution, and consumption. At present, the source segregation of food waste is not yet implemented in KSA, the majority of waste being sent to landfills and thus lost for recycling.

In a circular economy, organic waste is directed to treatment options that use the waste as a source of valuable resources such as nutrients, organic substances, and energy. For example, composting and anaerobic digestion are biological treatment methods that may be classified as recycling when the compost or digestate produced is used as a recycled product, material, or substance. Anaerobic digestion also produces biogas that can be either used to generate heat and electricity or upgraded into a low-carbon biofuel.[1]

4.2 Waste Streams Suitable for Biological Treatment of Waste

As a key element of the waste and resource management industry, biological treatment is the process of decomposing biodegradable waste. According to the IR of the WML, biodegradable waste "*is any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard*". The aerobic and anaerobic decomposition of biodegradable waste are two forms of biological treatment of waste. **However, not all biodegradable waste can be classified as suitable for biological treatment.**

Biodegradable materials such as contaminated paper, mixed paper, leather, and textile, are not generally suitable for biological treatment and the justifications are:

- Soiled paper, tissues, printed, coloured and glossy paper may contain some toxic heavy metals and when composted for example, can affect the quality of the compost. On the other hand, in the general practice, soiled paper is not collected separately, as it is no longer suitable for recycling, and is therefore mixed in most cases with general waste;
- Mixed paper – similar with the above. In addition, mixed paper may be combined with plastic or may contain toxic hazardous substances (e.g., substances used for adhesive) that are not suitable for composting;
- Textile and leather – natural fibres/leather are biodegradable, but this is not the case with synthetic materials. However, although natural materials are biodegradable, they are often produced with unknown chemicals, which can slow down the biological process and fertilizing behaviour. In general practice, municipal textile and leather waste is primarily reused or recycled mainly a to produce new materials for the textile industry.

The biodegradable waste fractions suitable for biological treatment refers to food waste and green waste generated from:

[1] Bio-waste in Europe — turning challenges into opportunities, EEA Report No 04/2020

- Production (agricultural assets such as open fields, greenhouses, animal farms etc);
- Processing (food preparation industry);
- Retail (fruits and vegetables markets and supermarkets);
- Consumption (restaurants, catering services, households etc); and
- Green waste from landscaping.

Differentiating organic waste by source type is essential, as treatment options may vary depending on the different characteristics of the materials, such as composition, homogeneity, percentage of impurities, moisture content, organic matter, nitrogen content, etc.

Organic waste is generated from different sources such as agriculture, horticulture, industry, distribution, and consumption. Main organic waste streams generated during the food supply chain and from landscaping are outlined in Figure 4-1.

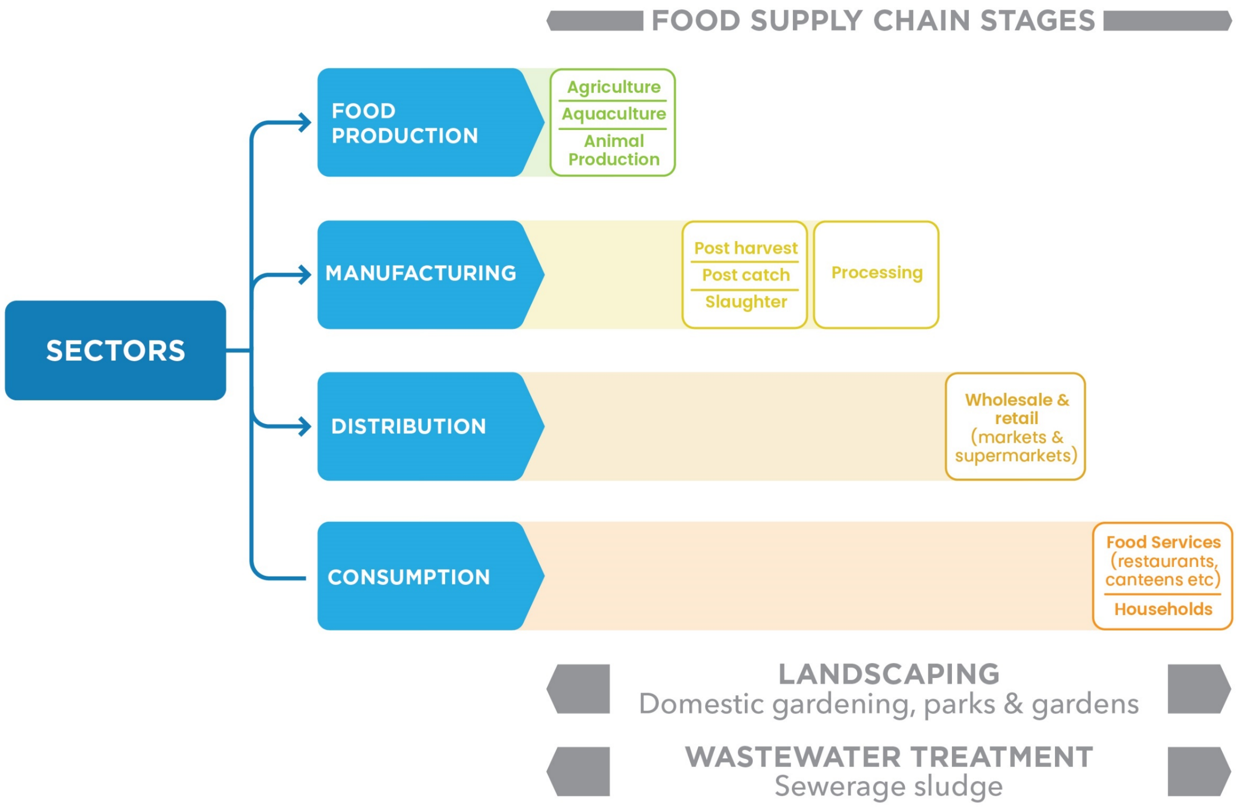

Figure 4-1: Sources of Organic Waste Generation

4.3 Treatment Technology Overview

The biological treatment of waste refers to the use of living microorganisms to decompose organic waste into either carbon dioxide and simple inorganics, or into simpler organics such as aldehydes and acids. The types of biological waste treatment technologies used for the treatment of organic waste discussed and included in the scope of this document are summarised briefly as follows:

- **Anaerobic treatment or anaerobic digestion of organic waste** is a process carried out in closed vessels in the absence of oxygen. This process results in the production of biogas, that can be used to generate electricity, heat or upgraded into a fuel, as well as the production of a digestate that can be used as an organic fertiliser or soil improver;

- **Aerobic treatment or composting of organic waste** is the natural biological degradation process whereby microorganisms break down the waste into carbon dioxide, water, nitrates, and sulphates in the presence of oxygen. This process produces a humic substance, compost, that can be utilised as a fertiliser or soil improver.

The following longlist of organic waste treatment technologies were identified:

1. **Anaerobic Digestion (AD):**
    a. Wet AD of solid and liquid organic wastes;
    b. Dry AD of solid organic wastes;
    c. Additional treatment of AD outputs:
        - Biogas - Biomethane upgrading;
        - Biogas – Carbon dioxide capture;
        - Digestate - Advanced digestate treatment.
2. **Aerobic Digestion – Composting:**
    a. Open Systems:
        - Windrow composting;
        - Aerated static composting.
    b. Contained Systems or In-vessel composting (IVC):
        - Situated within buildings;
        - Specifically designed vessels (e.g., tunnels, drums, or towers).
3. **Mechanical biological treatment (MBT)**:

While, typically, the feedstock for Aerobic and Anaerobic Digestion is source-segregated organic waste, Mechanical Biological Treatment is intended to treat mixed waste streams (residual waste).

Source-separation provides the best quality feedstock for both Aerobic and Anaerobic Digestion, offering a maximum organic content and minimum level of contamination with heavy metals and other hazardous substances. After digestion of source segregate organic waste, the output will be represented by a quality compost that can be reintroduced in the economy as a fertiliser and high volume of biogas.

Composting dominates the treatment capacity, but the use of anaerobic digestion is increasing. Anaerobic digestion generates biogas and is thus a source of renewable energy. The preferred treatment technique depends on the composition of the bio-waste and the properties of the separate collection system, but anaerobic digestion tends to deliver higher environmental benefits.[2]

The purpose of the MBT plants is to reduce the weight, and to render inert any biologically active organic materials (typically called 'stabilised residue'), extract recyclable materials and produce a solid recovered fuel for industrial thermal applications. MBT was initially conceived to reduce the organic matter content of waste which is sent to final disposal with the aim of reducing the production of biogas and leachate and ultimately to reduce the amount of waste directed to the landfill.

Note: MBT is not included in the scope of this document as it is covered in a separate Technical Guideline.

4.4 Anaerobic Treatment (Anaerobic Digestion)

Purpose

Anaerobic Digestion (AD), also known as 'biogas', technologies are designed and engineered to control and optimise the biological digestion of biodegradable materials to produce a methane rich gas for energy production and digestate. Figure *4-2* shows a block flow diagram for an AD process facility with inputs and outputs.

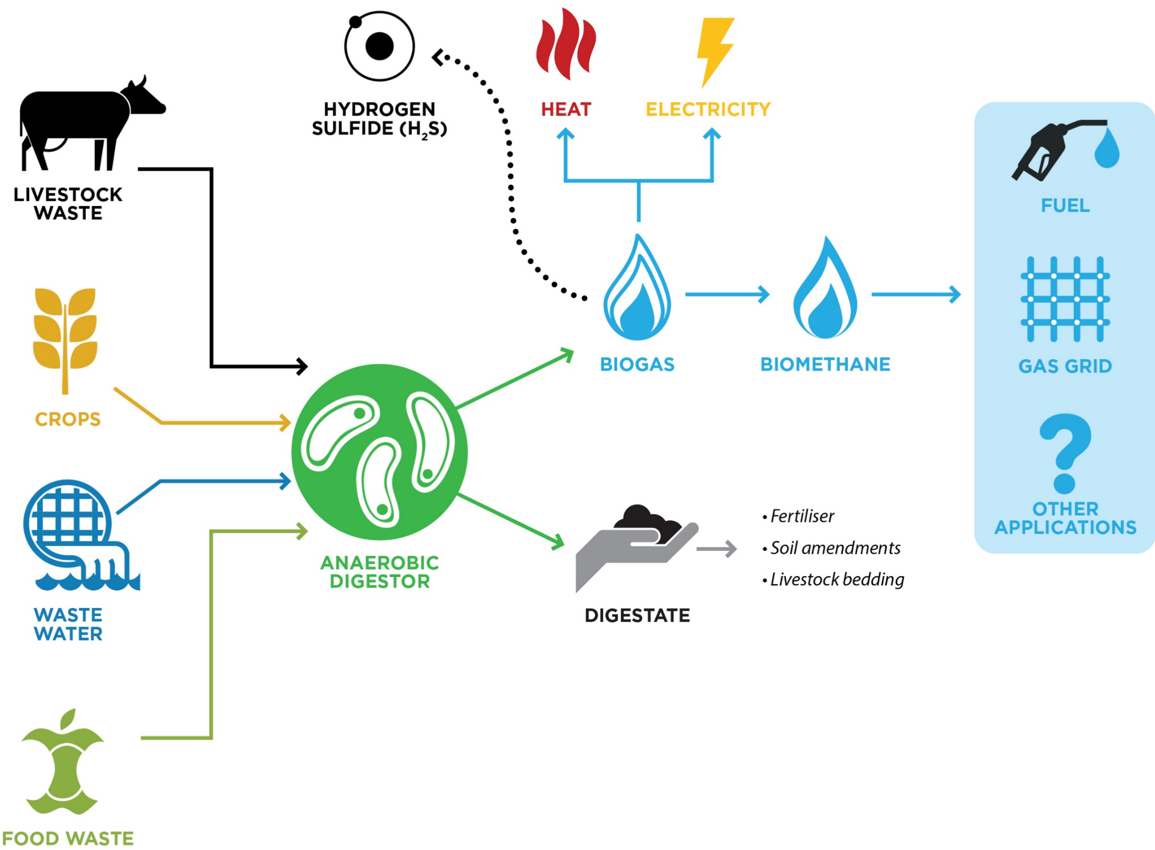

Figure 4-2: Schematic Overview of Anaerobic Digestion

Anaerobic Treatment process

[2] Bio-waste in Europe — turning challenges into opportunities, EEA Report No 04/2020

Anaerobic digestion generally involves four main steps such as a) feedstock reception; b) preparation (material separation and pre-treatment); c) digestion and d) finalisation (water extraction, biogas collection and treatment) as shown in Figure *4-3*. This process is discussed in more detail in Section 6.

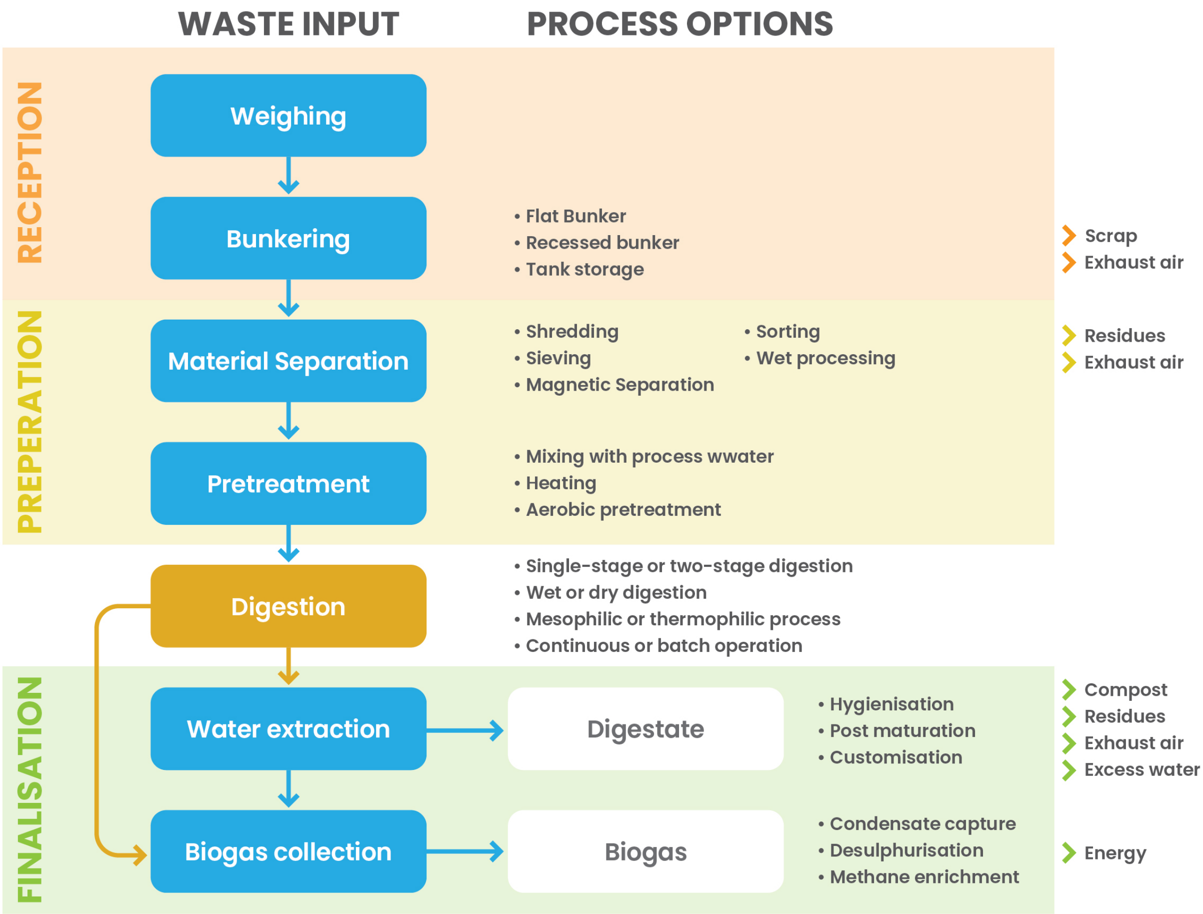

Figure 4-3: Example of an Anaerobic Digestion Plant

The feedstock delivered to an anaerobic digestion facility will require pre-treatment/ preparation prior to feeding into the process. The nature of the pre-treatment will be dependent on the feedstock and the objectives of the pre-treatment are generally to homogenise it (in both size and consistency) and to remove oversized components and contaminants from the feedstock. These contaminants include materials such as plastics, metals or chemicals which are toxic to the biology of the facility.

