Introduction

Water, contaminated with waste products, proper treatment before it is discharged from a plant. *Wastewater treatment plants* are designed to convert liquid wastes into a water stream of sufficient quality to be discharged and to dispose of solids recovered or generated during the treatment process. In most cases, treatment is required for both suspended and dissolved contaminants. Special processes may also be required for the removal of certain pollutants, such as oils or metals. With proper treatment, wastewater can be recycled for reuse within a plant in order to reduce disposal requirements and water consumption.

Pollutants

Organic Compounds : The amount of organic material that is permissible to discharge in waste waters is defined by the effect of the material on the dissolved oxygen level in the water. Organisms in the water use the organic matter as a food source. In a biochemical reaction, dissolved oxygen is consumed as the end products of water and carbon dioxide are formed. Atmospheric oxygen replenishes the dissolved oxygen supply, but only at a slow rate. When the levels of organic material present in the water causes oxygen consumption to exceed this re-supply, the dissolved oxygen level drops, leading to death of aquatic life. Organic compounds are normally measured as *chemical oxygen demand* (COD) or *biochemical oxygen demand* (BOD).

Nutrients : Organic and inorganic material present in the waste water is used by microorganisms as a food source and subsequently, consume oxygen. *Nitrogen and phosphorous* in particular are of concern because they are commonly used as food source for bacteria and algae. Excess phosphorous can cause algae blooms in surface waters. During the day, algae produce oxygen through photosynthesis but at night they consume oxygen.

Solids :. Settled solids cover the bottom of surface water sources, causing disruptions in population and accumulations of oxygen-consuming materials. Suspended solids increase the turbidity of the water, thereby inhibiting light transmittance. Deprived of a light source, photosynthetic organisms die.

Acids and Alkalides : The natural buffering system of a water source can be exhausted by the discharge of acids and alkalides. Aquatic life is affected by the wide swings in pH as well as the destruction of bicarbonate alkalinity levels.

Metals : Many metals are toxic and impact both the aquatic life systems and the users of the water source.

Removal of Insoluble Contaminants

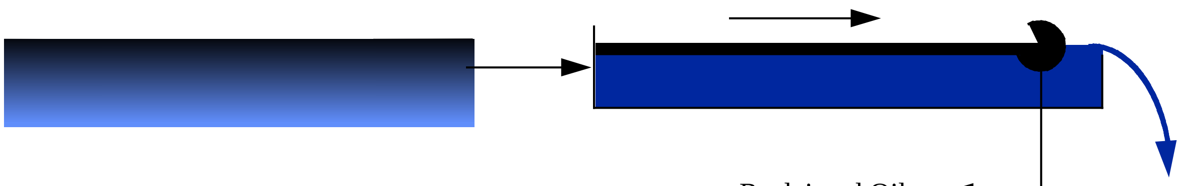
Various physical methods may be used for the removal of insoluble contaminants, such as suspended solids, oil and grease. In addition, the most common forms of treatment for removal of water-soluble contaminants is the chemical conversion to an insoluble form allowing removal by physical methods.

Gravity Separation : Most waste treatment systems employ a gravity separation step for suspended particle or oil removal.

Gravity settling is employed primarily for removal of inorganic suspended solids such as grit and sand. The equipment employed for gravity separation for waste treatment is normally either a rectangular basin with moving bottom scrapers for solids removal or a circular tank with a rotating bottom scraper. *Rectangular tanks* are typically sized to decrease horizontal fluids velocity to approximately 1 ft/min. Their lengths are three to five times their width and their depths are 3-8 ft.

Circular clarifiers are ordinarily sized according to surface area, because velocity must be reduced below the design particle's terminal velocity. The typical design provides a rise rate of 600-800 gpd/ft^2

When wastewater contains appreciable amounts of hydrocarbons, removal of these contaminants becomes a problem. Oil is commonly lower in density that water; therefore, if it is not



Schematic Diagram of Collection/Equilization Pond and API Separtor used for Primary Oil Removal from Waste Water

emulsified, it can be floated in a separate removal stage or in a dual-purpose vessel that allows sedimentation of solids. For example, the refining industry uses a rectangular clarifies with a surface skimmer for oil and a bottom rake for solids as standard equipment. This design is designated as an *API (American Petroleum Institute)* separator. The basic principles governing the separation of oil from water by gravity differential can also be expressed by Stokes' Law.

