E-CONTENT PREPARED BY

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Name of Course:
Chemistry in Natural Management

Topic of the E-Content:
Wastewater Management

WASTEWATER MANAGEMENT I

Typical municipal sewage contains oxygen demanding materials, sediments, grease, oil, scum, pathogenic bacterias viruses, salts, algal nutrients, pesticides, refractory organic compounds, heavy metals, and an astonishing ~~varil~~ variety of flotsam ranging from children's socks to sponges.

Several characteristics are used to describe sewage. These include turbidity, suspended solids, total dissolved solids, acidity or pH, and dissolved oxygen. Biochemical oxygen demand is used as a measure of oxygen-demanding substances.

current processes for the treatment of wastewater can be devided into three main categories of primary treatment, secondary treatment, and tertiary treatment.

Primary Waste Treatment

Primary treatment of wastewater consists of the removal of insoluble matters such as grit, grease, and scum from water. The first step in primary treatment normally is screening. Screening removes or reduces the size of trash and large solids that get into the sewage system. Those solids are collected on screens and scraped ~~of~~ off subsequent disposal. Most screens are cleaned with power ~~racks~~ rakes. Comminuting devices shred and grind solids in the sewage. Particle size can be reduced to the extent that the particles can be return to the sewage flow.

Grit in wastewater consists of such materials as sand and coffee-grounds that donot biodegrade well and generally have a high settling velocity. Grit removal is practiced to prevent its accumulation in other parts of the treatment system to reduce clogging of ~~pipes~~ pipes and other parts, and to protect moving parts from abrasion and wear. Grit normally is allowed to settle in a tank under conditions of low flow velocity, and it is then scraped mechanically from the bottom of the tank.

Primary sedimentation removes both settleable and floatable solids. During primary sedimentation there is a tendency for flocculant particles to aggregate for better settling, a process that may be aided by the ~~add~~ addition of chemicals. The material that floats in the primary settling basin is known collectively as grease. In addition of fatty substances, the grease ~~consists~~ consists of oils, waxes, free fatty acids, and insoluble soaps containing calcium and magnesium. Normally, some of the grease settles with the sludge and some floats to the surface, where it can be remoral by a skimming ~~dat~~ devices.

Secondary Waste Treatment

The most obvious harmful effect of biodegradable organic matter in wastewater is BOD, consisting of a biochemical oxygen demand for dissolved oxygen by microorganism-mediated degradation of the organic matters. Secondary wastewater treatment is designated to remove BOD, usually by taking advantage of the same kind of biological processes that would otherwise consume oxygen in water receiving the wastewater. Secondary treatment by biological processes takes many forms but consists basically of the action of microorganisms provided with added oxygen degrading organic materials in solution or in suspension until the BOD of the waste has been reduced to acceptable levels.

The waste is oxidized biologically under conditions controlled for optimum bacterial growth, and at a site where this growth does not influence the environment.

One of the simplest biological waste treatment processes is the trickling filter in which wastewater is sprayed over rocks or other solid support material covered with microorganisms. The structure of the trickling filter such that contact of the wastewater with air is allowed and degradation of organic matters occurs by the action of the microorganisms

Rotating biological reactors (contactors), another type of treatment system, consist of groups of large plastic discs mounted close together on a rotating shaft. The device is ~~positional~~ positioned such that at any particular instant half of each disc is immersed in wastewater and half exposed to air. The shaft rotates constantly, so that, the submerged portion of the discs is always changing. The discs, usually made of polyethylene or polystyrene, accumulate thin layers of attached biomass, which degrades organic matter in the sewage. Oxygen is absorbed by the biomass and by the layers of ~~wat~~ wastewater adhering to it during the time that the biomass is expressed to air.

Both trickling filter and rotating biological reactors are example of fixed film biological (FFB) or attached growth processes. The greatest advantages of these processes is ~~these~~ their low energy consumption.

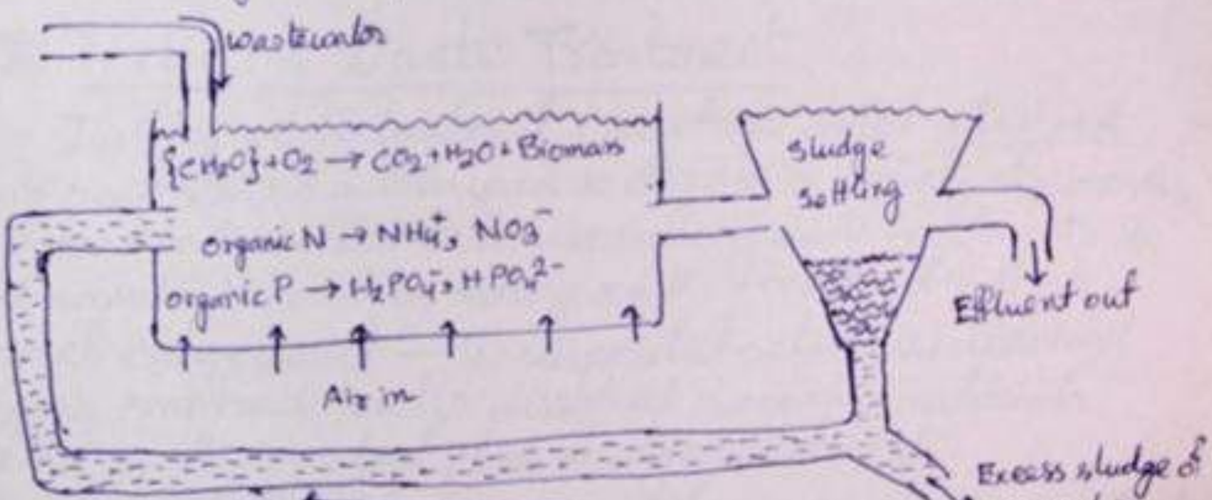


Fig. 1: Activated sludge process.

The activated sludge process is probably the most versatile and effective of all wastewater treatment processes. Microorganisms in the aeration tank convert organic material in wastewater to microbial biomass and CO_2. Organic nitrogen ~~is~~ is converted to ammonium ion or ~~ni~~ nitrate. Organic phosphorus is converted to orthophosphate. The microbial ~~att~~ cell matter formed as part of the waste degradation processes is normally kept in the aeration tank until the microorganisms are past the log phase of growth, at which point the cells flocculate relatively well to form ~~settlable~~ settleable solids. these solids settle out in a settler and a fraction of them is discarded. Part of the solids, the return sludge, is recycled to the head of the aeration tank and comes into with fresh sewage. The combination of a high concentration of 'hungry' cells in the return sludge and a rich food source in the influent sewage provides optimum conditions for the rapid degradation of organic matters.

In the activated sludge process, continual recycling of active organisms provides the optimum conditions for waste degradation, and a waste may be degraded within the very few hours that it is present in the aeration tank.

~~The~~ Tertiary Waste Treatment

Tertiary waste treatment (sometimes called advanced waste treatment) is a term used to describe a variety of processes performed on the effluent from secondary waste treatment. The contaminants removed by tertiary waste treatment fall into general categories of — (1) suspended solids, (2) dissolved organic compounds, and (3) dissolved inorganic materials, including the important class of algal nutrients.

Suspended solids are primarily responsible for residual biological oxygen demand in secondary sewage effluent waters. The dissolved organics are the most hazardous from the standpoint of potential toxicity. The major problem with dissolved organic materials is that presented by algal nutrients, primarily nitrate and phosphates. In addition, potentially hazardous toxic metals may be found among the dissolved inorganics.

• Physicochemical Treatment of Municipal Wastewater

Complete physical-chemical wastewater treatment systems offer both advantages and disadvantages relative to biological treatment systems. The capital ~~cost~~ costs of physical-chemical facilities can be

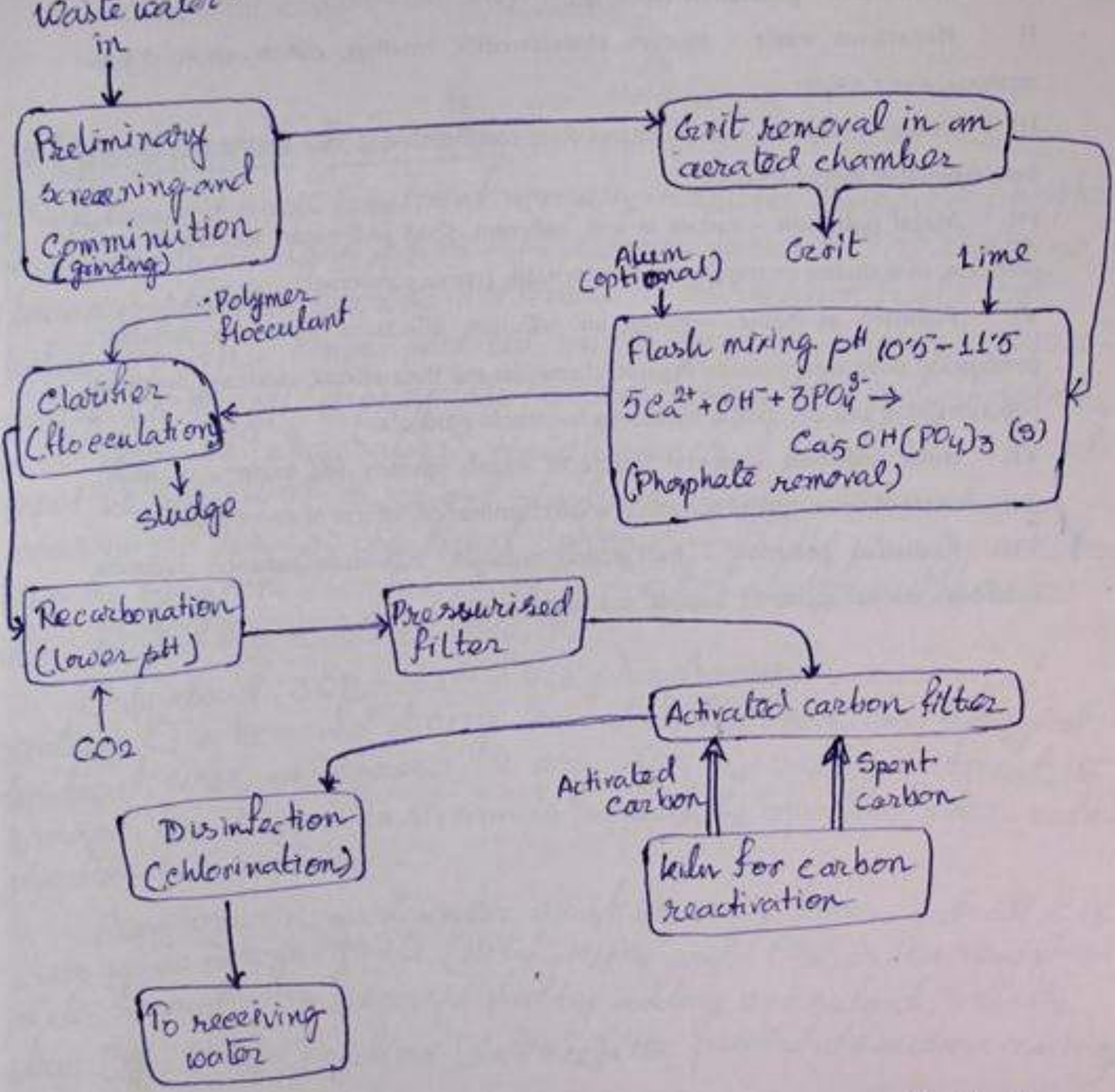


Fig 2: Major components of a complete physicochemical treatment facility for municipal wastewater.

less than those of biological treatment facilities, and they usually require less land. They are better able to cope with toxic materials and overloads. However, they require careful operator control and consume relatively large amounts of energy. Basically, a physico-chemical treatment process involves:

- Removal of scum and solid objects.

