Hazardous Waste Treatment

All the waste products whether from manufacturing process or treatment facility must be treated for the impurities hazardous to the nature to render them harmless to the environment.

The various treatment procedures can be classified as:

1. Physical.
2. Chemical.
3. Biological.
4. Thermal.

Physical Treatment:

- Physical treatment of hazardous waste includes a number of separation processes commonly used in industry.

- It is of first importance where waste containing liquids and solids are separated to reduce cost.

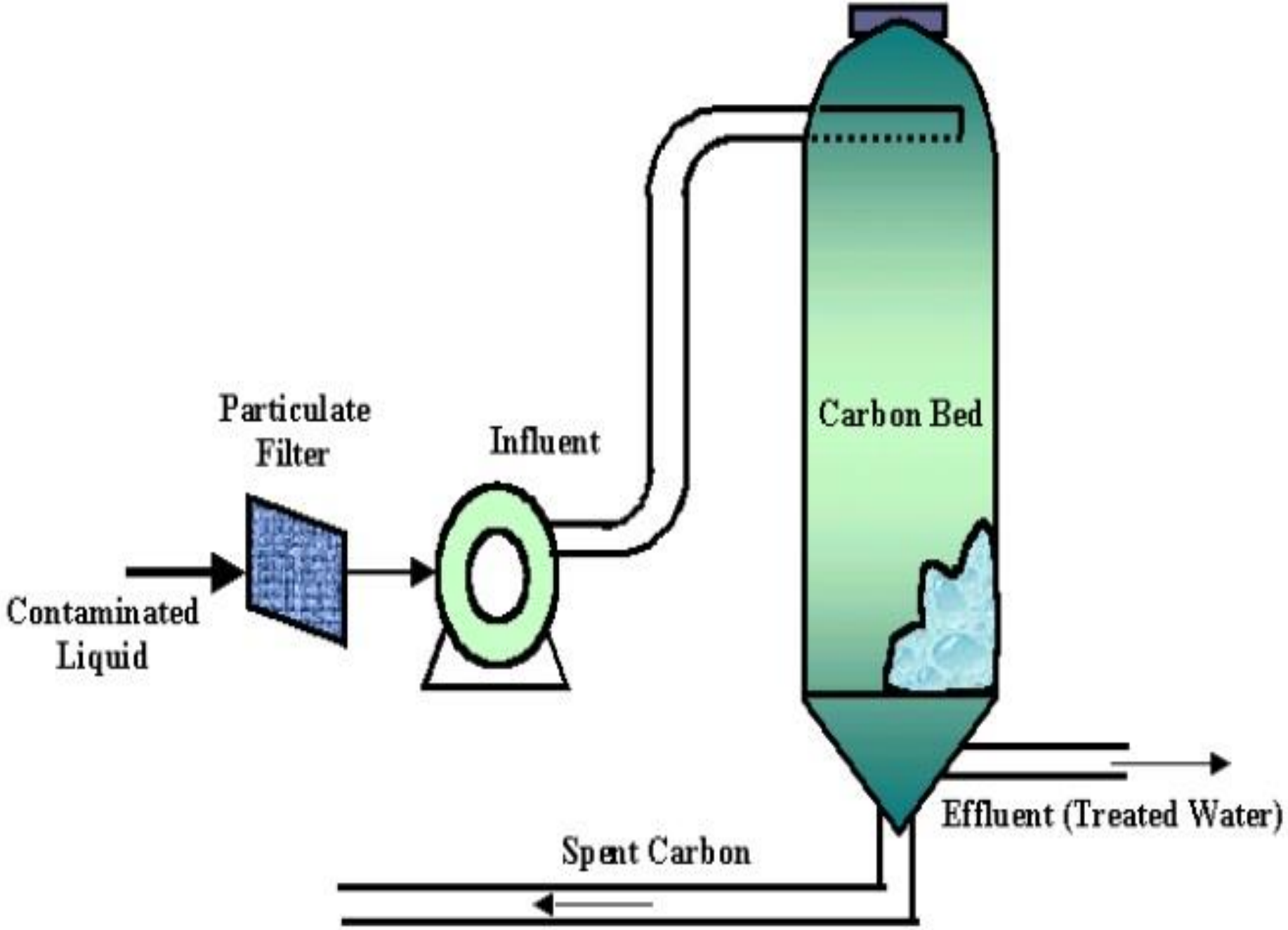
Physical treatment process

- Reverse osmosis
- Flocculation
- Filtration
- Sedimentation
- Carbon Adsorption
- Distillation

1. CARBON ADSORPTION

- The principal use of vapour phase activated carbon in the environmental field is for the removal of volatile organic compounds such as hydrocarbons, solvents, toxic gases and organic based odours.

