Endeco

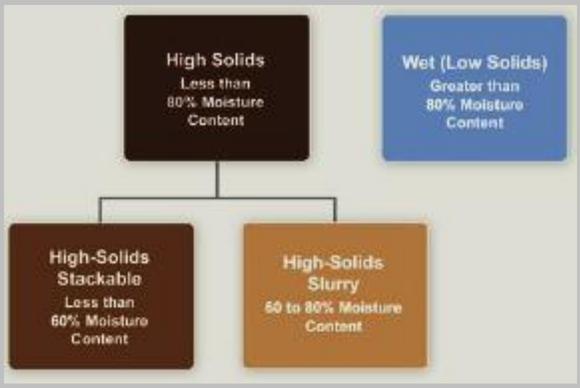



Anaerobic Processing Principles & Technologies

Anaerobic Processing Principles

Anaerobic digestion (AD) is a biological process that uses microorganisms to breakdown organic material in the absence of oxygen. The process takes place within reactors or chambers under controlled environmental conditions, such as moisture content, temperature, and pH levels. The digestion process generally occurs during a two-to-six week period.

Three by-products of AD
1. Digestate: Solid material
2. Effluent: Liquid (recirculated or waste)
3. Biogas (60% CH_4, 40% CO_2)

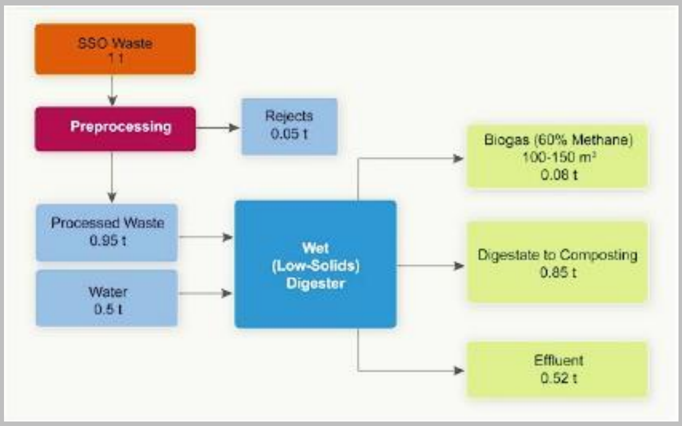


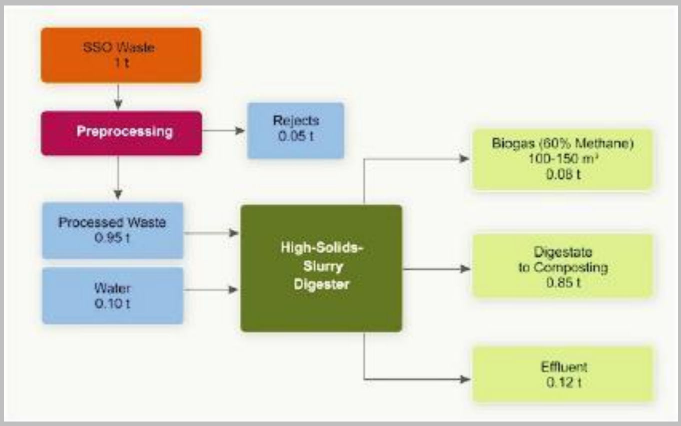
PROCESS OVERVIEW

The moisture content at which a digester is designed to operate determines the digester type (wet, high solids).
Digesters may be designed to operate as:
- High-temperature (thermophilic), at a temperature greater than 45 degrees Celsius (°C)
- Mid-temperature (mesophilic), at temperatures between 20 and 45°C
- Low-temperature (psychrophilic), at temperatures less than 20°C

STEPS
1. Feedstock Receiving and Pre-processing:
   Receiving, inspection for unacceptable materials(such as tires, metals, rocks or concrete), preparing (grinding, shredding, pH adjusting) for AD process.
2. Anaerobic Digestion:
   Biochemical decomposition of the organic fraction for a period of 14 to 40 days.
3. Biogas Capture and Utilization:
   Biochemical reactions produce biogas. The quantity of gas produced depends upon the biodegradability of the material in the digester, how many calories it has and how efficiently the digester operates.
4. Digestate Handling and Processing:
   The digestate is dewatered using centrifuges, or presses and a portion of the water reused within the AD. Exceeding water goes to a treatment plant. Farmers can directly land-apply digestate, or it can be composted.