- Clarification, generally with addition of a coagulant, and frequently with the ~~add~~ addition of other chemicals (such as lime ~~phosphate~~ phosphorus removal)
- Filtration ~~&~~ to remove filterable solids.
- Activated carbon absorption
- Disinfection.

PHOSPHORUS REMOVAL

Advanced waste treatment normally requires removal of phosphorous to reduce algal growth. Algae may grow at PO_4^{3-} levels as low as 0·05 mg/L. Growth inhibition requires levels well below 0·5 mg/L. Since municipal wastes typically contain approximately 25·00 mg/L of phosphate (as orthophosphates, polyphosphates, and insoluble phosphates), the efficiency of phosphate removal must be quite high to prevent algal growth. This removal may occur in the sewage treatment process — (1) the primary settler, (2) in the aeration chamber of the activated sludge unit, or (3) after secondary waste treatment.

Only about 30 percent of the phosphorous in municipal wastewater is removed during conventional primary and biological treatment. Since, phosphorous is very often the limiting nutrient, its removal from the waste stream is especially important when eutrophication is a problem.

Phosphorus in wastewater exist in many forms. but all of it ends up as orthophosphate (HPO_4^{2-}, $H_2PO_4^-$ and PO_4^{3-}). Removing phosphates is most often accomplished by adding coagulant, usually alum [$Al_2(SO_4)_3$] or lime [$Ca(OH)_2$]. The pertinent reaction involving alum is —

$$Al_2(SO_4)_3 + 2PO_4^{3-} \longrightarrow 2AlPO_4\downarrow + 3SO_4^{2-}$$

Alum is sometimes added to the aeration tank when the activated sludge process is being used, thus minimizing the need for additional equipment.

Activated sludge treatment removes about 20 percent of the phosphorus from sewage. Thus, an appreciable fraction of largely biological phosphorus is removed with the sludge. Detergents and other sources contribute significant amounts of phosphorus to domestic sewage and considerable phosphate ions remains in the effluent. However, some wastes, such as carbohydrate wastes from sugar refineries, are so deficient in phosphorus that supplimentation of the waste with inorganic phosphorus is required for proper growth of the microorganisms degrading the wastes.

Under some sewage plant operating conditions, much greater than normal phosphorus removal has been observed. In such plants, characterised by high dissolved oxygen and high pH levels in the aeration tank, removal of 60-90 percent of the phosphorus has been attained, yielding two or three times the normal level of phosphorus in the sludge. In a conventionally operated aerated tank of an activated sludge plant, the CO_2 level is relatively high because of the gas by the degradation of organic materials. A high CO_2 level results in a relatively low pH, due to the presence of carbonic acid. Thus, the pH generally is low enough that phosphate is maintained primarily in the form of the $H_2PO_4^-$ ion. However, at a higher rate of aeration in relatively hard water, the CO_2 is swept out, the pH rises, and reaction such as the following occur:

$$5Ca^{2+} + 3HPO_4^{2-} + H_2O \rightarrow Ca_5OH(PO_4)_3(s)\downarrow + 4H^+$$

Precipitated hydroxyapatite or other form of calcium phosphate is incorporated in the sludge floc. This reaction is strongly hydrogen ion (H^+) dependent, and an increase in the hydrogen ion concentration drives the equilibrium back to the left. Thus, under aerobic conditions when the sludge medium becomes more acidic due to higher CO_2 levels, the calcium return to solution.

Chemically, phosphate is most commonly removed by precipitation (some ~~precipita~~ common precipitants and their products are shown in Table-1). ~~Precipitant~~ Precipitation processes are capable of at least 90-95 percent phosphorus removal at reasonable cost. Lime, $Ca(OH)_2$, is the chemical most commonly used for phosphorus removal:

$$5Ca(OH)_2 + 3HPO_4^{2-} \longrightarrow Ca_5OH(PO_4)_3(s) + 3H_2O + 6OH^-$$

Table 1: Chemical precipitants for phosphate and their products.

Precipitants	Products
$Ca(OH)_2$	- $Ca_5OH(PO_4)_3$ [Hydroxyapatite]
$Ca(OH)_2 + NaF$	- $Ca_5F(PO_4)_3$ [Fluorapatite]
$Al_2(SO_4)_3$	- $AlPO_4$
$FeCl_3$	- $FePO_4$
$MgSO_4$	- $MgNH_4PO_4$

Lime has the advantages of low cost and ease of regeneration. The efficiency with which phosphorus is ~~remo~~ removed by lime is not as high as would be predicted by the low solubility of hydroxyapatite, $Ca_5OH(PO_4)_3$. Some of the possible reasons for this are slow precipitation of $Ca_5OH(PO_4)_3$, formation of nonsettling colloids; precipitation of Calcium as $CaCO_3$ in certain pH ranges, and the fact that phosphate may be present as condensed phosphates (polyphosphates), which form soluble complexes with calcium ion.

Phosphate can be removed from solution by adsorption on some solids, particularly activated alumina, Al_2O_3. Removals of upto 99.9 percent of orthophosphates have been achieved with this method.

• NITROGEN REMOVAL

Next to phosphorus, nitrogen is the algal nutrient most commonly removed as part of advanced wastewater treatment. The treatments techniques are as follows:

(i) Air Stripping Ammonia: Ammonia ion is the initial product of ~~biodegradable~~ degradation of nitrogen waste. It is removed by raising the pH to approximately 11 with lime, and stripping ammonia gas from the water by air in a stripping tower. Scaling, icing, and air pollution are the main disadvantages.

(ii) Ammonium Ion Exchange: clinoptilolite, a natural zeolite, selectively removes ammonium ion by ion exchange:
$Na^+(clinoptilolite) + NH_4^+ \rightarrow NH_4^+(clinoptilolite) + Na^+$. The ion

ion exchanger is regenerated with sodium or calcium salts.

(iii) Biosynthesis : The production of biomass is the sewage treatment system and its subsequent removal from the sewage effluent result in a net loss of nitrogen from the system.

(iv) Nitrification - Denitrification : This approach involves the conversion of ammoniacal nitrogen to nitrate by bacteria under aerobic conditions.

$$2NH_4^+ + 3O_2 \xrightarrow{Nitrosomonas} 4H^+ + 2NO_2^- + 2H_2O$$

$$2NO_2^- + O_2 \xrightarrow{Nitrobactor} 2NO_3^-$$

followed by production of elemental nitrogen (denitrification):

$$4NO_3^- + 5(CH_2O) + 4H^+ \xrightarrow[bacteria]{Denitrifying} 2N_2(g) + 5CO_2(g) + 7H_2O$$

Typically, denitrification is carried out in an anaerobic column with added methanol as a food source (microbial reducing agent)

(v) Chlorination : Reaction of ammonium ion (NH_4^+) and hypochlorite (from chlorine) results in denitrification by chemical reactions:

$$NH_4^+ + HOCl \longrightarrow NH_2Cl + H_2O + H^+$$

$$2NH_4Cl + HOCl \longrightarrow N_2(g) + 3H^+ + 3Cl^- + H_2O$$

Nitrogen in municipal wastewater generally is present as organic nitrogen or ammonia. Ammonia is the primary nitrogen product produced by most biological waste treatment processes. This is because it is expensive to aerate sewage sufficiently to oxidize the ammonia to nitrate through the action of nitrifying bacteria. If the activated sludge process is operated under conditions such that the nitrogen is maintained in the form of ammonia, the latter may be stripped in the form of NH_3 gas from the water by air. For ammonia stripping to work, the ammoniacal nitrogen must be converted to volatile ammonia gas, which requires a pH subsequently higher than the pka of the NH_4^+ ion. In predict, the pH is raised to approximately

11.5 by the addition of lime (which also serves to remove phosphates). The ammonia is stripped from the water by air.

Nitrification followed by denitrification is arguably the most effective technique for the removal of nitrogen from wastewater. The first step is an essentially complete conversion of ammonia and organic nitrogen to nitrate under strongly aerobic conditions, achieved by more extensive than normal aeration of the sewage :

$NH_4^+ + 2O_2$ (Nitrifying bacteria) $\rightarrow NO_3^- + 2H^+ + H_2O$

The second is the reduction of nitrate gas. This reaction is also bacterially catalyzed and requires a carbon source and a reducing agent ~~through~~ such as methanol, CH_3OH.

$6NO_3^- + 5CH_3OH + 6H^+$ (Denitrifying bacteria) $\rightarrow 3N_2(g) + 5CO_2 + 13H_2O$

The ~~nitrifi~~ denitrification process can be carried out either in a tank or on a carbon column. In pilot plant operation, conversions of ~~95~~ 95 percent of the ammonia to nitrate and 86 percent of the nitrate to nitrogen have been achieved. Although methanol is shown in the reaction as a source of reducing agent for the microbial ~~reducing~~ reduction of nitrate, other organic substances can be used as well. Ethanol from the fermentation of otherwise waste carbohydrates would serve as a reducing substances.

