Technical Guide On

"Anaerobic Digestion-Municipal Solid Waste"

Small and Medium Enterprises Development Authority
Ministry of Industries & Production
Government of Pakistan

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July 2022

Contents

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1.1 Introduction to SMEDA

The Small and Medium Enterprises Development Authority (SMEDA) was established in October 1998 with an objective to provide fresh impetus to the economy through development of Small and Medium Enterprises (SMEs).

With a mission "to assist in Employment Generation and Value Addition to the national income, through development of SME sectors, by helping increase the number, scale and competitiveness of SMEs", SMEDA has carried out 'sectoral research' to identify Policy, Access to Finance, Business Development Services, strategic initiatives and institutional collaboration & networking initiatives.

Preparation and dissemination of prefeasibility studies in key areas of investment has been a successful hallmark of SME facilitation by SMEDA.

Concurrent to the prefeasibility studies, a broad spectrum of Business Development Services is also offered to the SMEs by SMEDA. These services include identification of experts and consultants and delivery of need-based capacity building programs of different types in addition to business guidance through help desk services.

For more information on services offered by SMEDA, please contact our website: www.smeda.org

1.2 Industry Support Program

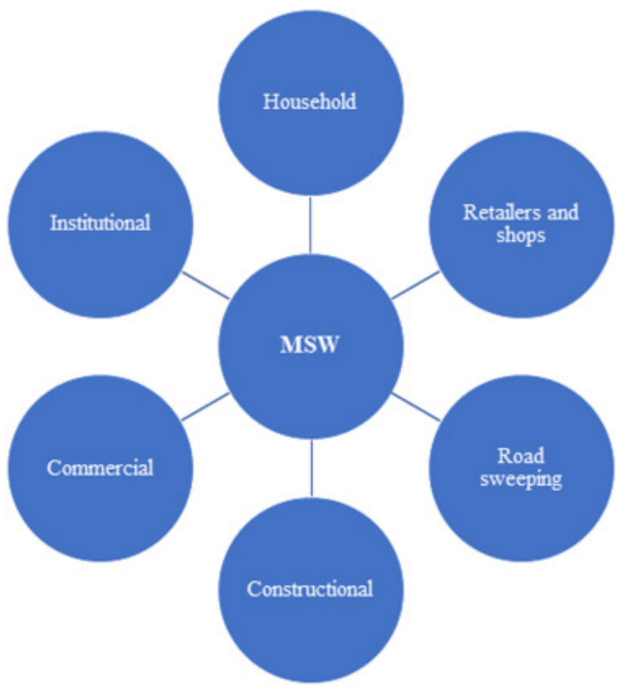
In order to enhance competitiveness of SMEs and achieve operational excellence, SMEDA established an Industry Support Cell (ISC) for provision of foreign technical support and knowledge transfer in collaboration with International Development Organizations. SMEDA's Industry Support Program (ISP) initially launched with Japan International Cooperation Agency (JICA) and actively engaged in reducing energy inefficiencies and improving production and quality of products with the support of Japanese Experts. Later on, similar activities with other international partner organizations like German Corporation for International Cooperation (GIZ), Training and Development Centers of the Bavarian Employers' Association (bfz), Germany, and United Nations Industrial Development Organization (UNIDO) were also successfully implemented.

2. Municipal Solid Waste (MSW)

It is waste generated by settlements, which includes households, commercial and industrials premises, schools, health care centers and public spaces.

Municipal solid waste includes primarily waste from intensive livestock operations, from poultry farms, cattle farms and slaughterhouses. Municipal solid waste also contains biodegradable fraction called biowaste or Organic Fraction of Municipal Solid Waste (OFMSW).

MSW can converted into liquid and gaseous biofuels for production of heat and power by employing various methods either by direct combustion (incinerator), by anaerobic digestion and landfill process. Power plants that burn MSW for energy are called waste-to-energy plants.



Municipal solid waste contains different proportion of waste whose details are given below:

Organic waste: Food waste, garden waste and kitchen waste.

Recyclable materials: Paper, cardboard, glass, bottles, jars, tin cans, aluminum cans, aluminum foil, metals, certain plastics, fabrics, clothes, tires, batteries, etc.