Following the pre-treatment, material is fed into a sealed vessel, the ‘digester’. In the digester the micro-organisms breakdown the feedstock into biogas and digestate. The characteristics of the feedstock, coupled with the technology provider, will define the most appropriate type of digestion process.

Biogas from the digester is drawn off and passed through a cleaning system, primarily for the removal of hydrogen sulphide and siloxanes. Following this cleaning process, the biogas is held in a gas balloon which serves as a buffer and mixing vessel to allow consistent biogas flow and quality to the biogas end use. Traditionally, the end use has been to combust the biogas in a reciprocating gas engine generating electricity and heat; however, the ability to separate the biogas into its two major components, methane and carbon dioxide is now considered a commercially available technology and considered in section 6.

Technology Overview

The technologies are, by their nature, enclosed, using specifically designed vertical and/or horizontal vessels, interconnecting pipework, mixers, macerators, and pumps. AD processes last around three to six weeks depending on the ease and degree to which materials are converted into biogas and the technology used.

There are two main classifications of AD techniques: ‘wet’ and ‘dry’. In essence, ‘wet’ AD systems process more liquid materials (>85% moisture), whereas ‘dry’ AD processes are used to treat drier materials (<80% moisture) ranging from thick slurry to a wet solid. Waste feedstock is mixed and macerated with a large proportion of process effluent and /or fresh waste to prepare the waste; giving it the moisture and flow properties required.

Based on the substrate moisture, flow, temperature, and digestion stages there are different technologies available on the market for wet anaerobic digestion, as outlined in Figure *4-4*.

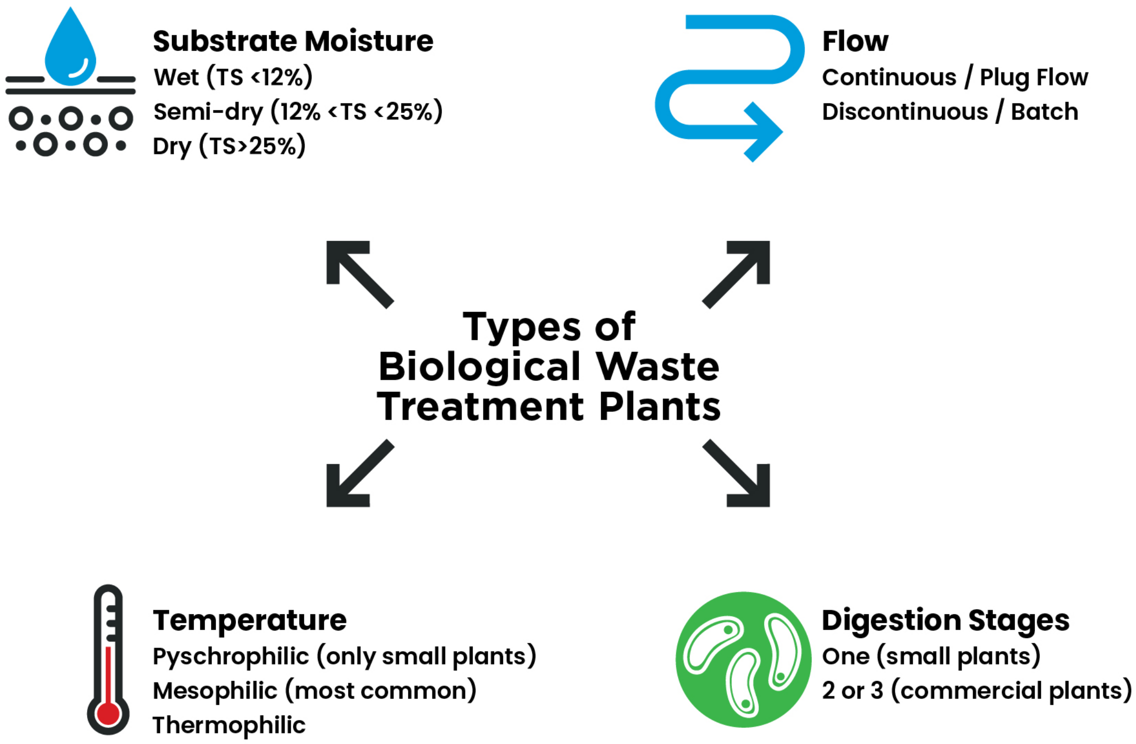

Figure 4-4: Anaerobic Digestion Technology Options

4.5 Aerobic Treatment (Composting)

Purpose

The main purpose of the aerobic treatment is to convert organic waste into compost that can be reintroduced in the economy (key principle of the circular economy) as a fertiliser, soil improver or, to a lower extend, recovered as fuel. Aerobic treatment can be used for biological stabilisation of waste prior to landfilling but this is generally part of the MBT Plants.

Aerobic Treatment process

Composting is a complex, aerobic microbiological process that can be optimised by controlling the quality of the feedstock and a number of operational parameters such as: aeration, moisture, PH, ration of carbon to nitrogen, temperature etc.

A basic design for composting plants involves four main steps: a) feedstock reception; b) preparation (or pre-composting stage); c) composting (intensive composting - thermophilic /mesophilic composting stage, aeration, and maturation); and d) finalisation (screening stage). This process is discussed in more detail in Section 6.

The composting process can be viewed as a generalised process diagram, as seen in Figure *4-5*.

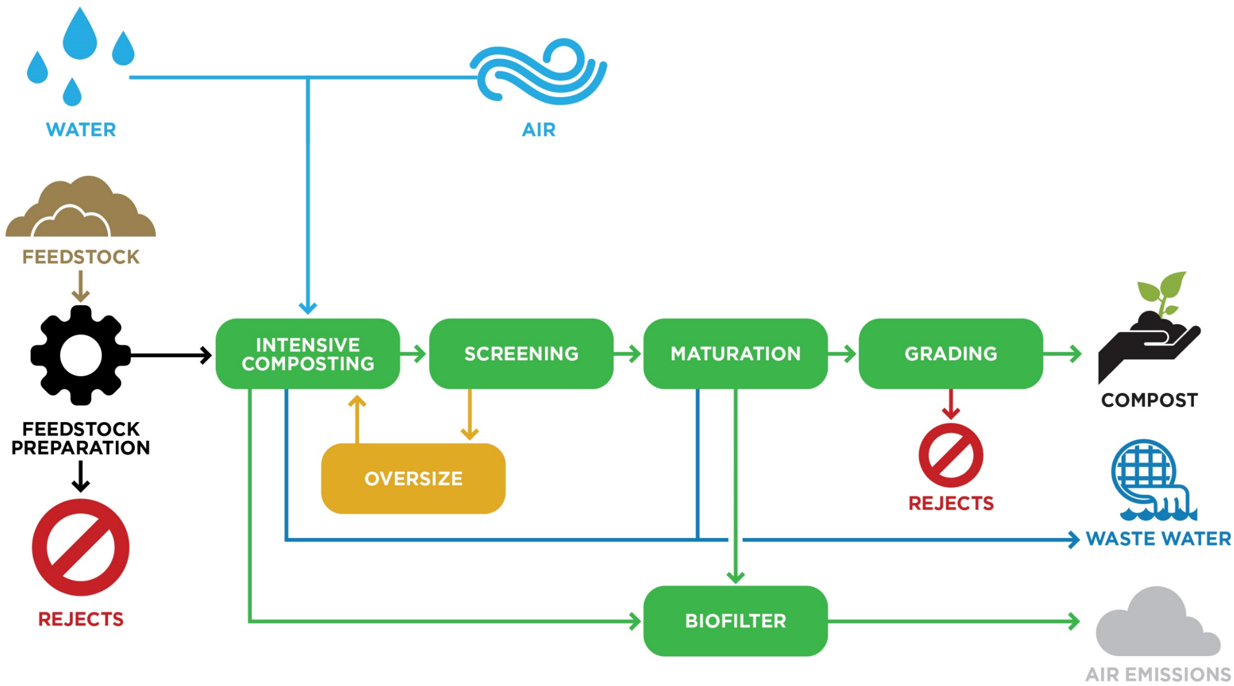

Figure 4-5: Aerobic Digestion Typical Flow

Technology Overview

Composting technologies come in a range of designs, all foreseen to control and optimise the biological stabilisation, sanitisation, and/or, in some cases, drying of biodegradable materials.

The composting technologies can be divided into two basic categories: those in which the composting process is carried out within some form of container, and those that are not.

Composting processes carried out in a container may called 'reactor', 'in-vessel', 'contained', 'enclosed' 'in-bay' or 'in-building' systems according to the nature of the container and the degree of containment. Composting processes not carried out within a container are referred to as 'open' or 'outdoors' systems. Composting technologies may be further classified according to whether the composting waste is moved or not, if forced air is supplied, and whether the composting process is carried out on a continuous or batch basis.

A. Open systems:
   a. Windrow composting;
   b. Aerated static composting.

B. Contained systems:
   a. Continuous or intermittent composting systems - vertical flow;
   b. Continuous or intermittent composting systems - horizontal or inclined flow:
      i. Rotary drums;
      ii. Agitated bins or bays: a) circular and b) rectangular;
      iii. Continuous tunnels.
   c. Batch composting systems:
      i. Open bays;
      ii. Fixed batch tunnels;
      iii. Mobile batch tunnel.

The following figure summarises the classification:

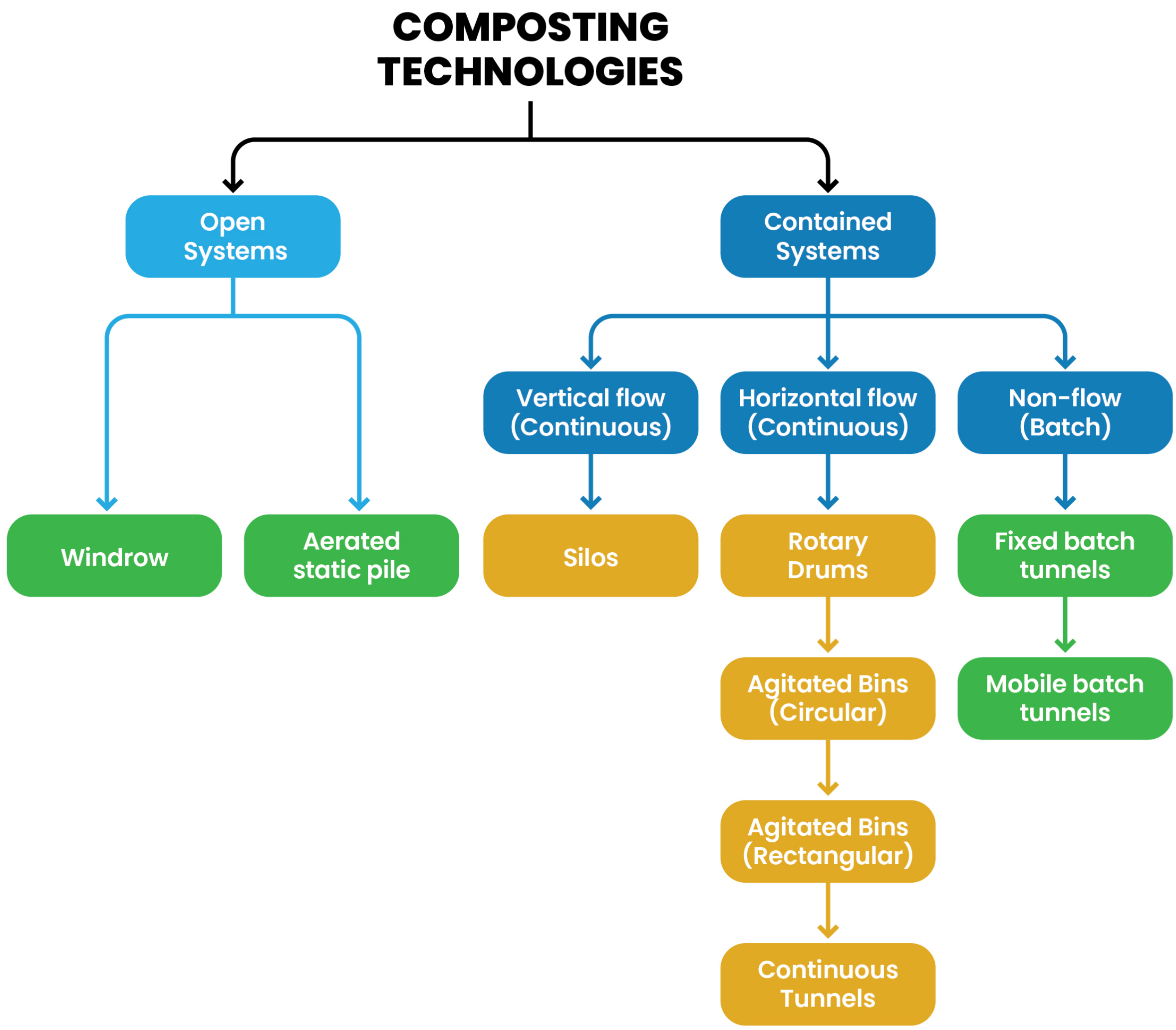

Figure 4-6: Composting Technologies

The composting technology chosen will depend upon a number of local parameters, such as the cost of competing organic waste disposal processes; the gate fee that can be obtained for receiving the feedstock; the availability of feedstock as well as the type and amount; the location of the composting facility; the type of compost required by available markets; and environmental legislation.

Table *4-1* provides a brief description of two types of composting, namely open and contained systems.

Table 4-1: Types of Aerobic Treatment

Type of Aerobic Treatment	Brief Description
OPEN Systems	
Open Air Windrow Composting	A type of composting where the waste is piled up in heaps, called windrows. These windrows are aerated regularly by manually or mechanically turning them.
Aerated Static Pile Composting	It is suitable for a relatively homogenous mix of organic waste and work well for larger quantity generators of yard trimmings and compostable municipal solid waste (e.g., food scraps, paper products), such as local governments, landscapers, or farms. This method, however, does not work well for composting animal byproducts or grease from food processing industries. In aerated static pile composting, organic waste mixed in a large pile. To aerate the pile, layers of loosely piled bulking agents (e.g., wood chips, shredded newspaper) are added so that air can pass from the bottom to the top of the pile. The piles also can be placed over a network of pipes that deliver air into or draw air out of the pile. Air blowers might be activated by a timer or a temperature sensors.
CONTAINED Systems	
In-vessel Composting	In-vessel composting can process large amounts of waste without taking up as much space as the windrow method and it can accommodate virtually any type of organic waste (e.g., meat, animal manure, biosolids, food scraps). This method involves feeding organic materials into a drum, silo, concrete-lined trench, or similar equipment. This allows good control of the environmental conditions such as temperature, moisture, and airflow. The material is mechanically turned or mixed to make sure the material is aerated. The size of the vessel can vary in size and capacity. The techniques used to control the supply of oxygen required by the process are the mechanical agitation of waste (turning) and/or blowing or sucking air through the waste (forced aeration) offering differing levels of process control and automation.