- In addition, chemically impregnated activated carbons can be used to control certain inorganic pollutants such as hydrogen sulphide, mercury, or radon.
- In the industrial area, the most common applications of activated carbon are for process off-gases, tank vent emissions, work area air purification, and odour control, either within the plant or related to plant exhausts.
- Additionally, activated carbon is used in the hazardous waste remediation area to treat off-gases from air strippers and from soil vapour extraction remediation projects.


Particulate
Filter
Influent
Carbon Bed
Contaminated
Liquid
Effluent (Treated Water)
Spent Carbon

2. Sedimentation

- Sedimentation is the process by which suspended particles are removed from the water by means of gravity or separation
- In the sedimentation process, the water passes through a relatively quiet and still basin.
- Sedimentation involves one or more basins, called “clarifiers.” Clarifiers are relatively large open tanks that are either circular or rectangular in shape.
- The velocity of the water is reduced in the sedimentation tank.
- Sedimentation may remove suspended solids and reduce turbidity by about 50 to 90 percent
- This technique has been widely used in the removal of heavy metals from iron and steel industry waste water; removal of fluoride from aluminium production waste water; and removal of heavy metals from waste water from copper smelting and from metal finishing industry and waste water stream from organic chemicals.

3. Reverse osmosis:

- Reverse osmosis, also known as RO, is **a membrane technology that uses a semipermeable medium to remove certain ions and particles from a liquid stream.** RO removes contaminants based on their particle size and charge—generally anything that is 0.0001 µm or larger, including:

- bacteria
- calcium
- colloidal particles
- fluoride
- iron
- manganese
- organic material
- pyrogens
- salt
- viruses

- Because of its filtration properties, RO is often used to:
- clean wastewater to acceptable effluent standards or for reuse

  concentrate solvents used in the food and beverage industry, such as whey create ultrapure process water streams, such as required in the microelectronics industry desalinate seawater or other brine solutions generate potable drinking water

- RO is **also the reverse process of *osmosis***, a phenomenon that occurs naturally when a lower-solute stream (with a higher-water concentration) migrates toward a higher-solute stream (with a lower-water concentration) through a semipermeable membrane to achieve concentrate equilibrium.
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4. Distillation

- Distillation is expensive and energy intensive and can probably be justified only in cases where valuable product recovery is feasible (e.g., solvent recovery). **This technique has only limited application in the treatment of dilute aqueous hazardous wastes.**
- Distillation refers to the selective boiling and subsequent condensation of a component in a liquid **mixture. It is a separation technique that can be used to either increase the concentration of a particular component in the mixture or to obtain (almost) pure components from the mixture.**
- It is important to note that distillation is not a chemical reaction but it can be considered as a physical separation process.

5. Evaporation:

- Evaporation process is used for the treatment of hazardous waste such as radioactive liquids and sludges and concentrating of plating and paint solvent waste among many other applications.