Inert waste: Construction and demolition waste, dirt, rocks.

Electrical and electronic waste (WEEE) - Electrical appliances, light bulbs, washing machines, TVs, computers, screens, mobile phones, alarm clocks, watches, etc.

Composite wastes: Waste clothing, waste plastics such as toys. Hazardous waste including most paints, chemicals, tires, batteries, light bulbs, electrical appliances, fluorescent lamps, aerosol spray cans, and fertilizers.

Toxic waste: It includes pesticides, herbicides, and fungicides. Biomedical waste, expired pharmaceutical drugs etc.

2.1 Composition of MSW in Pakistan

Composition of MSW in different cities of Pakistan varies, some of are given below:

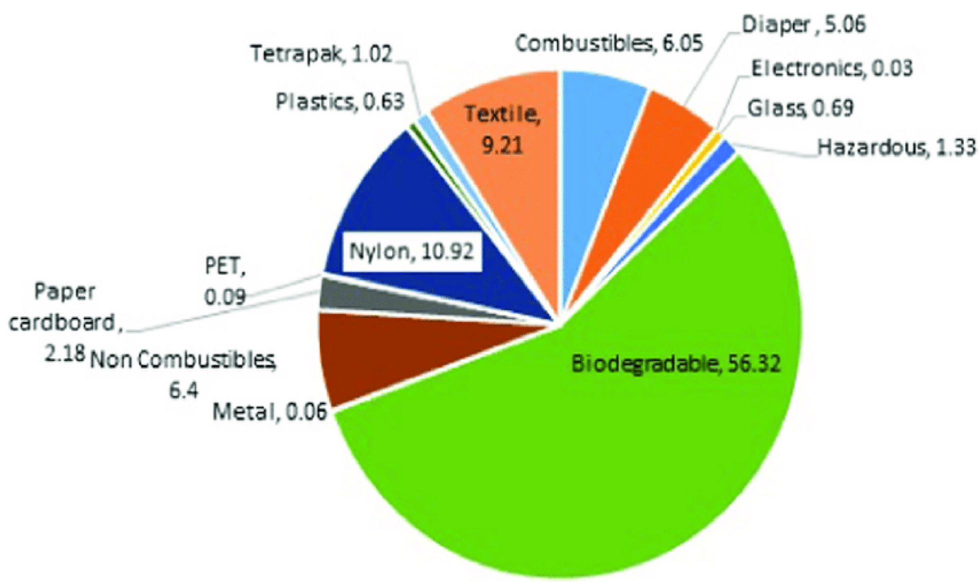


Fig: Composition of MSW in Pakistan[1]

In Pakistan, composition of MSW contains around 56 % of biodegradable proportion which include (Food, Fruit, vegetable and plants). MSW is mainly collected by municipalities and waste collection efficiencies range from zero percent in low-income rural areas to 90 percent in high-income areas of large cities. The proportion of waste collected is much less in poorer areas, where the only means of solid waste disposal is often informal scavenging by people and animals, natural biodegradation and dispersion, burning at the primary point of disposal, and local self-help for disposal to informal (technically illegal) dumping sites.

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[1]*Ref: Azam, Mudassar, et al. "Status, characterization, and potential utilization of municipal solid waste as renewable energy source: Lahore case study in Pakistan." Environment international 134 (2020): 105291.*

2.2 Waste Generation

Solid waste generation in Pakistan ranges between 0.283 to 0.612 kg/capita/day and the waste generation growth rate is 2.4% per year.

City	Population in million	Solid waste generation/day in tons
Karachi	20,500,000	16,500
Lahore	10,000,000	7,690
Faisalabad	7,500,000	5017
Rawalpindi	5,900,000	4,500
Hyderabad	5,500,000	3,973
Multan	5,200,000	3,680
Gujranwala	4,800,000	3,480
Sargodha	4,500,000	3,072
Peshawar	2,900,000	2,048
Quetta	600,000	716

Table : Solid Waste Generation in Major Cities of Pakistan[2]

Biomass suitable for digestion is called “substrate” or “feedstock”. The organic wastes that can be treated by anaerobic digestion cover a wide spectrum. Historically anaerobic digestion has been used to treat liquid wastes, with or without suspended solids, such as manure, sewage, industrial wastewater and sludge from biological or physical-chemical treatment. Using solid wastes such as agricultural and municipal solid waste only started to attract attention in the anaerobic digestion sector in recent time due to its high organic matter content and therefore high potential for biogas production.