- **FOOD-MICROORGANISM RATIO (F/M RATIO)**

Food to microorganism (F/M) ratio is one of the significant design and operational parameters of activated sludge system. A balance between substrate consumption and biomass generation helps ~~to~~ in achieving system equilibrium. The F/M is responsible for the decomposition of organic matter. The type of activated sludge system can be defined by its FM ratio.

- Extended aeration, $0.05 < F/M <$ [illegible] 0.15
- Conventional activated sludge system, $0.2 < F/M < 0.5$
- Completely mixed, $0.2 < F/M < 1.0$
- High rate, $0.4 < F/M < 1.5$

Two important parameters for operating the process are food: microorganism ratio (F:M) and the sludge age. These parameters originate from the mass balance for the systems.

The F:M ratio, U is

$$U = \frac{Q(S_o - S_e)}{V X_v} = \frac{S_o - S_e}{X_v \theta_d}$$

where ~~θd is the~~ θ_d is the hydraulic retention time (HRT)

The F/M ratio, $kg\ BOD_5/kg\ MLVSS.d$ is determined as follows:

$$F/M = \frac{[\text{BOD of wastewater } (g/m^3)]\,[\text{Influent flow rate } (m^3/d)]}{[\text{Reactor volume } (m^3)]\,[\text{Reactor biomass } (g/m^3)]}$$

The F/M ratio describes the degree of starvation of the microorganisms. Because, ~~at~~ biological treatment processes should remove nearly all of the influent substrate, the F:M ratio is often expressed as —

$$U = \frac{S_o}{X_v \theta_d}$$

This equation also expressed the potential food availability to the microbial population.

The sludge age, θ_x, describe the residence time of the sludge in the ecosystem. The sludge or biomass requires a certain amount of time assimilate the substrate and reproduce. If the sludge is not able to reproduce itself before being washed out of the system, failure will result. Also the sludge age is related to the F:M ratio describing the relative state of starvation of the microorganisms. Higher sludge ages cause the sludge to undergo more endogenous decay. This has an effect on the ~~settleable~~ settleability of the sludge as well as on the total amount of sludge produced in the system.

Storing the sludge under conditions that have a minimal effects on its activity and maintain it in a dormant state will not increase the sludge age. Because, the sludge is in an aerobic state in the aeration basin and the small amount of DO in the in the aeration basin effluent is rapidly exhausted in the clarifier, the sludge is in an anoxic or anaerobic condition in the clarifier. The changes in DO and lack of substrate mildly shock the sludge, putting it in an essentially dormant state. Therefore, residence time of the sludge in the clarifier does not contribute to the effective sludge age.

Under these conditions, the sludge age, or sludge residence time (SRT) is the average amount of time the sludge spends in the aeration basin. The SRT is completely analogous to the HRT which is the average residence time of a particle of water in the aeration basin, although the two times are not necessarily equal.

$$\theta_x = \frac{\text{Mass of solids in aeration basin } (VX_v)}{\text{Solids removal rate from the system}}$$

The specific expression of the solids removal rate is given below for each system. The concept of F:M ratio and SRT also become clearer after the mass balance relation are examined.

Sludge Volume Index (SVI)

A measure of the settlebility and compactibility of sludge is made from a laboratory column settling test. Mixed liquor with a know TSS content (X_T) is mixed and placed in a 1- or 2-L cylinder. The larger cylinder is desirable to minimize bridging of the sludge floc and wall effects. Gentle stiring during test is also reccommended to obtain the most efficient settling. The mixed liquor is allowed to settle for a period of time ranging from 30 min to 1 hr or 2 hr. One half hour is the more common settling time.

At the end of the settling period the volume of sludge is read from the cylinder. The sludge volume index (SVI) is defined as the volume in milliliters occupied by 1g of sludge after it has settled for a specified period of time. If a 1L cylinder is used and the sludge occupies a volume of y ml at the end of the settling periods

$$SVI \text{ (mL/g)} = \frac{y}{X_T} (1000 \text{ mg/g})$$

A low SVI is indicative of a sludge that settles well. The SVI can be used to estimate concentrations of VSS and TSS in the recycle line if the ratio of VSS to TSS in the mixed liquor is known.

The typically, the ratio of VSS to TSS in the mixed liquor is in the range of 0.75 to 0.80.

$X_{Tr} = \frac{10^6}{SVI}$, $X_{Vr} = \frac{X_V}{X_T} X_{Tr}$, where X_{Tr} and X_{Vr} are in mg/L.

The F:M ratio and the SRT (which is directly related to F:M) influence the settleability and compactibility of the sludge. When the biomass is in a state of endogenous decay, it tends to form polymers that result in natural flocculation under quiescent conditions. In a CM reactor at low sludge ages the sludge tends to become populated with filamentous organisms that exhibit poor settleability and the sludge does not flocculate well. At the other extreme of highly starved conditions or a very high SRT, the sludge forms pinpoint floc (like the head of the middle) and does not flocculate as well as in intermediate ranges (A typical plot of SVI versus F:M ratio shown in Fig 3). Using the relations developed, the F:M ratio can be related with the sludge age.

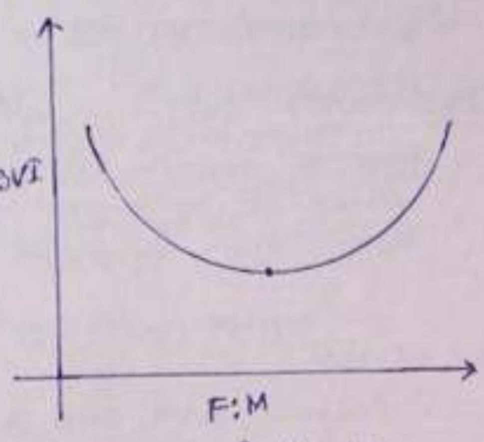


Fig 3. SVI as a function of F:M ratio.

Oxygen Requirement

Oxygen is used as an electron acceptor in the energy metabolism of the aerobic heterotrophic microorganisms present in the activated sludge process. Oxygen is required in the activated sludge process for oxidation of the affluent organic matter along with cell growth and endogenous respiration of the microorganisms. The aeration equipments must be capable of maintaining a dissolved oxygen level of about 2 mg/L in the aeration basin while providing through mixing of the solid and liquid phase. Oxygen requirement for an activated sludge ~~phase~~ system can be estimated by knowing the ultimate BOD of the waste water and the amount of biomass wasted from the system each day. If all the substrate removed by the microorganisms is totally oxidized for energy purpose, then the total oxygen requirement is calculated as:

$$\text{Total } O_2 \text{ requirement } (g/d) = \frac{Q(S_0 - S)}{f}$$

where, Q = flow rate of wastewater

f = ratio of BOD_5 to ultimate BOD.

But, all the substrate oxidized as is not used for energy. A portion of the substrate is utilized for synthesis of new biomass. As it is assumed that the system is under steady state condition, there is no accumulation of biomass and the amount of biomass produced is equal to the amount of biomass wasted. Therefore, the equivalent amount of substrate synthesized to new biomass is not oxidized in the system and exerts no oxygen demand. The oxygen requirement for oxidizing 1 unit of biomass = 1·42 units. The oxygen requirement for oxidation of biomass produced as a result of substrate utilization is required to substracted from the theoritical oxygen requirement to get actual oxygen requirement.

$$\text{Total } O_2 \text{ requirement } (g/d) = \frac{Q(S_0 - S)}{f} - 1{\cdot}42\, Q_w X_R$$

where, Q = flow rate of wastewater

S_0 = Return sludge O_2

S = Initial sludge O_2

X_R = SS concentration in return sludge

Although, this equation do not account for nitrification oxygen requirement. The carbonaceous oxygen requirement is only considered in this equations. When nitrification has be considered, the oxygen requirement will be.

$$\text{Total } O_2 \text{ requirement } (g/d) = \frac{Q(S_0 - S)}{f} - 1{\cdot}42\, Q_w X_R + 4{\cdot}57(N_0 - N)$$

Where, N_0 is the influent TKN (total Kjheldhal nitrogen) concenration, mg/L, N_2 is the effluent TKN concentration, mg/L, and 4·57 is the conversion factors for amount for oxygen oxidation of TKN.

Air supply in aeration tank must be ~~as~~ adequate to:

(i) Satisfy the BOD of the wastewater

(ii) Satisfy the endogenous respiration of the microorganisms

(iii) Provide adequate (15 to 30 KW/$10^3 m^3$) to keep biomass in suspension.

(iv) Maintain minimum DO of 1 to 2 mg/L through out the aeration tank.

WASTEWATER SAMPLING

The value of any laboratory result depends on the integrity of the sample. The object of sampling is to collect a portion of waste water small enough in volume to be conveniently ~~handled~~ handled in the laboratory and still representative of the wastewater to be examined. It must be collected in such manner that nothing is added or lost in the portion taken and no change occurs during the time between collection and laboratory examination.

The location of sampling points and collection of samples cannot be specified for all wastewater plants. Conditions vary different plants and the sampling procedure must be adapted to each plant.

General Principles of Sampling

1. The sample should be taken where the wastewater is is well mixed. This is most easily accompalished if the sampling point is located where the wastewater flow is turbulent.

2. Large particles should be excluded. Large particles are all those greater than 1 cm in diameter. This is reasonable because if one large piece was ~~s~~ included in a 1 gallon (3·7854 L) sample, it would mean that wastewater would contain one million large pieces ~~of~~ per million ~~of~~ gallon of

wastewater. Raw wastewater should be sampled after screening where ~~screening~~ screens or comminutor are used.

3. No deposits, growth or floating materials that have accumulated at the sampling point should be included. Obviously, such material would not be representative of the wastewater. This may be difficult if sampling is at a manhole, but it can be done if care is used.

4. Samples should be examined as soon as possible. If held for more than one hour, there should be cooled by immersion of the sample bottle in ice water. Cooling the sample greatly retarded bacterial action.

5. The collection of proper samples should be made as easy as possible. Sampling points should be readily accessible, proper equipment should be at hand, safety precautions established, and protection of personnel from inclement ~~water~~ weather provided, for the easier it is to take proper samples, the more likely it will be done.

6. Sample preservation may be necessary for some chemical constituents.

Types of Sample

There are two types of sample that may be collected, depending on the available, the tests to be made and the objects of the tests. One is called '<u>catch or grab</u>' sample and consists of portion of wastewater all taken at one time. The other is an '<u>integrated</u>' sample consisting of portions of wastewater taken at regular time intervals, the volume of each portion being proportional to the wastewater flow at time is collected.