4.6 General Consideration on Biological Treatment Technologies

While waste prevention and reuse are environmentally preferable, anaerobic digestion of separately collected organic waste is the second-best option followed by composting, because anaerobic digestion recovers both materials and energy. However, obtaining these benefits requires the following:

- Compost is needed as a soil improver;
- Compost obtained from direct composting and from composting of digestate are similar in composition and quantity;

- Energy recovery from the biogas produced displaces fossil fuel-based energy production;
- The digestion process is well managed.

However, in regions with low levels of organic matter in agricultural soils, composting might be the environmentally preferable option. Anaerobic digestion is not always technically feasible, for example for high shares of garden waste. When anaerobic digestion is not (technically) feasible, composting of organic waste should be assessed against energy recovery.[3]

[3] Best Available Techniques Reference Document for Waste treatment, Joint Research Centre (JRC), EC, 2018

5 SITE SPECIFICATIONS AND INFRASTRUCTURE REQUIREMENTS

5.1 Site Selection Criteria

As per Article 100 of Chapter 4 of the IR, the design of biological waste treatment facilities must be approved by the Centre, and the site design must be fulfilling the following as a minimum:

- Minimise potential environmental impacts;
- Minimise health and safety risks for workers and the public;
- Encourage waste resource recovery; and
- Use onsite resources efficiently.

Article 95 of Chapter 4of the IR provides general guidelines for site selection of waste facilities including biological waste treatment facilities. Those include:

- The distance between the suggested site and the production, collection, and storage of Waste locations;
- Availability of infrastructure and paths for facilitating the arrival to the location in all seasons, and the impact of the facility on the traffic at that area;
- Keeping away from historical sites and reserves;
- That the area has suitable capacity for all generated wastes throughout the facility's lifecycle;
- Avoidance of sites on very steep locations, as level grounds are preferrable;
- That the site is distant from valleys, reefs, flood streams, beaches, bodies of water and water sources, such that it does not pollute any water source;
- That the site is not in areas where the groundwater percentage is high, or in sabkhas;
- The dominant direction and speed of the winds, such that the facility must be located in the opposite direction from the wind direction in that area;
- That the site is distant from currently used lands or the lands that are planned for development purposes, such as urbanized, commercial, agricultural, or industrial areas;
- In case of choosing a location for a landfill, the suitable and fulfilling soil must be existent to cover the waste, taking into consideration that the soil has low permeability and coherence;
- That the site is as far as possible from any masts, electric lines, railways, airports, facilities' pipelines, and highways;
- Any other controls or requirements the Centre issues.

The Centre may exempt from any of these conditions in accordance with the nature of the project.

As per article 97 of the IR, it is forbidden to build a biological waste treatment facility on the following sites and areas:

- Sites adjacent to planned land for development purposes such as urban, commercial, and agricultural expansion areas;
- Sites located in valleys, reefs, and flood streams, where the treatment and disposal of Waste may expose the water to contamination, as a result of leakage of fluids to the ground;

- Sites with high groundwater attributed, especially in areas where this water is used for agriculture or drinking;
- Sites on very steep locations;
- Sites on historical archaeological or natural areas or environmental reserves;
- Areas adjacent to airports and subject to the classification of the General Authority of Civil Aviation; and
- Any other area deemed by the competent authorities as invalid for the establishment of a facility for the treatment and disposal of Waste.

According to the new Waste Management Law, all waste treatment facilities, including the biological waste treatment, should be designed, build, and operate in the base of the permit/licence issued by the Centre. The construction and operation of a biological waste treatment facility is classified as Category 3 under the new Environmental Law and therefore an Environmental and Social Impact Assessment (ESIA) is mandatory.

5.2 Siting – General Considerations

Biological waste treatment facilities should be configured and organized in accordance with the expected uses of the land within them; this form of spatial organization and planning is known as “zoning ”.[4]

Zoning helps by encouraging on-site economies of scale in utilities infrastructure concentration and utilization, for instance, as regards waste collection and treatment, internal transport networks and other amenities. It also smooths vehicular and pedestrian circulation by enabling clear movement patterns.

Biological waste treatment plants zoning maps are prepared based on such key site parameters as boundary (perimeter) shape, physical site features, area availability, environmental considerations, micro climatic conditions, compatibility issues, surrounding areas, accessibility, transportation issues and visibility.

Existing and adjacent land use are also critical considerations in deciding on nearby and future onsite land uses and zoning.

Zoning within the biological waste treatment plant can be designed furthermore in such a way as to encourage industrial symbiosis for the utilization of materials, industrial water, and energy by-products.

Energy efficiency optimisation can be attained by stimulating and facilitating ‘energy symbioses’ and cooperation amongst residents. Surplus energy (e.g., heat, steam, hot water, etc.) from a plant can be transferred to other companies, either within the biological waste treatment or in nearby communities.

Segregating polluting and non-polluting activity is another sound zoning practice.

In any case, the biological waste treatment plan must be within the approved plans as industrial zones, and proportional in size to the volume of work and the quantity of production, according to the areas approved in the industrial plans.

[4] (United Nations Industrial Development Organization, INTERNATIONAL GUIDELINES FOR INDUSTRIAL PARKS, 2019)

5.2.1 Surface Water Drainage

Surface water caused by run off of entrained water from the Waste mass and storm water drainage are collected and managed separately. Contaminated water is transferred to a treatment unit while storm water runoff is disposed on to a natural recipient.

The design of the drainage system must be taken into account pre-development. The drainage systems must be inspected at annual intervals throughout the operational life of the facility to ensure their integrity.

5.2.2 Utilities and Facilities

In order to ensure the health and safety of on-site personnel, and to enable control of operations on site the following utilities and facilities in combination with the appropriate equipment must be provided at all biological waste treatment plants[4]:

- Water supply:
  - Sufficient drinking and non-potable water, with separate distribution networks;
  - Water pumping station.
- Power supply:
  - Distribution substations at strategic locations, with network of underground cables or overhead lines.
- Street lighting:
  - Conventional or solar street lighting;
  - Smart energy-efficient lighting.
- Sewerage:
  - Sewage and effluent collection and storage systems;
  - Systems for removal of contaminants from wastewater, and storm run-off through primary treatment of effluents;
  - Treated and recycled water distribution system.
- IT connectivity, telecommunication, and ICT-enabled resident services:
  - High-speed Wi-Fi and internet services;
  - Robust data infrastructure system;
  - Communication system within the biological waste treatment plant.
- Safety and security:
  - Health care centre, medical facilities;
  - Emergency response centre/s (including for accidents and first aid, fire, and chemical hazards, security incidents, natural disasters, and crises, etc.);

- Public safety infrastructure, including lighting and CCTV surveillance systems.

5.2.3 Fencing and Security

A fence must be constructed around the perimeter of the biological waste treatment plant to reduce onsite trespass, provide a screen for the facility, delineate the property lines, and provide a control for litter blow. Fences must be a minimum of 2 metres tall around the entire perimeter of the site. Appropriate signage to discourage trespassers must be erected at the site entrance.

5.2.4 Waste Rejects Area

An area of the site must be made available to allow for the temporary segregation of suspect, burning or unacceptable waste loads which enter the site. This area should be located away from the main areas frequented by personnel. Firefighting equipment must be available in case of burning waste loads.

This area must be clearly marked with reference to its required purpose to ensure that there is no inadvertent mixing of waste materials.

6 DESIGN REQUIREMENTS AND BEST APPLICABLE TECHNICQUES

As per Article 100 of Chapter 4 of the IR of the WML, the design of Biological Treatment Facilities must be approved by the Centre, and the site design must be fulfilling the following as a minimum:

- Minimise potential environmental impacts;
- Minimise health and safety risks for workers and the public;
- Encourage waste resource recovery; and
- Use onsite resources efficiently.

Article 101 of Chapter 4 of the IR of the WML list the minim information to be provided at the design stage of a biological treatment facility. Furthermore, as per Article 103 of Chapter 4 of the IR of the WML, the design of the facility for the Biological Treatment of Waste will identify all relevant environmental controls, contingency plans, and emergency response plans.

In the next sections, the minimum design requirements for both anaerobic and aerobic digestion are presented including the potential emissions and best available techniques to prevent or reduce their generation.

6.1 Anaerobic Digestion

6.1.1 Process Description

In anaerobic digestion, organic matter in the feedstock is broken down by micro-organisms in the absence of oxygen. The organic matter is converted into digestate and biogas, which is composed primarily of methane (50 – 70%), carbon dioxide (30 – 50%), and small quantities of other gases such as hydrogen sulphide (50 – 4000 ppm).

The anaerobic digestion process in an anaerobic digestion plant generally involves four main steps:

1) Reception;
2) Preparation;
3) Digestion; and
4) Finalisation.

Reception

Upon the delivery of the organic waste to the reception area for treatment, the characteristics (type of organic waste, source segregated or mixed, etc.) of the waste through visual inspection are recorded as well as the weight of the waste.

Preparation

The waste is then prepared for treatment through waste separation and pre-treatment. This is essential to improve the digestion process. The nature of the pre-treatment will be dependent on the feedstock and the objectives of the pre-treatment are generally to homogenise it (in both size and consistency) and remove contaminants from the feedstock. These contaminants include materials such as packaging or chemicals which are toxic to the biology of the facility. Materials such as plastics (including biodegradable plastic bags), metals and oversized components are manually extracted from the waste. Size reduction to create a more homogenous material, facilitating the anaerobic digestion process, is then undertaken through screw-cutting, milling, drumming, pulping or shredding machines. As part of the pre-treatment process, preliminary aerobic decomposition can be performed over a period of two to four days to improve material breakdown and warm the substrate. This can be undertaken in box fermenters or in separate preliminary digestion unites (such as composting tunnels with forced aeration tunnels). Heating the substrate reduces the consumption of energy required to heat the digester. This decreases the amount of organic matter for anaerobic treatment; however, it increases the biogas yield. Furthermore, since anaerobic digestion is limited in its ability to degrade cellulose, hemicellulose and lignin, pre-treatment methods (whether physical, chemical, or biological) are preferred.

Typical feedstock for an anaerobic digestion plant include:

- Food waste;
- Animal manure / waste;
- Plant and crop waste;
- Sewage sludge.

As mentioned above, waste separation has an important impact on the feedstock quality. There are two main alternatives for waste separation:

- <u>Source separation</u> – this includes separation of the putrescible organic waste fraction and is generally accepted to provide the best quality of feedstock for both aerobic and anaerobic biological treatments, since it offers both a maximum organic content and a minimum contamination with heavy metals, glass, and plastics. Furthermore, the end result of the treatment will be the formation of a quality compost (aerobic treatment) or digestate and a high volume of biogas (anaerobic treatment);
- <u>Centralisation separation</u> – this includes mechanical processing, optical processing, and manual separation (hand-picking). The resulting feedstock is likely more contaminated than source-separated organic waste and therefore impacts the quality of the outputs of the treatment process. Furthermore, there is a risk of larger, non-separated components of the wate being carried over and resulting in physical damage to treatment plants further downstream (by abrasion, blockages, or tangling).

<u>Digestion</u>

Following pre-treatment, material is fed into a sealed vessel termed the "digester", in which anaerobic digestion takes place. During the anaerobic digestion treatment process, the material in the digester is continually drawn into a separation system, where the solid (the digestate) is separated from the liquid, with the liquid recirculated to keep the micro-organisms within the digestion system. Excess liquid is disposed of as wastewater.

The main types of digesters are:

- Vertical digesters with an agitator (typically used in wet digestion facilities);
- Horizontal digesters with a slow transport agitator using plug-flow technology (used in dry digestion facilities);
- Vertical digesters without mixing using plug-flow technology (used in dry digestion facilities);
- Box or percolation digesters (used in dry batch digestion facilities).

Furthermore, the mixing systems used in the digesters can be as follows:

- Mechanical by means of agitators;
- Hydraulic, by means of pumps that recirculate the substrate;

- Pneumatic, by recirculating biogas in the digester.

Anaerobic digestion takes place over four successive stages, shown in Figure 6-1and presented in detail as follows:

- Hydrolysis – Hydrolytic bacteria secrete extracellular enzymes that convert carbohydrates, lipids and protein into sugars, long chain fatty acids and amino acids respectively. The chemical bonds of these molecules are weakened and broken by the addition of water. The products are then able to diffuse through the cell membranes of acidogenic microorganisms. During hydrolysis, some hydrogen is formed which can be used for methane formation. As noted above, certain substances (such as lignin, cellulose, and hemicellulose) may be inaccessible to the microorganisms due to their complex structures which make it difficult to degrade them. The addition of enzymes may enhance the hydrolysis of these carbohydrates;
- Acidogenesis – By absorbing the aforementioned products of hydrolysis, acidogenic microorganisms are able to produce intermediate volatile fatty acids, such as acetates, propionate, and butyrate, as well as other products such as carbon dioxide and hydrogen. Small amount of ethanol and lactate may be produced;
- Acetogenesis – This is the process by which the volatile fatty acids and the other products produced through acidogenesis are converted into acetate, with hydrogen and carbon dioxide also being produced. This is the fastest step in the anaerobic digestion process;
- Methanogenesis – This is the final stage of the anaerobic digestion process, where products from acetogenesis are consumed by methanogenic microorganisms to produce methane and some carbon dioxide.

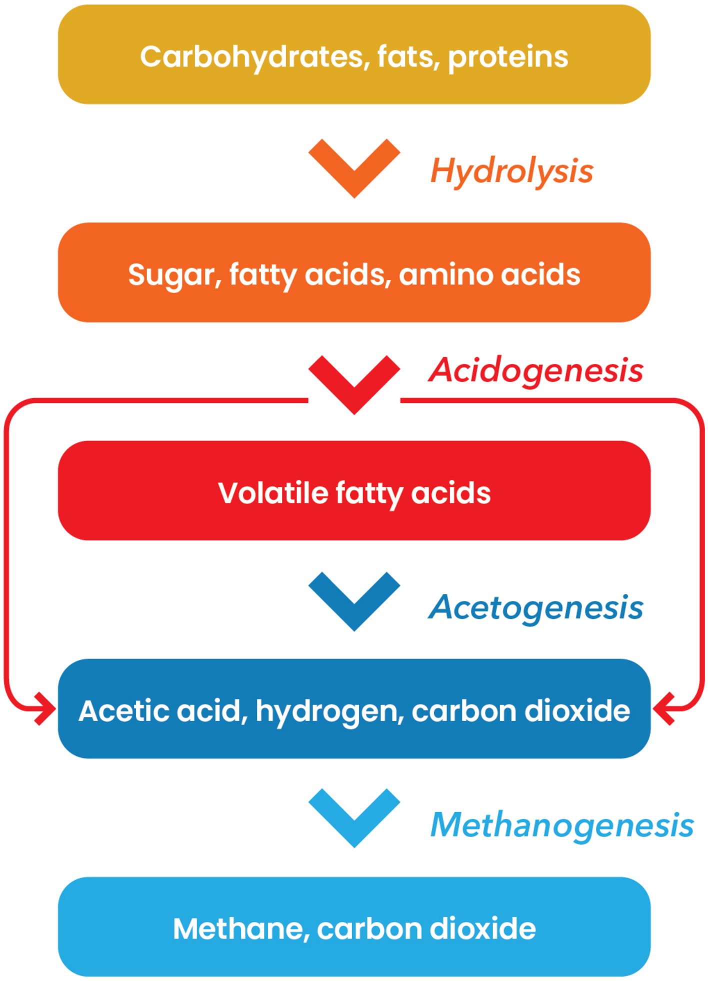

Figure 6-1: Anaerobic Digestion Process

A stable anaerobic digestion process requires maintaining a balance between several microbial populations. The hydrolysis and acidogenesis stages have the most robust microorganisms; they thrive in the broadest environmental conditions. However, this is not the case for acetogenesis and methanogenesis.