3. Waste to Energy Technologies

Following are the waste to energy treatment technologies:

1- Thermo-chemical process (e.g., Incineration, Gasification, Pyrolysis)
2- Physio-chemical process (Transesterification)
3- Biochemical process (Anaerobic fermentation, Aerobic fermentation)
4- Landfill

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[2]*Ref: https://www.trade.gov/country-commercial-guides/pakistan-waste-management*

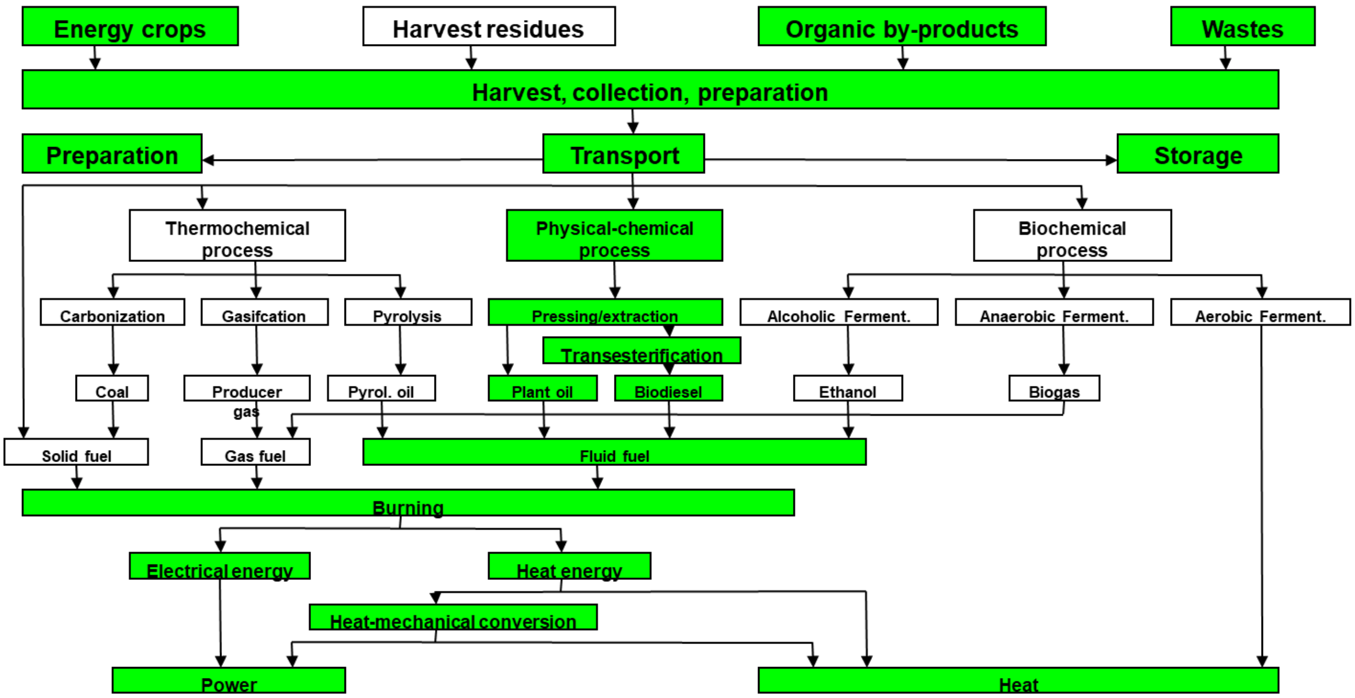

Fig: Waste to Energy Technologies

There are various methods available for the treatment of MSW but in this document anaerobic digestion technology is discussed.

