WASTEWATER TREATMENT

Every community produces both liquid and solid wastes. The liquid portion-wastewater-is essentially the water supply of the community after it has been fouled by a variety of uses.

Wastewater may be defined as a combination of the liquid –or water carried wastes removed from residences, institutions, and commercial and industrial establishments, together with such groundwater, surface water and storm water.

If untreated wastewater is allowed to accumulate, the decomposition of the organic material it contains leads to the production of large quantities of malodorous gases.

In addition, untreated wastewater usually contains numerous pathogenic, or disease causing, microorganisms that dwell in the human intestinal tract or that may be present in certain industrial waste.

Wastewater also contains nutrients, which can stimulate the growth of aquatic plants, and it may contain toxic compounds.

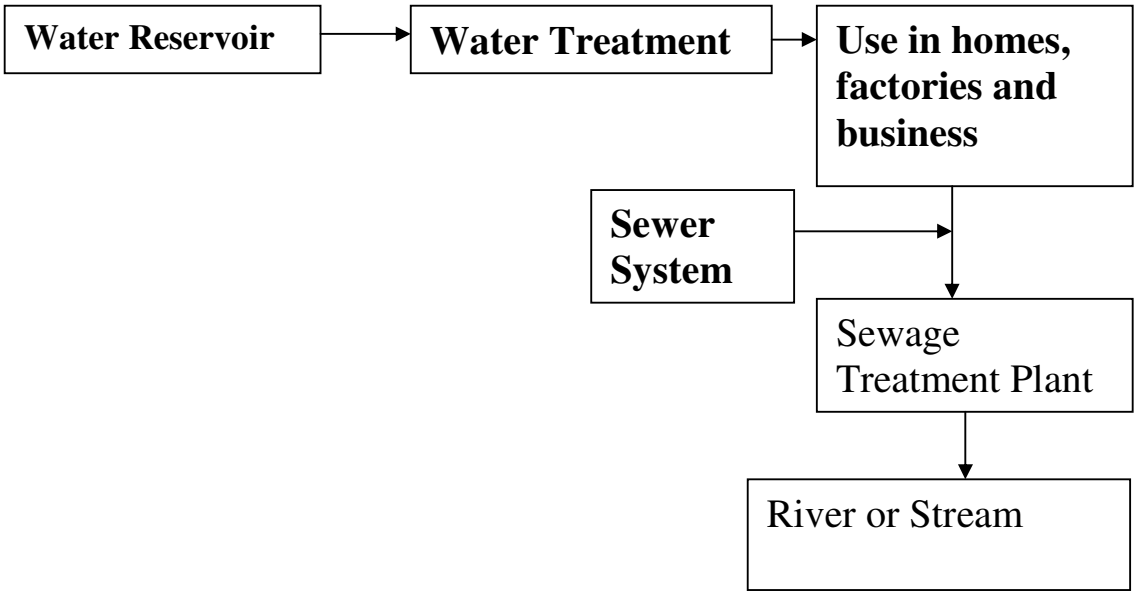
For this reason, the immediate and nuisance-free removal of wastewater from its sources of generation, followed treatment and

disposal, is not only desirable but also necessary in an industrialized society.

Wastewater collected from municipalities and communities must ultimately be returned to receiving waters or to the land.

The complex question of which contaminants in wastewater must be removed to protect environment- and to what extent-must be answered specifically for each case.

The answer to this question requires analyses of local conditions and needs, together with the application of scientific knowledge, engineering judgment based on past experience, and consideration of federal and state requirements and regulations.



Important contaminants of concern in wastewater treatment

- **Suspended Solids:**

  - ❖ Suspended solids can lead to the development of sludge deposits and anaerobic conditions when untreated wastewater is discharged in the aquatic environment.

- **Biodegradable Organics:**

  - ❖ Composed principally of proteins, carbohydrates, and fats
  - ❖ Biodegradable organics are measured most commonly in terms of

BOD (Biochemical Oxygen Demand) and
COD (Chemical Oxygen Demand)

- ❖ If discharged untreated to environment, their biological stabilization can lead to the depletion of natural oxygen resources and to the development of septic conditions.

- **Pathogens :**
  - ❖ Communicable diseases can be transmitted by the pathogenic organisms in wastewater.

- **Nutrients :**

  - ❖ Both nitrogen and phosphorus, along with carbon, are essential nutrients fro growth. When discharged to the aquatic environment, these nutrients can lead to the growth of undesirable aquatic life. When discharged in excessive amounts on land, they can also lead to the pollution of groundwater.

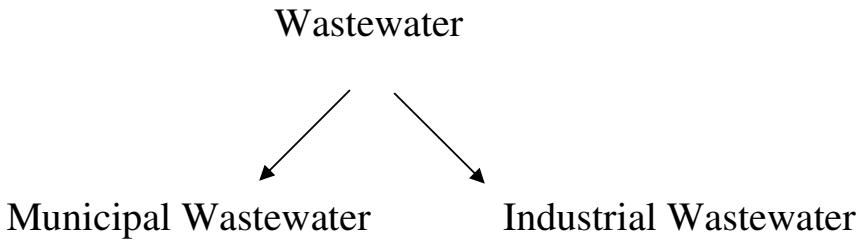
- **Priority Pollutants :**
  - ❖ Organic and Inorganic compounds selected on the basis of their known or suspected carciogenity, mutagenity, teratogenicity, or high acute toxicity.

