Water Treatment Processes

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Water World

Two thirds of our planet is covered by water.

97.5% of the water is saltwater.

The majority of freshwater is beyond our reach, locked into polar snow and ice.

Approximately 0.7% of water is available for daily use

Water Quality

- Water is in its purest form when it is in vapours.
- Water vapours needs a surface for condensation, impurities are imparted even at the moment of condensation.
- Water absorbs atmospheric gases as it falls in the form of rains
- Additional impurities are imparted as it flows through the water cycle

Safe drinking water

- Free from pathogenic organisms
- Clear
- Not saline
- Free from offensive taste or smell
- Free from compounds that may have adverse effect on human health
- Free from chemicals that cause corrosion of water supply systems

WATER QUALITY PARAMETERS

- Physical parameters
- Chemical
- Bacteriological

Physical Parameters

- Suspended Solids
- Turbidity
- Colour
- Odour
- Taste
- Temperature

Chemical Parameters

- pH, Alkalinity, hardness, dissolved solids, Cations, Anions, Toxic heavy metals, persistant organic pollutants, organic matter, etc.

Important Chemical Parameteres

- Fluoride: Causes Dental and Bone Fluorosis and is a major concern in India
- Arsenic: Poison, present in many parts of the country particularly in Eastern UP, West Bengal and in Ganga Basin
- Heavy Metals: sources industrial wastewater discharge (Metal plating industries). Most of them are Carcinogenic

Important Chemical Parameters

- Persistent Organic Pollutants
- Compounds that persist in environment for a longer duration of time and do not degrade naturally
- They can travel to long distances and can multiply in concentration through biological magnification through food chain.
- Most of them are Endocrine Disruptors and affects our harmonal system and decrease immunity.

Persistent Organic Polutants

- Persistant organic pollutants include
- Nine organochlorine based Pesticides
- Hexachlorobenzene
- Dioxines
- Furans
- (Dioxines and Furans are formed due to incomplete burning of solid waste)

- Toxic at very low concentration
- Such compounds are banned worldwide

Biological Parameters

- Disease causing bacteria and viruses
- It is impossible to test a water sample for millions of pathogens as it is expensive and time consuming.
- Test for Coliform bacteria is done as its presence and absence indicates the likely presence and absence of pathogens.
- Test is simple and can be performed on a routine basis