Air Flotation : Where the density differential is not sufficient to separate oil and oil-wetted solids, air flotation may be used for oil removal. Air bubbles are attached to the contaminants particles and the particles are floated to the surface.

Dissolved air floatation (DAF) is a method of introducing air to a side stream or recycle stream at elevated pressures. When this stream is introduced into the waste stream, the pressure is reduced to atmospheric , and the air is released as small bubbles. These bubbles attach to solid contaminants in the waste decreasing the effective density and aiding in their separation.

The primary parameters for the dissolved air flotation process are :

- Air pressure
- Recycle or slip stream flow rate

- Total suspended solids (TSS) including oil and grease
- Air bubble size
- Air dispersion

Air pressure , recycle, and influent TSS are normally related in an air-to-solids ratio expressed as:

$$A/S = KS_a(fP-1)R/SSQ$$

...where K = a constant, approximately 1.3

S_a = solubility of air at standard conditions, mL/L

f = ratio of air dissolved/S_a

P = operating pressure

R = recycle rate, gpm

SS = influent suspended solids, mg/L

Q = wastewater flow, gpm

The A/S ratio is most important in determining produced water TSS. Ideally, recycle flow and air pressure are varied to maintain an A/S ratio between 0.02 -0.06. The above relationship shows that as the concentration of suspended solids and waste water flow rate increase, higher air pressures and recycle rates are required in order to maintain floatation performance.

In a DAF system, the stream may be the entire waste water stream, a side stream, fresh water, or a recycle stream. Recycle streams are most common, because pressurization of a high-solids stream through a pump helps disperse oil and oil-wetted solids.

Similar to gravity settling processes, air flotation units are designed for a surface loading rate that is a function of the waste flow and rise velocity of the contaminants floated by air bubbles. The retention time is a function of tank depth. DAF units can be rectangular in design but are usually circular, resembling a primary clarifier or thickener.

Induced air flotation (IAF) is another method of decreasing particle density by attaching air bubbles to the particles; however, the method of aeration differs. A mechanical action is employed to create the air bubbles and their contact with the waste contaminants. The most common methods use high-speed agitators or recycle a slip stream through venturi nozzles to entrain air into the wastewater.

In contrast to DAF units, IAF units are usually rectangular and incorporate four or more air flotation stages in series. The retention time per stage is significantly less than in DAF circular tanks.

As in gravity settling, the diameter of the particle plays an important role in separation. For both IAF and DAF processes organic or inorganic polyelectrolytes may be added to the waste streams to increase effective particle diameters. Polymers can also be selected to destabilize oil-water emulsions, thereby allowing the free oil to be separated from the water. Emulsion breakers, surfactants, or surface-active agents are also used in air flotation to destabilize emulsions and increase the effectiveness of the air bubbles.

Filtration : Filtration can also be used to remove suspended solids. In practice, filtration is most often used to polish wastewater following the primary treatment step(s) such as clarification or floatation. Filters are commonly used following biological treatment, prior to final discharge or reuse.

A wide variety of filter types are used for waste treatment including single-, or multimedia, full flow or side stream and may be of the pressure or gravity type.

Removal of Insoluble Contaminants

pH Adjustment - Chemical Precipitation : Industrial wastewaters often contains high concentration of metals that are soluble under low pH conditions. An effective method of removing these metal ions is to raise the pH of the waste water stream and precipitate them as metal hydroxides.

$$M^{2+} + OH^{-} \overset{K_{sp}}{\Leftrightarrow} M(OH)_2$$

The pH is controlled to minimize the solubility of the contaminant. Although a number of chemicals may be used for pH adjustment, the most cost effective are lime (CaO), and soda ash (Na_2CO_3). The solids precipitated then be removed by gravity separation or floatation and must be disposed of either by land fill or incineration.