4. Anaerobic Digestion

Anaerobic digestion (AD) is a microbial process that decomposes organic materials in the absence of oxygen. This mechanism occurs in many natural habitats, such as wetlands and ruminant stomachs. The AD process uses an engineering technique and regulated design to process organic biodegradable matter in airproof reactor tanks known as digesters to produce biogas. The anaerobic degradation process involves many types of bacteria and produces two major products: energy-rich biogas and a nutritious digestate. The anaerobic decomposition of organic matter in the digester occurs in four phases which are as follows:

1- Hydrolysis - Conversion of proteins, carbohydrates and lipids (fats) into amino acids, monosaccharides and fatty acids

2- Acidogenesis - Sugars and amino acids converted into ethanol and acids such as propionic & butyric acid, acetate and ammonia

3- Acetogenesis - Long chain fatty acids, volatile fatty acids (VFAs) and alcohols are transformed by acetogenic bacteria into hydrogen, carbon dioxide and acetic acid

4- Methanogenesis - Methanogenic bacteria convert the hydrogen and acetic acid to methane gas and carbon dioxide

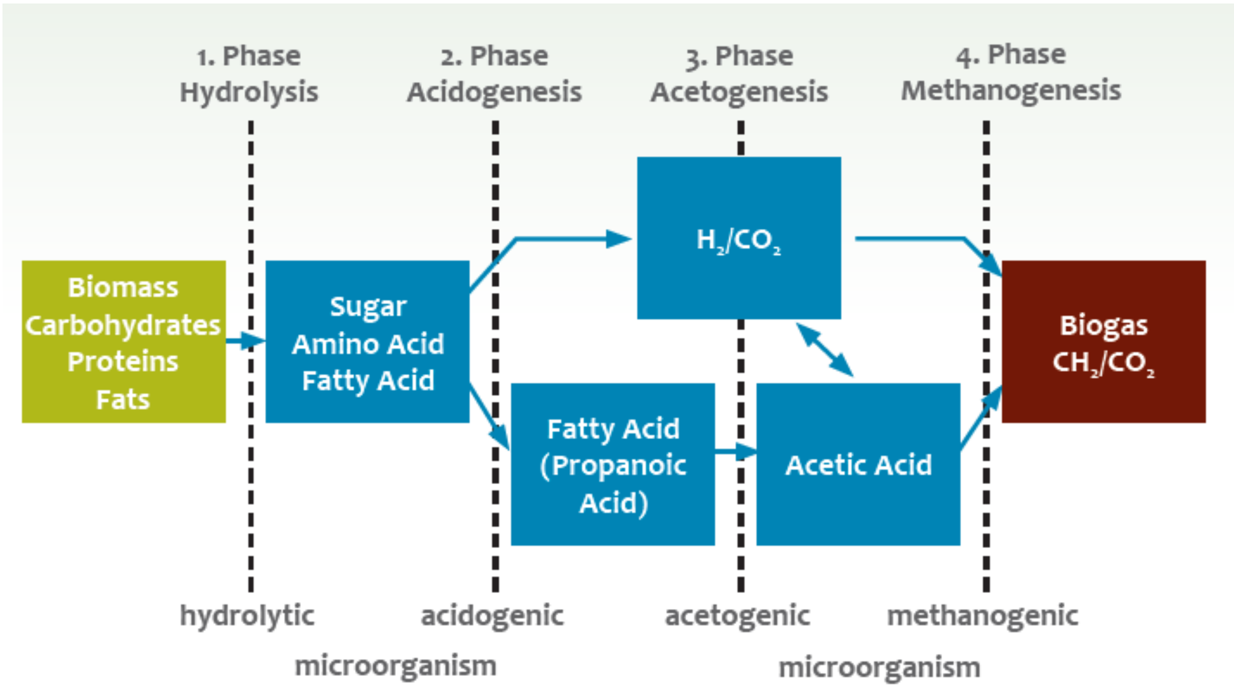

Fig: Phases in Digester

4.1 Process flow of Anaerobic Digestion

There are mainly three main components process flow which are following:

4.1.1 Substrate chain

The "substrate chain" includes the generation of waste, its collection, transportation, and delivery to the facility that breaks it down, as well as any pre-treatment of waste that is needed before it goes into the digester.