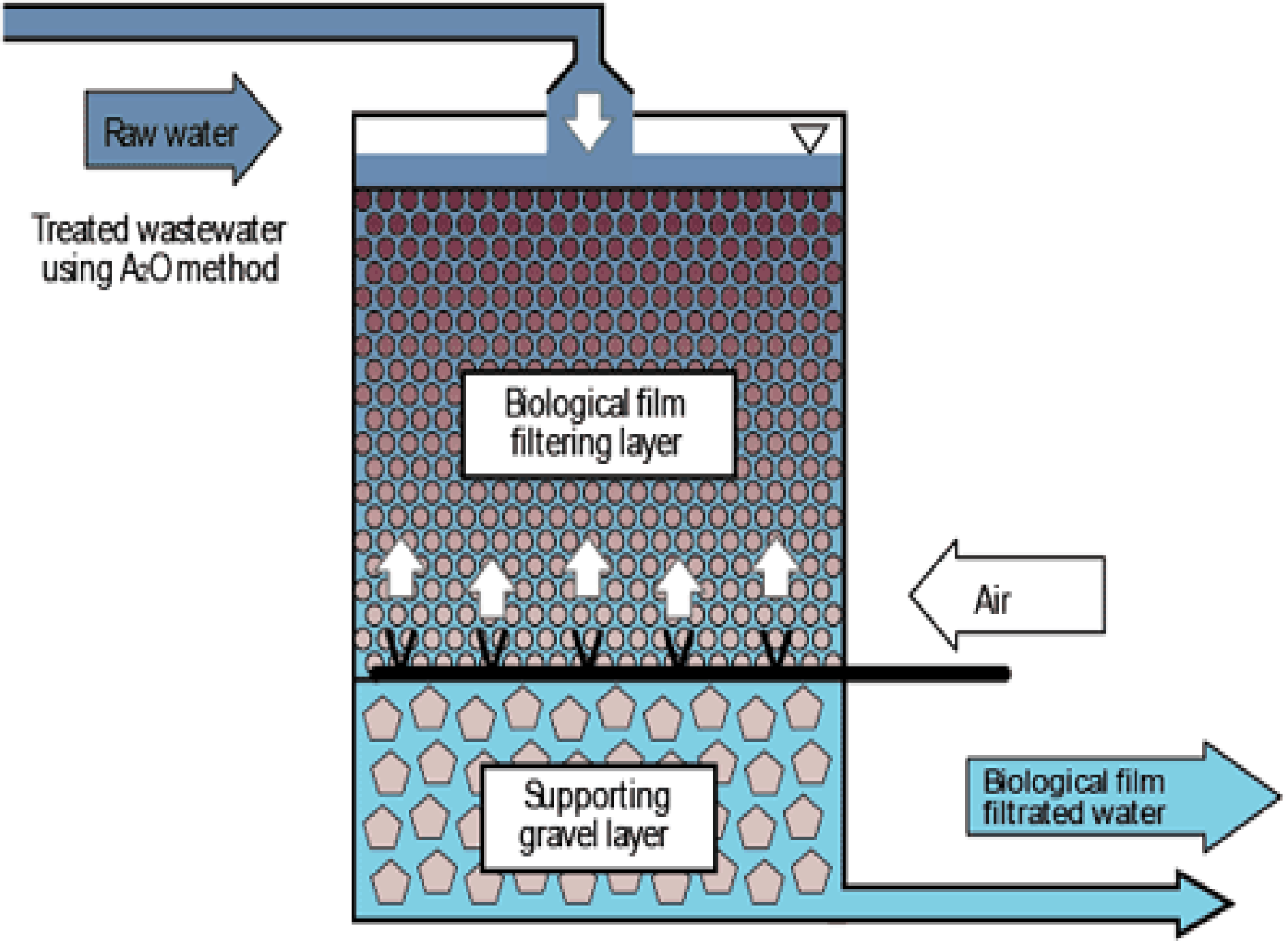
- It is capable of handling liquids, slurries and sometimes sludges, both organic and inorganic, containing suspended or dissolved solids or dissolved liquids

- The major disadvantages of evaporation are high capital and operating costs and high energy requirements. This process is more adaptable to waste waters with high concentrations of pollutants.

6. Filtration:

- Filtration is well-developed economical process used in the full scale treatment of many industrial waste waters and waste sludges. Energy requirements are relatively low, and operational parameters are well defined.

