CHAPTER 2

SLUDGE TREATMENT AND DISPOSAL

There are three main types of sludge which can be produced on sewage works:

1) Primary sludge, which consists of the solid matter settled out in the primary sedimentation tanks. According to Escritt (1965) it can be assumed that the sludge produced when settlement of domestic sewage takes place in hopper-bottomed tanks is 2.3 l/day ($\frac{1}{2}$ gal/day) per head of population (moisture content about 97.5 percent), with mechanically cleaned tanks 1.1 l/day ($\frac{1}{4}$ gal/day) (moisture content about 95 percent). This corresponds to about 0.057 kg (0.125 lb) of dry solids per head of population per day. But the actual amount produced will vary from works to works and is dependent on the suspended solids content of the raw sewage, the settlement period and the efficiency of the settling tanks. The nature of primary sludge varies, depending on the nature of the sewage and especially on its trade waste cohtent.. The presence of toxic metals can have an adverse effect on the use of the sludge as a fertilizer. Wastes from food processing factories and breweries can cause the sludge to ferment, and tripedressing and wool-scouring wastes will result in the production of a sludge with a high grease content. Trade wastes having a very high suspended soilds content, such as paper mill wastes, will, if not properly per-treated before discharge to the sewers, greatly increase the

volume of sludge produced. Where chemical coagulation is used to assist sedimentation, likewise a greater volume of sludge results containing more mineral matter than sludge from plain sedimentation, and having a lower moisture content.

2) Humus sludge, which consists of the solid matter settled out in humus tanks from the effluent of percolating filters. This sludge, with a moisture content of 94-97 percent, is rather difficult to dewater. It is greyish-brown in colour, and when fresh the odour is not unpleasant. According to Imhoff (1971), about 0.013 kg (0.029 lb) of dry humus solids are produced by conventional low-rate percolating filters per head of population per day. During the warmer weather of spring and early summer, the volume of humus sludge produced increases considerably due to 'sloughing off' or 'unloading from the filters when the biological film is attacked and broken up by the macro-organisms.

3) Activated sludge is the surplus sludge from an activated sludge plant. It is brownish, flocculent and has a pleasant earthy smell when fresh, but if allowed to become septic acquires a very offensive odour. It has a moisture content of 98-99.5 percent and is difficult to dewater. It contains 5-7 percent N and 2-4 percent P_2O_5 (dry basis, respectively). Very large volumesare produced by activated sludge plants, thus creating a difficult disposal problem.

2-1 Disposal of Liquid sludge

2-1-1 Sea Disposal

Wet sludge is collected in storage tanks adjacent to the landing stage from where it is run into tanks in specially designed ships and taken out to sea. When the vessel reaches an area of deep sea, valves are opened and the sludge is discharged into the sea while the ship is in motion. In the past this was considered an economic method of disposing of sludge, but owing to the present-day high costs of ships, labour, fuel and harbour dues, and the fact that ships are often tied up for appreciable periods of time, it is now regarded as costly. However, local conditions can be such that it is the only practicable and economic method of disposal. The method has, in the past, been only applicable for those communities which have convenient access to the sea, but improved methods of pipe - line construction have allowed inland local authorities to give serious consideration to this method of disposal.

2-1-2 Disposal on Land

Where large areas of suitable land are available these can be used for disposal of liquid sludge, and various methods are available.

Trenching Trenches are dug in the land and partially filled with liquid sludge, then refilled with soil. This method is not usually practical for the larger works.

Land Plots The land is ploughed and the sludge run into the furrows and allowed to dry, after which the land is re-ploughed and can be used for the growing of crops. This method makes use of the fertilizing constituents of the sludge, and any risks of transmission of diseased by pathogenic organisms are virtually ruled out if it is well ploughed in before cropping. Dressing of the land with lime will be necessary to prevent the development of acidity in the soil.

Lagoons These are virtually tips for liquid sludge, made by constructing high bankings round an area of land; natural depressions can sometimes be utilized, thus reducing the height of bankings required. Sludge is run into the lagoon. Provision is usually made for decanting off supernatant water which must be given suitable treatment before discharge into a watercourse; wherever possible it should be returned to the inlet of the sewage works. Digestion of the sludge takes place in the lagoon, with some reduction in volume. The sludge is never removed from this type of lagoon, and where suitable land is available this is a cheap method of disposal.

Lagoons can, however, be used as cold digestion tanks, and after a long period of digestion the sludge is run on to drying beds, or land to be dewatered.

Shallow lagoons can be used as drying beds, especially if they are underdrained.

In all these methods of disposing of sludge on land, if the land is underdrained this drainage may be polluted in character and should be treated before being discharged to a watercourse, preferably by being returned to the sewage works inlet.

