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EFFLUENT TREATMENT METHODS

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Environmental pollution has been defined as the unfavourable alteration of our surrounding, partly or largely as an impact of increasing industrialisation and related human activities, and also due to the activities of plants and animals. The continuous growth of industries in this century speeded up greater control of the environment by man but on the other hand, it accelerated pollution of air, land and water. The discharge of waste waters from different industries into rivers has given rise to offensive conditions in various parts of the country. The current practices adopted for the disposal of industrial wastes in the country include discharge into public sewers, rivers or into sea through creeks and estuaries and on land. Since little or no treatment was given, till recently, to most of these waste waters, it can be concluded that there is a possibility that considerable quantities of pollutants reach the rivers.

The quality of raw waters throughout the world is declining as a result of increased urbanisation and industrialisation and also as a result of agricultural practices. At the same time, desire for better quality of water enlarged the scope of water treatment as well as lowering the tolerance limits for discharge of industrial and domestic wastes into surface waters.

The water (prevention & control of pollution) Act 1974, brought out by Government of India has been a great step in India's march towards providing a clean environment. As per this Act, practically all the States in India and the Centre have established Boards to prevent and control water pollution due to human and industrial activity.

In order to achieve the objectives the Central and State Boards are initiating extensive river survey programmes to collect baseline data on the water quality for developing standards or tolerance limits for discharge of sewage and industrial effluents into surface waters. These standards are being revised from time-to-time based on the experience gained and new standards are added.

The steps involved in pollution abatement programme are, rivers and waste water sampling, sample preservation and characterisation, laboratory and pilot plant investigations, process design, plant construction and operation. The magnitude of the problem is quantitatively defined by a survey to determine the quantity and characteristics of waste water. It involves in plant survey, flow measurement, sample collection and preservation of sample and analysis of waste waters. This gives an understanding of the nature, quality and quantity of waste waters required in the design and operation of collection, treatment and disposal facilities and in management of environmental quality. It is, therefore, desirable to know the physical, chemical and biological

In: Workshop Manual on Treatment of effl characteristics of waste water.

The volume of fluid discharged can be measured by volumetric and velocity area methods.

Sampling

Inplant survey and examinations of drain drawings would help to determine sampling locations where flow conditions encourage a homogenous mixture. The velocity of flow at the sampling station should at all times, be sufficient to prevent deposition of solids. When collecting samples, care should be taken to avoid creating excessive turbulene that may liberate dissolved gases and yield. an unrepresentative sample. The degree of flow rate variation dictates the time interval for sampling, which must be short enough to provide a true representation of the flow. Even when flow rates vary only slightly the concentration of waste products may vary widely. Frequent sampling (with uniform intervals) allows estimation of the average concentration during the sampling period. The sampling stations and duration of samples should be such, in a waste water survey, that representative samples are obtained, because the data from the analysis of the sample will ultimately serve as a basis for designing treatment facilities.

Sample preservation

To maintain the physical, chemical and biological integrity of waste water sample during interim period between sample collection and analysis, preservatives are added. There is no universal treatment or method applicable to samples of all types and for all items.

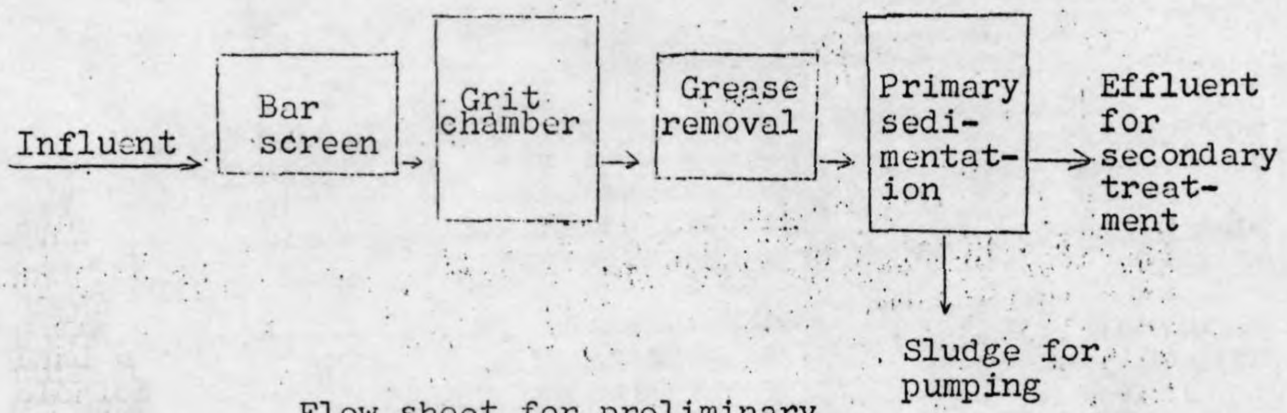
Sample analysis

The analysis used to characterise waste water vary from precise quantitative chemical determination to the more qualitative biological and physical determinations. Standard methods for the examination of water and waste water should be used for various estimations.