- **Refractory Organics :**

❖ These organics tend to resist conventional methods of wastewater treatment. Typical examples include surfactants, phenols and agricultural pesticides.

- **Heavy Metals :**

❖ Heavy metals are usually added to wastewater from commercial and industrial activities and may have to be removed if the wastewater is to be reused.



Industrial wastewater with characteristics compatible with municipal wastewater is often discharged to the municipal sewers.

Many Industrial wastewaters required pretreatment to remove noncompatible substances prior to discharge into the municipal system.

TERMINOLOGY IN WASTEWATER TREATMENT

Unit Operations: Methods of treatment in which the applications of physical forces predominates

Unit Processes: Methods of treatment in which the removal of contaminants is brought about by chemical or biological reactions.

Reactor : Refers to the vessel, or containment structure, along with all of its appurtenances in which the unit operations or unit process takes place.

Wastewater Treatment System : It composed of a combination of unit operations and unit processes designed to reduce certain constituents of wastewater to an acceptable level.

Municipal wastewater treatment systems are often divided into primary, secondary and advanced (or tertiary) subsystems.

In primary treatment ➔ Physical operations such as screening and sedimentation are used to remove the floating and settleable solids found in wastewater.

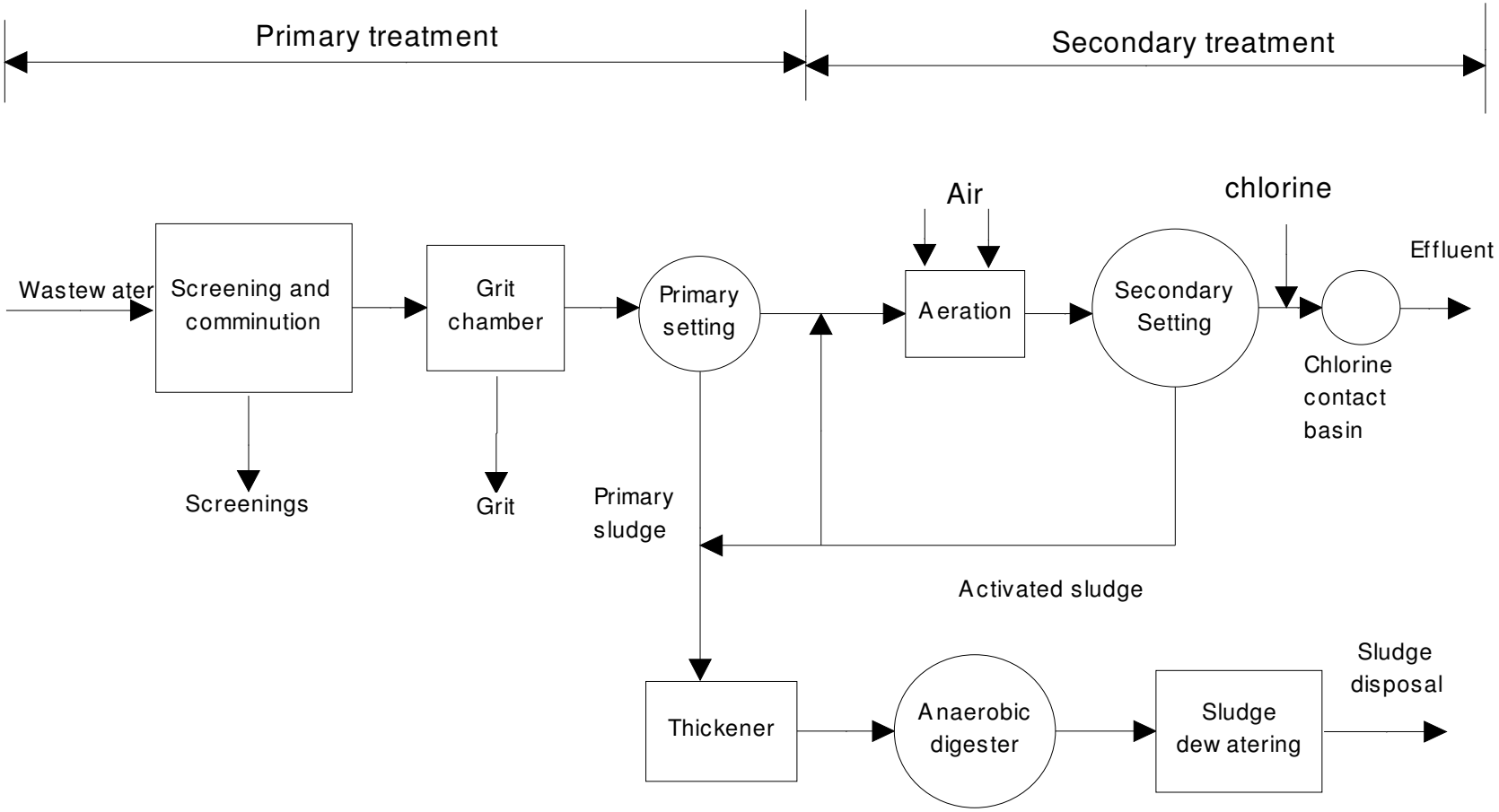
Secondary treatment ➔ biological and chemical processes are used to remove most of the organic matter.