Solubility Products of Selected Compounds (in aqueous solutions at 25°C)

Compound	Chemical Formula	Solubility Product pK_{sp}*
Aluminum Hydroxide	$Al(OH)_3$	31.7
Calcium Hydroxide	$Ca(OH)_2$	5.3
Calcium Carbonate	$CaCO_3$	8.1
Iron (II) Hydroxide	$Fe(OH)_2$	15.1
Iron (III) Hydroxide	$Fe(OH)_3$	37.4
Magnesium Hydroxide	$Mg(OH)_2$	10.9
Nickel Hydroxide	$Ni(OH)_2$	17.2
Zinc Hydroxide	$Zn(OH)_2$	16.9
Manganese Hydroxide	$Mn(OH)_2$	12.7

* $pK_{sp} \equiv -\log(K_{sp})$ and therefore a larger pK_{sp} corresponds to lower solubility.

Normally soluble chemical species may also be removed as a result of pH adjustment. Contaminants are removed either by the chemical reactions of precipitation or by adsorption of ions on an already formed precipitate. Adsorption onto precipitated solids is a common method of removal of oil, grease and organic species.

Biological Oxidation - Biochemical Reactions :. Bioxidation is the process whereby organic material are metabolized by bacteria and converted into carbon dioxide and bacterial floc. The solids generated can then be removed by gravity separation (settling).

Microorganisms feed on dissolved and suspended organic compounds. Bioxidation (biodegradation) processes harness this natural ability of microorganisms to break down complex organic chemicals present in wastewaters. The biodegradable contaminants in water are usually measured in terms of *biochemical oxygen demand (BOD).* BOD is the amount of oxygen consumed by microorganisms as a result of metabolizing nutrients. Bacteria consume oxygen along with nutrients to form, energy, carbon dioxide, water and for replication.

$$\text{Food (organic compounds)} + \text{Microorganisms} + O_2 + \text{Nutrients}$$
$$\Downarrow$$
$$\text{Cellular matter} + \text{Microorganisms} + CO_2 + H_2O + \text{Energy}$$

The effectiveness of the bioxidation process depends on consuming the maximum amount of "food" (organic compounds) in the waste water stream. Therefore, biological waste treatment facilities are operated to provide an environment that will maximize the health and metabolism of microorganisms. An integral part of the biological process is the conversion of soluble organic material into insoluble materials for subsequent removal.

Open Lagoon Biological Oxidation : In cases where BODs are low and sufficient land space is available, open lagoons may be used for bioxidation treatment. Lagoons provide an ideal habitat for microorganisms. Natural aeration is usually sufficient to provide oxygen for biological oxidation. However, mechanical aeration is often used to increase efficiency and to handle a higher BOD loading.

Bioxidation Process Factors	
Food	Measured as BOD, present in the waste water stream and consumed by the microorganism.
Dissolved oxygen	Proper aeration is required to provide sufficient oxygen levels for BOD removal
pH/toxins	Although bacteria are very adaptive to environmental conditions, rapid changes pH or type of waste organic inhibit the process.
Time	Adequate residence time within the bioxidation unit is required for BOD reduction.
Nutrients	Bacteria require trace amounts of nitrogen and phosphorus in order to metabolize food.
Temperature	Low temperatures slow reaction rates; higher temperatures kill many strains of bacteria.

Lagoons are simply basins used for long-term retention. The lagoons are typically shallow and depend on surface area, wind, and wave action for oxygen transfer. The biological process in the lagoon may be aerobic and/or anaerobic.