PRIMARY TREATMENT

Physical Methods

Some waste waters may contain coarse, suspended and floating solids, grease etc. These need to be removed before waste waters are subjected either to chemical or biological treatment. Physical operations are required for removal of coarse solids, grease etc. and also for the pumping of sludge. Racks and screens, grinders, grit chambers, grease traps, preaeration, flocculation, sedimentation, floatation, chemical precipitation, sludge pumping are the common operations. Generally, screens, grit chambers, grease traps flocculation and sedimentation without coagulant addition is resorted to waste treatment. This is because settleable solids removal can be accomplished by these steps and the effluent can be treated biologically. The purpose of the preliminary treatment is to remove inert material which will hinder the subsequent biochemical reactions. A typical flow sheet is given in the figure.



Flow sheet for preliminary treatment

Bar screens

These are to remove large floating matters as well as to avoid chogging of filter media and obstructing aeration in activated sludge process. The shape of bars may be square, rectangular, circular or tear drop.

Grit chambers

Grit chambers remove grit ie., sand, graval which have specific gravities greater than the suspended organic matter. Purpose of providing grit chamber is to protect the mechanical equipment and avoid deposition in pipelines. Many a times, grit chambers are provided ahead of treatment plants. The accumulated grit is disposed of as landfill in remote areas. The shape may be rectangular circular or square.

Grease removal

Removal of grease is necessary to increase treatability. Various patterns are available for grease traps. The most common is the one in which inlet is below the surface and outlet is at the bottom with sufficient retention period (10-30 min.). The floating material rises and remains on the surface of the wastes. Separation of greasy or oily matter can be hastened by a short pre-aeration (3-5 min), followed by detention upto 45 min. in a tank.

Primary sedimentation

This process is to reduce settleable suspended solid contents of waste waters. When a liquid containing such solids is detained without disturbance for a time, particles of higher specific gravity than liquid will settle and those with lower specific gravity will float. About 50-65% removal of suspended solids and 20-40% of the BOD can be achieved in a properly designed sedimentation tank. Common detention period is 90-150 min. based on average rate of flow. If these precede a biological treatment unit 30-60 min. detention is sufficient. These tanks may be rectangular or circular.

The volume of sludge will depend on nature of waste waters, detention period and the period between sludge removal operations. It is necessary to estimate sludge volume so that the sedimentation tanks and sludge disposal facilities can be designed properly.

CHEMICAL TREATMENT

Chemical treatment of waste water is used as an advanced treatment to the effluent after (biological) secondary treatment or as a substitute for the biological treatment. Under such circumstances, it is combined with physical processes discussed earlier.

The important unit operations and processes involved in the physical and chemical treatment of waste waters are:-

1. Chemical coagulation, flocculation and sedimentation: These reduce suspended and colloidal solids, phosphates, organic matter and certain toxicants.
2. Filteration: This removes finely divided suspended material. This may or may not be preceded by chemical coagulation.
3. Air stripping: for removal of ammonia.
4. Ion exchange: for the removal of phosphates, nitrogen and total dissolved solids.
5. Reverse osmosis: for removal of organic and inorganic substances.
6. Carbon adsorption: for reducing organic matter.

Equalisation

Different types of wastes may be produced and discharged at different intervals in an industry. Hence the wastes exhibit different characteristics from time-to-time and a proper treatment is not possible, unless the character is uniform. For this, different streams of effluents are allowed to hold in a holding tank for a specified period such that the character will be uniform. Equalisation is the best means of stabilisation of pH and BOD. During equalisation most of the solids also settle along with heavy metals.

Each unit volume of waste must be mixed thoroughly with the already discharged other unit volume of wastes to render a homogenous effluent. Proper mixing is brought about by

(1) appropriate distribution and baffling
(2) mechanical agitation and
(3) aeration.