TYPICAL MASS BALANCE (QUANTITIES RELATIVE TO 1 TON OF SSO PROCESSED)





KEY PROCESS MANAGEMENT PARAMETERS

The digestion process can be limited by certain factors and operational conditions that affect feedstock breakdown and biogas generation. Table 4-2 lists the key process parameters and typical parameter values for AD of SSO.

	High-solids		Wet
	Stackable	Slurry	Low solids
Moisture content	Less than 60%	Between 60 to 80%	Greater than 80%
pH	6.0 to 7.0 (in single stage digesters)		
Alkalinity	More than 100 mg/L		
VFAs	Less than 4000 mg/L		
Temperature	Mesophilic digesters: 30 to 38°C		
Retention time	Thermophilic digesters: 50 to 60°C		
C:N ratio	14 to 40 days		
Ammonia	30:1		
Sulphide	200 mg/L		

Moisture Content

Water must be added to dry wastes to meet the required moisture content of 80% or greater. High-solids-stackable digesters cannot accept a moisture content greater than approximately 60%. High-solids-slurry digesters can accept moisture contents between 60 and 80% by weight.

pH, Alkalinity, and Volatile Fatty Acids

Failing to maintain pH within an appropriate range could cause digester failure. The pH level in the digester is a good indicator of anaerobic process stability. A healthy reactor has VFA concentrations less than 4000 mg/L.

Temperature

Biochemical reaction rates approximately double for each 10°C increase in temperature. Thus, throughput rates can be increased in thermophilic systems, resulting in higher biogas production rates. The drawbacks of thermophilic operations include greater parasitic energy use to maintain the higher temperature, more expensive equipment design, and more sensitive process control requirements.

System	Operating range	Optimal conditions
Mesophilic	30 to 38°C	35°C
Thermophilic	50 to 60°C	55°C

Solids Retention Time

It is the average time a given particle of solids remains in the digester (generally in the range of 14 to 40 days). Short SRT lead to uncomplete biogas capturing, exceeding SRT reduce the recovery efficiency.

C:N Ratio and Ammonia Toxicity

Nitrogen (N) is a nutrient for cell growth but excess can lead to the accumulation of ammonia in the digester and consequently to substrate/product toxicity which hampers the digestion process. The concentration of nitrogen is controlled through the C:N ratio of the feedstock, which should be approximately 30.

Sulphide Concentration

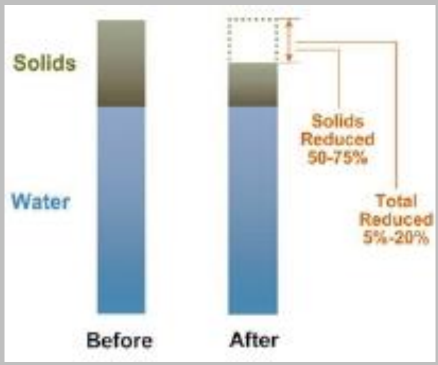
The presence of high sulphide (as H_2S) levels inhibits the digestion process. Proteins are the usual source of sulphides in MSW organics.

DIGESTATE CHARACTERISTICS

Digestate is the solid or semi-solid material left over at the end of the digestion process once any liquid effluents or percolates have been drained off. This material can be useful as compost or fertilizer after processing.

Characteristics and Processing

The digestate has a moisture content similar to the material in the digester. Unit weight of undewatered digestate is 1000÷1200 kg/m3. Digestate from wet (low-solids) digestion systems are usually dewatered to approximately 50% moisture content and further used as fertilizer (where allowed), composted or dried to 10÷15% moisture and pelletized for use as fertilizer.



Quantities

The total solids in the waste are reduced by approximately 50 to 75% by weight in the digestion process, but because the solids are only a part of the total (most of the waste is water), the total reduction in weight in a wet digester is only 5 to 20%.

	High Solids	Wet
Density	900÷1000 kg/m³	1200 kg/m³
Moisture content	60%	80%
Solids content	40%	20%
Mass reduction from raw waste	15%	5%
Volume reduction from raw waste	30 to 35%	10%

A typical quantity of digestate for all digester types is 0.85 t of dewatered digestate for each t of wet SSO added to the digester.

Typical Biogas Parameters
- ■ CH4: 60% by volume
- ■ CO2: 40% by volume
- ■ H2S: 200 to 4000 ppm
- ■Trace contaminants (highly variable): siloxanes, chlorinated organics, and VOCs

BIOGAS CHARACTERISTICS

Characteristics

Biogas generated from MSW organics typically contains 60% methane.
Other gases are also present in smaller concentrations:
- Hydrogen sulphide pose a health and safety risk to site personnel.
- Siloxanes when burned produce a hard silica residue.
- VOCs can produce acid gases when burned, which cause corrosion.