2-1-3 Composting

Wet sludge can be composted with household refuse and also with straw and grass. In the former case, metal objects, glass, broken crockery, cinders and fine dust, large pieces of paper and cardboard are first removed. The composting can be carried out in shallow pits , bays or composting cells. The heap is built up in layers of household refuse, the sludge being run on to the layer before the next layer is laid on top. The ratio of sludge to refuse is usually in the region of 2 or 3 to 1 by weight, depending on the absorbent properties of the refuse, but higher ratios have been used. There must be adequate ventilation of the heap. and a drainage system must be provided underneath. Some of the liquid draining from the heap can be used to keep the material moist but any surplus must be returned to the inlet of the sewage works, as it is a most polluting liquid. It is usual to turn the material periodically; in some systems the mixing is carried out before placing it in the composting cell. In an efficient compost heap temperatures of about 70°C will be reached, which will result in the destruction of harmful organisms and weed seeds. The time for composting will vary from 3 to 6 weeks, depending on the efficiency of the method used. After this period the compost is placed in heaps, preferably under cover, and allowed to mature for at least three months. Organic material such as bracken or straw may have to be added to household refuse before composting to maintain a final carbon/nitrogen ratio of from 15-20 to 1 in the compost . Sludge and refuse can thus be converted in to a valuable fertilizer but composting in this manner is generally considered to be uneconomic owing to the long period necessary to effect it efficiently and the heavy labour costs involved.

2-1-4 Thickening

Sludges from primary and secondary treatment units in industrial waste-treatment plants frequently require concentration before they undergo dewatering by air drying, vacuum filtration, or centrifugation. Primary sludges from sedimentation units of 1 to 2 percent concentration can usually be gravity-thickened to 6 to 10 percent; biological and chemical sludges can be thickened to 4 to 6 percent.

A thickener is designed on the basis of a unit area, square feet per pounds solid per day [1-3], in which the required surface area is related to the solids entering and leaving the unit. Thickener area requirements are also expressed in terms of a mass loading, pounds solids per square foot per day, which is the reciprocal of the unit area.

The required surface area is determined from a liquid material balance between the influent, the underflow, and the effluent.

2-2 Treatment of Sludge to Facilitate Dewatering.

2-2-1 Chemical Conditioning

Chemical conditioners are sometimes added to sewage sludge as a form of preliminary treatment to facilitate drying on beds or filter pressing, and it is essential to add them before dewatering sludges on vacuum filters.

Apart from sulphuric acid, copperas and lime, which have special uses, the commonly used chemicals are the compounds of the trivalent metals iron and aluminium. In order of effectiveness as sludge conditioners, starting with the most efficient, they are

Aluminium chlorohydrate , $Al_2(OH)_4Cl_2$

Aluminium chloride , $AlCl_3$

Ferric chloride , $FeCl_3$

Chlorinated copperas , $Fe \begin{matrix} Cl \\ SO_4 \end{matrix}$

Ferric sulphate , $Fe_2(SO_4)_3$

Aluminium sulphate, $Al_2(SO_4)_3\ 18H_2O$

Sulphuric acid is used to acidify primary tank sludges (to pH about 3.5) so as to liberate valuable wool greases from these highly greasy sludges before filter pressing.

Lime is used mainly to condition primary sludges ahead of filter pressing, the amount added being usually about 5-10 per cent, calculated on a dry sludge solids basis. Lime in conjunction with copperas was found to be the most economical combination of chemicals for conditioning digested sludge before dewatering on filter presses

Iron salts Ferric chloride is much used for coagulating sludges prior to vacuum filtration chlorinated copperas, used as a coagulant for the sludge before vacuum filtration, is prepared by passing chlorine into a solution of commercial copperas whereupon the divalent iron is oxidised to the trivalent state

$$6FeSO_4 7H_2O + 3Cl_2 = 2FeCl_3 + 2Fe_2(SO_4)_3 + 42H_2O$$

Aluminium salts—Aluminium chlorohydrate has been shown to be superior to ferric salts as a sludge conditioner and is now used at most plants using vacuum filtration for sewage sludge dewatering. It is also a useful compound for conditioning all types of sewage sludge which are to be dewatered on drying beds .

Organic polymers—In the U.S.A., synthetic organic water-soluble polymers have been introduced in recent years as flocculating aids, in conjunction with ordinary chemical coagulants, for conditioning sludge prior to vacuum filtration. It is claimed that the use of very small amounts of these polymers can reduce very considerably the ferric chloride dosage, thus resulting in overall savings in chemical material costs.

2-2-2 Elutriation

Elutriation is the process of washing sewage sludges (especially primary and digested sludges) prior to coagulation with chemicals (such as ferric and aluminium salts) and subsequent vacuum filtration. This method serves to remove soluble ammoniacal compounds which consume and waste the coagulant, substances which reduce ferric salts to much less efficient ferrous salts, and finely divided suspended matter which interferes with filtration.