Anaerobic digestion can be performed at two main temperatures: mesophilic (25 – 40ºC) and thermophilic (50 – 65ºC). The former operates at lower temperatures and so digestion is slower and yields less biogas; however, this is more cost effective compared to thermophilic digesters, which operate at higher temperatures and have increased biogas production. The thermophilic process is harder to control and requires more energy to heat up the substrate as well as compensate the higher heat losses from the tanks.

The characteristics of the feedstock, coupled with the technology provider, will define the most appropriate type of digestion process.

Finalisation

The final step in an anaerobic digestion facility is finalisation. This includes sanitation, maturation, and biogas treatment. If thermophilic digestion is performed, the sanitation can be considered complete; else, a separate sanitation stage may be required. Maturation (or post-composting) may be needed as it reduces the water content and prevents methane formation in solid digestate products. It can be performed in boxes or tunnels with forced aeration systems, and generally lasts between two to six weeks, depending on the desired degree of maturation. Lastly, biogas treatment is done to dehumidify and clean the biogas and ensure the removal of hydrogen sulphide. The biogas is then held in a gas balloon which serves as a buffer and mixing vessel to allow consistent biogas flow and quality to the biogas end use. The most common use of biogas is Combined Heat and Power (CHP) generation to produce heat and power. Alternatively, biogas can be upgraded, which requires the removal of carbon dioxide and other contaminant gases, in order to generate biomethane. The addition of propane to biomethane may also be required in order to achieve the required gas calorific value (CV). Process outputs can be summarised as follows:

- Biogas – which can be combusted to give the following outputs:
  - Electricity – a fraction can be utilised to power the equipment in the treatment facility;
  - Heat – a fraction can be utilised to provide heat in the treatment facility;
  - Air emissions from the combustion of biogas in the gas engine.
- Digestate – which is the digestate organic material:
  - Digestate fibre – may be used as a soil improver depending on feedstock and local land spreading regulations;
  - Digestate Liquor – may be used as a fertiliser in place of mineral fertiliser depending on feedstock and local land spreading regulations.
- Reject material – separated in the pre-treatment stage may be sent for landfilling or potentially as fuel for a Waste to Energy (WtE) facility, if and when available, depending on the composition.

The process outputs of biogas and digestate can be further refined with specialist technology detailed in Section 6.1.4.

6.1.2 Wet Anaerobic Digestion

The wet AD process takes place in a controlled manner using a series of sealed tanks to break down the organic material and produce biogas. The tanks have a range of other purposes, including storage and preparation of feedstock and digestate, but the term anaerobic digester specifically refers to the tank or vessel in which the biological process takes place. Design and layout vary depending on the quantity of material and its composition but will generally follow the same principles.

Wet AD is designed to process feedstocks with a low solid content, generally in the range of 5 – 15%. The feedstock will first undergo pre-treatment to remove any contamination; pre-treatment levels depend on the feedstock composition and form. The feedstock is mixed with process water or with liquid waste (liquid organic waste or recycled digestate liquor) to provide a diluted feedstock for feeding into the digester. Next, the material will be transferred to the digester where anaerobic digestion will take place. Wet AD can be undertaken in one (single stage) or two/multi-phase (multi-stage) processes. One phase process is the technique used most frequently, where all degradation steps take place in one vessel, while in two/multi-phase process typically comprises primary and secondary digestion vessels and divides the first two stages of the four-stage anaerobic digestion process in the first chamber (acid phase) and the last two stages in the second chamber (methane phase).

Digestate will be removed from the tank to make way for fresh feedstock, and this will be stored in a second tank ready for deployment or disposal. This could be done in a 'whole' form (as received) or run through de-watering equipment to produce a solid digestate fibre and a liquid digestate liquor.

Figure *6-2* presents a typical configuration of a wet AD process.

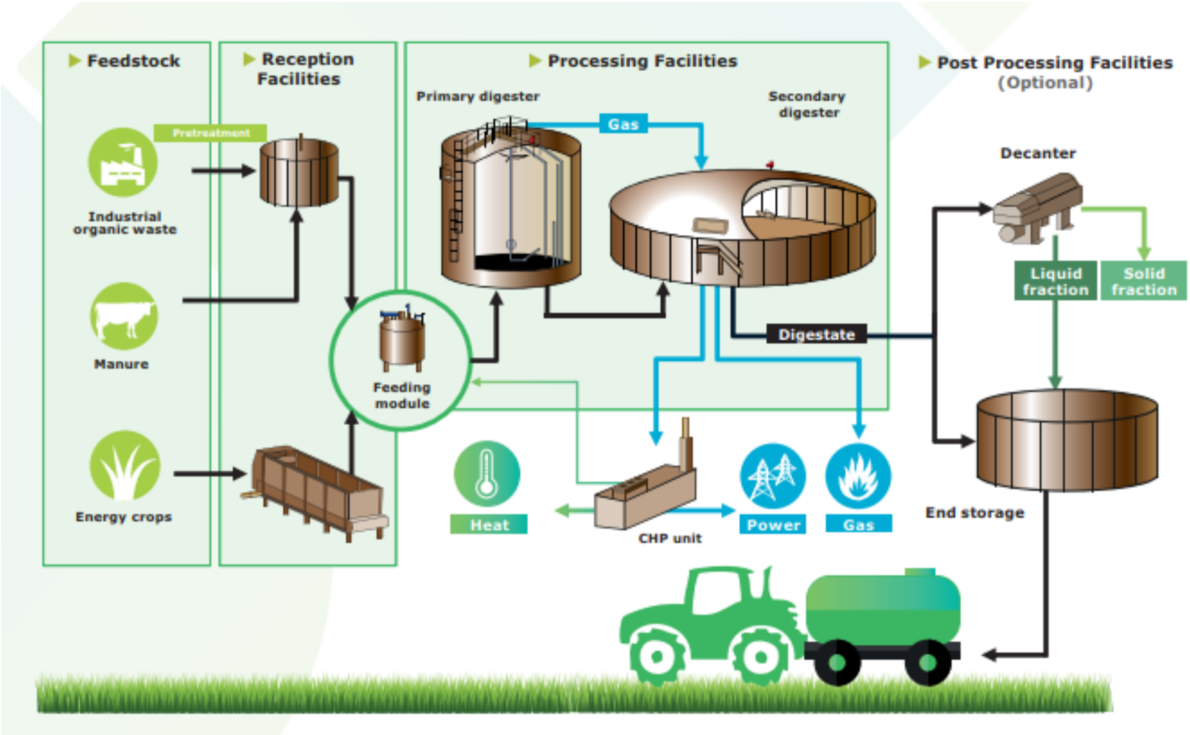

Figure 6-2: Typical Configuration of a Wet AD Process (Cre, 2018)[5]

6.1.3 Dry Anaerobic Digestion

Dry AD is designed to process feedstocks with high dry solid content in the range of 15 – 40%. Dry AD does not require comprehensive pre-treatment or mixing with water to create a pumpable slurry feedstock. Incoming waste is typically shredded, and if it is a high-density waste such as food waste, it will be blended with wood chips or green waste to give the material some structure. It is then loaded into a concrete tunnel (or similar vessel) and sealed with an air-tight door.

As the waste begins to degrade, the moisture will seep out of it as percolate. This percolate is captured in a drain in the floor and sprayed back on top of the material via pumps. The tunnel is then purged with an inert gas to prevent any combustion when the anaerobic digestion process begins, and biogas is produced. The biogas is captured and stored in a gas bag. Once the biogas production begins to drop off (typically after around 10-20 days), the tunnel is purged with a high volume of air to stop the AD process, and the tunnel will be opened for unloading. The digested material is often then subjected to a further period of aerobic composting to stabilise it prior to deployment to land or disposal.

Dry digestion can be undertaken as dry batch digestion or continuous dry digestion. Batch digestion, which is described above, involves the single addition of feedstock to the digester at the start of the process, after which the unit is sealed for the duration of the process with no additional material added. Continuous digestion or plug flow digestion systems involve the constant addition of feedstock in the aforementioned dry matter range, with products displaced as new material is added. As with dry batch digestion, the percolate or the outflow is often de-watered, and the resulting liquid is often recirculated back in order to inoculate new material with

[5] Source: "Guidelines for Anaerobic Digestion in Ireland", Composting and Anaerobic Digestion Associate of Ireland, 2018

microorganisms, improve stirring of the material as well as conditions suitable for microbial growth and nutrient transportation.

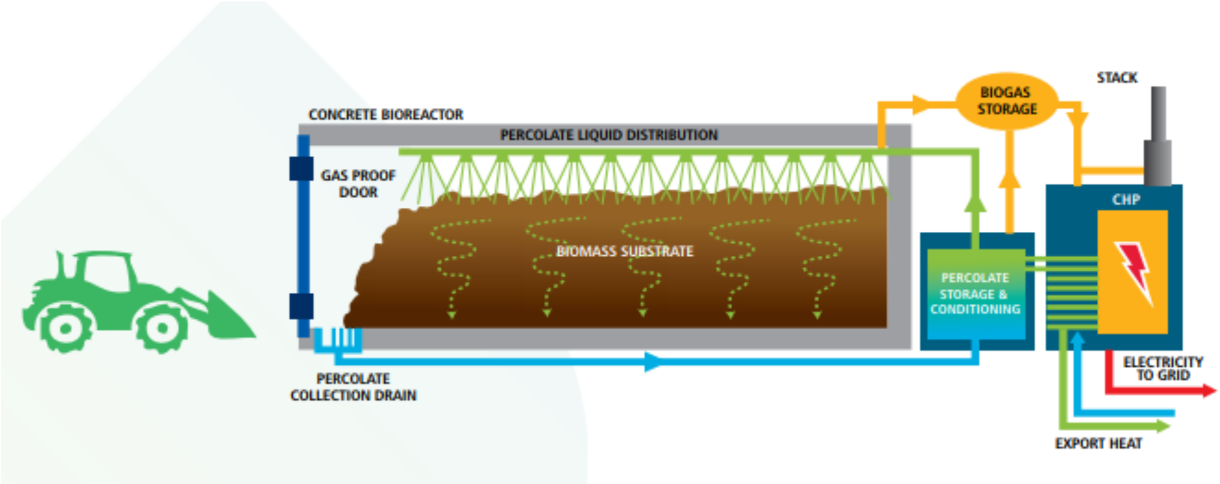

Figure 6-3: Typical Configuration of a Dry Batch AD Process (Cre, 2018)[5]

6.1.4 Anaerobic Digestion Output Treatment Technologies

6.1.4.1 Digestate Advanced Treatment

A clean biodegradable feedstock will increase the quality of the digestate. The solid digestate, if it complies with legislation and product specifications (if and when available), can be used as an organic fertiliser or soil improver in agriculture, either in a liquid form (about 5 – 15% dry matter) like manure, or in a semi-solid form (10–30%) like peat, or it can be further upgraded by composting, drying and/or pelletising in landscaping and horticulture as well as in private gardens. However, if the digestate is contaminated with heavy metals, which may be the case with sewage sludge as feedstock, the digestate may require further treatment and its uses may be limited.

The digestate produced can be further treated through pyrolysis, which involves heating the digestate in the absence of oxygen. Prior to heating the digestate, it is recommended to dry the digestate; this can be performed either by using heat from the gas engines used for the combustion of biogas in the AD plant, or by using heat from the pyrolysis process itself.

The pyrolysis of the digestate generates a syngas and biochar. The generated syngas can be combusted to provide heat which can be used to either heat the pyrolysis system itself or to generate steam which can be used to dry the digestate. The exhaust gas from the syngas combustion is cleaned to remove contaminants and then released to the atmosphere. The biochar can be used as a soil additive.

Technology also exists to further treat the char to extract the phosphorous within it. This is generally applied to sewage sludge derived char; whether this phosphorous removal is beneficial will be dependent on the levels within the feedstock and the benefits or risks of spreading char with a phosphorous loading on the land.

6.1.4.2 Biogas Treatment and Biomethane Upgrading

Biogas is composed primarily of methane (50 – 70%), carbon dioxide (30 – 50%), with small quantities of other gases such as hydrogen sulphide (50 – 4000 ppm). Biogas can be used as any combustible gas and burned to provide heat and generate electricity, among other uses. The most common biogas use is Combined Heat and

Power (CHP). Heat is most effectively used on site or locally whereas power can be used on site or transferred to the main electricity grid. The generated heat can be partly used to provide heating for the digester but may also be used for heating buildings or water for co-located processes.

Table *6-1* summarises the removal techniques for the components of the biogas. It should be noted that the removal of these biogas components is dependent on the end use of the biogas. By removing carbon dioxide from the biogas, the biogas can be upgraded to biomethane. The addition of propane to biomethane may also be required in order to achieve the required gas calorific value (CV). Biomethane can be injected into the natural gas distribution network or used as a transport fuel in a similar way as compressed natural gas or liquified natural gas.

Table 6-1: Removal Techniques for Biogas Components[3]

Biogas Component	Removal Technique
Water	▪ Cooling/Condensation; ▪ Adsorption of water on the surface of a drying agent; ▪ Absorption of water in glycol or hygroscopic salts.
Hydrogen Sulphide (H_2S)	▪ Precipitation by addition of ferric ions (FeCl2, FeCl3, FeSO4) in the digestor; the precipitate iron sulphide can then be removed with the digestate; ▪ Precipitation inside the digester by controlled addition of oxygen; ▪ Chemical adsorption by means of sodium hydroxide or iron oxide adsorption, or activated; ▪ Carbon adsorption; ▪ Biogas scrubbing; ▪ External (outside the digester) biological or chemical desulphurisation.
Carbon Dioxide (CO_2)	▪ Pressure swing adsorption (i.e., adsorption by activated carbon or zeolite under elevated pressure); ▪ Water scrubbing; ▪ Organic solvent scrubbing (e.g., with polyethylene glycol); ▪ Chemical scrubbing (e.g., with amine solutions); ▪ Membrane separation; ▪ Cryogenic condensation.

It should be noted that pre-treatment of biogas is often undertaken beforehand, and the primary techniques used are as follows:

- Activated carbon filtration;
- Sulphide precipitation;

- Water scrubbing.

Figure *6-4* below summarises the biomethane upgrading process.

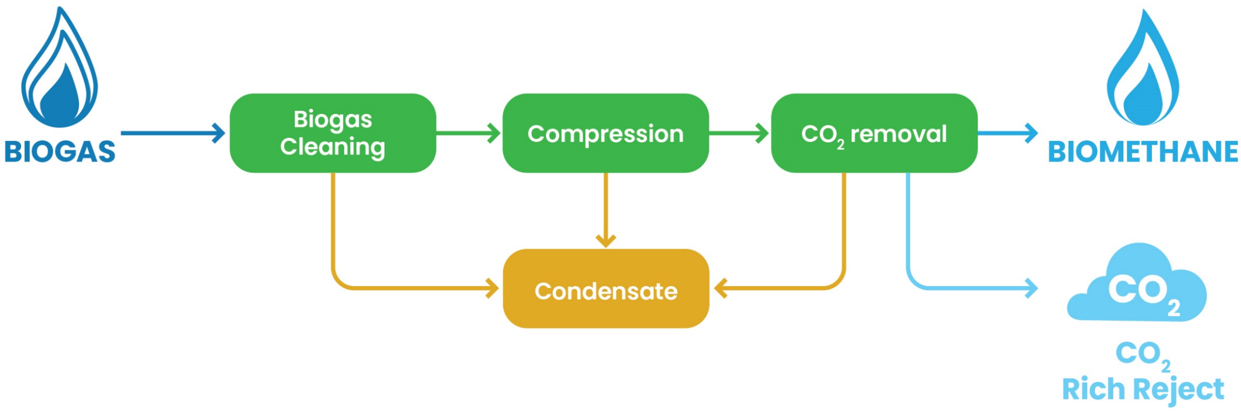

Figure 6-4: Biomethane Upgrading Process

The process outputs from biomethane upgrading include:

- Biomethane;
- Carbon dioxide rich reject gas stream, which can be further treated to produce liquified carbon dioxide;
- Condensate / wastewater.