For some wastes, a combination of these three is necessary.

Neutralisation

Wastes with extreme pH values should not be discharged without treatment. They are highly dangerous and hence should be neutralised properly.

Neutralisation of acid wastes

(1) Mixing of wastes

Mixing of acid wastes with alkaline wastes generated within the same plant or nearby industry is the cheapest method.

(2) Lime stone treatment

Acid waste is passed through the beds of lime stone either from the top or from bottom depending on the bed available. Sulfuric acid forms $CaSo_4$ which coats the lime stone and prevents further reaction. The lime stone beds must be replaced at periodic intervals and the disposal of used up lime stone beds is a serious problem.

(3) Lime slurry treatment

The advantages are: (1) it has a high neutralising power; (2) full utilisation of lime slurry; (3) calcium sulfate formed does not interfere in the further reaction as it is carried out along with the neutralised waste and (4) relatively inexpensive.

(4) Caustic soda treatment

It is the most effective method but expensive. The products formed during neutralisation are highly soluble in water. Only smaller volumes of caustic soda solutions are required.

Neutralisation of alkaline wastes

(1) Sulfuric acid treatment

This is the most efficient method but expensive.

(2) Carbon-dioxide treatment

Bottled carbondioxide may be employed. This is also expensive.

(3) Utilising waste boiler-flue gas

This is reported to be economical. Carbondioxide present in stock gases (about 14%) reacts with the alkalinity of waste water to form carbonates.

Chemical coagulation, flocculation and sedimentation

Aluminium sulphate, lime-ferrous sulphate when used in the way they are used as in normal water clarification, on waste waters, result in producing better effluent than by plain sedimentation. With favourable conditions, suspended matter can be reduced by about 90% if the plant is operated skillfully.

Coagulation is a process by which the colloidal particles are destabilised by the addition of certain chemicals and consequently aggregated and bound to form a floc which settles rapidly. The formed flocs absorb and entrap the colloidal and other suspended matter and bring them down.

Coagulants

The commonly employed coagulants are:

i) Alum (Aluminium sulfate, $Al_2(SO_4)_3\ 18H_2O$)

ii) Ferric sulfate ($Fe_2(SO_4)_3$

iii) Copperas ($Fe\ SO_4,\ 7H_2O$)

iv) Chlorinated copperas (a mixture of ferric sulfate and chloride, $Fe\ SO_4Cl$)

v) Ferric chloride ($Fe\ Cl_3$)

Among these, alum is the most popular coagulant used both in water and waste water treatment.

Neutralisation of colloid charge is the aim of coagulation. Most of the colloid present in effluents coagulate at a pH value less than 7 but the hydroxides of coagulants are insoluble only at pH values above 7 and over 9. Hence lime is added to raise the pH and also to aid in precipitation of colloids.

In addition to the coagulants, some other chemicals termed as coagulant aids are also added in minor quantities to enhance coagulation by promoting the growth to large and rapid settling flocs. Activated silica and polyelectrolytes (high mol. wt. polymers) are typical coagulant aids. They are unaffected by pH and can serve as coagulant by reducing the effective charge on a colloid.

A number of interacting variables of complex nature influence coagulation. Among these variables are pH, inorganic salts, organics, nature and concentration of colloidal matter and the coagulants. Because of these several factors, optimum coagulant dose is determined by tests rather than from a theoretical basis. The dosage of coagulants should be minimum otherwise reverse effect may take place. Jar test and final plant trials will indicate the appropriate dose.

Determination of coagulant dosage by Jar test.

1. Using 200 ml. of sample on a magnetic stirrer, add coagulant in small increments at a pH 6; after each addition provide a 1-min rapid mix followed by a 3 min. slow mix. Continue addition until a visible floc is formed.
2. Using this dosage place 1000 mil sample in each of six beakers.
3. Adjust the pH to 4,5, 6, 7, 8 and 9 with standard alkali or acid.
4. Mix rapidly each sample for 3 min.; follow this with 12 min flocculation at slow speed.
5. Measure the effluent concentration of each settled sample.
6. Plot the percent removal of characteristics versus pH and select the optimum pH.
7. At this pH repeat steps 2, 4, and 5 varying the coagulant dosage.
8. Plot the percent removal versus the coagulant dosage and select the optimum dosage.
9. If a polyelectrolyte is used repeat the procedure, adding polyelectrolyte towards the end of the rapid mix.

