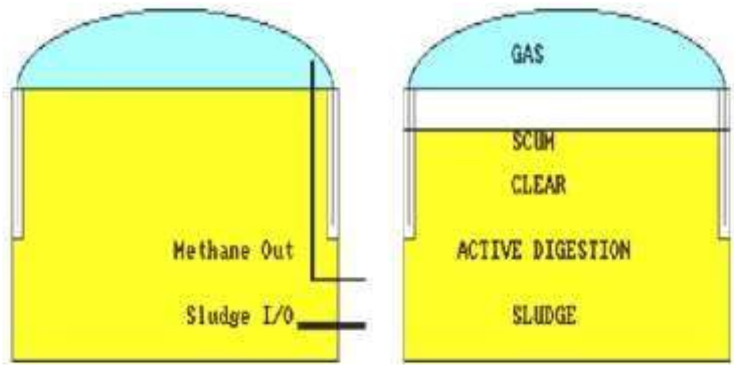
BIOGAS RECOVERY FROM SLUDGE:

In India about 30% of energy consumed by public is biological in nature. The fermentation of organic waste is carried out between 35 to 50^{0}C. Biogas, as a renewable energy, can be produced from a variety of organic raw materials and utilized for various energy services, such as heat, combined heat and power or as a vehicle fuel. Biogas can be produced by anaerobic digestion or fermentation of biodegradable materials such as biomass, manure, sewage, municipal waste, green waste, plants material and energy crops. Biogas is currently produced mostly by digestion of sewage treatment sludge, with minor contributions from fermentation of gasification of solid waste.

In today's energy demanding life style, biogas as the typical renewable as well as eco-friendly new energy source will replace fossil fuel inevitably. Anaerobic digestion (AD) or methane fermentation is an economical and eco-friend process for biomass, organic matter conversion to produce biogas; which mainly consists of methane and carbon dioxide. It is a biological conversion of complex substrates into biogas and inert digestate by microbial activity in oxygen free environment.

The digestion process involves four main steps, namely hydrolysis, acidogenesis, acetogenesis and methanogenesis. Sewage sludge used as substrate in this study was collected from municipal waste treatment plant (WWTP). Sludge sample was characterized before use. The used raw sludge was freshly collected and rich in anaerobic bacteria. At the end of the digestion, an average volume of biogas generated was evaluated.



The gas is collected in a steel gas holder placed at the top of digestion tank; the average composition of biogas is as follows Methane-55%, Carbondioxide 35%, Hydrogen 7.4% and Nitrogen 2.6%. Biogas improves local sanitation and health. The main objective during AD is to recover methane gas which could serve as combustible in various area of the economy, including generation of electricity, heating, and in kitchen.

Disposal of digested sludge:

The digested sludge from the digestion tank contains a lot of water, and is therefore, first of all, dewatered or dried up before further disposal either by burning or dumping. Dewatering, drying and disposal of sludge by sludge drying beds:

Drying of the digested sludge on open beds of land is quite suitable for hot countries like India. Sludge drying beds are open beds of land, 4 5to 60 cm deep and consisting of about 30 to 45 cm thick graded layer of gravel or crushed stone varying in size from 15 cm at bottom t o 1.25 cm a t op, and overlain by 10 to 15 cm thick coarse sand layer.

The sewage sludge from the digestion tank is brought and spread over the top of the drying beds to a depth of about 20 to 30 cm. A portion of the moisture drains through the bed while most of it is evaporated to the atmosphere. It usually takes about two weeks to two months for drying the sludge, depending on the weather and condition of the bed.

Disposal of dewatered sludge:

The dewatered sludge obtained from mechanical devices in western countries is generally heat dried, so as to produce fertilizers. The wet sludge after mechanical dewatering is sometimes directly disposed of either in sea or in underground trenches or burnt.