1. <u>Catch or Grab Samples</u>: Catch or grab samples are not representative of the average wastewater, since they reflect only the conditions at the instant of sampling. However, in many plants the time available for sampling is so limited that catch samples must be used. The samples should be collected at that hour of the day when the treatment plant is operating under maximum load. If good operating efficiency is indicated at this ~~by~~ time, it is reasonable to assume that plant efficiency will be satisfactory during other periods. When catch samples are used to determine the

~~24+5!~~ efficiency of a treatment process, the effluent sample should be collected after a period of time corresponding to the flowing through period so that approximately the same sewage is sampled at inlet and outlet.

2. Composite Sample: Composite samples indicate the character of the wastewater over a period of time. The effects of intermittent changes in strength and flow are eliminated. The portion used ~~of~~ should be collected with sufficient frequency to obtain average results. If the strength and flow do not fluctuate rapidly, hourly portions over a 12 hour periods are satisfactory. If the fluctuations are rapid, half-hourly or ~~quat~~ quarter-hourly samples may be required. Generally, integrated samples are used to determine the character of the wastewater to be treated and the efficiency of the treatment units.

The rate of wastewater flow must be measured when each portion is taken and the volume of the portion adjusted to the flow by the use of a factor.

Sampling of Sludge

As in the case of wastewater, the value of sludge analysis depends largely upon the accuracy of sampling. Thus it is necessary to observe strict precautions in the selection of sampling points and methods of sampling to insure the collection of representative samples at all times.

To collect samples of sludge from different depth in a tank, a sampling apparatus can be used that is made of cast iron or brass weighted with lead. To collect samples of sludge when sludge is being drawn or pumped, take catch samples of equal size in a dipper at the start, during and at the end of the period of drawing.

To ~~sa~~ collect samples of bed dried sludge, take portions of equal size from several scattered points on the bed, taking care not to include sand, mix ~~thro~~ thoroughly after pulverizing. Samples of filter cake sludge may be collected by cutting portions of the cake as discharged from the filter.

~~Exam~~ Examination of the sample should be made as soon as possible after collection.

• WASTEWATER TREATMENT THROUGH AERATION

A physical treatment process in which air is thoroughly mixed with water is called aeration. Thorough contact with air and oxygen can improve water quality in a number of ways. For example one of the common uses of aeration is for taste and odor control. Dissolved gases that tend to cause the taste and odor problems, such as hydrogen sulfide, are transferred from the water to the air during aeration. The application is also called air stripping.

Aeration is also used for the removal of iron and manganese from the water, particularly in groundwater supplies. The oxygen in the air reacts with the iron and manganese to form an insoluble precipitate (rust). Sedimentation and filtration are then necessary to clarify the water.

Several methods for aeration the water are available. The methods selected depends primarily on the type and concentration of material to be removed from the water and on the available pressure head. Aeration using spray nozzles provides a large total air-water contact area, but relatively high pressures and much space are required. Spraying the water into the air can be followed by allowing the water to cascade and flow in thin sheets, down several concrete or metal steps. Cascade structures require at least a 3m (10 feet) drop.

Another common method for aeration makes use of multiple tray aerators. These consists basically of a tall stack of perforated trays or slats with staggered openings. The water is applied at the top and trickles downward in thin films or sheets of flow. In some cases a fan or blower might be used to force air upward through the stack to increase the contact with air.

For very large volumes of water, the use of diffused-air aerators is generally the most practical method. In this type aerator, air is pumped by centrifugal blowers into a tank of water. The air enter the water at the tank bottom through special diffuser nozzles or porous fixtures, forming air bubbles that become ~~there~~ thoroughly mixed with the water. Mechanical aerators consisting of a large propeller that churns the water at the surface are also available.

Modified Methods

Step Aeration : A process called step aeration provides multiple feed points of the primary effluent into the aeration tank. By introducing the organics into the tank in increments or steps, rather than only once at the head of the tank, the oxygen

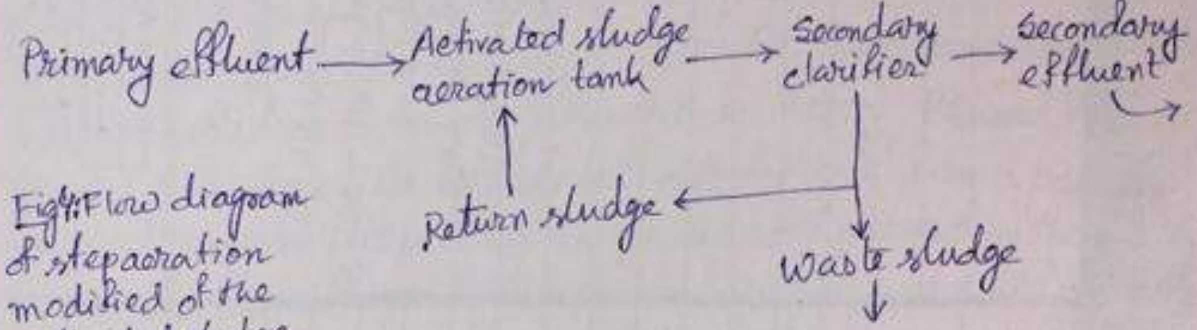


Fig 4: Flow diagram of step aeration modified of the activated sludge process.

demand is spread more uniformly over the length of the tank. In this manner, greater treatment plant than can be obtained using the conventional process.

Extend Aeration : For treating small sewage flow rates from suburban residential developments, hotels, schools, and other relatively isolated wastewater sources, a process called extended aeration is often used. These small systems are generally in the form of prefabricated steel tanks, and are called package plants. In the extended aeration system, the aeration tank and secondary clarifier are built in a single unit.

There are ~~al~~ two important distinctions between an extended aeration and conventional systems. First, screened or comminuted sewage is directed into the extended aeration tank without any primary settling. Second, the detention time or aeration period is about 30 hr, whereas, the conventional system's detention time is about 6-hr.

Another difference is that the ~~a~~ extended aeration process operates with F/M ratios as low as 0·05. This means that there is a large population of microorganisms compared to the amount of food (organics). The low F/M and the extended period of aeration allow for the stabilization of most of the organics in the wastewater. But, eventually some sludge has to be removed from the aeration tank for disposal.

Mechanical Aeration: Mechanical aeration systems, which employ ovalshaped basins and horizontal rotor-brush aerators, are efficient and easy to operate. These concrete-lined basins, called oxidation ditches, are between 1·2 and 1·8m (4 and 6ft) deep. The horizontal aerator acts like a paddle ~~st~~ wheel, ~~propelli~~ propelling the wastewater around in the channel at a velocity sufficient to prevent settling of solids. Atmospheric oxygen is transferred through the free-surface of the liquid. Most oxidation ditches are usually operated as extended aeration systems with aeration times greater than 12 hrs.

Contact Stabilization: In yet another modification of the activated sludge process, the effluent sludge process, the effluent sewage is mixed and aerated with return activated sludge for only 30 min. This process is called contact stabilization. The short contact period of 30 min is sufficient for the microorganisms to absorb the organic pollutants, but not to stabilize them.

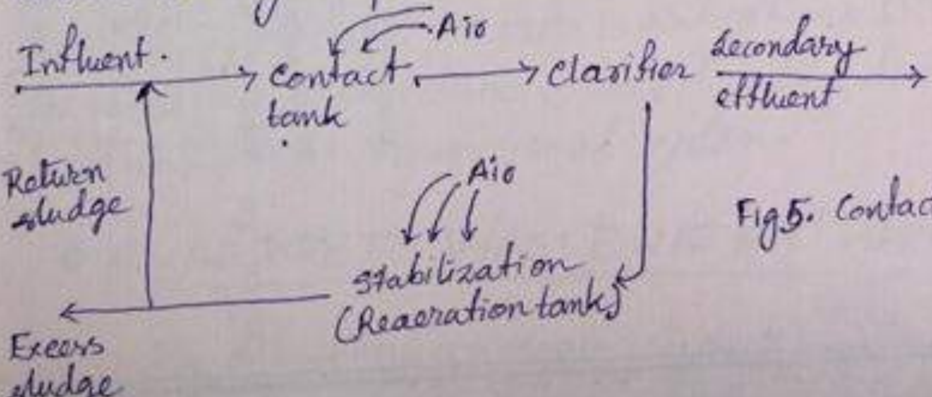


Fig 5. Contact stabilization

After the short contact time, the mixed liquor enter a clarifier and the activated sludge settles out; the clarified sewage flows over effluent weirs. The settled sludge is pumped into another aerated tank, called a reaeration or stabilization tank. The contents of the stabilization tank are aerated for about 3h, allowing the microbes to decompose the absorbed organic materials. The total size of a contact stabilization tank is generally less than of a conventional plant. This is because the volume of activated sludge being stabilized in the reaeration tank is considerable less than the total wastewater flow.

A typical instation consists of a field erected circular steel tank, with an inner tank providing a zone for clarification. An air-lift type of pump is usually used to transfer sludge between zones of the tank. With some minor modification of piping and baffling arrangements, a contact stabilization system can also be operated in the step aeration or in the extended aeration mode.

Pure Oxygen Aeration : Air is only 21 percent oxygen. Instead of using air, greater treatment capacities can be achieved by injecting high purity oxygen into the mixed liquor of an activated sludge sewage treatment plant. The oxygen is manufactured at the plant site. Primary effluent, return activated sludge, and oxygen are introduced into the first compartment of a multistaged, covered tank. Mechanically, agetators mix the oxygen with the wastewater as it flows through the tank. The total aeration period is only about 2h, and the F/M ratio is as high as 1·5. Consequently, the aeration tank volume is considerably less than that required for the conventional system.

ANAEROBIC WASTEWATER TREATMENT

By definition, anaerobic digestion (AD) is the use of microbial organisms, in the absence of oxygen, for the stabilization of organic materials by conversion to methane and inorganic products including carbon dioxide":

$$\text{organic matters} + H_2 \xrightarrow{\text{Anaerobes}} CH_4 + CO_2 + \text{New biomass} + NH_3 + H_2S + \text{Heat.}$$

The process is often used for a first stage treatment of high strength organic wastes. The objective is to use AD to reduce the high organic loads to magnitudes of COD that can be accomodated in conventional aerobic processes, most typically activated sludge. As such, AD is not a complete processor of wastewaters on its own. It is an addendum to existing conventional aerobic processes. The wide range of industrial wastewater treated AD include:

Breweries, dairy industries, food processing, chemical industries, pharmaceuticals, wineries etc.