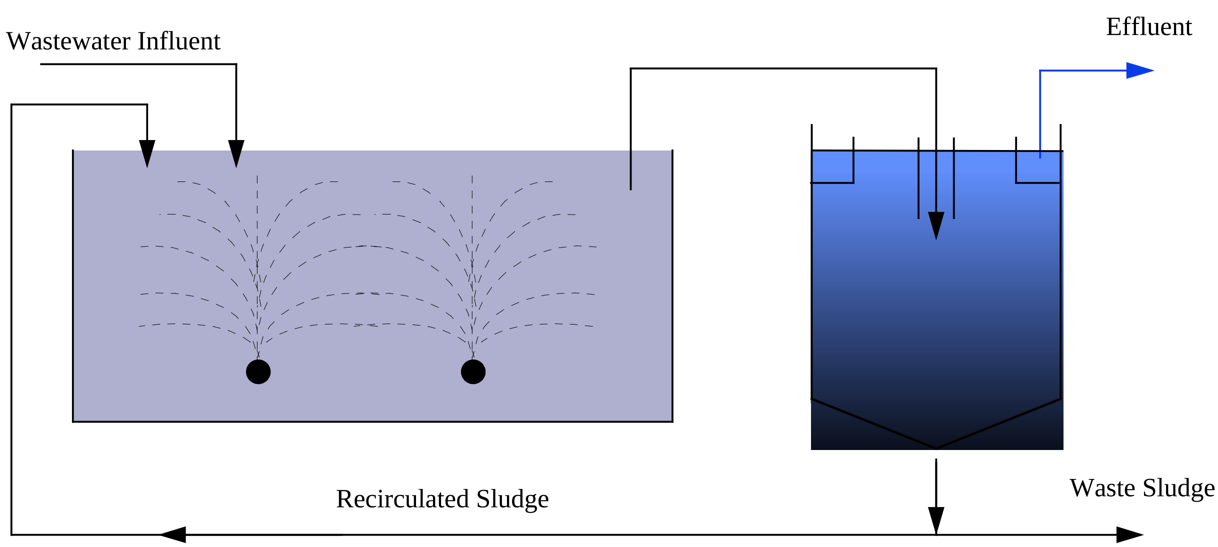
If supplemental oxygen is required to handle higher BODs, air is introduced either by mechanical agitators or by blowers and subsurface aerators. Aerated lagoons are usually constructed as 10 - 15 feet deep versus 3-5 feet deep for unaerated lagoons. The greater depth permits longer contact times and more efficient aeration.

Facultative Lagoons : Lagoons without mechanical aeration are usually populated by facultative organisms (aerobic and/or anaerobic). These organisms have the ability to survive with or without oxygen. A lagoon designed specifically to be facultative is slightly deeper than an unaerated lagoon. Suspended solids settle to the bottom of the lagoon and undergo further decomposition in an anaerobic environment.

Activated Sludge Oxidation : In the activated sludge process, reactants, food, and microorganisms are mixed in a controlled environment to optimize BOD removal. The process incorporates the return of concentration microorganisms to the influent waste. Sludge that has been settled from the treated wastewater is reintroduced to the influent wastewater. The sludge consists of biological solids and live bacteria that thrives when recirculated and aerated. The activated sludge oxidation process also includes a sedimentation step that serves to both to remove solids, as well as concentrate the microorganisms.

The performance of the activated sludge process is affected by BOD, the types of microorganisms present, aeration, retention time, nutrient concentration, and environmental factors such as temperature and pH. Because activated sludge is a continuous, steady-state process each plant operates differently, as determined by the retention time and growth rate of the organisms present..

Optimization of an activated sludge plant is a function of mechanical, operational and chemical factors. Mechanical problems can include excessive mixing/circulation rates, insufficient aeration and short-circuiting. Operational problems may include spills and shock loads, pH shocks, failure to maintain correct mixed liquor concentration and excessive sludge retention in the clarifier. Although microbes are eventually able to break down most complex organics and can tolerate very poor environments, they are very intolerant of sudden changes in pH, dissolved oxygen, and the organic compounds that normally upset an activated sludge system These upsets normally result in reduced BOD removal and excessive carryover of suspended in the final effluent.



Aerobic Digester and Settling Tank Utilizing Recirculated Activated Sludge

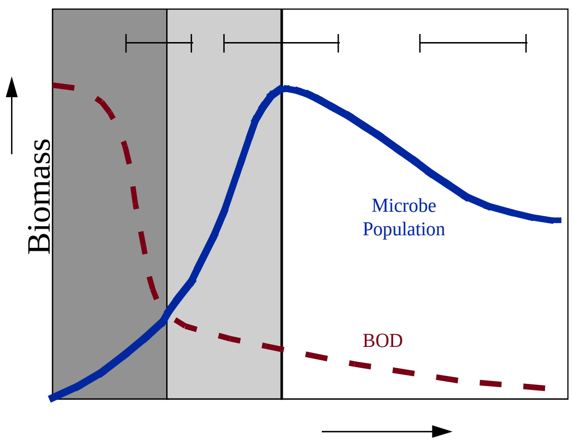
Typical removal efficiencies for oil refinery treatment processes are shown in the table below.