Disposal by dumping into the sea:

The dewatered wet sludge may sometimes be discharged at sea from hopper barges or through outfall sewers. This method can, however be adopted only in case of cities situated on sea shores and where the direction of the normal winds are such as to take the discharged sludge in to the sea away from the shore line.

Disposal by burial in to the Trenches:

In this method, the digested sludge without dewatering is run in to trenches. When the sludge has dried to a firm state, it is covered a top with a thin layer of soil. After about a month, the land is ploughed up with powered lime and planted with crops.

Disposal by incineration:

The dewatered wet sludge produced in waste water treatment plant may also be disposed of by burning in suitably designed incinerators, when sufficient space is not available for its burial near the plant site or the sludge cannot be dried and used as manure.

MECHANISM OF AEROBIC AND ANAEROBIC SLUDGE DIGESTION WITH MERITS AND DEMERITS:

Sludge digestion is a biochemical phenomenon involving organisms, enzymes, food and environment. The principal objective of sludge digestion is to subject the organic matter present in the settled sludge of the primary and final sedimentation tanks to anaerobic or aerobic decomposition so as to make it amenable to dewatering on sand beds or mechanical filter before final disposal on land, lagoon or sea. Sludge digestion brings about reduction in volume. While anaerobic digestion of sludge produces gas which can be utilized wherever feasible, aerobic digestion does not produce any utilizable by product other than well stabilized sludge.

Anaerobic digestion is the biological decomposition of organic matter in absence of oxygen. It consists of two distinct stages

First stage (Acid fermentation)

Second stage (Methane fermentation)

Advantages

a. Lower BOD concentration in digester supernatant

b. Production of odourless and easily dewaterable biologically stable digested sludge.

c. Recovery of more basic fertilizer value in digested sludge.

d. Lower capital cost

e. Fewer operational problems

Disadvantages

a. Higher power costs generate higher operating costs comparable with anaerobic digestion

b. Gravity thickening process following aerobic digestion and to generate high solids concentration in the supernatant

c. Some aerobically digested sledges do not dewater easily in vacuum filtration

d. No methane gas is produced for recovery as a byproduct.

OBJECTIVES OF SLUDGE TREATMENT:

- To reduce the water content in the sludge and make it easier for treatment and disposal
- To destroy all the pathogens
- To reduce the volume of sludge
- To stabilize the organic matter

FORMS OF SLUDGE:

• Primary sludge – When raw sewage is settled in a primary clarifier, the suspended solids settle down by gravity. These are drawn out from the conical floor of the clarifier. This is called primary sludge (PS). It will have mostly organic substances and also inorganic substances. If it is stored, the organic substances will undergo anaerobic reaction as in Figure 5.2. This will result in production of Methane and Hydrogen Sulphide gases.

• Secondary sludge – When the sewage is aerated in aeration tanks, biological microorganisms grow and multiply. The aerated liquid is called the mixed liquor. It is settled in secondary clarifiers to separate the microorganisms by gravity. These are drawn out from the conical floor of the clarifier. This is called secondary sludge.

• Return sludge – A major portion of the secondary sludge is returned to the aeration tank for seeding the microorganisms. This is called return sludge (RS).

• Excess sludge – A small portion of secondary sludge is wasted. This is equal to secondary sludge minus return sludge. This is called excess sludge (ES) on waste sludge (WS).

• Chemical sludge – When raw sewage or secondary treated sewage is subjected to chemical precipitation, the resulting sludge is called chemical sludge (CS).

NEED FOR SLUDGE DEWATERING AND EXPLAIN THE VARIOUS SLUDGE DEWATERING METHODS:

Sludge dewatering:

Dewatering is a physical unit operation used to reduce the moisture content of the sludge and thus to increase the solids concentration.

Need for sludge dewatering:

1. Cost of trucking sludge to ultimate disposal site is reduced because of reduced sludge volume consequent to dewatering.