Quantities

The biogas yield depends primarily on the waste type of the solid waste. The degradation rates of waste organic matter can vary significantly with the substrate composition. Food wastes typically have higher biogas production than high-cellulose materials such as grass, leaves, paper, and brush. Fats, oil, and grease provide the highest biogas yields, but require the highest retention times.

Waste type	Biogas yield (m³/ton waste)	Methane (%)	Methane yield (m³/ton waste)
Leaves	23	60	14
Grass	34	60	20
Mixed paper	112	60	67
Brush	67	60	40
Food waste	144	60	86
Fats, oil and grease	390	60	234

Waste mix Biogas production	Waste mix Biogas production
Organic fraction of MSW	100 to 150 m3/t of SSO
Food waste with grass cuttings	165 m3/t of SSO
Residential food waste	144 m3/t of SSO

Energy Potential

The energy content of biogas is completely determined by the biogas's methane content: the higher the concentration of methane, the higher the biogas's energy potential. Methane has a total energy potential of approximately 37 megajoules per cubic metre (MJ/m3). Biogas, at 60 to 70% methane, has a total energy potential of 22 to 26 MJ/m3.

Anaerobic Processing Technologies

Brief overview of the general types of AD methods and technologies suitable for facilities with capacities ranging from 10 tonnes per day (tpd) up to several hundreds of tpd.

GENERAL PRETREATMENT REQUIREMENTS

- Inspection for unacceptable materials.
- Physical/chemical alteration (grinding, shredding, pH change) to optimize digestion process.
- Nondegradable waste removal: skimming the top for light waste and draining the grit from the bottom for heavies.
- Mixing with heated water or steam to increase the moisture content and the temperature. For dry digestion systems, feedstocks may be mixed with “bulking agents” or “structural” organic materials.
- Starter inoculums might be added to initiate microbial activity at the mixing stage.

Pre-treatment Considerations

■ Determine material handling methods required by the quantity of liquids in the feedstock and feedstock particle size

■ Remove materials that may:

- Interfere with the digestion process (e.g., very high-salt-content food wastes)
- Interfere with equipment (e.g. large objects)
- Affect final compost quality (e.g., glass and plastic)

TYPES OF AD TECHNOLOGIES

There are two major categories of AD systems:

- High Solids: Systems with typically less than 80% moisture content (greater than 20% solids). Using front-end loaders, feedstocks are typically stacked into the digester as solid materials, or pumped in as a high-solids slurry.
- Wet: Systems with greater than 80% moisture content (less than 20% solids). Feedstocks are dissolved or suspended in a liquid form and are handled as a liquid.

Process Control Requirements for Optimal AD Operations Include Monitoring

■ Feedstock composition and contaminants

■ Water recirculation rates

■ Water addition rates

■ Digester temperature

■ Gas composition

■ Gas pressure and low rates

■ Digestion times & loading rates in 2nd stage

■ Percolate pH, dissolved solids, ammonia, sulphide, and temperature

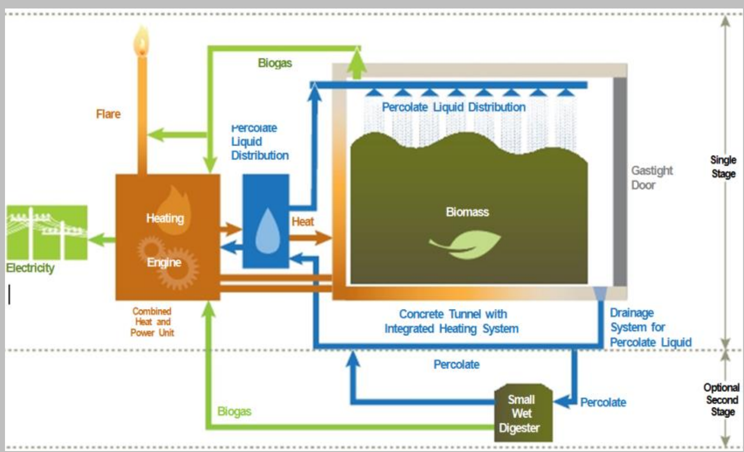
Digester type	Digester water	Net energy output	Digestate Dewatering	Leachate production
High-solids	Less than 60%	High	not required	low
Wet (low solids)	Greater than 80%	Low	required	high