Process	Process Influent	Removal Efficiency , %							
		BOD	COD	TOC	SS	Oil	Phenol	Ammonia	Sulfide
API separator	raw waste	5-40	5-30	NA	10-50	60-99	0-50	NA	NA
Primary Clarifier	API effluent	30-60	20-50	NA	50-80	60-95	0-50	NA	NA
Dissolved air flotation	separator effluent	20-70	10-60	NA	50-85	70-85	10-75	NA	NA
Filter	API effluent	40-70	20-55	NA	75-95	65-90	5-20	NA	NA
Secondary oxidation pool	API effluent	40-95	30-65	60	20-70	50-90	60-99	0-15	70-100
Aerated lagoon	primary effluent	75-95	60-85	NA	40-65	70-90	90-99	10-45	95-100
Activated Sludge	primary effluent	80-99	50-95	40-90	60-85	80-99	95-99+	33-99	97-100
Trickling Filter	API effluent	60-85	30-70	NA	60-85	50-80	70-98	15-90	70-100
Cooling Tower	primary effluent	50-95	40-90	10-70	50-85	60-75	75-99+	60-95	NA
Activated Carbon	primary effluent	70-95	70-90	50-80	60-90	75-95	90-100	7-33	NA
Tertiary filter granular media	secondary effluent	NA	NA	50-65	75-95	65-95	5-20	NA	NA
Activated carbon	secondary + filter effluent	91-98	86-94	50-80	60-90	70-95	90-99	33-87	NA

Aeration : Sufficient aeration is critical to the activated sludge process. The most common methods of aeration used are :

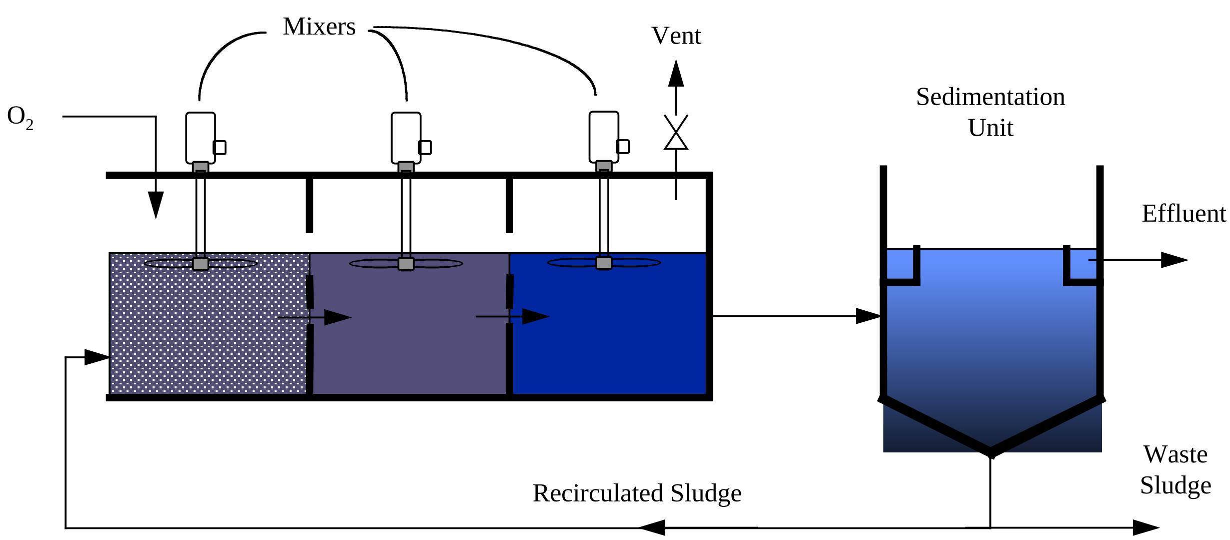
- *High rate aeration*. This is used when settling rates of the biological material is poor and high recirculation rates are required to maintain an active sludge. This has several advantages including low capitol cost and space requirements but the relatively poor effluent quality produced limits its use.

- *Conventional Aeration.* This is the most common design used for BOD and suspended solids removal prior to discharge.



- *Extended aeration* . This is used when longer oxidation periods are required for BOD reduction either because of high initial BOD levels or if the wastes are difficult to biodegrade.
- *Tapered aeration*: Tapered aeration provides more aeration at the head of the unit and reduces oxygen supply to match the demand as the waste flows through the basin. This results in reduced air costs and helps control the BOD removal process.