Water Treatment

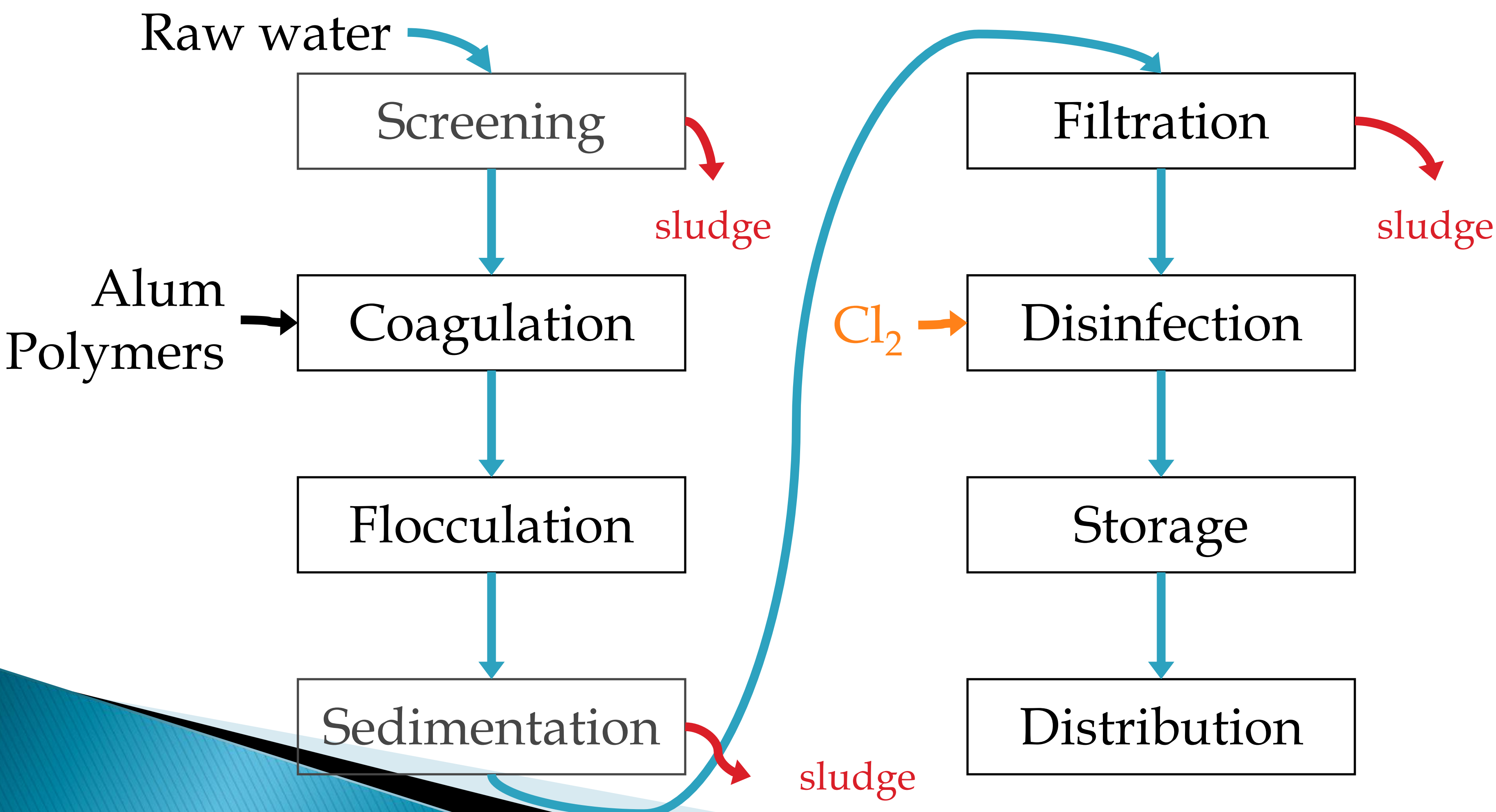
Water Treatment

- Goal: clean water
- Source: (contaminated) surface water
- Solution: separate contaminants from water
- How?
- Methodologies differ from water quality and end use

Water Treatment

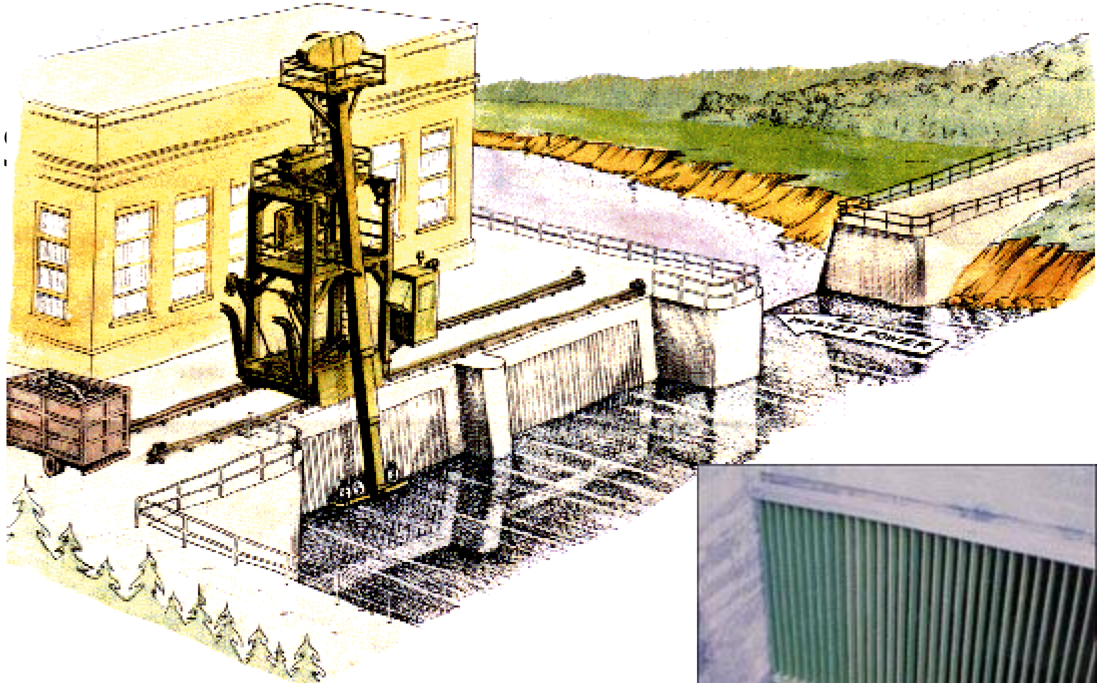
- Unit processes* designed to
  - Remove Suspended Impurities
  - Remove Dissolved Chemicals
  - Inactivate Pathogens