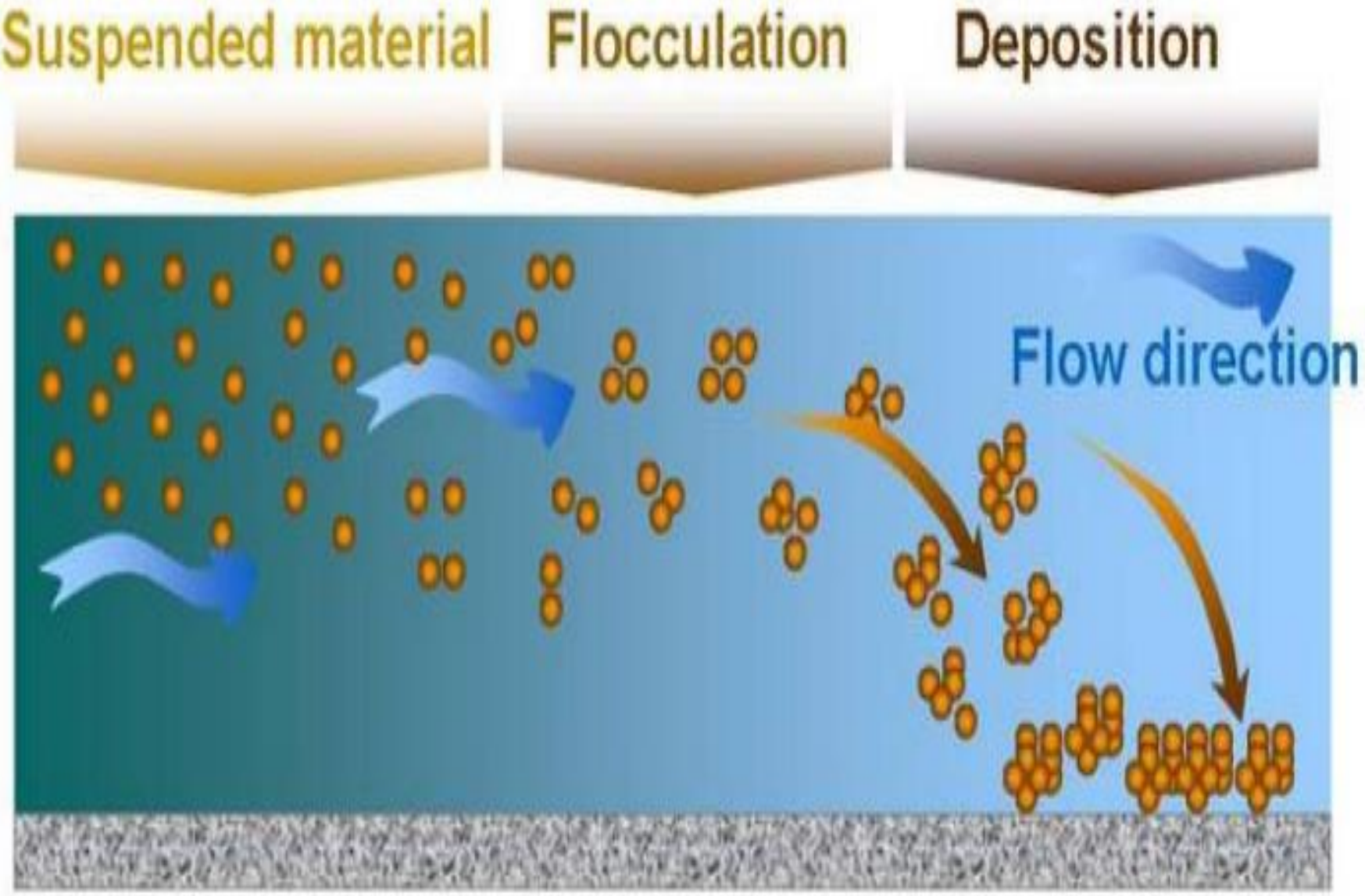
- Filtration is the process of passing water through material to remove particulate and other impurities, including floc, from the water being treated.
- Impurities like suspended particles (fine silts and clays), biological matter (bacteria, plankton, spores, cysts or other matter) and floc.


Raw water
Treated wastewater using A2O method
Biological film filtering layer
Air
Supporting gravel layer
Biological film filtrated water

7. Flocculation

- Flocculation, a gentle mixing stage, increases the particle size from submicroscopic microfloc to visible suspended particles. Microfloc particles collide, causing them to bond to produce larger, visible flocs called pinflocs.

- Chemicals used for flocculation include alum, lime, ferric chloride, ferrous sulphate and poly electrolytes. Poly electrolytes consist of long chain, water soluble polymers such as polyacrylamides.
- The inorganic flocculants such as alum, upon mixing with water, the slightly higher pH of water causes them to hydrolyse to form gelatinous precipitates of aluminium hydroxide.


Suspended material
Flocculation
Deposition
Flow direction


UNTREATED
TREATED

2. Chemical Treatment:

- Chemical treatment transforms waste into less hazardous substances using such techniques as pH neutralization, oxidation or reduction, and precipitation.
- These procedures involve the use of chemical reactions with the help of various chemicals to convert hazardous waste into less hazardous substances.
- The chemical treatment produces useful by- products and some-times residual effluent that are environmentally acceptable.
- Chemical reactions, either reduce the volume of the waste or convert the wastes to a less hazardous form.