- *Step aeration* : The bioxidation unit is divided into several stages, and raw wastewater is introduced to each stage proportionately. The recirculated sludge is introduces at the head of the unit. Aeration time is reduced to 3-5 hr, while BOD reduction efficiency is maintained.



Pure Oxygen Bioxidation Unit With Sedimentation Unit

- *Contact Stabilization :*. The raw wastewater is mixed with recirculated sludge within the aeration tank (*contact tank*). The entire sludge + waste water flow then goes to the sedimentation section where the sludge and captured organic material are separated and returned to a re-aeration tank. In the re-aeration tank the wastes are reacted at a high biomass population. Contact stabilization is designed to reduce tank volume and reduce the time necessary for the biomass to absorb the BOD contained in the influent waste water.

  Because only a portion of the active sludge is exposed to the raw waste water influent, it is less susceptible to deactivation by toxicants. This is beneficial for treatment of industrial waste waters that suffer from variation in composition and process leaks.

- *Pure Oxygen Sludge Processes :* Pure oxygen (90- 99%) is fed to the activated sludge instead of air. Since the bioxidation processes are often limited by the availability of oxygen, this [process increases BOD reduction efficiency and shorter reaction times. In addition, the net solids produced are often lower and therefore sludge disposal costs may be reduced.

- These units are multi-sectional with the raw wastewater, recirculated sludge, and pure oxygen being mixed in the first stage. The wastewater + sludge mixture passes from stage to stage in the underflow. Each stage contains a mechanical agitator for mixing and oxygen transfer. After reaction, the wastewater flows to a conventional sedimentation unit.

The characteristics of these most commonly used forms of aeration and several others are summarized in the table below.

Type	Aeration Retention time hr	MLSS, ppm	Aeration D.O. ppm	Sludge Recycle %	BOD Loading lb/Mft3	F/M lb BOD/ lb MLVSS	Sludge Production lb/lb of BOD	BOD Removal %
High rate	1/2 - 3	300 - 1000	0.5 - 2.0	5-15	2.5	1.5-5.0	0.65-0.85	75-85
Conventional activated sludge	6 - 8 (diffused)	1000 - 3000	0.5 - 2.0	20-30	20-40	0.2 -0.5	0.35 -0.55	85-90
	9 - 12 (mechanical)	500-1500	0.5-2.0	10-20	20-40	0.2-0.5	0.35-0.55	80-95
Extended aeration	18-36	3000 - 6000	0.5-2.0	75-100	10-25	0.03-0.15	0.15-0.20	90-95
Step aeration	3-5	2000-3500	0.5-2.0	25-75	40-60	0.2-0.5	0.35-0.55	85-90
Contact stabilization	3-6	1000-3000 (aeration)	0.5-2.0	25-100	60-75	0.2-0.6	0.35-0.55	85-90
		4000-10000 (contact basin)	0.5 - 2.0	25-100	60-75	0.2 -0.6	0.35 - 0.55	85-90
Pure oxygen	1 -3	3000 - 8000	2 - 6	25-50	100 - 250	0.25 - 1.0	0.35 - 0.55	95-98
Complete mix	3 - 5	3000 - 6000	0.5 - 2.0	25 -100	50 - 120	0.2 - 0.6	0.35 - 0.55	85-95

Chemical Treatment Programs : Chemical programs that are commonly used to improve the efficiency of bioxidation units are discussed below :

- *Nutrients*: Nitrogen and phosphorous may be added as necessary nutrients for the metabolic processes.
- *Polymers*: Polymers (coagulants) may be fed to improve the settling rate and increase the concentration of suspended solids within the sedimentation stage. These improvement in settling rates increases the overall efficiency of solids removal and can be used on a temporary basis during periods of high suspended or dissolved solids in the influent waste water.
- *Oxidizing Agents*: Peroxide, chlorine, or other agents may be used to aid in the "pre-oxidation" of filamentous bacteria allowing for more rapid consumption in the bioxidation process.

- *Antifoam Agents*: Control excessive foam.

Solid Waste

The solids removed from the wastewater stream as part of the treatment processes must then be disposed of. Usually the solids are contained in a stream that is too large, or too dilute to be disposed of economically. Further concentration of the solids contained in this stream is required and is referred to as “solid waste handling” operations.