Conventional Surface Water Treatment



Screening

- Removes large solids
  - logs
  - branches
  - rags
  - fish
- Simple process
  - may incorporate a mechanized trash removal system
- Protects pumps and pipes in WTP

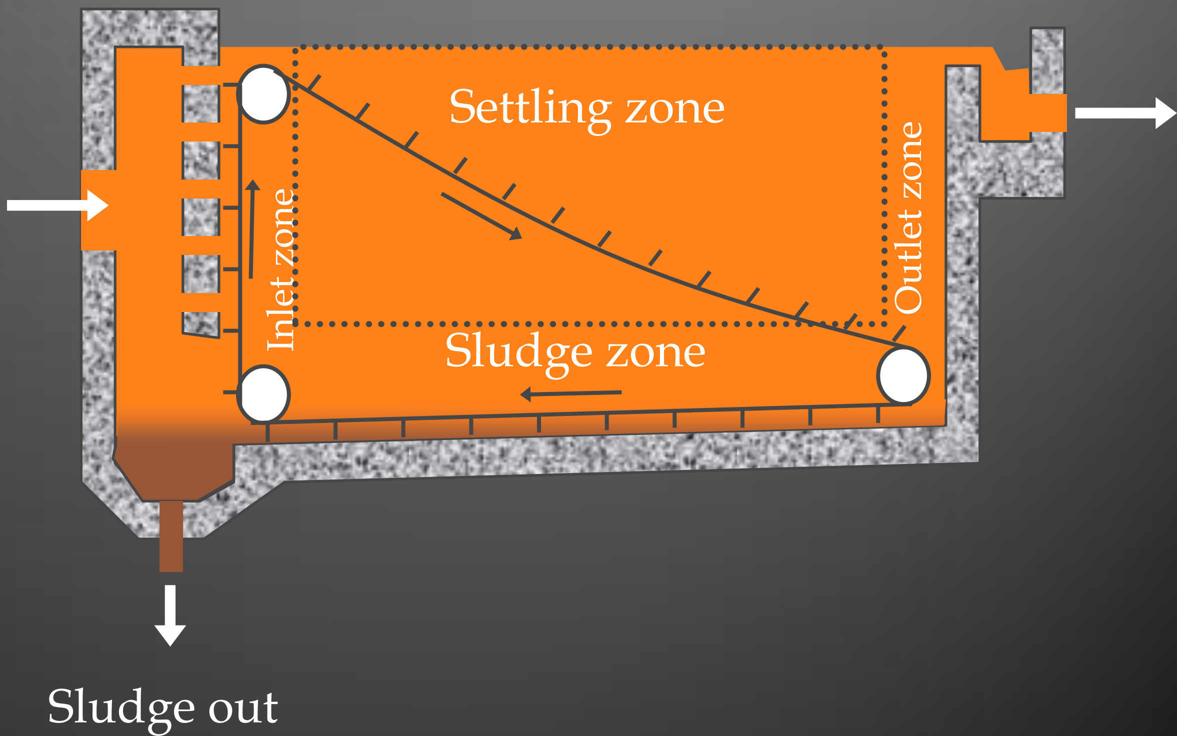


Sedimentation

- the oldest form of water treatment
- uses gravity to separate particles from water
- often follows coagulation and flocculation

