TREATMENT OF WATER AND WASTEWATER (LIQUID CONTAMINANTS)

DRINKING WATER QUALITY

Two major standards are set for drinking water:

1) Primary Standards: Specify Maximum Contaminant Levels (MCLs) based on health related criteria. These are enforceable regardless of cost.
2) Secondary Standards: Specify guidelines based on aesthetics such as: color, odor, taste and non-aesthetics such as: corrosivity and hardness. These are unenforceable.

(1) Primary Standards

Contaminants that fall into this group and for which primary standards are enforced include:

1.1 Inorganic contaminants: Such as: arsenic, barium, cadmium and lead (Table 6.1). Also standards are developed for asbestos and copper.

1.2 Organic contaminants: Can be classified in 3 groups:

1.2.1 *Synthetic Organic Chemicals (SOC):* These are compounds used in a wide variety of agricultural and industrial products, such as: pesticides and herbicides.

1.2.2 *Trihalomethanes (THM):* These are by-products of water chlorination, such as: $CHCl_3$ and $CHBr_2Cl$.

1.2.3 *Volatile Organic Chemicals (VOC):* These are chemicals that vaporize at room temperature, such as: paint thinners, dyes, some pesticides, benzene and vinyl chloride.

1.3 Radioactive Materials: They include: radon and radium-226.

1.4 *Microbiological Compounds:* Coliform bacteria (E. coli) is tested for (If the count is >1 coliform per 100 mL, then the water is contaminated).

DRINKING WATER TREATMENT SYSTEMS

Some or all of the below may be needed depending on sources of water and degree of contamination.

- Screening: To remove relatively large debris (particles).
- Mixing: Chemicals are added and mixed with water to encourage coagulation of suspended solids.
- Flocculation: Addition and mixing of coagulants (e.g., Alum

$Al_2(SO_4)_3.18H_2O$) to enhance the formation of larger particles.

- Sedimentation: It is achieved by adjusting the flow rate such that flocculants are given enough time (1-10 hr) to settle.
- Sludge Processing: Settled sludge is dewatered and disposed off.
- Disinfection: Additon of disinfectants (e.g., chlorine, sodium hypochlorite, NaOCl, Ozone) to kill pathogens ($Cl_2 + H_2O \rightleftarrows HOCl + H^+ + Cl^-$).

Water Hardness

Defined as the concentration of all multivalent metallic cations. The two most important are Ca^{+2} and Mg^{+2}. It causes *cleaning* problems (prevents leathering of soap) and forms *scale*. Can be divided into:

1) *Temporary Hardness:* Caused by presence of $CaCO_3$ and $Ca(HCO_3)_2$. It can be removed easily (simple heating).
2) *Permanent Hardness:* Cause by other Ca^{+2} and Mg^{+2} salts. Requires more complex processes to remove the hardness (e.g., $CaCO_3 \downarrow$ *and* $Mg(OH)_2 \downarrow$). The most applied softening processes are: *lime-soda process and ion-exchange process.*

2-1 Lime-Soda Process: In this process; lime (CaO) or hydrated lime ($Ca(OH)_2$) and soda (Na_2CO_3) are added to hard water.

$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 \downarrow + 2H_2O$$
$$Mg(HCO_3)_2 + 2Ca(OH)_2 \rightarrow 2CaCO_3 \downarrow + Mg(OH)_2 \downarrow + H_2O$$
$$MgSO_4 + Ca(OH)_2 + Na_2CO_3 \rightarrow CaCO_3 \downarrow + Mg(OH)_2 \downarrow + NaSO_4$$

2-2 Ion-Exchange Process: In this process an ion-exchange material (Na-form) is used.

$$R - Na_2 + CaSO_4 \rightarrow R - Ca + Na_2SO_4$$

To regenerate the ion-exchange material, NaOH or NaCl is used.

$$R - Ca + 2NaCl \rightarrow R - Na_2 + CaCl_2$$

WASTEWATER TREATMENT

Three main processes are usually applied for wastewater treatment:

1. Primary Treatment
2. Secondary (Biological) Treatment
3. Advanced (Tertiary) Treatment

1. PRIMARY TREATMENT

These are physical processes that include some or all of the followings:

(a) Screening

(b) Degriting

(c) Primary settling tank or Sedimentation basin or clarifier

(d) Primary sludge

(e) Disinfection (may be**)

2. SECONDARY (BIOLOGICAL) TREATMENT

In this step, BOD (Biological Oxygen Demand) is removed (removal of organics). Three commonly used approaches are:

(a) Trickling Filters: In this process, wastewater is sprayed over rocks that have attached microorganism (therefore, the name attached growth) as shown in Fig. 6.5.

(b) Rotating Disc Contactors: This is also an attached growth process. The surface of the disc containing the biomass moves in and out of wastewater (Fig. 6.6)

(c) Activated Sludge Process: The most commonly used type. The heart of the unit is the aeration tank. It contains, also, a settling tank. Portion of the settled activated sludge is returned to the aeration tank. It is classified as "suspended growth" process (Fig. 6.7).

The main advantages are: good contact between wastewater and microorganism; relatively smaller areas are needed compared to trickling filters and also less capital cost.

The disadvantages are: more energy is needed for blowers and pumps; thus higher operating cost.

3. ADVANCED (TERTIARY) TREATMENT

The main aim of this treatment is remove phosphorus and nitrogen (to avoid eutrophication) and to ensure complete removal of BOD.

3.1 *Nitrogen Removal:*

3.1.1 Ammonia stripping: $NH_4^+ + OH^- \rightarrow NH_3 \uparrow + H_2O$

3.1.2 A Two-step process:

(a) Nitrification: This step utilizes aerobic bacteria (Nitrosomonas and Nitrobacter) according to the following equation:

$NH_4^+ + 2O_2 \xrightarrow{bacteria} NO^{-3} + 2H^+ + H_2O$

(b) Denitrification: This step utilizes other anaerobic bacteria

$$2NO^{-3} + Organic\ matter \xrightarrow{bacteria} N_2 \downarrow + CO_2 + H_2O$$

3.2 *Phosphorus Removal*

The following reactions describe phosphorus removal.

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

$$5Ca(OH)_2 + 3HPO_4^{-2} \rightarrow Ca_5OH(PO_4)_3 \downarrow + 3H_2O + 6OH^{-1}$$

HAZARDOUS WASTE TREATMENT

Treatment processes are categorized as:

A. Physical:
   a. Sedimentation
   b. Adsorption
   c. Aeration
   d. Reverse Osmosis
   e. Electrodialysis

B. Chemical:
   a. Neutralization
   b. Chemical Precipitation
   c. Reduction-Oxidation (redox)

C. Biological:
   a. Activated Sludge
   b. Lagoons
   c. Trickling Filters
   d. In Situ Biodegradation (see Fig. 6.15)

D. Thermal:
   a. Incineration

E. Fixation/Stabilization:
   a. Removal of excess water from the waste and solidifying the remainder by mixing it with a stabilizing agent (e.g., cement)

LAND DISPOSAL

- Landfills
- Surface Impoundments
- Underground Injection