After processing, the sludge produced from primary waste treatment processes must be further treated for environmentally acceptable manner. The specific objectives of the sludge conditioning processes are :

- Decompose sludge organics
- Reduce mass and volume of sludge
- Obtain by-products

The most widely used sludge processing techniques are summarized below :

Anaerobic Digestion. : Anaerobic digestion is performed in an enclosed tank. The overall reactions that take place are :

$$\text{Organic Material} + \text{Microorganisms} \Rightarrow \text{Volatile acids}$$

$$\text{Volatile acids} + \text{Microorganisms} \Rightarrow \text{Methane} + CO_2$$

The mass of the sludge solids are decreased due to the conversion of biomass to methane and carbon dioxide. The methane can be recovered for its heating value.

Aerobic Digestion *:* Aerobic digestion of sludge is performed in an open tank in order to oxidize biodegradable matter. As with anaerobic digestion, the mass of sludge solids is decreased and odor formation is decreased.

Lime Treatment *:* Addition of lime is used to sterilize organic sludge for subsequent use as fertilizer, etceteras. Addition of sufficient lime to maintain the pH of the sludge above 11.0 for 1 - 14 days is considered sufficient to destroy most bacteria.

Composting : Sludge is combined with bulking materials, such as other solid wastes or wood chips, and naturally degraded under aerated conditions. The energy produced by the decomposition reaction can bring the waste temperature to 140 - 160 F, destroying pathogenic bacteria. At the end of the composting period, the bulking material is separated and the stabilized sludge is applied to land or sent to a landfill.

Dewatering

Waste sludge from most sedimentation units contain between 1 to 5% total suspended solids. In order to reduce the costs associated with handling large volumes, excess water is removed to concentrate the solids content and decrease the total volume to be disposed. Dewatering equipment is designed to remove water in a shorter time than by simple gravity process. Prior to dewatering, conditioning of the sludge is usually required to increase the efficiency of the mechanical dewatering process.

Conditioning is necessary due to the nature of the sludge particles. Both inorganic and organic sludge consist of colloidal (less than 1 μm), intermediate, and large particles (greater than 200 μm). The purpose of sludge conditioning is to prevent the sludge from compressing. Proper conditioning will provide a rigid sludge structure of porosity and pore size sufficient to allow water to drain. Typically, biological sludge are conditioned with $FeCl_3$, lime and synthetic cationic polymers, either separately or in combination. Heat conditioning and low-pressure oxidation are also used for biological sludge. Inorganic sludge are conditioned with $FeCl_3$, lime and either cationic or anionic polymers.

Belt Filter Press : Sludge is sandwiched between two tensioned porous belts and passed over and under rollers of various diameters. Water is squeezed out of the sludge by pressure exerted by the rollers. Many different designs of belt filter presses are in use, all of which include pre-conditioning with polymer, a gravity drainage zone, and a shear (high-pressure) zone.

Polymer Conditioning Unit : Inorganic or synthetic organic polymers are mixed with the sludge either in a premixing tank, drum or in the sludge line. Usually, a polymer conditioning unit is integral with the belt filter press.

Gravity Drainage Zone : In this section, sludge is dewatered by the gravity drainage of the free water. The gravity drainage zone usually increases the solids concentration of the sludge by 5 to 10 %. If not properly dewatered in this step, the sludge tends to squeeze out from between the belts in compression area.

Compression (Low-Pressure) Area. The sludge is “sandwiched” between the upper and lower belts. A firm sludge cake is formed in this zone prior to the high-pressure zone.