Conventional Sedimentation Basin

- long rectangular basins
- 4–6 hour retention time
- 3–4 m deep
- max of 12 m wide
- max of 48 m long



Coagulation

- Colloids are charged particles and do not settle by gravity
- Electrostatic repulsion
  - In most surface waters, colloidal surfaces are negatively charged
  - like charges repel
- van der Waals force
  - an attractive force
  - decays more rapidly with distance than the electrostatic force
  - is a stronger force at very close distances

Coagulation

- Coagulation is a physical-chemical process whereby particles are destabilized
- Several mechanisms
  - adsorption of cations onto negatively charged particles
  - decrease the thickness of the layer of counter ions
  - sweep coagulation
  - interparticle bridging

Coagulation Chemistry

- The standard coagulant for water supply is Alum [$Al_2(SO_4)_3 * 18H_2O$]
- Typically 5 mg/L to 50 mg/L alum is used
- The chemistry is complex with many possible species formed such as $AlOH^{+2}$, $Al(OH)_2^{+}$, and $Al_7(OH)_{17}^{+4}$
- The primary reaction produces $Al(OH)_3$

$$Al_2(SO_4)_3 + 6H_2O \rightarrow 2Al(OH)_3 + 6H^{+} + 3SO_4^{-2}$$

Coagulation Chemistry

- Aluminum hydroxide [$Al(OH)_3$] forms amorphous, gelatinous flocs that are heavier than water
- The flocs look like snow in water
- These flocs entrap particles as the flocs settle (sweep coagulation)

Coagulant introduction with rapid mixing

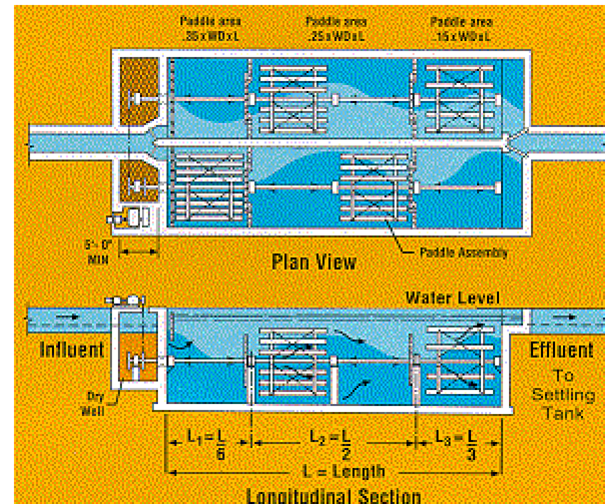
- The coagulant must be mixed with the water
- Retention times in the mixing zone are typically between 1 and 10 seconds
- Types of rapid mix units
  - pumps
  - hydraulic jumps
  - flow-through basins with many baffles
  - In-line blenders
  - In-line static mixers

Flocculation

- It is a slow mixing process wherein colloids combine to form large flocs that settle by gravity
- 20 to 30 minutes detention times is required for flocculation
- Generally Clariflocculators are used for the combined flocculation followed by sedimentation

Mechanical Flocculation

- Shear provided by turbulence created by <u>gentle</u> stirring
- Turbulence also keeps large flocs from settling so they can grow even larger!
- Retention time of 10 – 30 minutes
- Advantage is that amount of shear can be varied independent of flow rate
- Disadvantage is the tanks are far from plug flow



Coagulation/Flocculation

- Inject Coagulant in rapid mixer
- Water flows from rapid mix unit into flocculation reactor
- Water flows from flocculation reactor into sedimentation tank
  - make sure flocs don't break!
  - flocs settle and are removed