There is the possibility to further treat the rejected gas stream to capture and liquify the carbon. This is detailed in Section 6.1.4.3.

6.1.4.3 Carbon Dioxide Utilisation

Through the installation of a biomethane upgrading unit, carbon dioxide naturally separates into the reject stream. Capturing the CO_2 involves its transfer in pipework from the upgrading plant to treatment and storage, rather than venting it from a stack to the atmosphere. Technologies focus on cooling, dewatering, purifying, compressing, liquifying and bottling of CO_2. The purification stage can involve cryogenic technology, washing/scrubbing and/or filtration technologies.

While the separation of CO_2 and other contaminants is normally very efficient, the separated CO_2 will typically contain some CH_4, known as 'methane slip'. Methane slip can amount to loss of around 1% of the CH4 present in biogas. Some technologies employ a multi-stage process to recover the methane slip.

- Food Grade CO_2: Proven technology that extracts CO_2 from the biogas generated in an AD plant and purifies it to food grade quality dry ice, which is essential in the transport of perishable products. However, the quality control and verification measures for production of food grade CO_2 from a food waste AD facility (subject to the source, nature, and variability of the food waste) is likely to be much more onerous than from an agricultural feedstock AD facility;

- Methanation: Novel technology where CO_2 is reacted with a H_2 stream (possibly from a green hydrogen facility) to produce synthetic methane.

6.1.5 Techniques for the Control and Prevention of Emissions

The target of biological treatment is to provide for an overall reduction in the environmental impact that might otherwise arise from the waste. However, during the operation of anaerobic treatment plants, emissions and consumption arise, whose existence or magnitude is influenced by the facilities design and operation. This section, therefore, summarises the main environmental issues that arise directly from aerobic biological treatment plants installations and the available techniques to control, reduce, or prevent emissions.

Essentially, the potential emissions from aerobic treatment of waste fall into the following main categories:

- Emissions to air:
  - Fugitive emissions in particular odour, dust and bioaerosols:

    Odour emissions are limited in the case of anaerobic digestion. However, odour emissions may occur from activities such as the handling of waste input, transfer of waste to and from the digester, pre-treatment of waste, handling of the digestate as well as biogas cleaning and conditioning.

    Dust emissions and bioaerosols are generally generated from pre-treatment activities such as shredding and mixing of the organic waste.
  - Gaseous emissions:

    Biogas is a desired product of the anaerobic digestion process. However, fugitive emissions may arise from pressure relief valves, poorly sealed water straps or condensate handling and from methane slips from storage of biogas. 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.
  - Channeled emissions in air of dust, organic compounds, and odorous compounds, including H_2S and NH_3.
- Emissions to water from:
  - Leachate generated as a result of high moisture levels in organic waste:

    During the anaerobic digestion process itself, there is no excess water; however, during the storage, pre-treatment, and finalisation stages (such as cleaning of the biogas), water may be generated. Factors such as the extent of biodegradation of the waste upon arrival and during storage, the moisture content of the feedstock, and the operation settings of the digestor influence the quantity of excess water.
  - Washing water that is used to clean plant/equipment and surfaces and wastewater from run-off water that has fallen on storage and/or treatment areas.
- Noise - the anaerobic digestion process itself is enclosed, thus noise emissions are limited. In the case of aerobic digestion, noise can be generated from aeration and turning devices.
- Energy consumption - the energy sources which are used during the normal operation of anaerobic digestion are electricity, which could be generated on site, and heat, which may be needed for possible drying and/or heating processes and for heating the buildings.

Therefore, in the next paragraphs are presented the best available techniques, as per BAT documents[6], in order to control, reduce and prevent emissions:

- Techniques to reduce odour emissions and to improve the overall environmental performance of the biological treatment;
- Techniques to reduce channelled emissions to air of dust, organic compounds, and odorous compounds, including H_2S and NH_3;
- Techniques to reduce wastewater and water usage.

6.1.5.1 Techniques to Reduce Odour Emissions and to Improve the Overall Environmental Performance

As per BAT document, the best available techniques to reduce odour emissions and to improve the overall environmental performance consists of carrying out the pre-acceptance, acceptance, and sorting of the waste input so as to ensure the suitability of the waste input for the waste treatment in terms of nutrient balance, moisture or toxic compounds which may reduce the biological activity.

Table 6-2: Techniques to Reduce Odour Emissions and to Improve the Environmental Performance

Technique		Description
a	Pre-acceptance/ acceptance and sorting of waste input criteria	- Pre-acceptance procedures may include an operator carrying out up-stream audits on their feedstock suppliers to ensure waste is consistently presented in a manner which is suitable for their waste treatment operation. They may include a limit on the age of the waste by the time it reaches the facility to prevent the acceptance of highly odorous material; - Selection of the waste input to ensure its suitability for the waste treatment, e.g., to enable an appropriate nutrient balance, and to avoid toxic compounds (i.e., toxic in terms of reducing biological activity) entering the treatment plant; - Maximising the quality of the feedstock in line with the treatment.
b	Storage management	- The storage area of organic waste feedstock (non woody) shall be designed with an impermeable surface with a sealed drainage system, to prevent any spillage entering the storage systems or escaping off site. The design prevents the contamination of clean surface water; - The storage area shall be also designed to allow complete emptying and cleaning including drainage to allow appropriate leachate and washing water collection, transfer, and discharge.

[6] Commission Implementing Decision (EU) 2018/1147 of 10 August 2018 establishing best available techniques (BAT) conclusions for waste treatment, under Directive 2010/75/EU and Best Available Techniques Reference Document for Waste treatment, Joint Research Centre (JRC), EC, 2018

Technique		Description
		Other techniques related to the operational stage, such as the residence time, are presented in Section 7.
b	Monitor and/or control the key waste and process parameters	- Ensure a stable digester operation; - Minimise operational difficulties, such as foaming, which may lead to odour emissions; - Provide sufficient early warning of system failures which may lead to a loss of containment and explosions. This includes the monitoring and/or control of key waste and process parameters including the following: - pH and alkalinity of the digestor feed; - Digester operating temperature; - Hydraulic and organic loading rates of the digester feed; - Concentration of volatile fatty acids (VFA) and ammonia within the digester and digestate; - Biogas quantity, composition, and pressure; - Liquid and foam levels in the digester. In addition, operators should monitor for the signs of grit build-up in the bottom of digesters and have an appropriate de-sludging programme.

6.1.5.2 Techniques to Reduce Channelled Emissions

The AD process itself is enclosed but emissions to air, including odour emissions, can occur for example from:

- Handling of waste input;
- Transfer to and from the digester;
- Open storage;
- Separation, pre-treatment and mixing of waste (e.g., with digestate);
- Open reactors or tanks;
- Digestate conditioning;
- Biogas cleaning and conditioning;
- Post-treatment.

The principal gaseous emission (methane) is a desired product of the AD process, which, used as a renewable energy source, is a source of revenues and reduces greenhouse gas emissions.

However, fugitive emissions of biogas can arise from pressure relief valves, poorly sealed water traps or condensate handling and from methane slip from storage of biogas. 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.

In order to reduce channelled emissions to air of dust, organic compounds, and odorous compounds, including H_2S and NH_3, BAT is to use one or a combination of the techniques given below.

Table 6-3: Techniques to Reduce Channelled Emissions to Air

Technique		Typical pollutants abated relevant to anerobic biological treatment	Description
a	Adsorption	Volatile organic compounds, hydrogen sulphide, odorous compounds	- Typical adsorbents include granular activated carbon, zeolites, microporous polymer particles, silica gel, sodium-aluminium silicate. The most common adsorbent is granular activated carbon. - The application of adsorption includes: o the recovery of VOCs (raw material, product, solvent, etc.) for reuse or recirculation; o the abatement of pollutants (hazardous substances that cannot be recirculated or otherwise used; o its use as a guard filter after final treatment facilities. - Adsorption is a heterogeneous reaction in which gas molecules are retained on a solid or liquid surface that prefers specific compounds to others and thus removes them from effluent streams. When the surface has adsorbed as much as it can, the adsorbent is replaced, or the adsorbed content is desorbed. When desorbed, the contaminants are usually at a higher concentration and can either be recovered or disposed of.
b	Biofilter	Ammonia, hydrogen sulphide, volatile organic compounds, odorous compounds	- The waste gas stream is passed through a bed of organic material (such as peat, heather, compost, root, tree bark, softwood, and different combinations) or some inert material (such as clay, activated carbon, and polyurethane), where it is biologically oxidised by naturally occurring microorganisms into carbon dioxide, water, inorganic salts, and biomass. - A biofilter is designed considering the type(s) of waste input. An appropriate bed material, e.g., in terms of water retention capacity, bulk density, porosity, structural integrity, is selected. Also important are an appropriate height and surface area of the filter bed.

	Technique	Typical pollutants abated relevant to anerobic biological treatment	Description
			The biofilter is connected to a suitable ventilation and air circulation system in order to ensure a uniform air distribution through the bed and a sufficient residence time of the waste gas inside the bed. - A pre-treatment of the waste gas before the biofilter (e.g., with a water or acid scrubber) may be needed in the case of a high NH_3 content (e.g., 5– 40 mg/Nm3) in order to control the media pH and to limit the formation of N_2O in the biofilter. Some other odorous compounds (e.g., mercaptans, H_2S) can cause acidification of the biofilter media and necessitate the use of a water or alkaline scrubber for pre-treatment of the waste gas before the biofilter.
d	Thermal oxidation	Volatile organic compounds	The oxidation of combustible gases and odorants in a waste gas stream by heating the mixture of contaminants with air or oxygen to above its auto-ignition point in a combustion chamber and maintaining it at a high temperature long enough to complete its combustion to carbon dioxide and water.
e	Wet Scrubbing	Dust, volatile organic compounds, gaseous acidic compounds (alkaline scrubber), gaseous alkaline compounds (acid scrubber)	The removal of gaseous or particulate pollutants from a gas stream via mass transfer to a liquid solvent, often water or an aqueous solution. It may involve a chemical reaction (e.g., in an acid or alkaline scrubber). In some cases, the compounds may be recovered from the solvent. Water, acid, or alkaline scrubbers are used in combination with a biofilter, thermal oxidation or adsorption on activated carbon.
f	Segregation of the Waste gas streams	-	Splitting of the total waste gas stream into waste gas streams with a high pollutant content and waste gas streams with a low pollutant content.
g	Recirculation of waste gas	-	Recirculation of waste gas with a low pollutant content in the biological process followed by waste gas treatment adapted to the concentration of pollutants. The use of waste gas in the biological process may be limited by the waste gas temperature and/or the pollutant content. It may be necessary to condense the water vapour contained in the waste gas before reuse. In this case, cooling is necessary, and

Technique		Typical pollutants abated relevant to anerobic biological treatment	Description
			the condensed water is recirculated when possible or treated before discharge.

6.1.5.3 Techniques to Reduce Water and Water Usage

Although anaerobic systems can be operated in stages to reduce the overall COD in the effluent, they are generally operated for efficient methane production, and the liquid effluent thus tends to be more concentrated than the effluent from aerobic systems. During the AD process itself, there is no excess water; however, during storage, pre- and post-treatment, and side activities (like cleaning or condensation from biogas) this can be important. Run-off water can be collected and used in the AD process or for composting plants.

In order to reduce the generation of wastewater and to reduce water usage, BAT is to use all of the techniques presented in table.

Table 6-4: Techniques to Reduce Wastewater and Water Usage

Technique		Description
a	Segregation of water streams	- Leachate is segregated from surface run-off water and washing water.
b	Water recirculation	- Recirculating process water streams or using as much as possible other water streams (e.g., water condensate, rinsing water, surface run-off water). The degree of recirculation is limited by the water balance of the plant, the content of impurities (e.g., heavy metals, salts, pathogens, odorous compounds) and/or the characteristics of the water streams (e.g., nutrient content).
c	Minimisation of the generation of leachate	- Optimising the moisture content of the waste in order to minimise the generation of leachate.

6.2 Aerobic Digestion

6.2.1 Process Description

This section presents the general aerobic digestion process and the minimum design requirements of each phase of the process, followed by a more detailed description of open-air windrow composting and enclosed systems (IVC).

Performing this process in a controlled environment enables the air flow, moisture, and temperature of the composting process to be monitored and optimised. This control reduces the duration of the composting process and delivers a consistent and biologically stable compost material.

Feed and output stream

Some examples of suitable input materials are vegetable, garden and fruit waste, vegetable waste from agriculture, vegetable waste from the food sector, trimmings, clippings, shredded wood, digestate, etc.

For decomposition to take place in the shortest possible time, input materials must be a mixture of easily degradable, wet organic substances and structure-improving organic matter. Moisture content is important to maintain microorganism activity; low moisture content can lead to microorganisms becoming dormant. If the moisture content becomes too high the porosity of materials is reduced and anaerobic conditions can flourish within the composting material.

The output of the plants is mainly compost (fresh or mature), but also fuel.

Aerobic digestion process

The aerobic digestion process (generally applicably for both open and enclosed aerobic digestion systems) typically involves four main steps such as:

1) Reception;
2) Preparation (Pre-treatment phase);
3) Composting (Treatment phase); and
4) Finalisation (Post-Treatment phase).

Reception

The composting process begins with the delivery of the organic waste to the reception area, where the characteristics (type of organic waste, source segregated or mixed, etc) of the waste through visual inspection and weight of the waste by use of a scale will be recorded.

The design of the reception area (e.g., way of discharging the feedstock, encapsulation of the reception area) depends on the type of substrate, on air pollution control, and on hygiene requirements. Flat or recessed bunkers and tanks provide a buffer.

Preparation (Pre-treatment phase)

The pre-treatment phase is used to optimize the material characteristics of the waste, such as C/N ratio, moisture content and structure, as well as to remove contaminants and reduce obstructive materials that could hinder the composting process. Equipment, which is generally used include tipping floors, front end loaders, bag openers, shredders, screw mills, mixing drums, screens, magnetic separators, grinding equipment, centrifuges for dewatering, etc.

The preparation stage of the feedstock for the composting process involves:

- The manual removal of larger, visible contaminants such as plastic bags, metal items and large items such as tree stumps that cannot be processed;
- Shredding - source segregated green waste from landscaping activities may require shredding or pulverisation. However, source segregated food waste may require a greater degree of pre-processing to remove contaminants and poorly segregated wastes. Mixing of different types of organic waste can also be undertaken. Shredders are fed by wheel loader, crane, and other conveying systems, or by means of belt and auger conveyors. Depending on the feedstock, the shredding can take place either before or after the sorting step;
- Automatic sorting and homogenising - drum screens are frequently used to classify and homogenise material. When necessary, metals, plastic, and other non-biodegradable materials are removed, by means of magnetic and eddy current separators and air classifiers respectively. Once the organic fraction is separated, it may also undergo shredding or pulverisation to give a size range between 1 and 10 cm^2, depending on the type of waste. The composting process can then begin.

Composting (Treatment phase)

Based on the evolution in the microbial activity and the corresponding temperatures, the composting phase can be divided into two sub-phases: a first, high-rate decomposition phase or intensive composting and a second, slow rate decomposition phase, also known as maturation:

- The first stage, intensive decomposition, occurs during the first two to three weeks of the process, when the degradation curve is very steep. Most of the emissions are linked to this phase: aerobic degradation releases carbon dioxide, water, ammonia, and heat. The temperature of the rotting material climbs to up 70 °C in the pile, giving rise to a greater release of odorous compounds;

  To keep temperatures below this point, it is essential to ensure aeration across the organic matter. Oxygen availability is crucial to maintain aerobic degradation and for preventing the formation of anaerobic zones releasing methane. Furthermore, the aeration system simultaneously removes heat and moisture from the windrow. In windrow composting, this is done by turning the organic matter, either manually or with the use of a machine. In aerated static pile composting, this is done through perforated pipes. In in-vessel composting, aeration is controlled.