Single stage AD systems	Two stages AD systems
• Lower capital cost • Easier to operate • Fewer technical failures • Lower biogas yields	• Higher capital cost • More technical complexity • More technical failures • Potentially higher gas yields

Considerations	Digestion type		
	High-solids stackable	High-solids slurry	Wet (low solids)
Waste pretreatment/ preparation	Requires limited pretreatment: - Debagging, screening, and mixing - No aggressive size reduction - Needs bulking material - Particle size < 20 cm	Requires some pretreatment: - Debagging, shredding - No bulking material - Particle size < 5 cm	Requires high pretreatment: - Debagging, shredding - Remove loatables and settleables - No bulking material - Particle size < 5 cm
Moisture addition	• Usually no water addition • Moisture content < 60% • Add 0.05 m3/ton of water	• Requires water addition • Moisture content > 60% • Add 0,10 m3/ton of water	• Requires water addition • Moisture content > 60% • Add 0,50 m3/ton of water
Digester design	- Concrete tunnels with tight doors - 10.000÷100.000 Tpy of waste - Retention time: 14–30 days • Mode: batch	- Plug flow or stirred tank - 3.000÷250.000 Tpy waste - Retention time: 14–30 days • Mode: continuous	- Stirred tank - 3.000÷250.000 Tpy waste - Retention time: 14–34 days • Mode: continuous
Digestate handling and characteristics (quantity and quality)	• Handling by front-end loaders • Digestate H2O: 50÷60 %wt • No dewatering before composting • Composting: - added to other feedstocks - separately (short compost times) • Quantity: 0.85 ton/ton of waste	• Handling by pumping • Digestate H2O: 70÷90 %wt before dewatering • Dewatering to 50% before composting (centrifuge or press) • Composting: - to a humus like condition (reduced composting time) - drying and use as fertilizer (if allowed) • Quantity: 0.85 ton/ton of waste	
Effluent characteristics (quantity and quality)	Consists of excess percolate water. Quantity: up to 0,1 m3/ton • recirculated up to 100% • excess percolate may need to be disposed to a treatment facility Quality: • BOD5: 2000÷5000 mg/L • SS: 50÷5000 mg/L • Ammonia as N: 1000÷3000 mg/L	From digestate dewatering. Quantity: 0,1÷0,3 m3/ton • recirculated max 70% Quality: • BOD5: 1500÷15000mg/L • SS: 50÷5000mg/L • NH3 as N: 1000÷3000mg/L	From digestate dewatering. Quantity: 0,4÷0,7 m3/ton • recirculated max 70% Quality: • BOD5: 1500÷15000mg/L • SS: 50÷5000mg/L • NH3 as N:1000÷3000mg/L
Unacceptable materials	Contaminants, such as glass, metals, and plastics, present in feedstocks and removed before, during, or after digestion. Typically landfilled		
Net el energy output	170 to 250 kWh/ton of SSO	145 to 220 kWh/ton of SSO	110 to 160 kWh/ton of SSO

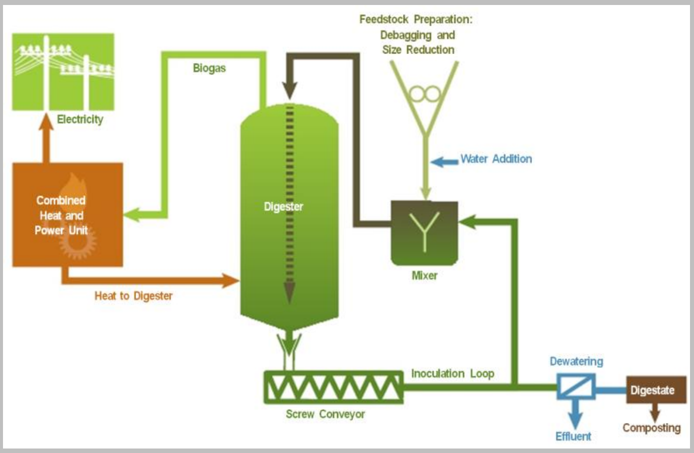
High-Solids-Stackable Digestion Systems

Materials are placed in tunnels using front-end loaders and closed by a gas-tight door.
Percolating effluent water is recirculated to spray nozzles above the waste.
Typical digestion time is 14÷30 days. Process may be thermophilic or mesophilic, single or double stage. Biogas is collected directly from the tunnel. Biogas is being used as fuel in a combined heat and power unit, generating electricity by burning the gas and heat from engine's cooling water.
Tunnels built from materials other than concrete, are less expensive and may be cost-effective at capacities as low as 10.000 Tpy. This process is appropriate for commercial and residential food wastes.