Elutriation is carried out in one or two stages by mixing the sludge with several volumes of water, purified plant final effluent or even settled sewage. This can be done either mechanically in tanks equipped with stirring and scraping devices or else with diffused air. The mixture is then allowed to settle for several hours and the supernatant liquor run off and returned to the sewage inlet for treatment.

Economy in wash waters can be secured by using 'counter-current' washing in which the weaker elutriates, before being returned to the sewage inlet, are used to elutriate a fresh batch of sludge. This procedure is suitable for the larger plants where it can be operated continuously in two tanks in series.

The chief advantage of elutriation is that it reduces very greatly (often by as much as 80 per cent) the coagulant demand and so results in considerable savings in chemicals. It also renders the use of lime unnecessary when filtering primary sludges in vacuum filters.

In sludge digestion plants, elutriation is sometimes used to 'clean up' the primary tank digested sludge, thus allowing considerable reduction in the capacity of the secondary digestion tanks.

2-2-3 Freezing

It has been shown that alternate slow freezing and thawing of primary, digested and activated sludges alters the character of the sludges to such an extent that water separates out quite easily. The addition of conditioning chemicals (e.g. Al salts or chlorinated copperas) before freezing increases the subsequent filtration rate. Filtration of the sludge then gives cakes with as high a dry solids content as 23-30 per cent. The process is patented and, though not likely to be cheap, is being tried out on a working scale.

The principle of slow freezing is to form large ice crystals so that, on thawing, the water will separate easily from the solids. If rapid freezing were carried out small crystals would be formed, and on thawing the water would be taken up again in to the solid matter.

2-2-4 Porteous Process

This process, which owes its successful development to W.K. Porteous is a method of conditioning the sludge by heat under pressure. The sludge is heated in steel cylinders with live steam at about 180° C and 103×10^4 N/m^2 (150 lb/in^2) pressure for 45 min or longer, which breaks down the gel structure of the sludge so that, after cooling, water separates out easily by settlement. The conditioned sludge can then be dewatered on filter presses. An important part of the plant is the heat exchanger, or 'coactor', which is essential to achieve a high heat recovery. Foul gases are produced by this process, which could be a nuisance to local residents. Steps may have to be taken to deal with these gases, as far as posible. Gases from the heater have been discharged under the boiler fires, where they are burned.

In all heat treatment plants the production of foul liquors presents a treatment problem due to the additional load they place on the sewage works, and in some cases it may be necessary to provide special pre-treatment plant to deal with these liquors. At the least they have to be balanced out over the day. The production of foul smelling gases also presents problems, especially if the sewage works is situated in a built-up area.

2-2-5 Anaerobic Digestion

Anaerobic decomposition involves the breakdown of organic wastes to gas (methane and carbon dioxide) in the absence of oxygen. Although the process kinetics and material balances are similar to the aerobic systems, certain basic differences require special consideration.

The conversion of organic acids to methane gas yields little energy; hence the rate of growth is slow, and the yield of organisms by synthesis is low. The kinetic rate of removal and the sludge yield are both considerably less than in the activated sludge process. The quantity of organic matter converted to gas will vary from 80 to 90 percent. Since there is less cell synthesis in the anaerobic process, the nutrient requirements are correspondingly less than in the aerobic system. High process efficiency requires elevated temperatures and the use of heated reaction tanks. The methane gas produced by the reaction can be used to provide this heat. Wastes of low COD or BOD concentration will not provide sufficient methane for heating, and a supplementary source of heat is necessary.

Digestion is accomplished in sludge-digestion tanks, or digesters, which are ordinarily cylindrical in shape and may be equipped with mixing and sampling devices, temperature recorders, and meters for measuring gas production. Digesters are usually covered to retain heat and odors and permit collection of gas. They are commonly built of reinforced concrete with capacities (for ordinary domestic sewage) between 1 and 3 cu ft per capita and depths of about 20 ft. Digestion proceeds most rapidly at temperatures of 90° to 95° F, and hence digesters require some means of heating. Some digesters are provided with circumferential pipe coils inside of the tank through which hot water is circulated. The temperature of the coils should not exceed 130° F, or sludge will cake on the coils and impede heat transfer. Heating coils must be replaced every 5 to 10 yr because of the corrosive action of the sludge on the metal. Still another method of heating to preheat the sludge and continuously to circulate digester liquid from the digester to a heat exchanger. With this system, mixing of sludge in the digester is accomplished by currents set up in the tank by the circulating liquid. Also, gas is sometimes recirculated under pressure to accomplish the mixing. Stirring mechanisms are sometimes provided within the tank to facilitate mixing and break up the surface scum. The desirability ofmechanical devices in a digestion tank is debatable. Many digesters rely entirely on the gases bubbling up through the sludge to provide mixing. If mechanical mixing devices are used, they should be slow-moving to provide a gentle agitation of the sludge.