- The second stage is the maturation phase. Here, temperatures decline and stabilise, and mesophilic bacteria reappear to decompose the remaining organic materials and convert them to biologically stable humic substances, the mature compost. Lignin and cellulose are resistant to degradation and therefore make up the bulk of the finished compost product;

  The duration of the intensive phase and the maturation phase varies in function of the composting system. Windrow and static pile systems are comparable in process time, while more complex composting systems (in-vessel composting systems, etc.) or composting systems with higher turning frequencies are characterised by a shorter duration, as shown in Table *6-5*.

Table 6-5: Duration of Some Industrial Composting Processes[3]

Example	Preliminary Phase	Stabilisation Phase
Windrow Composting System	3 – 9 weeks depending on the type of material and frequency of turning	-

Example	Preliminary Phase	Stabilisation Phase
Aerated Static Pile Composting System	3 – 5 weeks	-
Windrow Composting System Covered with GORE Cover System (Central Europe)	8 weeks	
Windrow Composting System Covered with GORE Cover System (South Europe)	6 weeks	
Closed Hall Windrow Composting System (WIPS – Belgium)	8 weeks	Some additional weeks
Tunnel Composting	7 – 21 days	4 – 8 weeks (composting in piles)
Automated In-Vessel Composting System (Laois Council Canteen Composting Programme – Ireland)	2 weeks	4-6 weeks

Finalisation

The final step in a composting plant is the finalisation of the product, the compost. When required, the compost is sent to a final treatment, where size classification and removal or any remaining impurities (such as glass, plastics, metals) through drum screens, air classifiers and metal separators is undertaken.

Compost can be used as soil amendment, fertilizer, mulch, etc. The most common markets are agriculture and horticulture. The amount of produced compost will vary in function of the input material. When 1000 kg of vegetable, garden and fruit waste is composted, approximately 350 – 420 kg compost will be obtained at the end of the process.

In order to ensure the good quality of compost, national standards for compost are recommended to be established.

6.2.2 Factors Affecting the Composting Process

6.2.2.1 Material Characteristics

Composting is a microbial-driven process. Bacteria constitute 80 – 90% of the microorganisms; the remaining microorganisms include fungi, yeast, mould, centipede, and moulds. The properties of the feedstock of the composting process can affect the efficiency of degradation of the organic matter by the microorganisms. Therefore, several operational parameters must be considered in the composting process to provide the right environment for the microorganisms to survive and thrive to ensure the success of the composting process. These are as follows:

- C:N – At lower ratios, there is a surplus of nitrogen which can be lost to the atmosphere as ammonia gas and cause odours. At higher ratios, the microorganisms will deplete the nitrogen and use it for their own metabolic needs, slowing the degradation process of the organic matter. The ideal ratio ranges from 25:1 – 35:1;
- Particle size – Particle size of feedstock impacts the porosity and consequently the airflow in the compost pile, influencing the oxygen level which is key for the microbial activity. Porosity is defined as the total volume of pores divided by the total volume of compost. Pores are filed with air and water. During the composting process, the volume of the pile is often reduced by compaction, thereby reducing the pore and consequently the airfield porosity, restricting the airflow in the pile and oxygen level. It is therefore recommended to have an airfield porosity of 45 – 60%. It should be noted that porosity can be increased by adding materials such as branches and hard fruits shells (these are called bulking materials);
- Moisture content – The ideal moisture content is 45 – 60% by weight. Low moisture content will slow the composting process as microorganisms need a moist environment. However, a moisture content > 60%, means that the pore spaces will be filled with water as opposed to air, leading to anaerobic conditions, under which oxygen is depleted, bad odours arise and methane, a greenhouse gas, is generated;
- Ph – Bacterial microorganisms prefer pH of 6 – 7.5, while fungi prefer 5.5 – 8. Optimal pH ranges from 6.5 – 8. However, it should be noted that gaseous losses of ammonia are more likely to occur when pH > 7.5. While it is difficult to control pH, certain materials such as lime, potassium carbonate and daily manure can raise pH, while food processing wastes and decomposed tree leaves can reduce pH;
- Temperature – Higher temperatures result in faster breakdowns; however, excessively high temperatures can inhibit microbial activity. Thermophilic temperatures (approximately 40 – 70ºC) are the most effective for composting, with an optimal range of 55 - 65ºC. Temperatures can be adjusted through aeration, as well as changing pile moisture contents and pile sizes.

6.2.2.2 Oxygen supply

A continuous and homogeneous supply of oxygen is required to ensure overall aerobic conditions. In windrow composting, this is done by turning the organic matter, either manually or with the use of a machine. In aerated static pile composting, this is done through perforated pipes. In in-vessel composting, aeration is controlled. Ideal oxygen concentrations in the compost pile are more than 10%.

6.2.3 Composting methods

6.2.3.1 Windrow Composting

Windrow composting is a simple method with low investment costs and a low level of process control. In this method the waste is piled in triangular or rectangular heaps, which are turned to enhance aeration and *homogenization as shown in* Figure 6-5 *and*

Figure 6-6. The need of turning can be reduced by installing air piping under the pile, providing passive aeration or aeration by over- or under pressure. The windrows can be placed in open air or in a closed hall.

When windrow composting is used for the treatment of food waste, it is recommended to be performed in closed halls, in order to control the effluents and odours, which are released during the intensive phase. For the maturation phase, open air and roofed windrow systems are widely used, as its requirements for aeration, moistening and air control are less stringent.

Figure 6-5: Open Air Windrow Composting Process

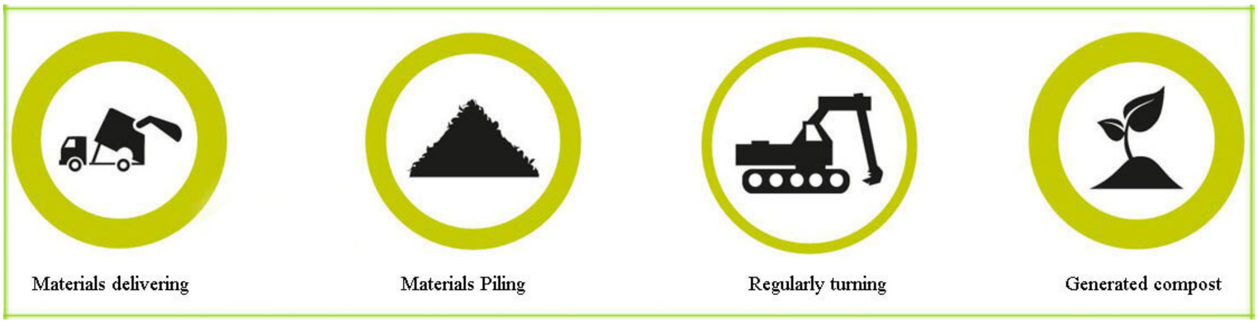

Figure 6-6: Example of Open-Air Windrow Composting at Al Ain Composting Facility

6.2.3.2 In Vessel Composting

In Vessel Composting (IVC) refers to composting process that take place in a controlled environment, which can include:

- Vessels;
- Tunnels;
- Enclosed bays;
- Enclosed hall;
- Rotating drums.

As detailed in Section 6.2, the feedstock, after being received at the facility, will undergo preparation in the form of pre-treatment. Pre-treatment is dependent on the feedstock and is performed to homogenise the feedstock (in both size and consistency) and remove contaminants.

To ensure all organic matter is broken down with no localised un-composted areas, all the aforementioned composting processes will have a mechanism to turn the compost, the mechanism depending on the type of IVC. This stage of the composting process is the intensive composting process and takes between 1 and 3 weeks. Intensive decomposition is performed in an enclosed space with forced aeration that captures all exhaust air. Fresh compost is typically produced once the intensive decomposition stage ends. The compost is screened to remove oversize material which can be shredded and fed back into the start of the intensive composting process.

The screened material is generally moved to a large, enclosed area, again with forced ventilation to draw air through the compost pile. This is the maturation stage of the compost, which lasts between 6 to 12 weeks, where the compost is turned periodically and allowed to stabilise. There is a final screening stage after maturation to size grade the compost to suit the intended end uses and also to remove any unwanted materials such as stones and glass.

The air used in forced aeration of the intensive and maturation phases is discharged through a cleaning system to remove odour and dust, which is typically a bio-filter and in some instances a scrubber for removal of ammonia.

Process outputs can be summarised as follows:

- Compost, which may be used as a soil improver depending on feedstock and local land spreading regulations;
- Wastewater;
- Air emissions from the biofilter;
- Reject material separated in the pre and post treatment stages.

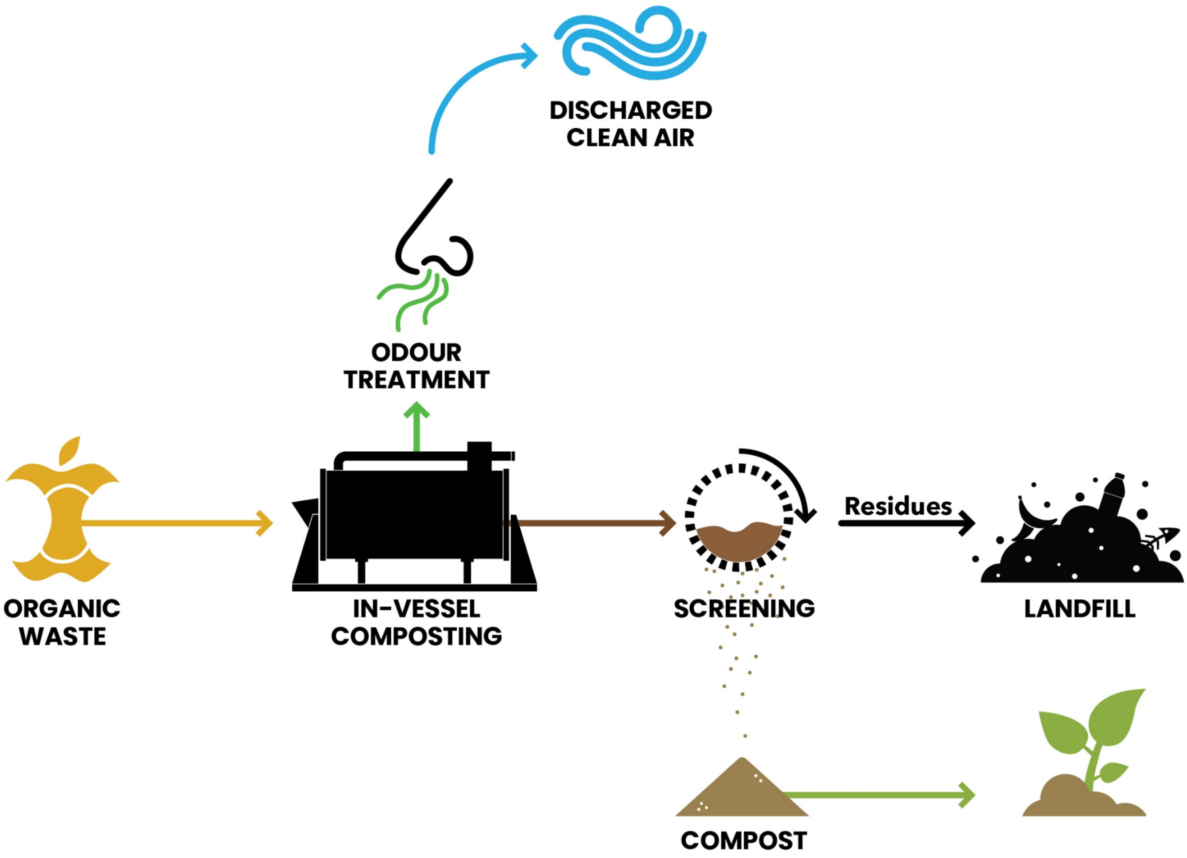

Figure 6-7: Typical IVC Process

Figure 6-8: Example of In-Vessel Composter – B1400 Rocket Composter

6.2.4 Techniques for the Control and Prevention of Emissions

Similar to the anaerobic treatment of waste, during the operation of aerobic treatment of waste, emissions and consumption arise, whose existence or magnitude is influenced by the facilities design and operation. This section, therefore, briefly, summarises the main environmental issues that arise directly from aerobic biological treatment plants installations and the available techniques to control, reduce, or prevent emissions.

The potential emissions from aerobic treatment of waste fall into the following main categories:

- Emissions to air:
  - Fugitive emissions in particular odour, dust and bioaerosols;
  - Channelled emissions in air of dust, organic compounds, and odorous compounds, including H_2S and NH_3.
- Emissions to water from:
  - Leachate generated as a result of high moisture levels in organic waste and from natural precipitation seeping through the compost piles (in the case of open composting plants);
  - wastewater from run-off water that has fallen on storage and/or treatment areas, and of washing water that is used to clean plant/equipment and surfaces.

    Note: Run-off water from roofs or from areas that are not used for storing and treating waste are considered 'clean' water and may be discharged directly to the environment or can be used to keep the waste moist, for vehicle cleaning and hygiene
- Noise caused by aeration and turning devices;
- Energy consumption;

Therefore, in the next paragraphs are presented the best available techniques, as per BAT documents, in order to reduce emissions and to

- Techniques to reduce odour emissions and to improve the overall environmental performance of the biological treatment;
- Techniques to reduce diffuse emissions to air;
- Techniques to reduce channelled emissions to air of dust, organic compounds, and odorous compounds, including H_2S and NH_3;
- Techniques to reduce wastewater and water usage.

6.2.4.1 Techniques to reduce odour emissions and to improve the overall environmental performance

As per BAT document, the best available techniques to reduce odour emissions and to improve the overall environmental performance consists of carrying out the pre-acceptance, acceptance, and sorting of the waste input so as to ensure the suitability of the waste input for the waste treatment in terms of nutrient balance, moisture or toxic compounds which may reduce the biological activity.

Table 6-6: Techniques to Reduce Odour Emissions and to Improve the Environmental Performance

Technique		Description
a	Pre-acceptance/ acceptance and sorting of waste input criteria	- Pre-acceptance procedures may include an operator carrying out up-stream audits on their feedstock suppliers to ensure waste is consistently presented in a manner which is suitable for their waste treatment operation. They may include a limit on the age of the waste by the time it reaches the facility to prevent the acceptance of highly odorous material; - Selection of the waste input to ensure its suitability for the waste treatment, e.g., to enable an appropriate nutrient balance, and to avoid toxic compounds (i.e., toxic in terms of reducing biological activity) entering the treatment plant; - Maximising the quality of the feedstock in line with the treatment. Techniques include: o ensure the right balance of the nutrient content (e.g., N/C); o minimise the presence of toxic and unwanted materials; o minimise the presence of non-biodegradable components in the feedstock.
b	Storage management	- The storage area of organic waste feedstock (non woody) shall be designed with an impermeable surface with a sealed drainage system, to prevent any spillage entering the storage systems or escaping off site. The design prevents the contamination of clean surface water; - The storage area shall be also designed to allow complete emptying and cleaning including drainage to allow appropriate leachate and washing water collection, transfer, and discharge. Other techniques related to the operational stage, such as the residence time, are presented in Section 7.

	Technique	Description
c	Monitor and/or control the key waste and process parameters	- Monitoring and/or control of key waste and process parameters, including: o Waste input characteristics (e.g., C to N ratio, particle size); o Temperature and moisture content at different points in the windrow; o Aeration of the windrow (e.g., via the windrow turning frequency, O_2 and/or CO_2 concentration in the windrow, temperature of air streams in the case of forced aeration); o Windrow porosity, height, and width. - Monitoring of the moisture content in the windrow is not applicable to enclosed processes when health and/or safety issues have been identified. In that case, the moisture content can be monitored before loading the waste into the enclosed composting stage and adjusted when it exits the enclosed composting stage.