2. Ease in handling dewatered sludge.

3. Increase in calorific value of sludge by removal of moisture, prior to incineration.

4. Rendering the sludge totally odourless and non-putrisible.

5. Sludge dewatering is commonly required prior to land filling to reduce lechate production at landfill site.

Various methods:

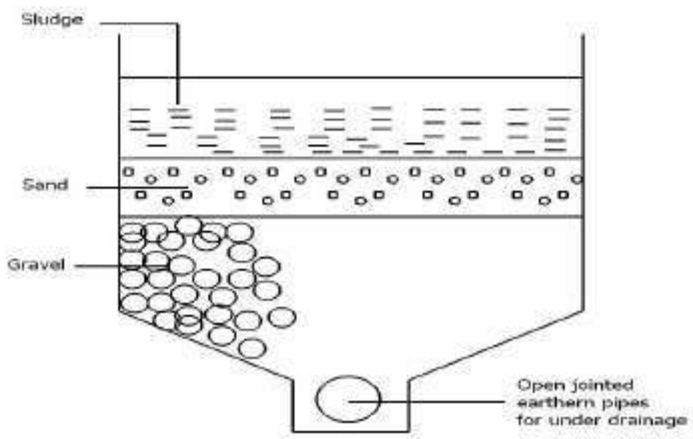
1. Sludge drying beds.

2. Mechanical methods.

3. Vacuum filters.

1. Sludge drying beds.

This method of dewatering and drying the sludge is especially suitable for those locations where temperature is higher,similar to the one prevailing in our country



A sludge drying bed usually consists of a bottom layer of gravel of uniform size over which is laid a bed of clean sand. Open jointed tile under drains are laid in the gravel layer to provide positive drainage as the liquid passes through the sand and gravel.

Under drains are made of vitrified clay pipes or tiles of at least 10cm diameter laid with open joint. Under drains are placed not more than 6m apart. Graded gravel is placed around the under drains in layers up to 30cm with a minimum of 15cm above the top of the under drains. At least 8cm of the top layer should consist of gravel of 3t o 6mm size.

Clean sand of effective size of 0. 5 to 0.75mm and uniform co-efficient not greater than 4.0 is placed over the gravel. The depth of sand may vary from 1 5t o 30cm. The drying beds are commonly 6t o 8m wide and 3 0t o 45m long. A length of 30m away from the inlet should not be exceeded with a single point of wet sludge discharge, when the bed slope is about 0.5% multiple discharge points should be used with large sludge beds to reduce the length of wet sludge travel. In order to have flexibility in operation, beds should be atleast two in number.

The area needed for dewatering the sludge is dependent on total volume of sludge, climate, temperature and location. Areas required for drying beds range from 0. 1t o 0.15m2/capita with dry solids loading of 60 to 120Kg/m2/year for digested mixed sludge. Sludge should be deposited evenly to a depth of not greater than 20cm.

When digested sludge is deposited on a well drained bed of sand described above,the dissolved gases tend to buoy up float the solids leaving a clear liquid at the bottom which drains off in a few hours after which drying commences by evaporation. The sludge cake shrinks producing cracks which accelerates evaporation from the sludge surface. With good drying conditions t, he sludge will dewater satisfactorily and become fit for removal in about 2t o 3 weeks producing a volume reduction of 20 to 40%.driedsludge can be removed by shovel or forks when the moisture content is less than 70%.when the moisture content reaches 40%, the cake becomes lighter and suitable for grinding.wheel barrows or pickup trucks are used for hauling of sludge cakes.

2. Mechanical methods.

Vacuum filtration is the most common mechanical method of dewatering,filter presses and centrifugation being the other methods. Chemical conditioning is normally required prior to the mechanical methods of dewatering.

Mechanical methods may be used to dewater raw or digested sludge’s preparatory to heat treatment by vacuum filtration because the coarse solids are rendered fine during digestion. Hence filtration of draw primary or a mixture of primary and secondary sludge’s permits slightly better yields, lower chemical requirements and lower cake moisture contents than filtration of digested sludge’s.