Advantages	Disadvantages
• Can process waste with contaminants (e.g., plastic, metals, and rocks) • Handles wastes that are in a liquid or slurry condition upon arrival • Produces less efluent than wet (low-solids) digestion • More energy-eficient than wet (low-solids) systems • Entirely contained system (high level of odour control)	• Slurry typically is not completely mixed, so can cause uneven digestion if not carefully managed • Produces more effluent than high-solids-stackable digestion • Less energy-efficient than high-solids-stackable digestion • May require water addition to make the feedstocks • pumpable

High-Solids-Slurry Digestion Systems



Process appropriate for a wider variety of materials. The feedstock receiving and separation/sorting areas need to be enclosed in a building equipped with air quality/odour control systems. Feedstocks must be reduced to a pumpable slurry through size reduction and water addition (60% or greater moisture content).

Conveyance equipment is more expensive than that used in wet systems, but it's more robust and flexible regarding acceptance of nonbiodegradable material in the digester, such as rocks, glass, metals, and plastics. Digester may be either batch or continuous feed. Batch digesters give irregular gas generation rates and are typically used in very small applications (less than 5000 tpy) where energy recovery is not the major focus. Continuous-feed digesters are typically a better it for larger AD systems that aim for energy recovery.

Processing capacity ranges from 3 000 to greater than 250 000 tpy.

Typical retention times is 14 to 30 days. Double stage is rarely used.

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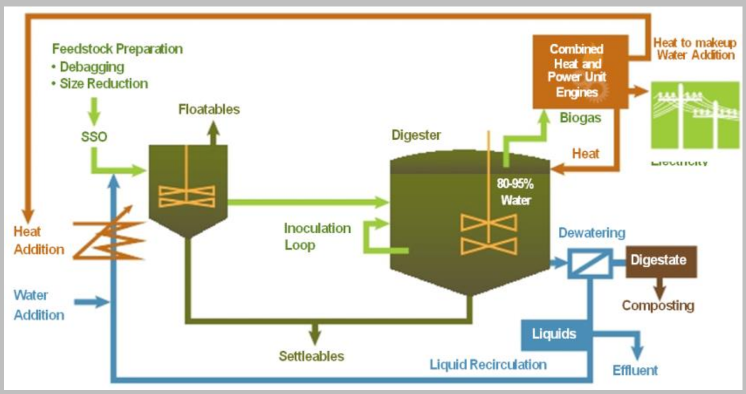
Wet (Low-Solids) Digestion Systems



Wet systems heavily rely on pretreatment, size must be reduced for an efficient reaction and to preserve the stirring equipment.

Processing capacity is 3.000÷250.000 Tpy.

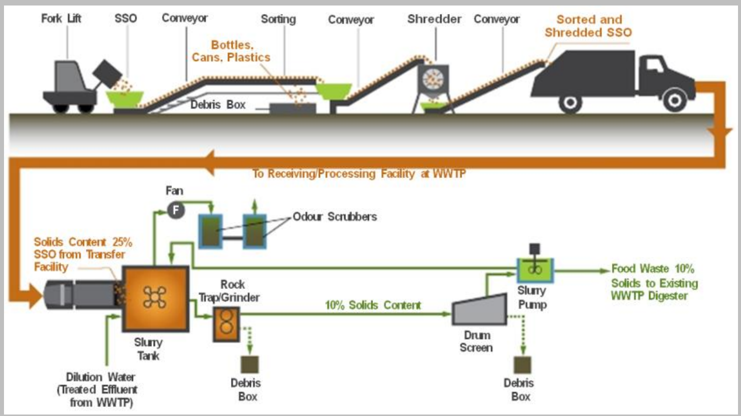
The footprint for a complete large facility is approximately 4ha.

Most appropriate for very low-solids feedstocks (dairy manure and food processing wastes).

Typical retention times are 14 to 40 days.

Advantages	Disadvantages
• Handles wastes that are in a liquid or slurry condition upon arrival • Entirely contained system (high level of odor control)	• Cannot generally handle waste with contaminant material • Requires significant pretreatment and operational care • Produces more effluent than the other two digester types • Requires more energy consumption than high-solids digesters

Codigestion in Wastewater Treatment Plant Biosolids Digesters



Codigestion of food waste in WWTP sludge digesters requires minor modifications: receiving, pretreatment, and feed equipment for the food wastes.

Excess capacity in digester is a prerequisite. Feed total solids (TS), carbon to nitrogen ratio, must be considered to determine how much feedstock can be added.

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