Chemical treatment process

- Solubility
- Neutralization
- Precipitation
- Coagulation and flocculation
- Oxidation and reduction
- Ion exchange methods

1. Solubility

- Hazardous waste may be organic and inorganic containing various chemical elements and with various structural configurations.
- Water, known as the universal solvent, will dissolve many of these substances, while others have only limited water solubility.
- Solubility of various salts inorganic and organic is utilized as a means of treatment of hazardous waste when waste water treatment facilities are available and land fill options are limited

2. Neutralization

- Neutralization can be defined as the treatment of industrial waste so that it is neither too acidic nor too alkaline for safe discharge
- There are several possible reasons that an industry neutralized its wastewater
- Neutralization of acids and alkaline waste streams is an example of the use of chemical treatment to mitigate waste characterized as corrosive.
- Neutralization of an acid or base is easily determined by measuring its pH. Acid based reactions are most common chemical process used in hazardous waste treatment.
- Neutralization prior to land fill will be necessary so that inter reactions are avoided in land fill.

3. Precipitation:

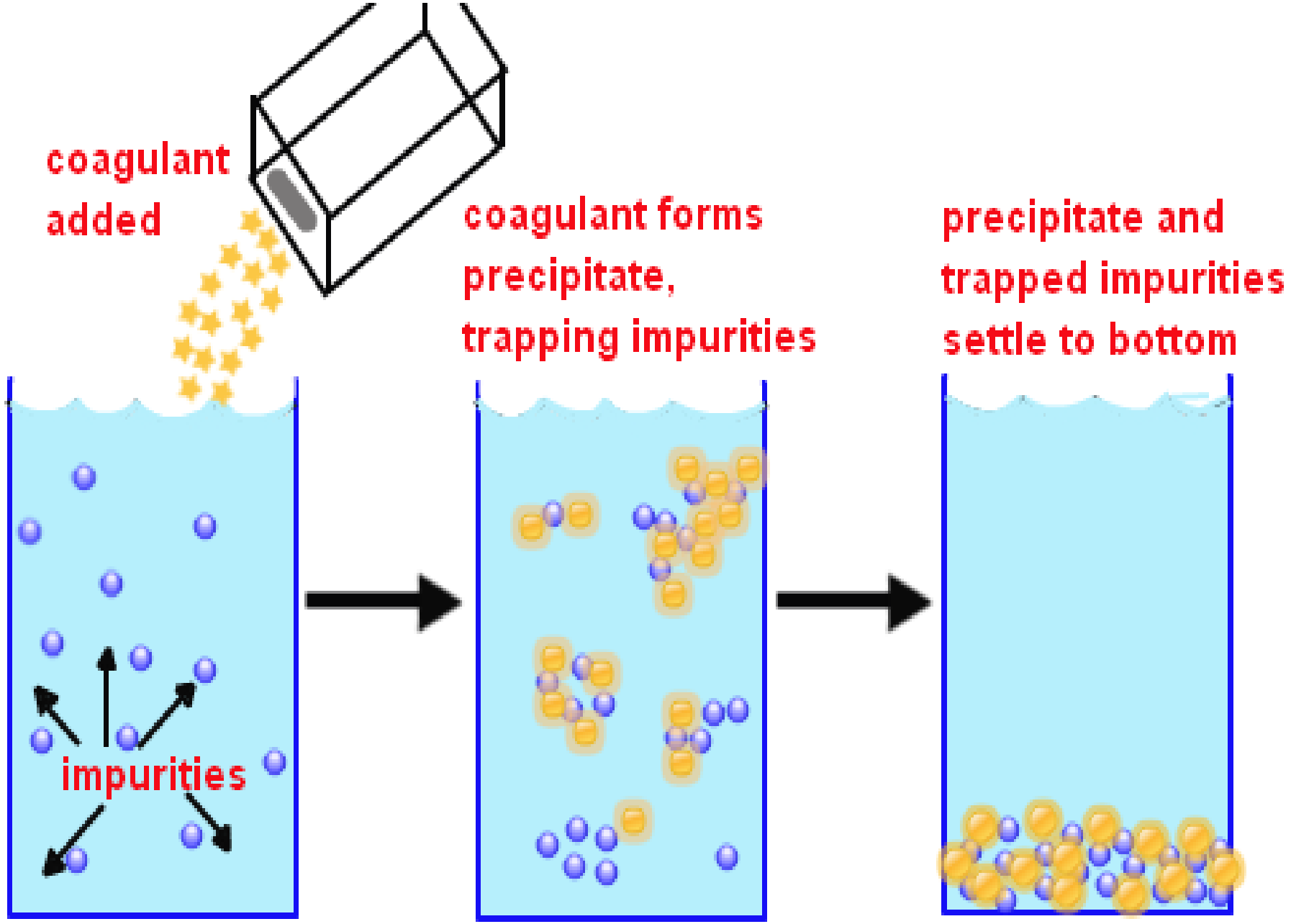
- Often undesirable heavy metals are present in liquid and solid wastes which are in slurry form. Simple precipitation.
- The usual method of removal of in organic heavy metals is chemical precipitation.
- Metals precipitate at varying pH levels depending on the metal ion, resulting in the formation of an insoluble salt.
- Hence neutralization of an acidic waste stream can cause precipitation of heavy metals.
- They hydroxides of heavy metals are usually insoluble so lime or caustic is commonly used to precipitate them.