Agricultural wastes include those from:

Pigs, chickens, cattle farmyards, waste products — crop residues, offal etc.

Municipal waste treated include:

Sludges — principally raw sewage and the organic fraction of municipal solid wastes (MSW).

The benefits of using AD include:

1. Reduction of pollution potential of waste.
2. Elimination of pathogens and weed seeds (if mesophilic or thermophilic)
3. Improvement of fertilizer (fuel value of waste products)
4. Production of biogas as an energy source.

• Microbiology of Anaerobic Digestion

Four different trophic microbial groups (bacteria) are recognised in AD, and it is the cumilative effect of all of these groups that ensures process continuity and stability. The four metabolic stages required for the production of methane from organic wastes (Fig. 6) are:—

Initially, the complex polymeric materials such as proteins, carbohydrates, lipids, and grease are hydrolysed by extracellular enzymes to simpler soluble products of a size small enough to allow their ~~process~~ passage across the cell membrane of the

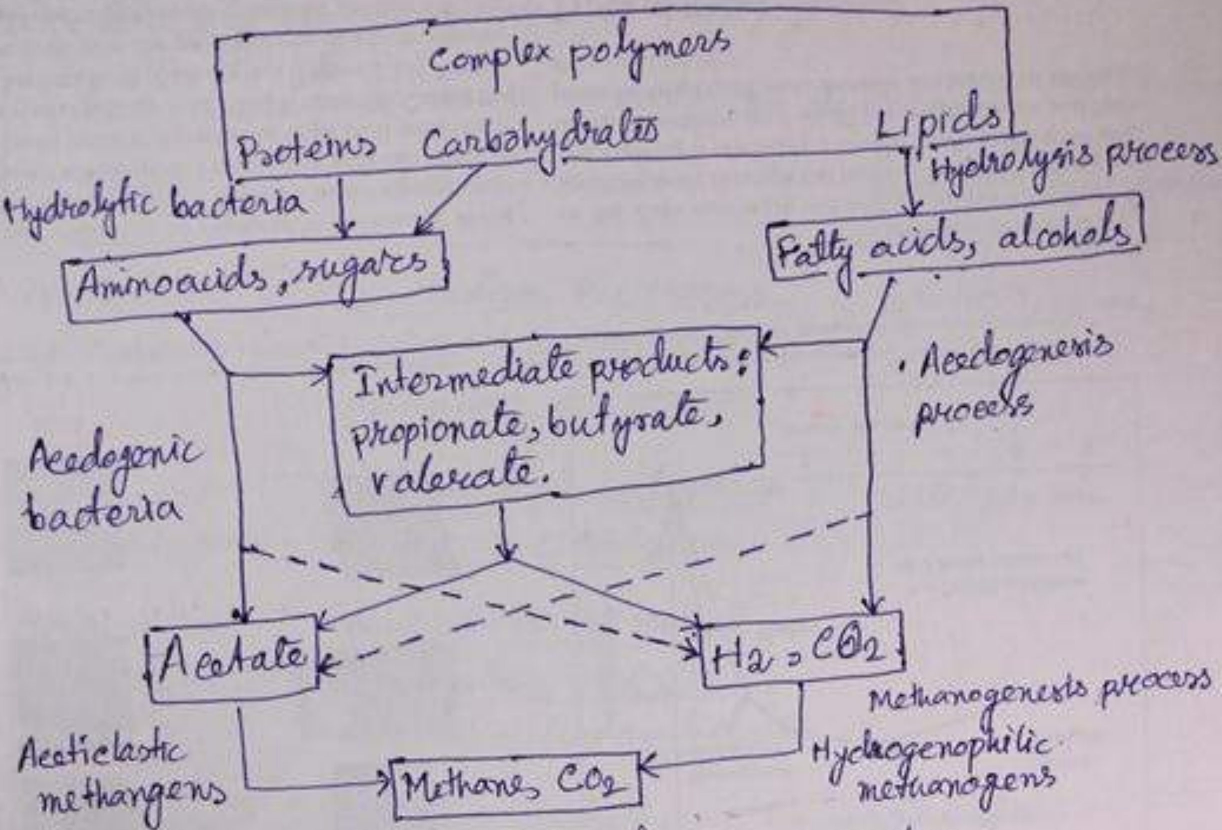


Fig 6: Stages in methane production from organic wastes.

microorganisms. These simple compounds of amino acids, sugars, fatty acids and alcohols are fermented to short-chain fatty acids, alcohols, ammonia, hydrogen and carbon dioxide. The final stage is methane production from hydrogen by the hydrogenophilic methanogens and from acetate by aceticlastic methanogens.

Gujer and Zehnder (1983) organised the anaerobic process into seven subprocesses as follows:

1. Hydrolyses of complex particulate organic matter
2. Fermentation of aminoacids and sugars.
3. Anaerobic oxidation of long-chain fatty acids and alcohols.

4. Anaerobic oxidation of intermediary products.
5. Acetate production from CO_2 and H_2.
6. Conversion of acetate to methane by aceticlastic methanogens.
7. Methane production by hydrogenophilic methanogens using CO_2 and H_2O.

The biological agents of anaerobic digestion are bacteria but fermenting ciliate and ~~flagellage~~ flagellate protozoa and some anaerobic fungi may play minor roles in some systems.

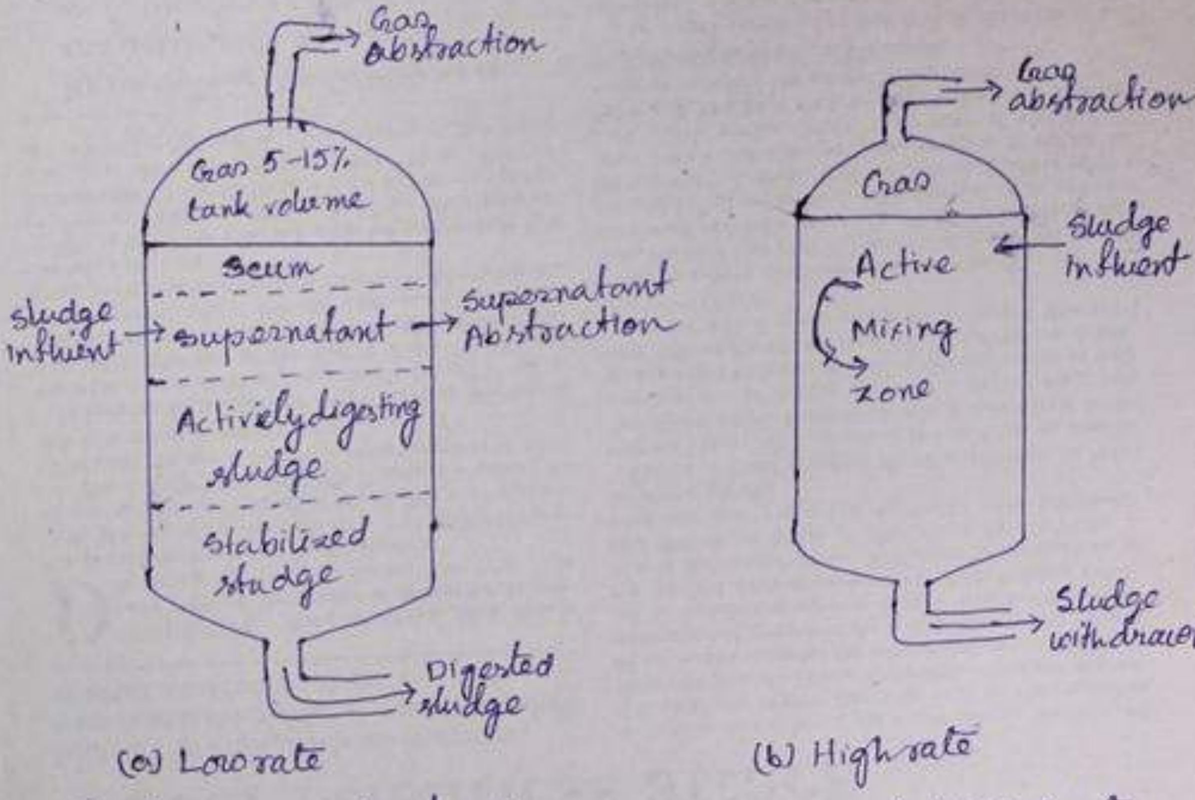
Table 2. Some bacterial species in anaerobic digestion.

Stage	Genera / Species	Population in mesophilic sewage sludges
Hydrolytic acetogenic	Clostridium, Peptococcus, Lactobacillus, Streptococcus, Acetivibrio, Butyrivibrio	$10^8 - 10^9$ per mL
Acetogenic homoacetogenic	Acetobacterium, Acetogenium, Pelobacter, Clostridium	$\approx 10^5$ per mL
Oligo-proton reducing acetogens	Syntrophobacter wolinii, Syntrophus buswelii, Methanobacillus omelianskii	
Methanogenic	Methanobacterium, Methanogenium, Methanococcus	$\approx 10^8$ per mL

The huge range of genera and species indicates the complex nature of the microbial population and in each of the stages the population densities (in sewage sludge) range from 10^5 to 10^9 per mL. The bacteria involved in AD have a pH range 6 to 8 with values close to 7 for optimum activity. Volatile fatty acids depress the pH unless there is sufficient bicarbonate alkalinity present to neutralize the acids. Bicarbonate is formed when CO_2, which is soluble in water, reacts with hydroxide ions to for bicarbonate ions, HCO_3^-. It is important that sufficient alkalinity is available at all times, up to the level of ~3000 mg/L, for sufficient buffering to be maintained.

• <u>Anaerobic Reactors Configurations</u>

The Low-rate conventional system shown (fig 7(a)) is made up of several layers. The influent sludge enter the tank close to the top at the location of the supernatant layer (a partially purified liquid layer). Below this is a layer of actively digesting sludge and at the bottom of the tank ~~sits~~ sits the stabilized sludge, ready for abstraction (withdrawal). Conventional or low-rate digesters are characterised by intermittent mixing, intermittent sludge feeding and intermittent



(a) Low rate (b) High rate

Fig. 7: Basic anaerobic digestion processes: (a) Low rate, (b) High rate.

sludge withdrawl. When mixing is not being carried out the digester content become stratified.

High-rate digesters are (Fig. 7b) characterised by continuous mixing except at times of sludge withdrawal. High-rate digesters have hydraulic retention time (HRT) about one-half of these low-rate and gas production is as much as twice.