6.2.4.2 Techniques to reduce diffuse emissions to air

In the case of open systems, the emissions to air are diffuse emissions. As there are no abatement techniques, the process management aiming at the minimisation of emissions to air in particular of odour, dust and bioaerosols, as well as the selection of a suitable location for the composting plant are essential.

The following activities/events can generate dust and/or bioaerosols and odour:

- Vehicle and equipment movement around the site;
- Shredding of feedstock or bulking materials;
- Formation and turning of compost piles/windrows and filling of vessels;
- Forced aeration of outdoor windrows without covers;
- Screening of finished compost;
- Spraying of leachate when it is reused in the composting process, in particular when sprinklers are used (resulting primarily in the generation of bioaerosols;
- Strong wind.

Specific management measures to reduce dust, odour and bioaerosol emissions are listed below. These control measures are covered by a facility's diffuse emissions management plan, unless evidence is provided that these measures are not feasible, effective, or useful in a specific situation.

Table 6-7: Techniques to Reduce Diffuse Emissions

	Technique	Description
a	Use of semipermeable	- Active composting windrows are covered by semipermeable membranes which is a method of treating emissions, such as odours, ammonia, VOCs, dust and bioaerosols;

Technique		Description
	membrane covers	- 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 a liquid condensate layer being 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. Following the force of gravity, droplets are formed and drip off thus maintaining a steady exchange with unsaturated water which in turn ensures the odour retention capability. Another important function of the semipermeable membrane cover as a system component is to provide for optimum moisture management during the biological treatment processes.
b	Adaptation of operations to the meteorological condition	- Taking into account weather conditions and forecasts when undertaking major outdoor process activities. For instance, avoiding formation or turning of windrows or piles, screening or shredding in the case of adverse meteorological conditions in terms of emissions dispersion (e.g., the wind speed is too low or too high, or the wind blows in the direction of sensitive receptors); - Orientating windrows, so that the smallest possible area of composting mass is exposed to the prevailing wind, to reduce the dispersion of pollutants from the windrow surface. The windrows and piles are preferably located at the lowest elevation within the overall site layout.

6.2.4.3 Techniques to Reduce Channelled Emissions

In order to reduce channelled emissions to air of dust, organic compounds, and odorous compounds, including H2S and NH3, BAT is to use one or a combination of the techniques given below.

Table 6-8: Techniques to Reduce Channelled Emissions to Air

Technique		Typical pollutants abated relevant to aerobic biological treatment	Description
a	Adsorption	Volatile organic compounds,	- Typical adsorbents include granular activated carbon, zeolites, microporous polymer particles, silica gel,

	Technique	Typical pollutants abated relevant to aerobic biological treatment	Description
		hydrogen sulphide, odorous compounds	sodium-aluminium silicate. The most common adsorbent is granular activated carbon; - The application of adsorption includes: o the recovery of VOCs (raw material, product, solvent, etc.) for reuse or recirculation; o the abatement of pollutants (hazardous substances that cannot be recirculated or otherwise used; o its use as a guard filter after final treatment facilities. - Adsorption is a heterogeneous reaction in which gas molecules are retained on a solid or liquid surface that prefers specific compounds to others and thus removes them from effluent streams. When the surface has adsorbed as much as it can, the adsorbent is replaced, or the adsorbed content is desorbed. When desorbed, the contaminants are usually at a higher concentration and can either be recovered or disposed of.
b	Biofilter	Ammonia, hydrogen sulphide, volatile organic compounds, odorous compounds	- The waste gas stream is passed through a bed of organic material (such as peat, heather, compost, root, tree bark, softwood, and different combinations) or some inert material (such as clay, activated carbon, and polyurethane), where it is biologically oxidised by naturally occurring microorganisms into carbon dioxide, water, inorganic salts, and biomass; - A biofilter is designed considering the type(s) of waste input. An appropriate bed material, e.g., in terms of water retention capacity, bulk density, porosity, structural integrity, is selected. Also important are an appropriate height and surface area of the filter bed. The biofilter is connected to a suitable ventilation and air circulation system in order to ensure a uniform air distribution through the bed and a sufficient residence time of the waste gas inside the bed; - A pre-treatment of the waste gas before the biofilter (e.g., with a water or acid scrubber) may be needed in the case of a high NH_3 content (e.g., 5– 40 mg/Nm3) in order to control the media pH and to limit the formation of N_2O in the biofilter. Some other odorous compounds

	Technique	Typical pollutants abated relevant to aerobic biological treatment	Description
d			(e.g., mercaptans, H_2S) can cause acidification of the biofilter media and necessitate the use of a water or alkaline scrubber for pre-treatment of the waste gas before the biofilter.
d	Thermal oxidation	Volatile organic compounds	The oxidation of combustible gases and odorants in a waste gas stream by heating the mixture of contaminants with air or oxygen to above its auto-ignition point in a combustion chamber and maintaining it at a high temperature long enough to complete its combustion to carbon dioxide and water.
e	Wet Scrubbing	Dust, volatile organic compounds, gaseous acidic compounds (alkaline scrubber), gaseous alkaline compounds (acid scrubber)	The removal of gaseous or particulate pollutants from a gas stream via mass transfer to a liquid solvent, often water or an aqueous solution. It may involve a chemical reaction (e.g., in an acid or alkaline scrubber). In some cases, the compounds may be recovered from the solvent. Water, acid, or alkaline scrubbers are used in combination with a biofilter, thermal oxidation or adsorption on activated carbon.
f	Segregation of the Waste gas streams		Splitting of the total waste gas stream into waste gas streams with a high pollutant content and waste gas streams with a low pollutant content.
g	Recirculation of waste gas		Recirculation of waste gas with a low pollutant content in the biological process followed by waste gas treatment adapted to the concentration of pollutants. The use of waste gas in the biological process may be limited by the waste gas temperature and/or the pollutant content. It may be necessary to condense the water vapour contained in the waste gas before reuse. In this case, cooling is necessary, and the condensed water is recirculated when possible or treated before discharge.

6.2.4.4 Techniques to Reduce Water and Water Usage

Generally, there are three main sources of wastewater resulting from the operation of the composting treatment plants:

- Leachate seeping from composting piles and windrows, with a high content of organic substances, which has the potential to cause eutrophication in surface water, groundwater and flora and can cause soil contamination. It also has a high potential for generating odours;
- Washing water that is used to clean plant/equipment and surfaces; and
- Surface run-off water that has fallen on storage and/or treatment areas and might be contaminated.

  Run-off water from roofs or from areas that are not used for storing and treating waste are considered 'clean' water and may be discharged directly to the environment or can be used to keep the waste moist, for vehicle cleaning and hygiene.

In order to reduce the generation of wastewater and to reduce water usage, BAT is to use all of the techniques presented in Table *6-9*.

Table 6-9: Techniques to Reduce Wastewater and Water Usage

Technique		Description
a	Segregation of water streams	- Leachate is segregated from surface run-off water and washing water.
b	Water recirculation	- Recirculating process water streams or using as much as possible other water streams (e.g., water condensate, rinsing water, surface run-off water). The degree of recirculation is limited by the water balance of the plant, the content of impurities (e.g., heavy metals, salts, pathogens, odorous compounds) and/or the characteristics of the water streams (e.g., nutrient content).
c	Minimisation of the generation of leachate	- Optimising the moisture content of the waste in order to minimise the generation of leachate.

Further considerations:

- The biological waste treatment plants shall be designed with a sufficient capacity for collection and storage of dirty run-off, leachate and washing water (dirty waters);
- The generation of wastewater is minimised, recirculated and the excess collected and pre-treated/treated on site before being discharged to the natural water bodies/ centralised sewage system;
- Wastewater 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 provided the dirty waters do not contain a significant amount of contaminants that may compromise the quality of the compost produced;
- The appropriate dimensioning of the intermediate wastewater tank(s) takes 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;

- The impermeable area covers 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 cuttings), straw, or similar biologically inactive, 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 feedstocks are mixed, with the exception of the area where woody materials (tree and bush cuttings) only are shredded;

    - The active decomposition area and maturation, irrespective of whether it is roofed or not;

    - The storage area for matured compost with any possible exception to be approved by the centre and taking into account at least: i) local precipitation; ii) ground and surface water protection; iii) coverage by a water-repellent fleece or roof.

- All storage and treatment areas allow for the controlled drainage of all liquids to avoid waterlogging at the window or feedstock base. This is achieved by constructing the composting pad on a slope to avoid water stagnating. The minimum slope of the site is determined by the windrow height, the annual precipitation, the existence of roofing, the method of aeration and the presence of drainage/aeration tubes.

7 OPERATIONAL REQUIREMENTS AND MAINTENANCE

The following sections includes a series of techniques applicable to all biological treatment plants in order to improve the overall performance based on Best Available Techniques (BAT), including:

- Waste pre-acceptance procedures;
- Waste acceptance;
- Waste storage and handling procedures;
- Facility and Equipment Maintenance;
- Output Management.

7.1 Waste Pre-Acceptance

Waste pre-acceptance procedures aim to ensure the technical (and legal) suitability of waste treatment operations for a particular waste prior to the arrival of the waste at the plant.

The waste pre-acceptance procedure requires the following in writing or in electronic form prior to the arrival of the waste at the facility:

- Details of the waste producer including their organisation name, address and contact details;
- A description of the waste;
- The waste's List of Wastes Regulations code;
- The source of the waste;
- The waste's composition (based on representative samples if necessary); and
- An estimate of the quantity you expect to receive in each load and in a year.

Verification of the written information provided may be required, and this may require contact with or a visit to the producer. Additional factors may become apparent when dealing with staff directly involved in the waste production.

Pre-acceptance procedures may also include waste sampling and waste characterisation in order to understand the composition of the waste.

7.2 Waste Acceptance

Acceptance procedures aim to confirm the characteristics of the waste, as identified in the pre-acceptance stage. These procedures define the elements to be verified upon the arrival of the waste at the plant as well as the waste acceptance and rejection criteria. They may include waste sampling, inspection, and analysis.

The waste acceptance procedure provides details of the following steps which are undertaken by operators when the waste arrives at the facility. It also takes into consideration the objectives of the treatment.

Acceptance:

- Other than in an emergency, the operator only receives onto the site prebooked wastes that have been adequately pre-accepted and that are consistent with the pre-acceptance information;
- All wastes are checked and verified against pre-acceptance information and transfer documentation before being received on site;
- The operator sets out and follows clear and unambiguous criteria for the rejection of wastes;
- Waste is only received and accepted under the supervision of a suitably qualified person;
- All transfer documentation is checked and validated;
- The operator ensures that the facility has the necessary capacity to receive the waste for all storage areas (quarantine, reception, general and bulk) and treatment processes. Wastes are not received if the capacity is not available.

Sampling:

Other than some wastes such as solid municipal non-hazardous waste (including green waste and food waste), all waste, bulk or containerised, are representatively sampled and undergo verification and compliance testing. Reliance solely on the written information supplied is not sufficient.

- A representative sample is one that takes account of the full variation and any partitioning of the load such that worst case scenarios are accounted for;
- Sampling takes place on site under the supervision of the site's qualified staff. Where the driver arrives at the site with a sample taken elsewhere, there is a full risk assessment to check that the sample is representative, reliable and was only taken for specific health or safety purposes (for example, air- or water-reactive wastes);
- A record of the sampling regime, process and justification is maintained in the computerised waste process control system;
- Acceptance samples are retained on site for an appropriate amount of time (e.g., 2 days) after the waste has been treated or removed from the facility including all residues from its treatment.

Inspection and analysis:

- The tests required for verification purposes at acceptance (for example, metal content, total petroleum hydrocarbons, colour, pH, and odour) are listed in the computerised waste process control system. If visual inspection is not feasible (e.g., for occupational safety reasons), the compliance of the waste input is checked by analytical equipment (e.g., viscometry, infrared, chromatography, mass spectrometry), laboratories and adequate human resources;
- Analysis of waste is carried out by a laboratory with suitably recognised test methods.

Reception:

Selection of the waste input to ensure its suitability for the waste treatment, e.g., to enable an appropriate nutrient balance, and to avoid toxic compounds (i.e., toxic in terms of reducing biological activity) entering the biological systems. A key technical factor for selecting the appropriate system is its capability to provide proper contact between the organic constituents of the waste and the microbial population. Important features, for consideration, of the selected biological system are the uniform distribution of the nutrients and the moisture of the waste to be treated (homogeneity) as well as the availability of the treatment selected.

As with waste pre-acceptance procedures, waste acceptance procedures are also risk- based considering, for example, the hazardous properties of the waste, the risks posed by the waste in terms of process safety, occupational safety, and environmental impact, as well as the information provided by the previous waste holder(s).

7.3 Organic Waste Storage

The following are requirements for the management and optimisation of the storage of putrescible waste input:

- 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 washing water collection, transfer, and discharge into gullies via a sump for use within the process, discharge into sewers where required, tankering to a Wastewater Treatment Plant (WWTP) or other authorised waste treatment plant or use on land where this is allowed;
- Some input woody materials (bulky bush and tree cuttings) are stored in a dedicated area for blending with other incoming bio-wastes and sludges. These are stored in such a way as to mitigate fugitive emissions and fires;
- The level of protection measures is proportional to the risk of surface water and/or groundwater pollution. All storage areas for putrescible, non-woody feedstock have an impermeable surface with a sealed drainage system, to prevent any spillage entering the storage systems or escaping off site. The design prevents the contamination of clean surface water;
- 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 time is minimised;
- Depending on the feedstock type (C:N ratio, degradability, etc.), the capacity for optimal residence time for feedstock material stored prior to processing is an important factor in a site's potential for odour generation. Untreated and improperly mixed material can increase the generation of odours. The separate storage of different waste types may be useful to create specified compost products;
- Storage of putrescible wastes is preferably carried out in an enclosed area. If not:
  - Freshly delivered grass and leaves are treated (‘treated’ can also mean mixed, covered, or made silage, etc.) within a maximum of 72 hours;
  - Other putrescible wastes (e.g., food waste, kitchen waste, waste from the food industry) are treated (‘treated’ can also mean mixed, covered, or made silage, etc.) within a maximum of 24 hours.
- When enclosed buildings are used, fast-acting doors are provided for access and egress for delivery and other vehicles, or other adequate measures are taken to minimise diffuse emissions from offloading areas (e.g., air curtain). Buildings are sized so that offloading can be carried out within the building with the doors shut. This can be helped by the insertion of sensor-controlled rolling shutter gates or flap gates and by sufficient dimensioning of the manoeuvring area in front of the hall. It needs to be recognised that the discipline of the hall and vehicle fleet staff is at least equally important to actually realise the short opening times. For an underground bunker, which the vehicles approach backwards and then tip their load into, the installation of a curtain with the vehicle outline behind the actual door may be a way to minimise air exchange during unloading as far as possible;

- Where the waste storage area is required to be in an enclosed building, it includes a building ventilation system and an emission abatement system that maintain the building under negative air pressure in order to minimise fugitive odour and dust releases from the building. Exhaust air is captured and can be reused to aerate the composting piles before discharge and treatment;
- In the case of intermediate storage of source-separated green waste and food waste from households (in countries where this is allowed outdoors), physical protection against wind drifting of light fractions (contaminants such as plastics) is installed (fences, walls, fleece coverage) or they are removed from the surface.