When the ratio of secondary and primary sludge increase, it become more and more difficult to dewater the filter. The feed solids concentration would demand unduly large filter surface I. n t his method, conditioned sludge is spread out in a thin layer on t he filtering medium,the water portion being separated due to the vacuum and the moisture content is reduced quickly.

3. Vacuum filters:

Vacuum filters consists of a cylindrical drum over which is laid a filtering medium of wool, cloth or felt, synthetic fiber or plastic or stainless steel mesh or coil springs. The drum is suspended horizontally so that one quarter of its diameter is submerged in a tank containing sludge. The valves and piping's are arranged to apply a vacuum on the inner side of the filter medium as the drum rotates slowly in the sludge. The vacuum holds the sludge against the drum as it continues to be applied as the drum rotates out of the sludge tank. This pulls water away from the sludge leaving a moist cake mat at the outer surface. The sludge cake on the filter medium is scraped from the drum just before it enters the sludge tank again. The filtration rate is expressed in kg of dry solids per square meter of medium per hour. It varies from 10kg/m2/h for activated sludge alone to 50kg/m2/hr f \or primary sludge's.

SLUDGE THICKENING :

This is to thicken the concentration of sludge solids generated in the clarifier to make sludge digestion and sludge dewatering more effective. Sludge to be thickened may be primary sludge or combined sludge from primary and excess sludge. Thickening may be broadly classified into three types namely, gravity, centrifugal and floatation. The floatation can further be dissolved-air floatation or dispersed-air floatation. When the thickening of sludge is inadequate, the filtrate from dewatering will have large amounts of suspended solids returning to the STP and affect the water quality.

Hence, excess sludge is increasingly being mechanically thickened using centrifugal thickening machines or floatation thickeners. Moreover, when performing sludge treatment for sludge collected from various STPs, sludge with varying properties is likely to be treated; therefore, forced sludge thickening process such as by using mechanical thickening equipment is indispensable. De gritting and debris removal equipment preferably be installed as the pre-treatment process before thickening unless the STP itself has such facilities in the raw sewage stage.

Gravity Thickening:

Gravity thickening is the most common practice for concentrating the sludge. It is adopted for primary sludge or combined primary and activated sludge, but is not successful in dealing with excess sludge independently. Gravity thickening of combined sludge is not effective when excess activated sludge exceeds 40% of the total sludge weight. In such cases, other methods of thickening of the excess activated sludge have to be considered.

Gravity thickeners are either continuous flow or fill and draw type, with or without addition of chemicals. Use of slowly revolving stirrers improves the efficiency. Continuous flow tanks are deep circular tanks with central feed and overflow at the periphery. They are designed for a hydraulic loading of 20,000 to 25,000 lpd/m2. Loading rates less than 12.000 lpd/m2 are likely to give too much solids to permit this loading hence, it is necessary to dilute the sludge with plant effluent and it is referred to as dilution water. Better efficiencies can be obtained for gassy sludge by slow revolving stirrers.

Air Floatation Thickening:

Air floatation units employ floatation of sludge by air under pressure or vacuum and are normally used for thickening the waste activated sludge. These units involve additional equipment, higher operating costs, higher power requirements, and more skilled maintenance and operation. However, the removal of oil and grease, solids, grit and other material as also odour control are distinct advantages.

In the pressure type floatation units, a portion of the subnatant is pressurized from 3 to 5 kg/cm2 and then saturated with air in a pressurization chamber. The effluent from this is mixed with influent sludge immediately before it is released into the flotation tank. Excess dissolved air then rises up in the form of bubbles at atmospheric pressure attaching themselves to particles which form the sludge blanket. Thickened blanket is skimmed off while the un-recycled subnatant is returned to the plant.