Anaerobic digestion reactors can be classified as:

1. First generation type, meaning that hydraulic retention time (HRT) is equal to the solids retention time (SRT). The include:
   (a) the batch digester
   (b) the plug flow digester
   (c) the continuously stirred tank reactor (CSTR)
   (d) the anaerobic contact reactor (ACR)

2. Second generation type, meaning that the SRT is greater than the hydraulic retention time. They include:
   (a) the upflow-downflow anaerobic filter
   b) the down-flow stationary fixed film reactor
   (c) the fluidized bed reactor.
   (d) the upflow anaerobic sludge blanket reactor
   (e) the hybrid anaerobic sludge reactor.

WASTE WATER MANAGEMENT II

BOD REMOVAL IN ACTIVATED SLUDGE PROCESS

The degradation of organic matter that occurs in an activated sludge facility also occurs in streams and other aquatic environments. However, in general, when a degradable waste is put into a stream, it encounters only a relatively small population of microorganisms capable of carrying out the degradation process. Thus, several days may be required for the buildup of a sufficient population of microorganisms to degrade the waste. In the activated sludge process, continual recycling of active organisms provides the optimum conditions for waste degradation, and a waste may be degraded within the very few hours that it is present in the aeration tank.

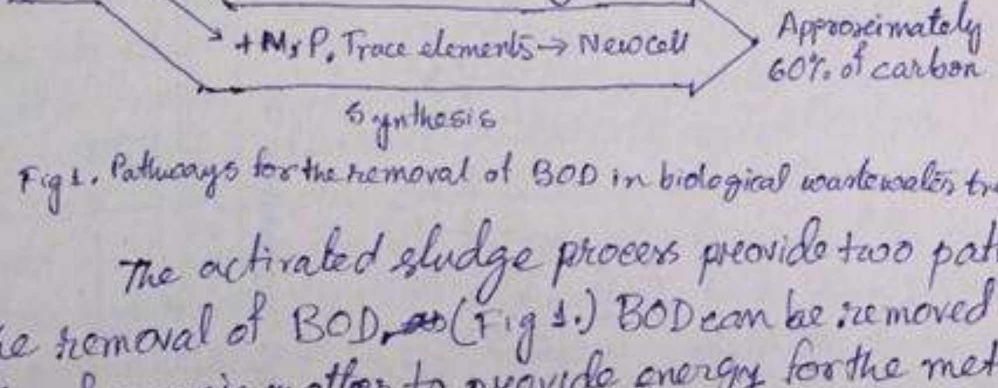


Fig 1. Pathways for the removal of BOD in biological wastewater treatment.

The activated sludge process provide two pathways for the removal of BOD, (Fig 1.) BOD can be removed by (1) oxidation of organic matter to provide energy for the metabolic processes of the microorganisms, and (2) synthesis, incorporation of the organic matter into cell mass. In the first pathway, carbon is removed in the gaseous form as CO_2. The second pathway provides for removal of carbon as a solid in biomass. That portion of the carbon converted to CO_2 is vented to the atmosphere and does not present a disposal problem. The disposal of waste sludge, however, is a problem, primarily because it is only about 1.0 percent solids and contains many undesirable components. Normally, partial water removal is ~~accomp~~ accomplished by drying on sand filters, vacuum filtration, or centrifugation. The dewatered sludge can be incinerated or used as landfill. ~~To certain~~ To a certain extent, sewage sludge can be digested in the absence of oxygen by methane-producing anaerobic bacteria to produce methane and carbon dioxide

$$2\{CH_2O\} \rightarrow CH_4 + CO_2$$

reducing both volatile-matter content and sludge volume by about 60%. A carefully designed plant can produce enough methane to provide for all of its power needs.

SUBSTRATE REMOVAL IN ATTACHED GROWTH TREATMENT PROCESS

In an attached growth treatment process, a biofilm consisting of microorganisms, particulate material, and extracellular polymers is attached and covers the support packing material, which may be plastic, rock, or other material. The growth and substrate utilization kinetics for the suspended growth process were related to the dissolved substrate concentration in the bulk liquid. For attached growth process, substrate is consumed within a biofilm. Depending on the growth conditions and the hydrodynamics of the system, the biofilm thickness may range from 100 μm to 10 mm. A stagnant liquid layer (diffusion layer) separates the biofilm from the bulk liquid that is flowing over the surface of the biofilm or is mixed outside of the fixed film (Fig.2). Substrates, oxygen, and nutrients diffuse across the stagnant liquid layer to the biofilm, the products of biodegradation from the biofilm enter the bulk liquid ~~Stor~~ diffusion across the ~~stang~~ stagnant film.

The substrate concentration at the surface of the biofilm, Ss, decreases with biofilm depth ~~at the~~ as the substrate is consumed and diffuses into the film layers. As a result, the process is said to be diffusion limited. The substrate and oxygen concentrations within the film are lower than the bulk liquid concentration and change with biofilm depth and the substrate utilization rate. The overall ~~subst~~ substrate utilization rate is less than could be predicted based on the bulk liquid substrate concentration.

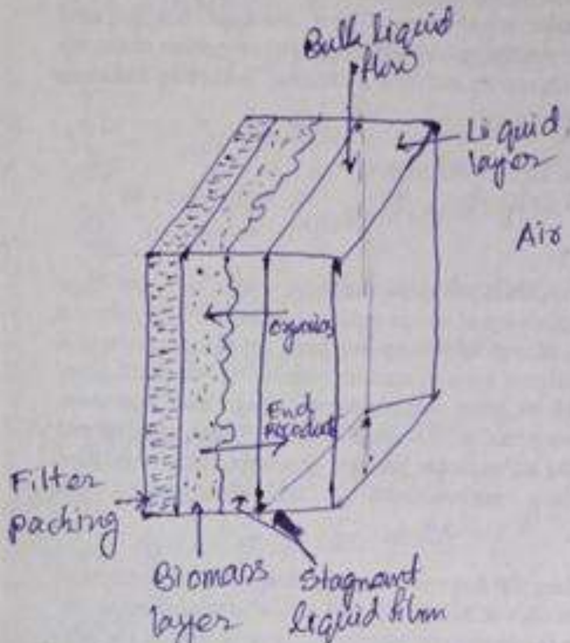


Fig. 2: Schematic representation of the ~~trickling filter~~ cross section of a biological slim in a trickling filter.

The total amount of substrate used per unit of biofilm cross sectional area must diffuse across the stagnant layer. This rate of mass transfer is termed the surface flux and is expressed as mass per unit area per unit time ($g/m^2.d$). The biofilm layer is not simply a planar surface. ~~The~~ The biofilm layers are very complex non-uniform structures with uneven protrusions much like peaks and valleys, and are believed to have verticle and horizontal pores through which liquid flows. The biomass can be very dense in biofilms, and may ~~des~~ also vary in density and depth. Biofilm concentrations of VSS may range from 40 to 100 g/L. Uniform growth across the support packing also does not occur, because the periodic sloughings, as well as the hydrodynamics and media configuration.

Mechanistic models have been developed by a number of investigators to describe mass transfer and biological substrate utilization kinetics in biofilms and provide useful tools for the evaluation of biofilm processes.

Substrate flux in Biofilms: The ~~sub~~ substrate flux across the stagant layer to the biofilm, a function of the substrate diffusion coefficient and concentration, is given by Eq. (i).

$$r_{sf} = -D_w \frac{dS}{dx} = -D_w \frac{S_b - S_s}{L} \quad \text{.........(i)}$$

In equation-(i), the negative sign is used because the substrate concentration is decreasing along the stagnant layer and substrate is removed from the bulk liquid, and where,

r_{sf} = Rate of ~~surf~~ substrate surface flux, $g/m^2.d$

D_w = diffusion coefficient of substrate in water, m^2/d

$\frac{dS}{dx}$ = Substrate concentration gradient, $g/m^3.d$

S_b = bulk liquid substrate concentration, g/m^3

S_s = Substrate concentration at outer layer of biofilm, g/m^3

L = effective thickness of stagnant film, m.

The thickness of the stagnant layer will vary with the fluid properties and fluid velocity. Higher velocities result in thinner films with greater substrate flux rates.

Substrate Mass Balance for Biofilm: A substrate mass balance around a differential element (dx) within the ~~bioh~~ biofilm yields:

Rate of substrate accumulation within differential element = Rate of substrate flow into differential element − Rate of substrate flow out of differential element + Rate of substrate utilization in differential element

For steady state conditions, the mass balance is

Accumulation = Inflow − outflow + generation

The changes in substrate concentration within the ~~B~~ biofilm require two boundary conditions. The first boundary condition is that the substrate flux at the biofilm surface ~~e~~ equals the substrate flux through the stagnant film. The second boundary condition is that there is no flux at the packing surface.

Substrate Flux Limitations: An important implication of diffusion-limited processes is the relationship between the bulk liquid electron donor and electron acceptor concentrations. An assumption in the mechanistic models used is that ~~eg~~ either the electron donor or electron acceptor (i.e., oxygen or nitrate) is limiting. The substrate limitation may be due to reaction rates within the biofilm or to bulk liquid concentrations diffusion rates across the stagnant layer. These are referred to as substrate and surface flux limitations, respectively. There are situations where the substrate limitations may switch between electron donor and electron acceptor with depth in the biofilm. For the situation where the substrate limitation can switch, numerical analysis techniques must be used evaluate the biofilm behavior.

Nitrification rates in fixed film systems are often limited by the bulk liquid DO concentration. ~~and the following examples~~

MANAGEMENT OF TREATED EFFLUENT

After treatment, waste-water is either reused or discharged into the environment:

A. Effluent Reclamation and Reuse:

Effluent reclamation and reuse has received much attention lately, owing to growing demand for water and unsustainable rates of consumption of natural water resources. A major concern in reuse application is the quality of the reclaimed water, which is the main factor dictating the selection of the waste-water treatment process sequence.

1. **Irrigation**: Treated waste-water effluent can be used for the irrigation of crops or landscaped areas. The main consideration associated with this effluent application method is the quality of the treated water and its suitability for plant growth. Some constituents in reclaimed water that are of particular significance in terms of agricultural irrigation include elevated concentrations of dissolved solids, toxic chemicals, residual chlorine and nutrients. Another highly important consideration is public health and safety hazards resulting from the ~~intended irrigation use~~ potential presence of bacterial pathogens, parasites, protozoa and viruses. Concerns vary with the intended

irrigation use and the degree of human contact. Potential constraints associated with the use of reclaimed waste-water for irrigation include the marketability of crops and public acceptance, surface and ground water pollution in the absence of adequate management, and high user costs, notably the cost of pumping effluents to irrigated land.