Filtration

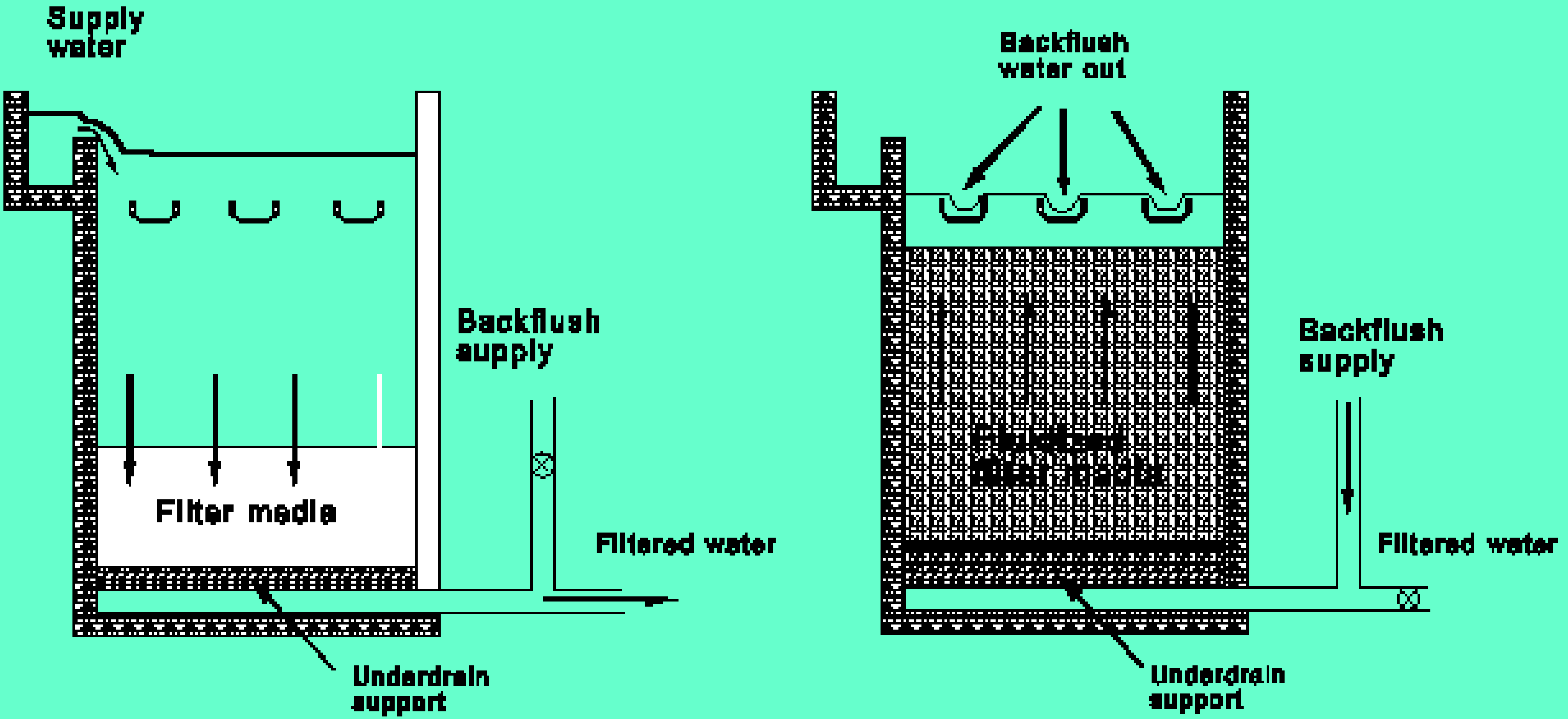
- Slow sand filters
- Rapid Sand Filters
- Membrane filters
- Rapid sand filters (Conventional Treatment)

Slow Sand Filtration

- First filters to be used on a widespread basis
- Fine sand with an effective size of 0.2 mm
- Low flow rates (10 – 40 cm/hr)
- Schmutzdecke (Filter Cake) forms on top of the filter
  - causes high head loss
  - must be removed periodically
- Used without coagulation/flocculation!