The vacuum type employs the addition of air to saturation and applying vacuum to the unit to release the air bubbles which float the solids to the surface. The efficiency of air floatation units is increased by the addition of chemicals like alum and polyelectrolytes. The addition of polyelectrolytes does not increase the solids concentration, but improves the solids recovery rate from 90% to 98%.

Centrifugal Thickening:

Thickening by centrifugation is applied only when there is space limitation or sludge characteristics will not permit the adoption of the other two methods. This method involves high maintenance and power costs. Centrifuges employed are of either disc or solid bowl type. Disc centrifuges are prone to clogging while the latter gives a lower quality of effluent.

Sludge Feed Pump:

Decide the sludge feed pump after considering the following:

1. Select a pump with adequate capacity.

2. Install separate pumps for each centrifugal thickener.

Appurtenances:

Decide the appurtenances after considering the following:

1. If necessary, install de-gritting and debris removal equipment before thickening.

2. Install sludge feed tank.

3. Install thickened sludge storage tank.

4. Install water supply system for internal cleaning of the centrifugal thickener and for cooling the bearing.

5. Install equipment for controlling the water content of thickened sludge.

6. If necessary, install chemical dosing equipment.

STAGES IN THE SLUDGE DIGESTION PROCESS:

Three distinct stages have been found to occur in the biological action involved in the natural process of sludge digestion. The stages are

1. Acid fermentation

2. Acid regression

3. Alkaline fermentation

1. Acid fermentation stage or acid production stage:

In this first stage of sludge digestion, the fresh sewage-sludge begins to be acted upon by anaerobic and facultative bacteria called acid formers. These organisms solubilize the organic solids through hydrolysis. The soluble products are then fermented to volatile acids and organic alcohols of low molecular weight like propionic acid, acetic acid, etc. Gase like methane, CO_2, and H_2S are also evolved. Intensive acid production makes the sludge highly acidic,and lowers the pH, value to less than 6.Highly putrefaction odours are evolved during this stage, which continues for about 15 days or so(at about 21°C). BOD of the sludge increases to some extent, during this stage.

2. Acid regression stage:

In this intermediate stage, the volatile organic acids and nitrogeneous compounds of the first stage are attacked by the bacteria, so as to form acid carbonates and ammonia compounds, small amount of H_2S and CO_2 gases are also given off. The decomposed sludge has a very offensive odour and its pH value rises a little, and to be about 6.8, the decomposed sludge also entraps the gases of decomposition, becomes foamy and rises to the surface form scum. This sludge continues for a period of about 3 months or so. BOD of the sludge remains high even during this stage.

3. Alkaline fermentation stage:

In this final stage of sludge digestion more resistant materials like proteins and organic acids are attacked at broken up by anaerobic bacteria, called methane formers, into simple substances like ammonia, organic acids and gases. During this stage, the liquid seperates out from the solids, and the digested sludge is formed. This sludge is granular and stable, and does not give offensive odours (. It has a musty earthy odour). This digested sludge is collected at the bottom of the digestion tank and is also called ripened stage. Digested sludge is alkaline in nature. The pH value during this stage rises to a little above 7, in n the alkaline range. Large volumes of methane gas (having a considerable fuel value) along with small amount of CO_2 and nitrogen are evolved during this stage. This stage extends for a period of about one month or so. The BOD of the sludge also rapidly falls down during this stage. It is thus, seen that several months (about 4.5 months or so)are required for the complete process of digestion to take place under natural uncontrolled conditions at about 21°C. This period of digestion is however very much dependent upon the temperature of digestion and other factors.

ANAEROBIC SLUDGE DIGESTION:

General:

This is the biological degradation of organic matter in the absence of oxygen. In this process, much of the organic matter is converted to methane, carbon-dioxide and water and therefore, it is a net energy producer. Since, little carbon and energy alone is available to sustain further biological activity, the remaining solids are rendered stable.