2. Industrial Uses: Reclaimed water is ideal for industries using processes that do not require water of potable quality. Industrial uses of reclaimed water include evaporative cooling water, boiled-feed water, process water, and irrigation and maintenance of the grounds and landscape around the plant. Each type of reuse is associated with a number of constraints on its applicability; the use of reclaimed water in cooling towers, for example, creates problems of scaling, corrosion, biological growth, fouling, and foaming. These problems are also encountered when fresh water is used, but less frequently. Reclaimed water used as boiler feed water must be softened and demineralized, while process water quality is dependent on the requirements of the manufacturing process involved.

3. Recreational Uses: Reclaimed water is widely used for recreational purposes, including landscape maintenance, aesthetic impoundments, recreational lakes for swimming, fishing, and boating, ornamental fountains, snow making and fish farming. The required treatment level for reclaimed water is dictated by the intended use: the greater the potential for human contact, the higher the treatment level required. For example, non-restricted recreational water use requires the treatment of secondary effluent by coagulation, filtration, and disinfection to achieved a total coliform count of fewer than 3 per 100 mL.

4. Groundwater Recharge: Groundwater recharge using reclaimed wastewater serves to mitigate water table decline, protect groundwater in coastal aquifers against salt-water

intrusion, and store reclaimed water for future use. Ground water recharge method include surface spreading in basins and by direct injection into aquifers. Surface spreading utilizes flooding, ridges and furrows, constructed wetlands, and infiltration basins. This application method improves the quality of the reclaimed water considerably as it percolates successively through soil, unsaturated zone and aquifer. Direct injection involves the pumping of reclaimed water directly into an aquifer. Drawbacks of this method include high effluent treatment cost and the high cost of the necessary injecting facilities. The major disadvantage of groundwater recharge using reclaimed water is the increased risk of groundwater contamination.

5. Potable Use: The issue of the used of reclaimed water for drinking purposes has been approached with extreme caution because of public rejection and because of health, safety and aesthetic concerns. At the present time, the option of direct potable use of reclaimed municipal wastewater is limited to extreme situations.

B. Effluent Disposal

Treated waste-water effluent, if not reused, is disposed of either on land or into water bodies. Discharge into water bodies is the most common disposal practice. It takes advantage of the self purification capacity of natural waters to further treat the effluent. Excessive quantities of organic material may cause rapid bacterial growth and depletion of the dissolved oxygen resources of the water body. In addition, changes in pH or concentrations of some organic and inorganic compounds may be toxic to particular life forms. Depending on the characteristies of the receiving waters, ~~in order to avoid~~ many factors are considered for proper mixing and dispersal of effluent.

These factors include flow velocity, depth stratification due to salinity and temperature, shape, reversal of current and wind circulation. The temperature and salinity of the effluent should ~~be~~ also be taken into consideration. The disposal area should be downstream from any location where water ~~of~~ is to be withdrawn for human consumption.

1. **Discharge into Rivers and Streams:** Wastewater effluent discharge into rivers should be such as to ensure rapid vertical mixing of the effluent over the full river depth and avoid foaming problems. This can be achieved by using a multiport diffuser that extends across the width of the river. A diffuser is a structure that ~~ex~~ discharges the effluent through a series of holes or ports along a pipe extending into the river.

2. **Discharge into Lakes:** Being larger and deeper than rivers, lakes are subject to temperature stratification and less pronounced natural mixing via currents. Consequently, the lower strata in a lake are usually subject to conditions of low temperature and low dissolved oxygen, which slow down the ~~the~~ decomposition of organic matter. Consequently, it is essential to ensure that appropriate mixing occurs when wastewater effluent is discharged into a lake in order to prevent the formation of an anaerobic stratum. In shallow lakes, effluents are adequately dispersed by wind-induced currents that ensure appropriate mixing.

3. **Discharge into Seas and Oceans:**

Oceans are extensively used for wastewater disposal because of their great assimilation capacity. Waste-water is of density than sea-water, and consequently, ~~upon~~ upon discharge, the effluent forms a rapidly rising water plume which entrains large amounts of ambient water, enhancing wastewater dilution. If the water is not ~~stratified~~ stratified, the plume will rise to the surface, where the wastewater will be diluted by ambient currents. A marine outfit should be designed to ensure sufficient dilution of the effluent before it reaches the surface of the water or is carried inshore by ambient currents. The outfall carries the wastewater to an offshore discharge point through a pipe laid on or ~~buri~~ buried in the ocean floor. The discharge may be through a single port or a multiport outfall structure that is similar to a river outfall.

• COLLECTION OF MUNICIPAL WASTEWATER

• Wastewater Collection Systems.

Waste water collection systems gather the used water from our homes, business and industries and convey it to a wastewater treatment plants. This type of system is also called a sanitary sewer. A similar system known as a storm water collection system conveys water resulting from runoff of rain and snow from buildings and paved and unpaved areas to a natural watercourse or body of water, usually without treatment. This type of system is also known as a storm ~~sw~~ sewer. Sanitary wastes were first discharged into the storm sewers, which then carried both sanitary waste and ~~storm water~~ sewers, which ~~then carried both sanitary waste and~~ is known as combined sewer. During heavy rains the wastewater treatment plants served by combined sewers often became hydraulically overloaded and washed out into the receiving stream causing a complete treatment ~~failure~~. system failure. For this reason, combined sewers are now uncommon.

Modern wastewater ~~collector~~ collection systems are a sophisticated combination of components that include; gravity sewer lines, force mains, manholes, and lift stations.

Estimating Wastewater Quantities

The term sewage is mean only domestic wastewater. Domestic wastewater flows vary with the season, day of the week, and hour of the. In addition to sewage, however, sewer also must carry industrial wastes, infiltration, and inflow and the amount of flow contributed by each of these sources must be estimated for design purposes.

The quantity of industrial wastes may usually be established by water use records, or ~~f~~ the flow may be measured in manholes that serve only a specific industry, using a small flow meter, like ~~a~~ a Parshall flume, in a manhole. The flow proportion of the flow depth. Industrial flows often vary considerably throughout the day and continuous recording is necessary.

Infiltration is the flow of groundwater into sanitary sewers. Sewers are often placed ~~bel~~ below the groundwater table, and any cracks in the pipes will allow water to seep in. Infiltration is least for new, well-constructed sewers, but can be as high as 500 m^3/km-day. For older systems, 700 m^3/km-day is the commonly estimated infiltration. Infiltration flow is detrimental since the extra volume of water must go through the sewers and the wastewater treatment plant. It should be reduced as much as possible by maintaining and repairing sewers and keeping ~~sewa~~ sewerage easements clear of large trees whose roots could severely damage the sewers.

Inflow is storm water that is collected unintentionally by the sanitary sewers. A common source of inflow is a perforated manhole cover placed in a depression, so that storm water flows into the manhole. Sewers laid next to creeks and drainageways that rise up higher than the manhole elevation, or where the manhole is broken, are also a major source. Some connections to sanitary sewers, such as roof drains, can substantially increase the wet weather ~~s~~ flow over the dry weather flow. The ratio of dry weather flow to wet weather flow is usually between 1:1.2 and 1:4.

The three flows of concern when designing sewers are the average flow, the peak or maximum flow, and the extreme minimum. The ratio of the ~~aga~~ average flow to both the maximum and minimum flows in a function of the total flow, since a higher average daily discharge implies a larger community in which the extremes are evened out. Commonly experienced ratios of average to extremes as a function of the average daily discharge.

System Layout

Sewers that collect wastewater from residences and industrial establishments almost always operate as open channels or gravity flow conduits. Pressure sewers are used in a few places, but these are expensive to maintain and are useful only when there are severe restrictions on water use or when the terrain is such that gravity flow conduits cannot be efficiently maintained.

Building connections are usually made with clay or plastic pipe, 6" in diameter, to the collecting sewers that run under the street. Collecting sewers are sized to carry the maximum anticipated peak flows without surcharging (filling up) and are ordinarily made of clay, cement, concrete, or cast iron pipe. They discharge in turn into intercepting sewers, or interceptors, that collect from large areas and discharge finally into the wastewater treatment plant.

Collecting and intercepting sewers must be placed at sufficient grade to allow for adequate flow velocity during periods of low flow, but not ~~stop~~ so stop as to promote excessively high velocities when flows are at ~~minimum~~ their maximum. In addition, sewers must have manholes usually every 120 to 180m to facilitate cleaning and repair. Manholes are necessary whenever the sewer changes grade (slope), size, or direction.

Gravity flow may be impossible in some locations, or may be uneconomical, so that the wastewater must be pumped.

Waste Water Collection Systems

Major components of waste water collection systems include

1. Gravity sewer lines
2. force mains
3. Manholes
4. Lift stations.

1. Gravity Sewer Lines: The largest component of a waste-water collection system is usually the gravity sewer. Gravity sewers ~~have~~ follow the topography of the surrounding area (lay of the land), to take advantage of the natural slope. They are designed to provide a flow velocity between 0·6 and 2·4 meter per second (mps), with 0·8 mps being ideal. If the velocity is too low, settleable solids will deposit in the sewer lines, if the velocity is too high, erosion and damage of the collection system will occur. Gravity sewers are divided into the ~~b~~ building sewers, lateral and branch sewers, main sewers, trunk sewers and intercepting sewer.

Wastewater collection systems are designed to convey the peak flow from a service area when the area ~~tho~~ has reached its maximum population density and has been fully developed commercially and industrially. Domestic wastewater flow is often calculated by ~~the must~~ multiplying the estimated population in a service area by the per capita flow. Business and industries will contribute varying flows and so ~~much be~~ must be accounted for differently. In addition to the expected wastewater flows, allowances must be made for infiltration and inflow (I and I). The wastewater in a sewer line should move at a speed that will prevent the deposition and buildup of solids in the sewer this is called a 'scouring velocity'. ~~Sewer~~ Sewers should be ~~desined~~ designed to provide a scouring velocity at average flows, or at the very least, during peak flows. Sewer lines are typically placed at a depth 1·2 to 2·4m. The depth and width of a trench the backfill materials and the method of compaction determine the load placed on the sewer line and therefore influence which piping materials are appropriate.