Secondary Treatment

Secondary treatment removes the dissolved organic matter and thereby reduces BOD. Commissioning and maintenance of secondary treatment systems involve more economy. All the secondary treatments are biological processes and bacteria are the major organisms carry out the oxidation. They consume organic matter as food and thus positively remove dissolved organics.

The most common biological treatments are:

(1) Aerated lagoon
(2) Trickling filtration
(3) Activated sludge process
(4) Oxidation ditch
(5) Oxidation pond
(6) Anaerobic digestion

Other treatments not much practised are:

(1) Dispersed growth aeration
(2) Contact stabilisation
(3) Bio-disc system
(4) Spray irrigation

The effectiveness of the treatment is dependent on the bacterial slime, pH, temperature, and nutrients. It is highly affected by the presence of extreme pH values, and toxic constituents such as chronium, lead, nickel and hydrogen sulfide etc.

Aerated lagoons

These are large holding tanks or ponds, depth varies from 3-5 M. The effluent after primary treatment is passed on to these tanks and aerated mechanically. Floating aerators are the most commonly employed to supply the necessary oxygen and mixing power.

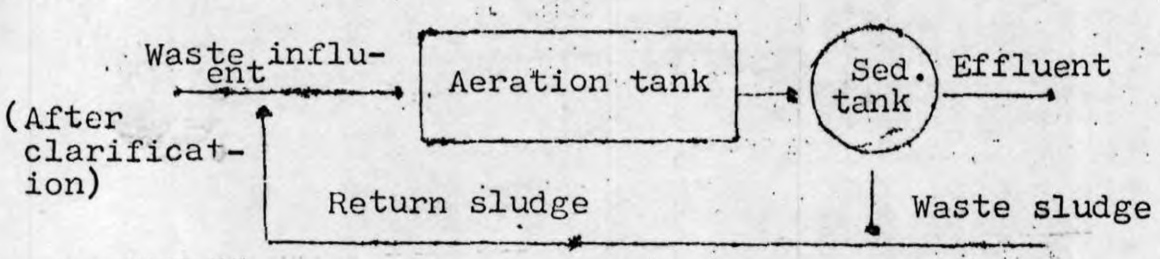
Recommended detention period ranges from 2-6 days, during which time a healthy flocculent sludge is formed which carry out oxidation of organic matter. It is reported that 90% of BOD removal is achieved with aerated lagoons. Another advantage is that the operation and maintenance are much simpler. The major disadvantage is the requirement of space.

Trickling filtration

In this method, waste water after primary treatment is sprinkled over a bed of broken stones. The bacterial slimes formed on the stones oxidise the waste water during its passage. The effluent from trickling filter is allowed to settle and then discharged.

Activated sludge process

The most versatile biological oxidation method for treating industrial wastes is activated sludge process. In this process, industrial waste is continuously exposed and subjected to biological degradation carried out by the microbial floc suspended in the reaction tank into which oxygen is introduced by mechanical means. The effluent from the reaction tank is allowed to settle and a portion of the sludge is recycled to the tank itself for effective microbial population.



The flocs formed in activated sludge process are zoogleal masses of living organisms, embeded with their food and slime material and are the active centres of biological oxidation and hence the name activated sludge. The desired concentration of floc is maintained in the system by recirculation of the settled sludge (about 20%). A young light sludge is preferable over an old heavy sludge.