4.1.2 Transformation

Biological and chemical changes to the feedstock in the digester that led to products that have value.

4.1.3 Product chain

Product chain include the utilization of end products by converting OFMSW through anaerobic digestion.

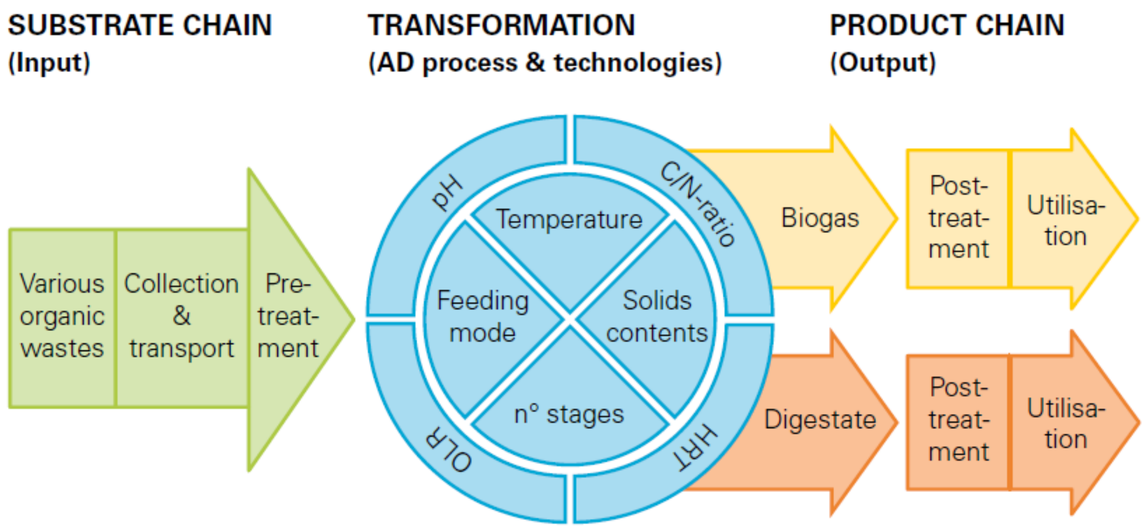

Fig: Steps of Anaerobic Digestion

4.2 Critical parameters

There are several critical parameters that can affects the overall process of anaerobic digestion some of them are given below:

4.2.1 Pre-Treatment

Pretreatment of OFMSW is an effective method to enhance the efficiency of process. For reduction of particle size, it is necessary to do pretreatment of substrate before AD process. There are four methods that can be used for pre-treatment:

1- Mechanical pretreatment
2- Thermal pretreatment
3- Chemical pretreatment

4.2.1.1 Mechanical Pretreatment

Mechanical pretreatment is described as the breaking down or crushing of the substrate's particles, resulting in an increase in surface area (specific) that is responsible for enhancing contact between substrate and methanogens, which will eventually increase the biogas production. There are several mechanical pretreatment procedures available including sonication, lysis-centrifuge, liquid shear, collision, high-pressure homogenizer, maceration, and liquefaction. Researchers have found that the degradation of chemical oxygen demand (COD) slows down when particles are bigger. This means that particle size is inversely proportional to the rate of maximum substrate utilization.

4.2.1.2 Thermal Pretreatment

One of the most common and successful pre-treatments for large-scale industrial use is thermal treatment. Thermal pretreatment results in the removal of pathogens, which makes dewatering work better, reduces the viscosity of the digestate and easier to handle. Researchers suggest wide range of temperatures (50–250°C) to make AD of different organic solid wastes more effective.

4.2.1.3 Chemical pretreatment

Chemical pretreatment involves the use of strong acids, alkalis, or oxidants to break down organic molecules. Because alkali pretreatment is the primary chemical pretreatment approach for AD, pH must be adjusted by increasing the amount of alkalinity. Process type and substrate characteristics both influence the outcome of chemical pretreatment. Chemical pretreatment is not ideal for substrates that are rapidly biodegradable and include a large number of carbohydrates because of their rapid decomposition and consequent buildup of VFA, which prevents the methanogenesis process from taking place.