2. Manholes : Manholes are structures installed in lateral, main, trunk and interceptor sewers for the purpose of allowing access for maintenance and cleaning operations. Manholes are also placed at changes in sewer direction, elevation, slope, pipe size and at junctions. Drop manholes are used when the difference in elevation of an incoming and outgoing sewer line cannot be accommodated by a drop in the manhole channel without creating excessive turbulence and splashing. Manholes in straight runs of sewer lines should be spaced no farther apart than the distance that can be cleaned by available equipment, usually 90 – 150 m.

Manholes are sometimes equipped with steps and sometimes entered using ladders. The corrosive gasses in the collection system can cause steps to deteriorate so use care if they are used for entry. Manholes can be constructed from materials such as brick, precast concrete barrels and fiberglass.

3. Lift Stations : Lift stations are used to raise wastewater from a lower elevation. Pumps are used to move wastewater through a discharge pipe known as a force main. After discharge from the force main, wastewater resumes gravity flow. The location and design of lift stations is decided by economies and practicality. Some of the reasons that a lift station may be required include:

- Excavation costs to maintain gravity flow and scouring velocity become excessive
- Soil stability is unsuitable for trenching.
- Groundwater table is too high for installing deep sewers, and
- Present wastewater flows are insufficient to justify extension of sewer main and lift station offers economical short-term solution.

Lift station should be designed to move the wastewater with maximum efficiency.

Lift stations can be described with two broad categories :

(i) Dry Well Lift Station : Dry well lift station contain two chambers. One for collecting the wastewater before it is pumped and the other to contains the pumps, motors, valves, electrical controls and auxiliary equipment in a dry well where access is easy for service. Dry well lift stations range in size from just large enough for a man to enter to large installations that may even be constantly manned.

(ii) Wet Well Lift Station : wet well lift station contain only one chamber, the wet well where wastewater is collected before it is pumped. The pumps may be located above the wet well, which is known as a suction lift pumping arrangement, or the pumps may be located inside the wet well itself (submersible pumps). Both locations have their advantages and disadvantages. Suction lift pumps can be easily serviced and repaired, but these types of pumps are prone to losing their prime, ~~when they~~ particularly when they age. If a pump loses prime, the motor will run and the impeller will turn but the pump will not in a shallow pit where they can be easily serviced and repaired, but these types of pumps are prone to losing their prime, pump anything. Submersible pump installations never loze prime because the pump intakes always have standing water over them (suction head condition). However, because the pumps are located in the wet well they can be hard to access if not designed properly. When submersible pumps are used in wet well lift stations they should be designed to be removed from the surface without entry into the wet well, which is considered a confined space.

Dynamic pumps are often classified by suction conditions. In wastewater there are commonly two types lift. The primary difference between the two is the number of tanks. The wet well has one tank and the dry well has two.

4. Force Mains: A force main is the discharge line for the lift station. The discharge lines of the pumps come together in a manifold and then enter the force main. Air accumulation in force main can create a problem know a water ~~hammer~~ hammer, which is a high pressure shock wave that travels up and down a force main. This problem is associated with pump check valve slamming, sometimes repeatedly, which causes damage valves and piping. Air release valves are normally installed at the high points in force mains to automatically blow off accumulated air.

Infiltration and Inflow (I & I)

Ground water that enters into the sewer system through broken joints and leaking manhole barrels is referred to as infiltration. Storm water that enters manhole covers and illegal connections like gutter drains grouted into house clean outs is known as inflow. Both infiltration and inflow can contribute significant amounts of water to the wastewater collection system. Once in the collection system the I & I becomes wastewater that must be treated by the treatment plant. Some treatment plants become hydraulically overloaded during storm events from inflow or during the spring run-off from infiltration. Because of this the identification and control of infiltration is important to the wastewater collection system operator.

Identification of I & I

Studies conducted to identify I & I can be very elaborate involving engineering consultants and costing large amounts of money or they can be basic and conducted ~~by~~ by system operators. The size of the system and the extent of the problem will dictate with measures are necessary. Methods that are commonly used for identifying the location and extent of I&I are:

- Late Night Survey – very little flow should be occurring in the collection system in the early morning hours (2:00 AM – 4:00 AM). By surveying manholes for clear water that is near ground temperature a generalized idea of the extent of infiltration can be made.

- Smoke Testing – Smoke testing is used to identify broken joints and leaking manhole barrels that could allow infiltration to enter the system and to identify illegal taps or connections to the sewer system that would allow storm water to enter. For this test smoke is forced into the collection system by an engine driven fan located over a manhole opening.

- Flow Records — Wastewater treatment flow records often are used to identify storm events that introduce inflow into the collection system. Also, flow records that show a constant early morning flow during periods of run-off can be used to identify infiltration. chart recording flow measurement devices allow the volume and during of I&I to be characterised.

Control of I&I.

Numerous methods are available to designers and engineers to correct infiltration and inflow problems once they have been identified. These include sewer replacement, slip lining (in-situ form), pipe bursting, chemical grouting and improvement of ~~storm~~ storm sewer.

Not many of these options are within the capabilities of the average collections department, so contractors most often ~~average~~ perform them. Collection crews do have the ability to minimize some infiltration and inflow problems such as repairing or replacing individual deteriorated manholes, raising manhole rings and covers in area that ~~flood~~ floods, and repairing broken joints when they are discovered. Whenever possible, collection system operators should work to limit I&I so that the treatment plant can perform its job of treating wastewater.

• PRETREATMENT OF INDUSTRIAL WASTEWATER

Sewage conveyed by municipal sewers into publicly owned treatment works (POTW) comes from several sources, including industrial plants. Wastewater discharged by industry often contains toxic chemicals, such as cyanide from electroplating processes and lead from battery manufacturing plants. Several serious problems can occur when industrial wastewater is discharged into a POTW, such as the following:

Passthrough: Nondegradable toxic substances may pass through the treatment plant, causing water pollution; this pollution can pose a threat to aquatic life and, through the food chain, to public health.

Interference: Toxic industrial wastes may interfere with the operation of the treatment plant, particularly in those processes that use bacteria to stabilize organic matter in the wastewater.

Contamination: Industrial wastes with high levels of toxic metals or organic substances can contaminate sewage sludge thereby limiting sludge disposal options and raising disposal costs.

Corrosion: Industrial wastewater may corrode and damage the pipes and equipment in the sewage collection system and treatment plant.

Hazards: Some industrial wastes are highly volatile and can explode. Other wastes may produce toxic gases, posing a threat to persons at the plant and in the local community.

These problems can readily be avoided by pretreatment of wastewater at the industrial site before it is discharged into the public sewer system.

Two sets of pretreatment standards can be imposed for different industrial wastewaters —

(1) ~~Cont~~ Categorical pretreatment standards are industry specific; they mandate different requirements for each type of industry. For example, there is a categorical standard for the iron and steel industry that limit the ammonia and cyanide discharged by any firm in that industry into a municipal sewerage system.

(2) Prohibited discharged standards are substance specific; ~~this~~ they prohibit any discharge to sewer systems of certain types of wastes from all sources. For example, the discharge of any wastewater with ~~popul~~ pollutants that can create a fire hazard or explosion in the sewage system is not allowed. Also, discharges that have a pH of less than 5·0 or a temperature of more than 40°c are prohibited from any industry.

As the generator of toxic pollutants, industry must finance construct, and operate any pollution control facility necessary to comply with regulations of pretreatment rules. Industry compliance ensures that toxic industrial pollutants will not harm the environment or pose a public health hazard.

DEFINITIONS

Grit chamber : In primary treatment process, the reduction in velocity and the collection of the grit is usually accomplished in long narrow tank called grit chamber.

Primary Clarifier : settling tanks that receive sewage after grit removal are called primary clarifiers. The tanks may be circular or rectangular shape.

Comminutor : In some treatment plants, a mechanical cutting or shredding device is installed just after the coarse screens, called a comminutor.

Sloughing : In trickling filter, as the microorganisms grow and multiply, the slime layer gets thicker. Eventually, it gets so thick that the flowing wastewater washes it off the surfaces of the stones. This is called sloughing (pronounced "sluffing").

Secondary Clarifier: The trickling filter effluent is collected in the underdrain system and then conveyed to a sedimentation tank called a secondary clarifier, or sometimes called final clarifier.

Hydraulic ~~Bo~~ Load: The rate a which the wastewater flow is applied to the trickling filter surface is called the hydraulic load. The hydraulic load includes the recirculated flow Q_R, the total flow through the trickling filter is equal to $Q + Q_R$. It is expressed as —

$$\text{Hydraulic load} = \frac{Q + Q_R}{A_S}$$

Where, Q = Raw sewage flow rate
Q_R = Recirculated flow rate
A_S = Trickling filter surface area (plan view).

BOD Load: The rate at which organic material is applied to the trickling filter is called organic or BOD load. Organic load is expressed in terms of kilograms of BOD per cubic meter of bed volume per day, or $kg/m^3 \cdot d$.

$$\text{Organic load} = \frac{Q \times BOD}{V}$$

where, Q = Raw wastewater flow, ML/d (mgd)
BOD = BOD_5 in the primary effluent, mg/L (ppm)
V = Volume of trickling filter bed, m^3 (ft^3)

Activated ~~Sta~~ Sludge: The aerobic microorganisms in the tank grow and multiply, forming an active suspension of biological solids called activated sludge.

Mixed Liquor: The combination of the activated sludge and wastewater in the aeration tank is called the mixed liquor.

Mixed Liquor Suspended Solids: The suspended solids in the ~~mix~~ mixed liquor consists ~~as~~ mostly of living ~~organism~~ microorganisms, the suspended solid concentration is used as as measure of the amount of microorganisms in the tank. This concentration is called the mixed liquor suspended solids or MLSS.

Sludge Bulking: Under certain conditions in an activated sludge sewage treatment ~~process~~ plant, filamentous or stringy bacteria grow prolifically in the aeration tank, making the sludge very fluffy and light. Sludge with excessive growth of these filamentous organisms settles very slowly, and a clear supernatant is not formed in the secondary clarifier. Much of the sludge flows out with the effluent. This condition is called sludge bulking.

Contact Stabilization: In a modification of activated sludge process, the influent sewage is mixed and aerated with return ~~sludge~~ activated sludge for only about 30min. The short contact period of 30min is sufficient for the microorganisms to absorb the organic pollutants, but not to stabilize them. This process is called contact stabilization.

Effluent Polishing: The removal of additional BOD and TSS from secondary effluents is sometimes referred to as effluent polishing.