filter cake

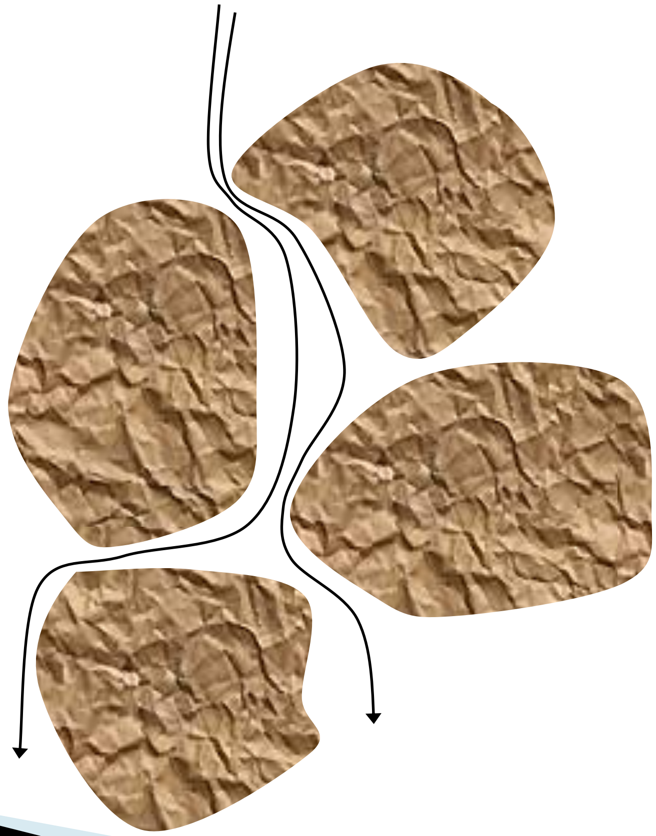
Filter Operation



a) Operation during filtration

b) Operation during cleaning

Particle Removal Mechanisms in Filters



Transport

Molecular diffusion

Inertia

Gravity

Interception

Attachment

Straining

Surface forces

Membrane Filters

- More recent development and use in drinking water
- Microfilters:
  - nano- & ultra-filters: retention by molecular weight cutoff
    - Typically 1,000-100,000 MWCO
- Reverse osmosis filters: pore size small enough to remove dissolved salts; used to desalinate (desalt) water as well as particle removal
- High >99.99% removal of cellular microbes
- Virus removals high >9.99% in ultra-, nano- and RO filters
- Virus removals lower (✂99%) by microfilters
- Membrane and membrane seal integrity critical to effective performance

Adsorbers and Filter-Adsorbers

Adsorbers:

- **Granular activated carbon adsorption**
  - remove dissolved organics
  - poor retention of pathogens, esp. viruses
  - biologically active; develops a biofilm
  - can shed microbes into water

Filter-adsorbers

- **Sand plus granular activated carbon**
  - reduces particles and organics
  - biologically active
  - microbial retention is possible

Disinfection

- Disinfection: operations aimed at killing or Inactivating pathogenic microorganisms
- Ideal disinfectant
  - Toxic to Pathogens
  - Non Toxic to humans
  - Fast Rate of Kill
  - Residual Protection
  - Economical

Disinfection Options

- Chlorine
  - chlorine gas
  - sodium hypochlorite (bleach)
- Ozone
- Irradiation with Ultraviolet light

Chlorine

- First large-scale chlorination was in 1908 at the Boonton Reservoir of the Jersey City Water Works in the United States
- Widely used throughout the globe
- Typical dosage (1-5 mg/L)
  - variable, based on the chlorine demand
  - goal of 0.2 mg/L residual
- Trihalomethanes (EPA primary standard is 0.08 mg/L)

Chlorine Reactions

$$Cl_2 + H_2O \rightarrow H^+ + HOCl + Cl^-$$
$$HOCl \leftrightarrow H^+ + OCl^-$$

- The sum of HOCl and OCl^- is called the Free Chloring Residual
- HOCl is the more effective disinfectant
- Therefore chlorine disinfection is more effective at low pH
- HOCl and OCl^- are in equilibrium at

Ozone

- Widely used in Europe
- O_3 is chemically unstable
- Must be produced on site
- More expensive than chlorine (2 – 3 times)
- Typical dosages range from 1 to 5 mg/L
- Often followed by chlorination so that the chlorine can provide a protective residual

residual

Thanks !