4. Coagulation and flocculation:

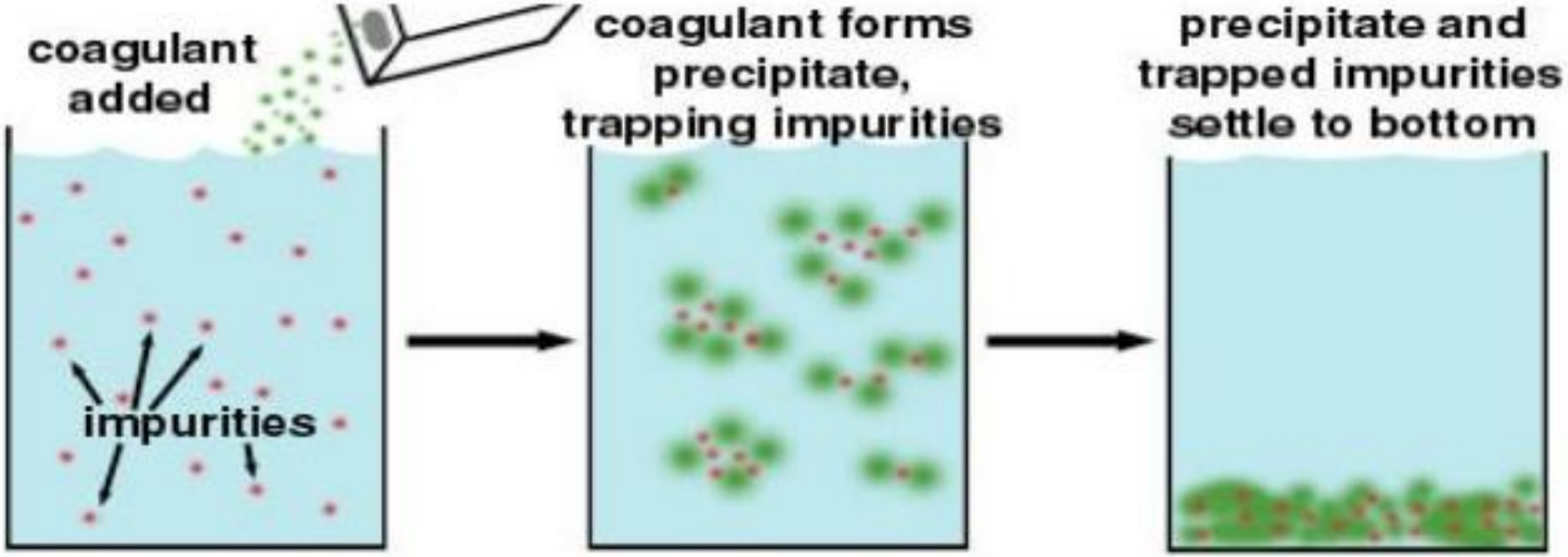
- Precipitation is greatly improved by adding coagulants. Most commonly used coagulant is alum.
- Many poly electrolytes are used as coagulants. These coagulants neutralize the charge of colloids in suspended condition thus by allowing them to settle rapidly.