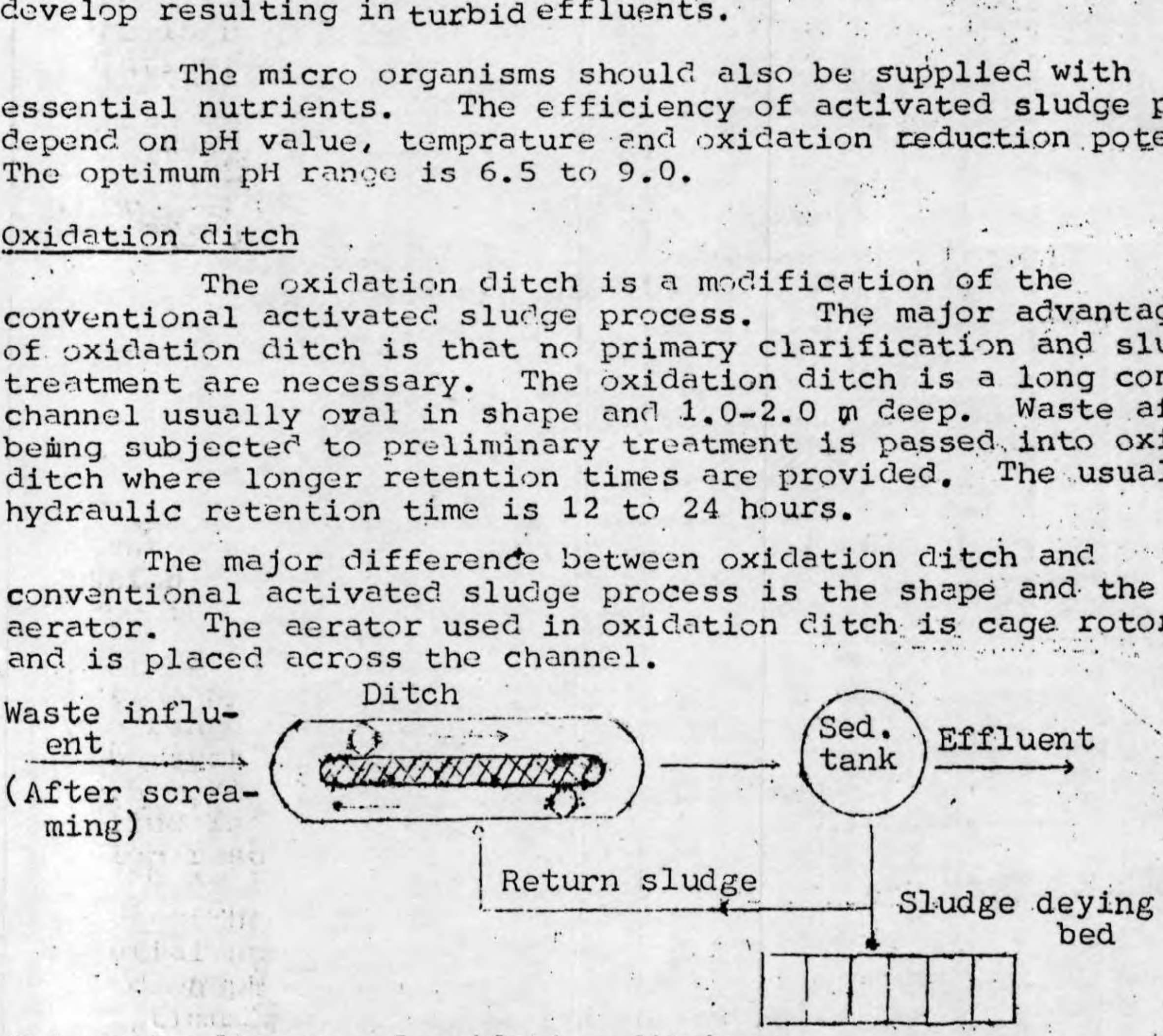
Oxygen is supplied either by mechanical or diffused aeration systems. The average period of aeration for industrial waste ranges from 6 - 24 hours and for sewage about 6 hours. If the system has to be operated properly, at least a residual of 0.5 mg/l should be present at all times. If the oxygen supplied is less than the amount required, anaerobic conditions develop resulting in turbid effluents.

The micro organisms should also be supplied with essential nutrients. The efficiency of activated sludge process depend on pH value, temprature and oxidation reduction potential. The optimum pH range is 6.5 to 9.0.

Oxidation ditch

The oxidation ditch is a modification of the conventional activated sludge process. The major advantage of oxidation ditch is that no primary clarification and sludge treatment are necessary. The oxidation ditch is a long continuous channel usually oval in shape and 1.0-2.0 m deep. Waste after being subjected to preliminary treatment is passed into oxidation ditch where longer retention times are provided. The usual hydraulic retention time is 12 to 24 hours.

The major difference between oxidation ditch and conventional activated sludge process is the shape and the aerator. The aerator used in oxidation ditch is cage rotor and is placed across the channel.



Schematic diagram of oxidation ditch

Cage rotors (of 70 cm dia) are reported to provide 3 kg of O_2 per metre length per hour with the usual immersion depth of 15 cm and 70 rpm. It is reported that 80 to 85% BOD is removed.