7.4 Output Management

This technique involves setting up and implementing an output quality management system, so as to ensure that the output of the waste treatment is in line with the expectations. While there may be a demand for compost, the reality is that farmers may refrain from buying the compost resulting from the biological treatment processes, even if they do require it, due to low confidence levels in the quality of compost / digestate produced. Therefore, the implementation of an output management system allows the performance of the waste treatment to be monitored and optimised, and for this purpose may include a material flow analysis of relevant components throughout the waste treatment. The use of a material flow analysis is risk-based considering, for example, the hazardous properties of the waste, the risks posed by the waste in terms of process safety, occupational safety, and environmental impact, as well as the information provided by the previous waste holder(s). It is essential to ensure the compliance of the output with set standards and each biological treatment facility must have procedures in place to check and validate the quality of the outputs.

In regard to biogas, biogas flow must be continuously monitored, as well as the quality and composition of the biogas. The following is to be considered:

- Hydrogen sulphide levels in the biogas to determine the efficiency of the removal methods applied. This can be done by monitoring both before and after gas cleaning equipment;
- If oxygen is used for the desulphurisation of biogas, oxygen levels must be monitored and high-level alarms that are set to automatically stop air addition before the lower explosive limit is reached must be provided;
- If carbon filters, for example for gas cleaning prior to combustion, are utilised, procedures to minimise the risk of exothermic reactions occurring during their maintenance must be implemented, for example, by purging with nitrogen;
- Inspect, maintain, and routinely test all gas storage and treatment plant and equipment in accordance with manufacturers’ recommendations. All routine and nonroutine inspection and maintenance must be recorded.

7.5 Facility and Equipment Maintenance

Facility and equipment maintenance are a critical component of the daily operations at any treatment facility as it will allow to maintain performance levels and product quality.

The following are some considerations to follow related to facility and equipment maintenance at a biological waste treatment facility:

- Perform frequent preventative maintenance of equipment used for pre-treatment operations (i.e., shredding etc) as well as the biological treatment operation;
- Conduct periodic testing of storage equipment to search for signs of decaying structural integrity;
- Regularly inspect the facility looking for cracks, worn equipment, leaks, etc;
- Floors and walls should be cleaned frequently;
- Drain holes should be cleared of debris.

Best practice dictates that equipment maintenance should be performed outside of working hours to prevent equipment downtime, and also to prevent maintenance being conducted on working equipment which could represent serious health risks.

8 HEALTH AND SAFETY CONSIDERATIONS

8.1 Occupational Health

As per Article 105 of Section 4 of the IR of the WML, the Service Provider shall comply with the Centre's controls and requirements in relation to the facility workers' qualifications, fitness, and health ability, enter and exit procedures, and supplying the facility with the necessary tools and equipment that prevent or minimise the entry of non-personnel to the facility.

In order to prevent risks for workers, particularly biological risks associated with bio-aerosol and dust inhalation, all operations inside the facility must be performed inside conditioned vehicles; or if performed manually, workers must wear appropriate protective equipment including disposable suits, safety gloves and shoes, dust-filtering breathe masks, glasses, and helmet (see Figure *8-1*). Furthermore, the following needs to be accounted for and communicated with the staff:

- Personal hygiene when entering and exiting the plant. The employer shall ensure that all work clothes are cleaned regularly. Lockers, showers, toilets must be equipped with separated clean and dirty areas;
- Adequate training in handling waste and the utilization of equipment;

- Periodical health check against the most probable risks: biological agents, dust, noise, vibrations (for those spending part of their activity on wheel loaders);
- Allowing smoking, eating and the consumption of food in specially designated areas only.

As a minimum, temporary structures must be located on site providing accommodation to on-site personnel. Such structures must be designed to provide;

- Office space for general site management duties and records storage;
- Sanitation facilities for site staff and visitors;
- Storage space for site equipment and for maintenance purposes;
- First Aid area, fully stocked for minor accidents.

All structures must be located in a suitable area of the site to allow control of day activities whilst also taking account of health and safety aspects.

8.2 Safety equipment

All licensed waste facilities should be equipped with the following:

- Suitable personal protective equipment (PPE) appropriate for the type(s)waste being handled, including hazardous wastes, for all staff involved. Such PPE should include, as a minimum:
  - Eye protection, such as safety glasses, goggles, or a visor;
  - Gloves of suitable material to prevent penetration by sharp objects or by chemicals according to what is handled;
  - Safety boots;
  - Safety helmets if working under beams with high objects;
  - Suitable skin protection/covering;
  - Face masks to prevent inhalation of particulates in dusty atmospheres; and where working with plant or where vehicles are present;
  - High-visibility vests or similar.
- An internal communications or alarm system capable of providing immediate emergency instruction or warning to all personnel;
- A device, such as a telephone (immediately available at the scene of operations) or a hand-held, two-way radio, capable of summoning emergency assistance from local fire departments, ambulance, or emergency response teams;
- Where combustible and/or flammable wastes are stored, storage areas should be equipped with automatic smoke detection and, where necessary, fire suppression systems such as automatic sprinklers or other fire suppression systems;
- Portable fire extinguishers, fire control devices (including special extinguishing equipment, such as that using foam, inert gas, or dry chemicals), spill control materials and decontamination supplies; and
- Water at adequate volume and pressure to supply hoses, foam-producing equipment if appropriate.

All PPE and emergency equipment must be tested regularly and maintained to ensure proper operation. Where combustible wastes or flammable hazardous wastes are stored or processes, it is good practice to develop a fire prevention and management plan, agreed with the relevant emergency services and approved by the Centre, which covers the management of combustible and/or flammable wastes, fire detection, suppression and fighting equipment and emergency procedures.

Figure 8-1: Protective Work Gear (Cre, 2018)[5]

8.3 Professional Training and Certification

Facilities will only be operated by qualified and trained personnel. Therefore, the Biological Treatment Facilities' Service Provider will regularly offer adequate training and education to its staff to ensure they are well-equipped to manage the waste streams safely. Furthermore, the Service Provider will ensure to provide certificate, inhouse or via a 3rd parties, proving the fitness and health of workers on an annual basis.[7]

The level and nature of staffing and training should be adequate for environmentally responsible and safe management of the biological waste treatment facility. Staffing levels should ensure that the facility can comply at all times with all provisions of its licence. Furthermore, staff training should ensure that:

- The layout of the site, including the different processing and storage areas and their functions, the location of emergency equipment;
- An overview of the wastes received for treatment in the Plant, their processing/treatment, pre and after storage, transport, and disposal/management;
- The characteristics of the waste they will deal with, including all the different categories of any hazardous waste, where these arise and how to manage them;

[7] (The Implementing Regulations of the Waste Management Law, 2021)

- All personnel who inspect incoming organics are skilled at identifying organics that are unacceptable and can record data accurately;
- The hazards presented by the wastes and ways to prevent or to mitigate any danger;
- All operators of mobile plant equipment are skilled at undertaking all the tasks required of them;
- PPE, its purpose, how to use it, care for it and when to change it;
- Use of first aid kits and medical emergency equipment;
- All personnel should be trained to identify, prevent, minimise, or manage actions or behaviour that is likely to cause adverse impacts on human health and environment as a result of operation of the facility.

Staffing requirements will vary as a function of the type of facility, size of the facility, the type of organics received, managed, and treated at the facility, and the diversity and complexity of site operations.

Employee training to include developing, implementing, and documenting training programmes for all personnel at the MRF. Prior to commencing work involving handling chemical substances or hazardous wastes, all personnel must be familiar with the relevant hazardous properties and instructed on what to do in case of emergency. Such instruction or training must include, as a minimum, the following:

- How to report a fire, injury, chemical spill, or other emergency;
- The location of emergency equipment, such as safety showers, eyewashes and first aid kits;
- The location of fire extinguishers and spill control equipment;
- The locations of all available exits for evacuation; and
- Names and phone numbers of the designated emergency coordinator and an alternate.

Training-related documents and records must be kept at the facility. These must include a job title for each person and the name of the employee filling that position. Also, a written job description is needed for each position and records documenting that the employee holding that position has completed the training or job experience satisfactorily. Finally, the files must contain the training records on current personnel and past employees for three years.

8.4 Accident Management Plans

An Accident Management Plan must be in place (reviewed at least once every three years, or in an event of an accident) which identifies:

- The likelihood and consequence of accidents; and
- Actions to prevent accidents and mitigate any consequences.

A structured accident management plan includes the following:

- Identifying the hazards to the environment posed by the treatment facilities;
- Particular areas to consider may include waste types, overfilling of vessels, failure of equipment (e.g. over-pressure of vessels and pipework, blocked drains), failure of containment (e.g. bund and/or overfilling of drainage sumps), failure to contain firefighting water, making the wrong connections in drains or other systems, preventing incompatible substances coming into contact, unwanted reactions

and/or runaway reactions, emission of an effluent before adequate checking of its composition has taken place, vandalism/arson, extreme weather conditions, e.g. flooding, very high winds;

- Assessing all risks (hazard multiplied by probability) of accidents and their possible consequences. Having identified the hazards, the process of assessing the risks can be viewed as addressing six basic questions:
  - What is the estimated probability of their occurrence? (Source, frequency);
  - What may be emitted and how much? (Risk evaluation of the event);
  - Where does it go? (Predictions for the emission – what are the pathways and receptors?);
  - What are the consequences? (Consequence assessment – the effects on the receptors);
  - What is the overall risk? (Determination of the overall risk and its significance for the environment);
  - What can be done to prevent or reduce the risk? (Risk management – measures to prevent accidents and/or reduce their environmental consequences).

In particular, identifying fire risks that may be posed for example by:

- Arson or vandalism;
- Self-combustion (e.g., Due to chemical oxidation);
- Plant or equipment failure & other electrical faults;
- Naked lights & discarded smoking materials;
- Hot works (e.g., Welding or cutting), industrial heaters and hot exhausts;
- Reactions between incompatible materials;
- Neighbouring site activities;
- Sparks from loading buckets;
- Hot loads deposited at the site.

The depth and type of assessment will depend on the characteristics of the plant and its location. The main factors taken into account are:

- The scale and nature of the accident hazard presented by the plant and the activities;
- The risks to areas of population and the environment (receptors);
- The nature of the plant and complexity of the activities and the relative difficulty;
- In deciding on and justifying the adequacy of the risk control techniques.

- Identifying the roles and responsibilities of personnel involved in accident management. Together with this, clear guidance is available on how each accident scenario needs to be managed; for example, containment or dispersion, to extinguish fires or to let them burn;
- Establishing communication routes with relevant authorities and emergency services both before and in the event of an accident. Post-accident procedures include an assessment of the harm that may have been caused and remediation actions to be taken;
- Putting in place emergency procedures, including safe shutdown procedures and evacuation procedures;
- Appointing one facility employee as an emergency coordinator to take leadership responsibility for implementing the plan. It is important that the facility offers training to its employees to perform their duties effectively and safely so that staff know how to respond to an emergency.

9 DATA RECORDING, MONITORING AND REPORTING

9.1 Data recording

It is the responsibility of the operator of a Biological Treatment Plant to implement, use and maintain a computerised waste tracking system to hold up-to-date information about the available capacity of different parts of the Biological Treatment Facility, to make sure that the facility has enough waste storage and process capacity for the incoming acceptable waste. The Service provider (plant operator) shall record, monitor, and report data on waste according to the license requirements as issued by the Centre. The minimum information to be kept up to date are as follows:

- The details of all waste received at the site, including date and time, the source and nature of waste, including the original producer's details and any waste code(s), weight, details of the transporter, the vehicle, and the driver;
- Details of any non-conformances and rejections, including consignment notes for waste rejected because is hazardous;
- The details of the outputs obtained after the waste treatment in the plant including the weight and the final destination. In the case of residues/rejects redirected to another waste facilities the information recorded will include also details of the transporter, the vehicle, and the driver;
- The details on the duration of the outputs stored within the site awaiting recovery/recycling (the stick);
- Any incidents that did result, or could have resulted, in an uncontrolled or unpermitted release from the site, such as a spillage of waste into the surface water drainage system; and
- Any accidents involving waste or waste transporting vehicles or waste processed in the plant that result in injury to staff or the public or serious damage to property.

The waste recording system shall be able to generate information for the waste streams accepted for treatment in the waste facility, the following as a minimum:

- The total amount of waste present on site at any one time;
- A breakdown of the waste quantities stored pending on-site treatment or awaiting onward transfer;
- Where a batch of waste is located based on a site plan;
- The quantity of waste on site compared with the limits set out in the license/permit;
- The length of time the waste has been on site compared with the limits in the license/permit.

Note: in addition to the above the service providers shall record, monitor, and report all environmental related parameters (water quality, air quality, noise, dust etc) according to the requirements of the Environmental Permit issued by the competent authority (NCEC) for the plant.

9.2 Periodic inspections and internal audits

Each facility should be monitored, either at random or at regular intervals to ensure that the site is being operated in accordance with:

- the working plan agreed with the Centre and incorporated into the licence; and
- any conditions in the licence issued by the Centre.

This monitoring should be conducted by the designated responsible person, who should, *inter alia*:

- Periodically but irregularly undertake inspections to check the integrity of the equipment in the facility to prevent/reduce the risk of major accidents and to ensure that all primary and secondary containment is fit for purpose;
- The responsible person should ask questions of those responsible for handling the waste as to whether they have encountered any problems and what suggestions, if any, they may have for improvements; and
- The data on waste inputs and outputs should be interrogated and the amount and types of different wastes in store compared with the amount of waste visible in the temporary storage area and any differences noted and acted upon.

9.3 Waste Data Reporting

The designated person should use the data recorded above to monitor the production and/or the management of waste at the biological waste treatment facility on an ongoing basis. The designated person must prepare reports regarding all aspects related to the waste such as production, storage, transport, and processing and provide a copy of these to the Centre competent authorities periodically as determined by these authorities.

All reporting must be carried according to the license requirements as issued by the Centre, which can be on a monthly or yearly basis, and the data to be reported can include the following as an example:

A. General data:

   - The facility name, address, and permit number;
   - Site location (e.g., address of the site where works are carried out);
   - Name and contact detailed of the person in charge with data recording and reporting.

B. Data on the waste processed in the Facility:

   - Amount of waste accepted in the facility by waste stream and fraction including any waste code;
   - The total quantity in tons of output (compost, digestate, biogas) produced at the facility during the period covered by the report;
   - The total quantity in tons of output (compost, digestate, biogas) removed for use or disposal from the facility during the period covered by the report; and
   - The results of analytical testing of the marketable outputs (compost, digestate, biogas), as well as all effluent to be disposed of or to undergo further treatment;
   - Amount of waste/products awaiting transfer.

C. Data on Service Providers.

Appendix 1 Displays a table that can be used as template for recording and reporting waste data.

Failure to maintain records or provide documentation when solicited is a violation of the Law and will lead to legal consequences.

In addition, the Centre should analyse the data from each facility to compare the amounts of different categories of waste reported and seek reasons or explanations for any significant differences.

APPENDIX 1 Date Reporting – Template

A. General Information

- Name of the Waste Facility;
- Site Location;
- Period covered by the report and Completion date;
- Name and contact details of the person who filled in the data and approved the figures.

B. Information on Resources and Waste

B.1 Waste processed

Crt	Waste received in the Plant				
	Waste generator	Waste Transporter	Waste Stream/Fraction	Waste code	Amount Tones
1					
2					

B.2 After Treatment Products

Crt	Waste/products	Total Amount	Amount directed to 3rd parties, tone	Amount in stock, tone
1	Recycling materials, tonnes			
	- Paper/cardboard			
	- Glass			
	- Plastic			
	- Others			
2	RDF/SRF, tonnes			
3	Digestate/compost, tonnes			
4	Digestate liquor, tonnes			
5	Biogas production, in cm			
5	Rejects, in tonnes			

C. Information on 3rd parties

- Information on waste transporters
- Details of the entities who has purchased the products including name and address, amount of waste/materials purchased (by stream and total).

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