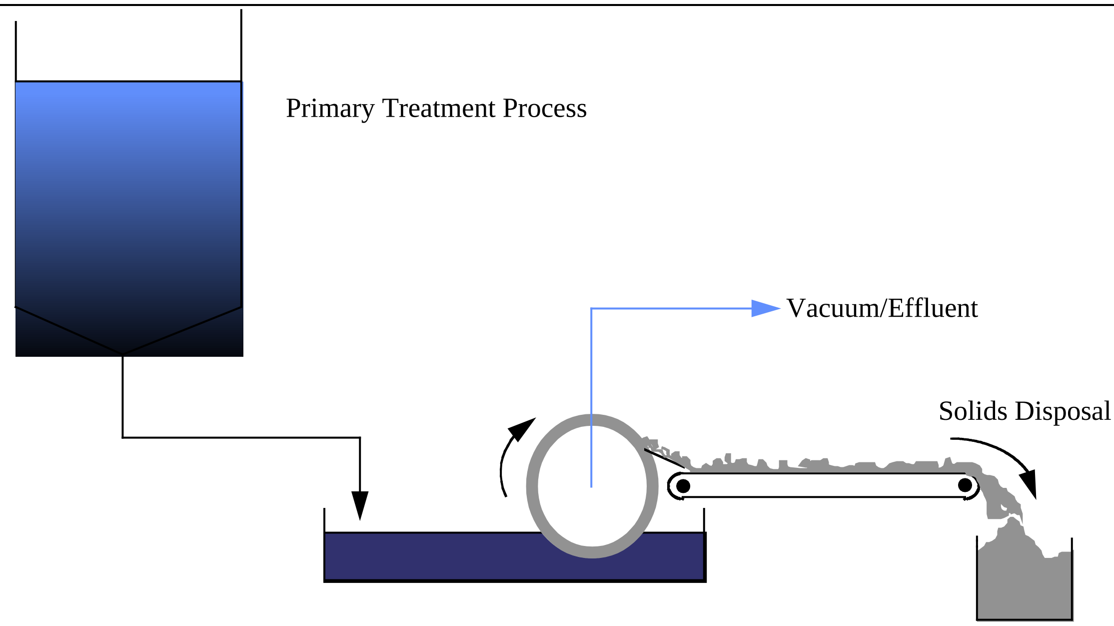
Shear (High-Pressure) Zone. The sludge is exposed to high shear force by the movements of the belts between the series of rollers. A dry cake suitable for incineration or lad fill is produced by this step.

Usually, cationic polymers are applied to increase the efficiency of the sludge dewatering process. The polymer must be selected based upon empirical testing and evaluation of waste sludge properties.

Screw Press : These are used primarily in the pulp and paper industry and are capable of producing solid contents of 50 to 55 %. Free water is collected in the pan located under the screw press.

Vacuum Filters. Vacuum filtration is used with various porous materials as filter media, including cloth, steel mesh, and tightly wound coil springs and in a variety of configurations including belt, and rotary.

Under an applied vacuum, water is drawn through the porous media and the solids are retained as a cake. As with other dewatering processes, polymers can be used to produce a drier cake.



Schematic Diagram of Batch Primary Waste Water Treatment and Vacuum Rotary Filter

Centrifuges. Centripetal force within a rotary centrifuge is used to increase the sedimentation rate of solid sludge particles. The most common centrifuge in waste water treatment dewatering applications is the *continuous bowl centrifuge.*

Dewatering aid polymers are usually fed inside the bowl because shear forces inside the unit may destroy pre-formed flocs. Also, large particles settle rapidly in the first stage of the bowl. Thus, economical solids recovery can be achieved through internal feeding of polymers after the large particles have settled.

Plate and Frame Press. This method uses a batch press operation consisting of vertical plates held in a frame. A filter cloth is mounted on both sides of each plate. Sludge pumped into the unit is subjected to pressures of up to 25 psig as the plates are pressed together. As the sludge fills the chamber between individual plates, the filtrate flow ceases, and the dewatering cycle is completed. This cycle usually lasts from 1/2 to 2 hr.

Sludge Drying Beds These consists of a layer of sand over a gravel bed. Underdrains spaced throughout the system collect the water. Water is drained from the sludge via gravity through the sand and gravel bed. This process is complete within the first two or three days and all subsequent dewatering occurs by evaporation. Climatic conditions, such rainfall, wind velocity, temperature and relative humidity, play an important role in the dewatering process.

Sludge Disposal

After conditioning and de-watering, ultimately the waste sludge removed from the waste water stream must be disposed of in an environmentally acceptable method. The primary methods of sludge disposal include the following :

- Recovery of elements and components for re-use and/or re-sale. Examples include burning of produced gases, reclamation of CaO, and metallic salts recovery.
- Incineration for purposes of disposal and generation of steam/electricity.
- Application to land as fertilizer or soil conditioner.
- Landfill . The proper containment of the land filled solids must be used to avoid contamination of soil and ground water.