Oxidation ponds (Waste stabilization ponds)

An oxidation pond is a large shallow pond in which wastes are added at one end and effluent removed at another end. Stabilization of organic matter is brought about by bacteria. Oxygen required for its metabolism is supplied by algae in the pond. In turn it utilizes the carbondioxide released by bacteria for its photosynthesis. For effective waste treatment maximum sun light penetration of photosynthesis of algae, wind action for mixing, maximum natural aeration are necessary. To satisfy these requirements, oxidation ponds are constructed shallow (0.5m to 1.5m depth) and not so deep. During night time algae also require oxygen which is taken out from the pond itself. This oxygen must be supplemented by surface aeration. If the pond is devoid of oxygen, then anaerobic conditions set up leading to putrification of wastes and release of foul orders. In this condition, in addition to natural aeration, mechanical aeration can also be provided.

Anaerobic digestion

This treatment is mainly employed for the digestion of sludges as well as liquid waste containing soluble organies. As the name implies, oxidative digestion is carried out in the absence of air in a closed vessel and methane and ammonia are liberated as the end products. It is to be mentioned that pH must be controlled to near neutral point in the digesters.

Many reasons exist for the the utilization of anaerobic processes for waste management such as:-

1. Higher loading rates than are possible for aerobic treatment
2. Useful end products such as digested sludge
3. Stabilization of organic matter and
4. Alteration of water-binding characterestics to permit rapid sludge devatering. The digested solids do not have an offensiv odour. Inadequately digested solids are capable of generating odours. Factors that should be evaluated when considering anaerobic waste treatment include mixing, loading, temperature solids retention time, nutrient availability and buffer capacity.

In anaerobic processes microorganisms are used under anaerobic conditions to convert organic solids to methane, carbon dioxide and non biodegradable solids.

If volatile acids are produced at a faster rate than they are utilized, adverse conditions will not occur as long as the buffer capacity of the system can neutralize the excess acids. Low or decreasing volatile acid concentrations are indicative of satisfactory anaerobic metabolism. Signs of anaerobic process failure include decreasing alkalinity, decreasing pH, increasing volatile acids, and increasing carbon dioxide content of the digester gas.

Alkaline earth metal salts, such as those of sodium, pota calcium or magnesium which may be in high concentrations in certain wastes can be the cause of the inefficiency or failure of anaerobic systems. Free ammonia concentration can be toxic. Low concentration of copper, zinc, chromium and Nickel can be toxic to anaerobic treatment. Excessive concentrations of sulfides are toxic and should be prevented. Sulfates are the major precursors of sulfides in anaerobic treatment units. Excessive concentrations of sulfides can be precepitated to reduce the sulfide toxicity in the anaerobic unit. Iron salts can be used for such preceipitation.

Oxygen and oxidised material such as nitrates should not be added to anaerobic units. When nitrates have been added to anaerobic units as a source of nitrogen or in hopes of increasing the buffering capacity of the units, volatile acids have increased and gas production decreased significantly. Whenever chemical additives are required in a anaerobic system they should be added in the most reduced forms. For example, the reduced forms of nitrogen such as ammonium carbonate, chloride and hydroxide and unhydrous ammonia are suitable.

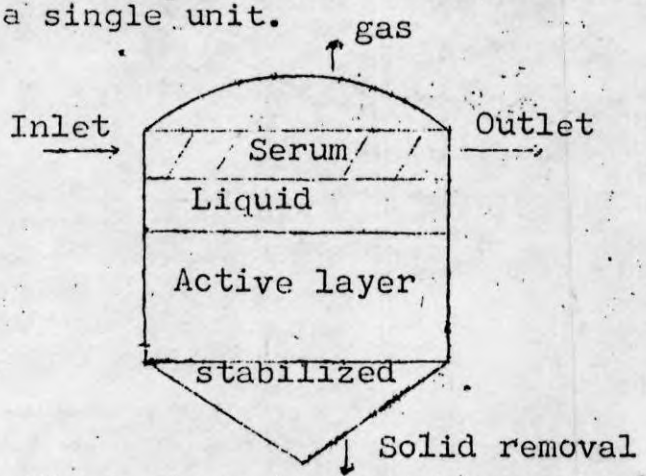
The maximum rate of biological reaction takes place when the organisms are brought continuously into contact with the organic material.

Basic Anaerobic Processes

There are four basic processes that can be employed for anaerobic waste treatment.