4.2.2 Temperature

There are two significant temperature zones in anaerobic digestion. Two types of micro-organisms, mesophilic and thermophilic are responsible for digestion at the two temperature ranges. The optimum mesophilic temperature lies at about 35^0C, while the optimum thermophilic temperature is around 55^0C. The operation of a digester in the mesophilic temperature range is more steady as compared to thermophilic temperature range. Moreover, mesophilic bacteria have a lower metabolic rate, which means that a longer retention period in the digester is required to achieve the highest possible biogas generation. Thermophilic range result in a greater production of biogas in a shorter amount of time. However, mesophilic processes are frequently chosen since high temperatures demand greater input energy to achieve operation temperatures and the creation of ammonia, which is harmful to the anaerobic microbe that produces biogas.

4.2.3 PH Value

The optimum range of PH in AD process is between 6.5 to 7.5. Micro-organisms are highly active, and biodegradation is quite efficient in this range of PH. It is harmful to methanogenic organisms to have a pH of less than 6.5 or greater than 7.5. It should always be observed that there should be no rapid changes in pH caused by the addition of any item that could induce an imbalance in the bacterial growth.

4.2.4 Carbon to Nitrogen ratio

The Carbon to Nitrogen ratio (C:N ratio) represents the connection between the amounts of carbon and nitrogen in organic compounds. The C:N ratio is crucial for determining nutritional deficit and ammonia inhibition. Optimal Carbon to Nitrogen ration is 15 to 25 in anaerobic digesters. A high C:N ratio indicates that methanogens are rapidly consuming nitrogen, resulting in decreased gas generation. While A low C:N ratio, produces ammonia accumulation and pH values can lead up to 8.5. These circumstances may be hazardous to methanogenic bacteria.

4.2.5 Organic Loading Rate (OLR)

Organic loading rate (OLR) is defined as the amount of organic waste fed per unit volume of the digester per day. It is an essential parameter, directly affects the biogas production rate. An increase in OLR results in higher biogas production rates but excessive organic loading will lead to process inhibition, thus decreasing gas production.

4.2.6 Hydraulic Retention Time (HRT)

Hydraulic retention time (HRT) is defined as the average time interval over which the substrate is kept inside the digester. High HRT requires a large digester volume with increased operational cost while a less HRT will remove the active bacterial population (Sreekrishnan et al., 2004). Maximum methane production and its upgradation essentially occur at optimized HRTs. The optimized HRT mainly depends on the type of biocatalyst, OLR and the type of digester. A shorter retention period leads to VFA accumulation that causes severe fouling, resulting in decreased biogas production, whereas if the retention time is longer, the biogas components are not utilized effectively, resulting in decreased biogas production.

$$HRT = V/Q$$

Where;

V: Reactor volume (m3)
Q: Flow rate (m3 / day)

5. Annexure – Examples of Operational Biogas Plants

Following are few examples of the biogas plants which are using organic substrate for biogas production.

Location	Digester type	Digester Volume (Active Slurry Vol.)	Feedstock	Organic Loading Rate (OLR) (kg VS/m3 d)	Daily Gas Production (m3/d)
Kumbalangi, Kochi, India	Floating drum	25	Market waste (Mainly fish waste)	0.57	4.97
Emilia, Santa Fe, Argentina	Horizontal plug-flow	24.75	OFMSW (Mixed waste)	0.69	25
Gobernador Crespo, Santa Fe, Argentina	Floating drum	150	Domestic organic waste	n/a	55
Dar es Salaam, Tanzania	Floating drum	4	Canteen waste	0.52	0.79

More information on the aforesaid examples , please follow the following link:

https://www.eawag.ch/fileadmin/Domain1/Abteilungen/sandec/publikationen/SWM/Anaerobic_Digestion/biowaste.pdf

6. For More Information - Energy Desk Contact Details

Need to ask more questions regarding the renewable energy technologies , please send your queries to SMEDA – UNIDO Energy Desk email:

Email: energydesk@smeda.org