2-3 Methods of Dewatering Sewage Sludge

2-3-1 Drying Beds

The most common method of dewatering sewage sludge is by means of sludge drying beds. These are generally rectangular in shape and usually have concrete floors, except in places where there is an impervious sub-soil, when the floor can be dispensed with. They are surrounded by low walls, about 0.9 m (3 ft) high, made of brickwork, reinforced concrete or even earth, but in the latter case it is advisable to cover them with asphalt or similar materials to prevent distribution of weed seeds on the sludge. There are gaps in the walls at certain points to provide access to the beds, closed by movable pieces of timber when the beds are in use. A herringbone pattern underdrainage system of field tiles is laid and channels are often provided for this purpose in concrete floors. This underdrainage system is covered by the drying bed which consists of a layer, about 300 mm (12 in) deep, of 25-38 mm (1-$1\frac{1}{2}$ in) clinker, on top of which is another layer, 50-75 mm (2-3 in) deep, of 6-13 mm ($\frac{1}{4}$-$\frac{1}{2}$ in) clinker. Provision is made for removing supernatant water from the bed, often in the form of a penstock composed of pieces of timber 25-38 mm (1-1½ in) wide fitted into vertical grooves. The supernatant water is run off by removing the top pieces of timber down to just above sludge level, thus allowing the water to run into a manhole into which also flows the water from the underdrainage system.

2-3-2 Filter Pressing

This is an old batch process for dewatering sewage sludge, having the advantages of cheapness and of giving a product of lower moisture content than most other methods; moreover, its efficiency is independent of weather conditions. The press cake can be used as a manure on agricultural land. Automated filter presses are now available.

The sludge is generally pre-treated with lime or other suitable chemicals to assist subsequent pressing.

The older type of filter press consists essentially of a series of rectangular cast-iron ridged hollow plates between which are jute or nylon filter cloths. The press is closed and the plates pressed together hydraulically or by winding screws. The sludge is forced through holes in the centre of the plates into the spaces between the filter cloths, pressure being maintained at $4.2\text{-}8.4 \times 10^5$ N/m^2 (60-120 lb/in^2). Water is forced through the cloth leaving behind the solids which form into a cake. Pressing time may vary from a few hours to as much as 30 hr. depending on the nature of the sludge. The filter cakes, which have to be discharged by manual labour on the older types, generally have a moisture content of about 50-65 per cent.

The press liquors are highly polluting and must be returned to the sewage inlet for treatment.

2-3-3 Vacuum Filtration

Vacuum filtration is used to dewater a slurry under applied vacuum by means of a porous medium which retains the solid but allows the liquid to pass. Media used include cloth, steel mesh, and tightly wound coil springs.

In vacuum filter operation, a rotary drum passes through a slurry tank in which solids are retained on the drum surface under applied vacuum. As the drum passes through the slurry, a cake is built up and water is removed by filtration through the deposited solids and the filter medium. The time the drum remains submerged in the slurry is called the form time. As the drum emerges from the slurry tank, the deposited cake is further dried by liquid transfer to air drawn through the cake by the applied vacuum. This period of the drum's cycle is called the dry time. At the end of the cycle, a knife edge scrapes the filter cake from the drum to a conveyor. The filter medium is usually washed with water sprays before it is immersed again in the slurry tank.

The amount of solids which can be dewatered per unit time and the dryness of the cake formed are a function of the filterability of the sludge solids and the porosity of the cake formed.

2-3-4 Centrifugation

Centrifugation is one of the recent methods applied to the dewatering of sewage and waste sludges. In a typical continuous centrifuge, sludge is fed through a stationary feed pipe from which it is thrown out through feed ports into the conveyor hub; the solids are settled out against the bowl wall be centrifugal force. From the bowl wall they are continuously conveyed by a screw to the end of the machine, at which point they are discharged. A pool volume is maintained in the machine. The liquid effluent discharges out of effluent ports after passing the length of the pool under centrifugal force. The variables involved in centrifuge operation are the speed of rotation, the liquid throughput, the solids throughput, and the pool depth. Increasing the pool depth decreases the drainage beach for the dewatered solids and reduces the effluent solids (increased recovery). Readily dewaterable solids require less drainage time, so that a higher poll depth can be maintained. Increasing the liquid flow rate will reduce the recovery because of decreased retention in the pool. Increasing the mass flow rate will reduce the recovery because of the lessened conveyability of the deposited solids ....