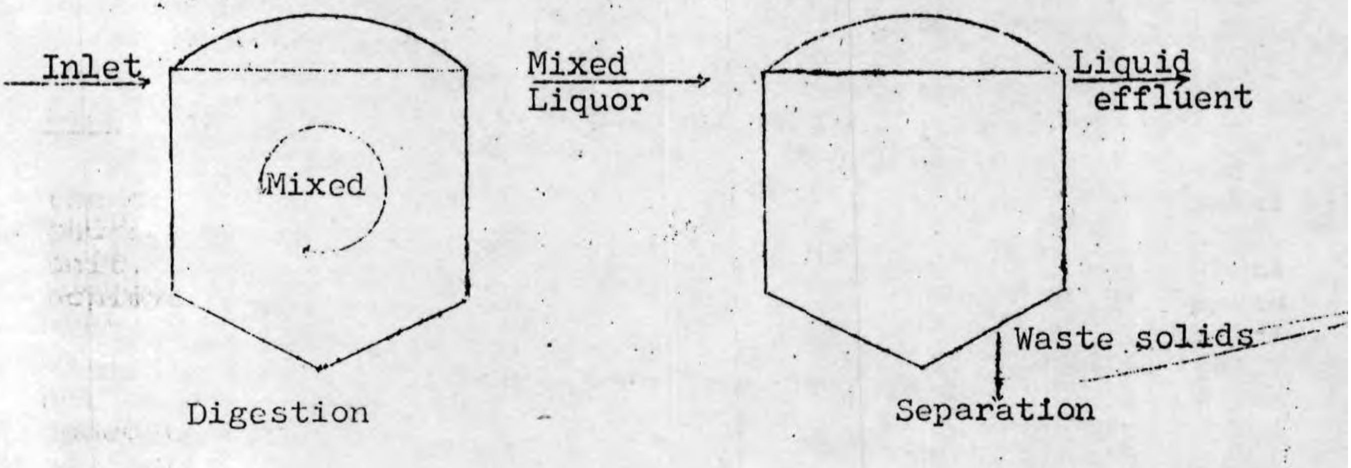
Single Stage

The single stage anaerobic unit represents one of the oldest anaerobic processes. Both biological stabilization and solid-liquid seperation are to be accomplished in the same unit. Conditions optimum for both factors are difficult to achieve in a single unit.



Two stage

The first stage is a continuously fed and completely mixed, temperature controlled biological unit. The second stage is a solids concentrator and spearator.



Two stage with solids return

Systems of this type provide greater flexibility in maintaining a minimum SRT, in maintaining a higher active mass of micro organisms in the system and in permitting the use of smaller first stage tank capacities with sludge return, the microbial population can be maintained at levels to obtain better efficiency in a unit having greater stability than that found in single stage and two stage anaerobic units without sludge return. This anaerobic system is analogous to an activated sludge system.

Anaerobic filter

The anaerobic filter represents the newest anaerobic treatment process. The unit is useful for the treatment of dilute soluble wastes and in denitrifying oxidised effluents for nitrogen control. The filter consists of a bed of submerged media through which waste flows in an upward direction. The anaerobic organisms grow within the bed and either cling to the media or grow in the voids. The filter has a large capacity for retaining microorganisms.

Tertiary Treatment

Tertiary treatment is applied to the waste for the removal of dissolved inorganic solids and bacteria and some times for the removal of final traces of organics.

Removal of bacteria especially of fecal origin is achieved by keeping the effluents from secondary biological treatment units in maturation ponds for specified periods. If the final effluent still contains enoggh bacteria, it is chlorinated. Evaporation, reverse osmosis, dialysis, ion exchange, chemical precipitation and removal by algae are some of the tertiary treatment methods.

Removal of dissolved solids by algae is still in the experimental stage. Algae require carbon, nitrogen, phosphorous sulphur, potassium, calcium and magnesium for their growth. In addition they also need iron, manganese, zinc, boron, cobalt, copper, molybdenum and silicon in trace quqntities. Algal uptake of these elements reduces the dissolved solids content of waste water. It is to be mentioned that algae must be removed prior to final disposal into a water course used as a public water supply.

Waste waters from an industry can usually be treated to the required degree in two main steps, namely primary treatment and secondary treatment which together achieve an efficiency of more than 90 percent. To reclaim and re use the waste water for any other useful purposes the above treatment is not enough. The reclamation can be achieved by tertiary treatment for the removal of non-biodegradables, dissolved salts, nutrients and microorganisms. The cost of tertiary treatment can be made attractive by employing simple low cost methods of treatment and by planning and integration of the waste water reuse programme into an over all disposal, conservation and water supply plan.

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