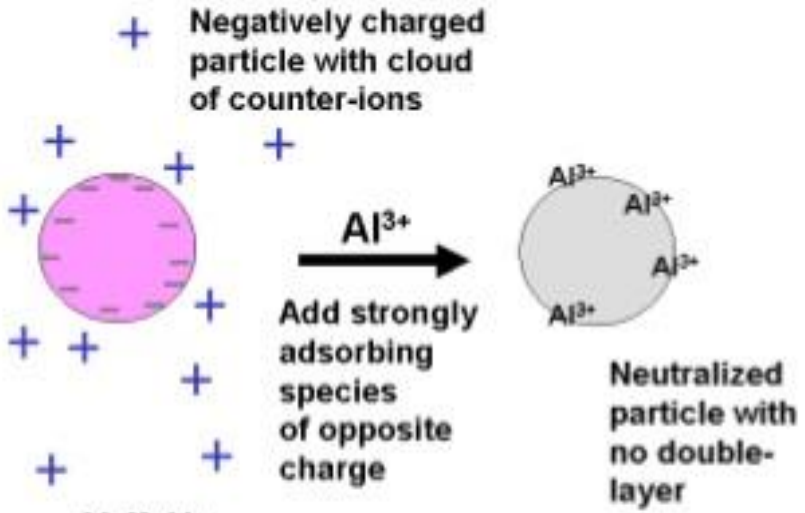
Theory of coagulation

- **Coagulation is the destabilization of colloids by addition of chemicals that neutralize the negative charges**
- **The chemicals are known as coagulants, usually higher valence**
- **cationic salts (Al^{3+}, Fe^{3+} etc.)**
- **Coagulation is essentially a chemical process**
- **Ionic layer compression**
- **Adsorption and charge neutralization**
- **Entrapment in a flocculent mass**


coagulant
added
coagulant forms
precipitate,
trapping impurities
precipitate and
trapped impurities
settle to bottom
impurities

Coagulation aim





5. Oxidation and Reduction:

- The chemical processes of oxidation and reduction can be used to convert toxic pollutants to harmless or less toxic substances. Heavy metals wastes are subjected to reduction process to precipitate to safer compounds of heavy metals.
- Example is Hexavalent chromium is precipitated into trivalent chromic hydroxide. Similarly alkaline chlorination of cyanide neutralizes highly toxic cyanide wastes.

6. Ion exchange methods:

- Ion exchange is reversible exchange of ions between liquid and solid phases.
- Ions held by electrostatic forces to charged functional groups on the surface of an insoluble solids are replaced by ions of similar charge in a solution Ion exchange is stoichiometric, reversible and selective removal of dissolved ionic species.

3. Biological Treatment:

- Biological treatment uses microorganisms to degrade organic compounds in the waste stream
- Biological treatment is an effective, efficient and cost- effective way to treat remove hazardous substances from wastewater through biological agents.
- Hazardous waste materials are toxic to some of the microorganism. But a substance, which is toxic to one group of organism, may act as valuable source of food for another group.
- Bio-treatment is required in ideal conditions for better growth of bio-agents and hence is a limitation factor also.
- These involve the use of microorganisms under optimised conditions to mineralise hazardous organic substances e.g. the use of pseudomonas under aerobic conditions break down phenols.

Biological treatment process

- Bioremediation
- Metal uptake through plant species
- Composting
- Bacterial culture

Bioremediation

- Bioremediation is a process that treats a polluted area either by altering environmental conditions to stimulate growth of microorganisms or through natural microorganism activity, resulting in the degradation of the target pollutants.
- Broad categories of bioremediation include biostimulation, bioaugmentation, and natural recovery (natural attenuation).
- Bioremediation is either done on the contaminated site (in situ) or after the removal of contaminated soils at another more controlled site (ex situ).

- One of their concerns is that the toxic chemicals would lead to the microbe's gene degradation, which would then be passed on to other harmful bacteria, creating more issues, if the pathogens evolve the ability to feed off of pollutants.