It uses microorganisms to decompose the suspended organic material in wastewater. Water is aerated and circulated through bacteria-rich particles and microorganisms are allowed to settle out, forming sewage sludge, a slimy mixture of bacteria-laden solids.

Advanced Treatment ➔ additional combinations of unit operations and processes are used to remove other constituents such as nitrogen and phosphorus, that are not reduced significantly by secondary treatment.

Even after primary and secondary treatment, wastewater still contains pollutants; they include dissolved materials, heavy metals, viruses and synthetic organic compounds. Advanced wastewater treatment methods, also known as tertiary treatment, include a variety of biological, chemical, and physical processes. Tertiary treatment must be employed to remove phosphorus and nitrogen.

Schematic of an example wastewater treatment facility providing primary and secondary treatment using the activated sludge process.



Primary Treatment

Bar Screening: Removal of coarse solids by interception

Comminution: Grinding of solids

Grit Chamber: Removal of grit, sand, and gravel, usually following screening and comminution

Primary Setting (Sedimentation Tank): Removal of readily settleable solids and thus reduce the suspended solids (SS) content

Secondary Biological Treatment

Activated Sludge Process: Consists of aeration tank plus secondary sedimentation tank. It is mainly to remove BOD_5 (i.e., organic compounds) and SS. The purpose of the return of activated sludge is to maintain a sufficient concentration of activated sludge in the aeration tank.

Trickling Filters: It is a bed of media (e.g., rocks) over which wastewater is continuously distributed. The spaces between the rocks allow air to circulate easily so that aerobic condition can be maintained. Nowadays, plastic media are becoming increasingly popular as a replacement for rocks because of the heavy weight of rocks.

Rotating Biological Contactor: RBC consists of a series of closely spaced, circular, plastic disks. The bottom 40% of each disk is submersed in a tank with a wastewater to be treated.

Sludge Treatment

Thickening: It is a procedure used to increase the solids content of sludge by removing a portion of the liquid fraction. Thickening is generally accomplished by physical means including gravity belts and centrifugate.

Anaerobic Digestion: It is a traditional method of sludge processing. It involves bacteria that thrive in the absence of oxygen. In this sludge process, organics are converted into carbon dioxide and methane gas.

$$\text{complex, large organic matter} \xrightarrow{\text{acid - forming bacteria}} \text{organic acids} \xrightarrow{\text{methane - forming bacteria}} CH_4 \;\&\; CO_2$$

Sludge dewatering: It is a physical (mechanical) process used to reduce the moisture content of sludge so that it is easier to handle.

Advanced Treatment

Ammonia Stripping: Ammonium nitrogen can be removed from wastewater by volatilization of gaseous ammonia. The fate of ammonia transfer is enhanced by converting most of the ammonia into a gaseous form at a high pH, usually in the range of 10.5 to 11.5 by the addition of lime.

$$NH_{3(g)} + H_2O \leftrightarrow NH_4^+ + OH^- \quad K=1.82 \times 10^{-5}$$

$$\frac{[NH_4^+][OH^-]}{[NH_3]} = 1.82 \times 10^{-5}$$

$$\Rightarrow \quad \frac{[NH_4^+]}{[NH_3]} = \frac{1.82 \times 10^{-5}}{[OH-]} = \frac{1.82 \times 10^{-5}}{\frac{10^{-14}}{[H^+]}} = \frac{[H^+]}{5.5 \times 10^{-10}}$$

Nitrification/Denitrification: Nitrification of ammonium nitrogen is a two-step process involving two types of microorganisms, Nitrosomonas and Nitrobacter. In the first step, ammonium is converted aerobically to nitrite; in the second step, nitrite is converted to nitrate. In denitrification process, nitrates are converted to nitrogen gas.

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

$NO_2^- + \frac{1}{2}O_2 \xrightarrow{Nitrobacter} NO_3^-$

Denitrification: $2NO_3^- + organic\ \ matter \xrightarrow{bacteria} N_{2(g)} + CO_2 + H_2O$

e.g. $6NO_3^- + 5CH_3OH \xrightarrow{bacteria} 5CO_2 + 3N_2 + 7H_2O + 6OH^-$

Phosphorus Precipitation: Removal of phosphates is accomplished by adding a chemical such as alum or lime.

Species: $H_2PO_4^-$, HPO_4^{2-}, PO_4^{3-}

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

$2PO_4^{3-} + Al_2(SO_4)_3 \rightarrow 2AlPO_{4(s)} + 3SO_4^{2-}$