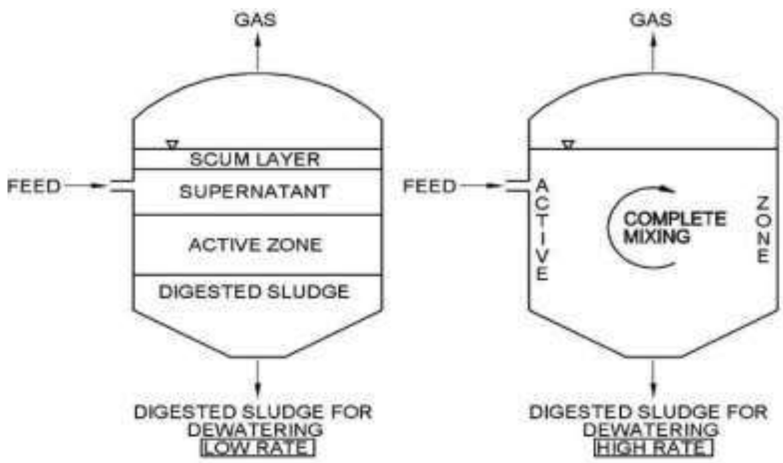
Microbiology of the Process:

Anaerobic digestion involves several successive biochemical reactions earned by a mixed culture of microorganisms. There are three degradation stages namely, hydrolysis, acid formation and methane formation.In the first stage of digestion, complex organic matter like proteins, cellulose, lipids are converted by extra cellular enzymes into simple soluble organic matter. In the second stage, soluble organic matter is converted by acetogenic bacteria into acetic acid, hydrogen, carbon dioxide and other low molecular weight organic acids. In the third stage, two groups of strictly anaerobic methanogenic bacteria, are active. While one group converts acetate into methane and bicarbonate, the other group converts hydrogen and carbon-dioxide into methane. For satisfactory performance of an anaerobic digester, the second and third stages of degradation should be in dynamic equilibrium, that is, the volatile organic acids should be converted into methane at the same rate as they are produced.

However, methanogenic microorganisms are inherently slow growing compared with the volatile acid formers and they are adversely affected by fluctuations in pH, concentration of substrates and temperature. Hence, the anaerobic process is essentially controlled by the methanogenic microorganisms.

Digestion Types:

Two different types in anaerobic sludge digestion processes are namely, low rate and high rate and are used in practice. The basic features are in Figure



Low Rate Digestion:

Raw sludge is fed into the digester intermittently. Bubbles of sewage gas are generated and their rise to the surface provides some mixing. In the case of few old digesters, screw pumps have been installed to provide additional intermittent mixing of the contents, say once in 8 hours for about an hour. As a result, the digester contents are allowed to stratify, thereby, forming four distinct layers: a floating layer of scum, layer of supernatant, layer of actively digesting sludge and a bottom layer of digested sludge; essentially the decomposition is restricted to the middle and bottom layers. Stabilized sludge that accumulates and thickens at the bottom of the tank is periodically drawn off from the centre of the floor. Supernatant is removed from the side of the digester and returned to the treatment plant.

High Rate Digestion:

The essential elements of high rate digestion are complete mixing and more or less uniform feeding of raw sludge. Pre-thickening of raw sludge and heating of the digester contents are optional features of a high rate digestion system. All these four features provide the best environmental conditions for the biological process and the net results are reduced digester volume requirement and increased process stability. Complete mixing of sludge in high rate digesters creates a homogeneous environment throughout the digester. It also quickly brings the raw sludge into contact with microorganisms and evenly distributes toxic substances, if any, present in the raw sludge. Furthermore, when stratification is prevented because of mixing, the entire digester is available for active decomposition, thereby increasing the effective solids retention time.

Pre-thickening of raw sludge before digestion results in the following benefits:

1. Large reduction in digester volume requirements

2. The thickener supernatant is of far better quality than digester supernatant; thereby, it has less adverse impact when returned to the STP

3. Less heating energy requirements

4. Less mixing energy requirements