4. Thermal Treatment:

- These are the treatment processes which involve the application of heat to convert the waste into less hazardous forms. It also reduces the volume and allows opportunities for the recovery of energy from the waste.
- **incineration**
- In incineration, in general, waste is destroyed or reduced to CO_2, H_2O and other inorganic substances and these substances are harmless. The only limitation with this treatment process is generation of effluent or emission which is rather secondary pollution.
- Incineration is the controlled combustion process which can be used to degrade organic substances.
- In practice, complete combustion is difficult if not impossible to achieve but for hazardous waste 99.99% or greater destruction or removal is required for the process to be generally acceptable

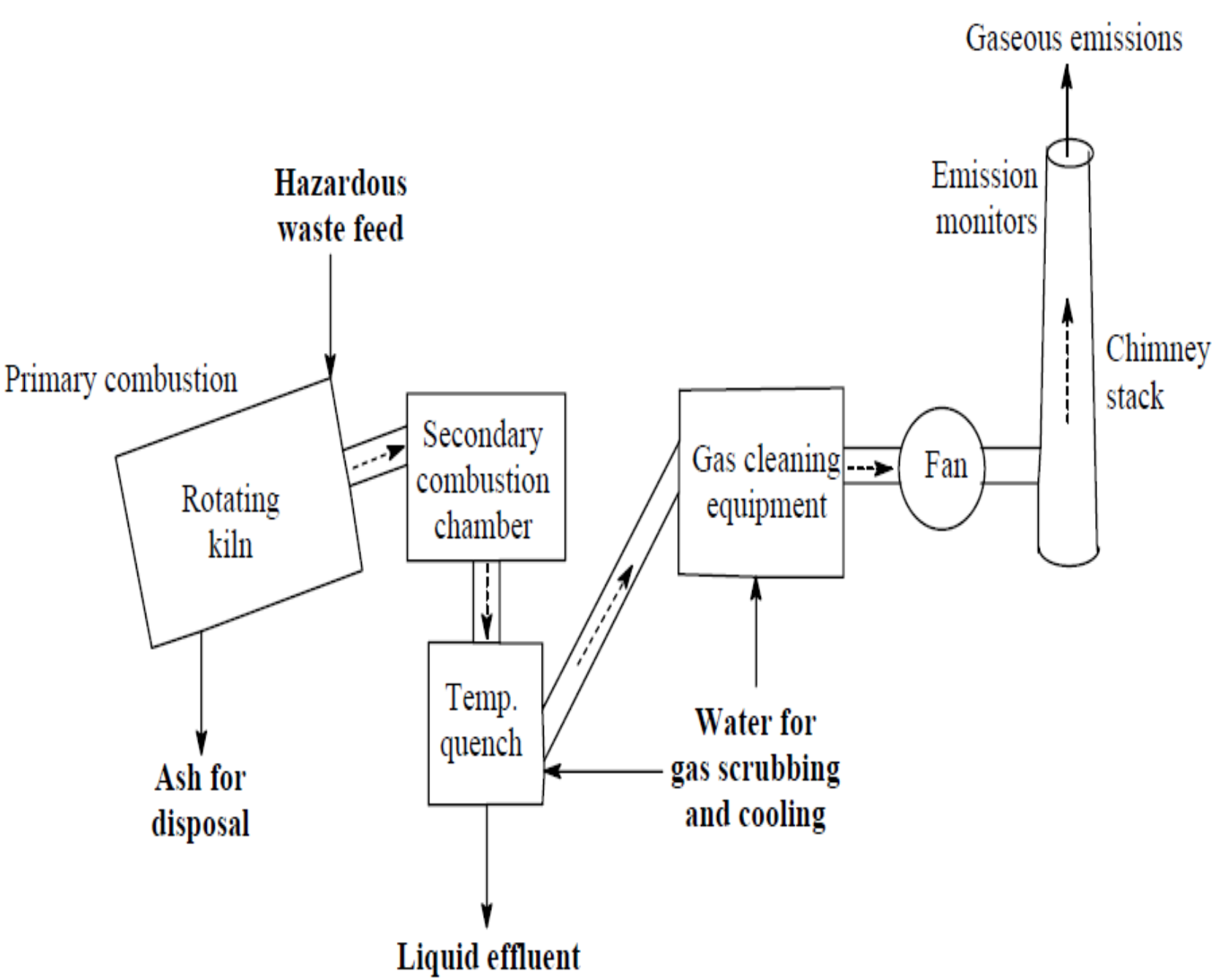


Figure 5 - High Temperature Incineration