CE 213A
Introduction to Environmental Science

L15: Water Pollution

Water Quality Standards and Water Treatment

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Schedule : LEC Mon Wed Fri 5:10 – 6 pm

Water quality standards and Laws for controlling pollution

Water Quality Standards and Guidelines

Why do we have water-quality standards and guidelines?

- Standards and guidelines are established to **protect water for designated uses** such as drinking, recreation, agricultural irrigation, or protection and maintenance of aquatic life.
- Standards for **drinking-water quality** ensure that public drinking-water supplies are as safe as possible.

Who sets these standards and guidelines?

International: WHO, FAO

Country specific

India: CPCB, ICMR, BIS

USA: EPA

In India, the design of water supply systems has been done using certain standards. Currently the standard being used is BIS 1172: 1993, reaffirmed in 1998.

Bureau Of Indian Standards
IS 10500-1991

Parameters	**Desirable limit**	**Permissible limit**
Colour Hazen unit	5	25
Turbidity-NTU	5	10
pH	6.5-8.5	6.5-8.5
Hardness (as $CaCO_3$) mg/l	0.3	1
Total Dissolved Solids mg/l	500	2000

Bureau Of Indian Standards
IS 10500-1991

Parameters		Desirable limit	Permissible limit
Nitrate	mg/l	45	45
Chloride	mg/l	250	1000
Fluoride	mg/l	1	1.5
Arsenic	mg/l	0.05	0.05
Aluminum	mg/l	0.03	0.2

Drinking water standards recommending agencies

(All values except P^H is in mg/L.)

	Standards	Recommended Agency
P^H	6.5 - 8.5	ICMR / BIS
Total Alkalinity	120	ICMR
Total Hardness	300	ICMR / BIS
T.D.S.	500	ICR / BIS
Calcium	75	ICMR / BIS
Magnesium	30	ICMR / BIS
Chloride	250	ICMR
Nitrate	45	ICMR / BIS
Sulphate	150	ICMR / BIS
D.O.	5.0	ICMR / BIS
B.O.D.	5.0	ICMR

Laws for Controlling water pollution

- The Shore Nuisance (Bombay and Kolaba) Act, 1853
- The Orient Gas Company Act, 1857
- Indian Penal Code, 1860
- The Serais Act, 1867
- The North India Canal and Drainage Act, 1873
- The Obstruction in Fairways Act, 1881
- The Indian Easement Act, 1882
- The Indian Fisheries Act, 1897
- The Indian Ports Act, 1908
- The Indian Steam Vessels Act, 1917

- The Poison Act, 1919
- The Indian Forest Act, 1927
- The Damodar valley corporation (Prevention of Pollution of Water) Regulation Act, 1948
- The Factories Act, 1948
- The Mines Act, 1952
- The Orissa River Pollution Act, 1953
- The River Boards Act, 1956
- The Merchant Shipping Act, 1958
- The Maharashtra Prevention of Water Pollution Act, 1969
- **The Water (Prevention and Control of Pollution) Act, 1974**
- **The Water (Prevention and Control of Pollution) Cess Act, 1977**

Water Act, 1974

-Control, abate and prevent water pollution to preserve/restore national water quality

-Set water quality standards/ criteria

Responsibilities

* Consent to Establish; Section 25 (NOC EIA)
* Consent to Operate; Section 21 (Consent Conditions, discharge Standards)
* Renewal of Consent; Section 21

- **Punitive Measures**

  Non- Compliance may result in
  Closure of Industry (Section 33A)
  - Imprisonment 1-1/2 to 6 years
  - Fine upto Rs. 5000/- per day

  Rights
- Notice of Inspection
- Deemed Consent (automatic and unconditional),
- Right to Appeal (Appellate Authority),
- Opportunity to file Objection (against Closure) in 15 days

Water Cess Act, 1977

To collect Cess on Water Consumption

(i)Minimize Water Uses/wastage
(ii)Resources for PCBs

Responsibilities and Obligations

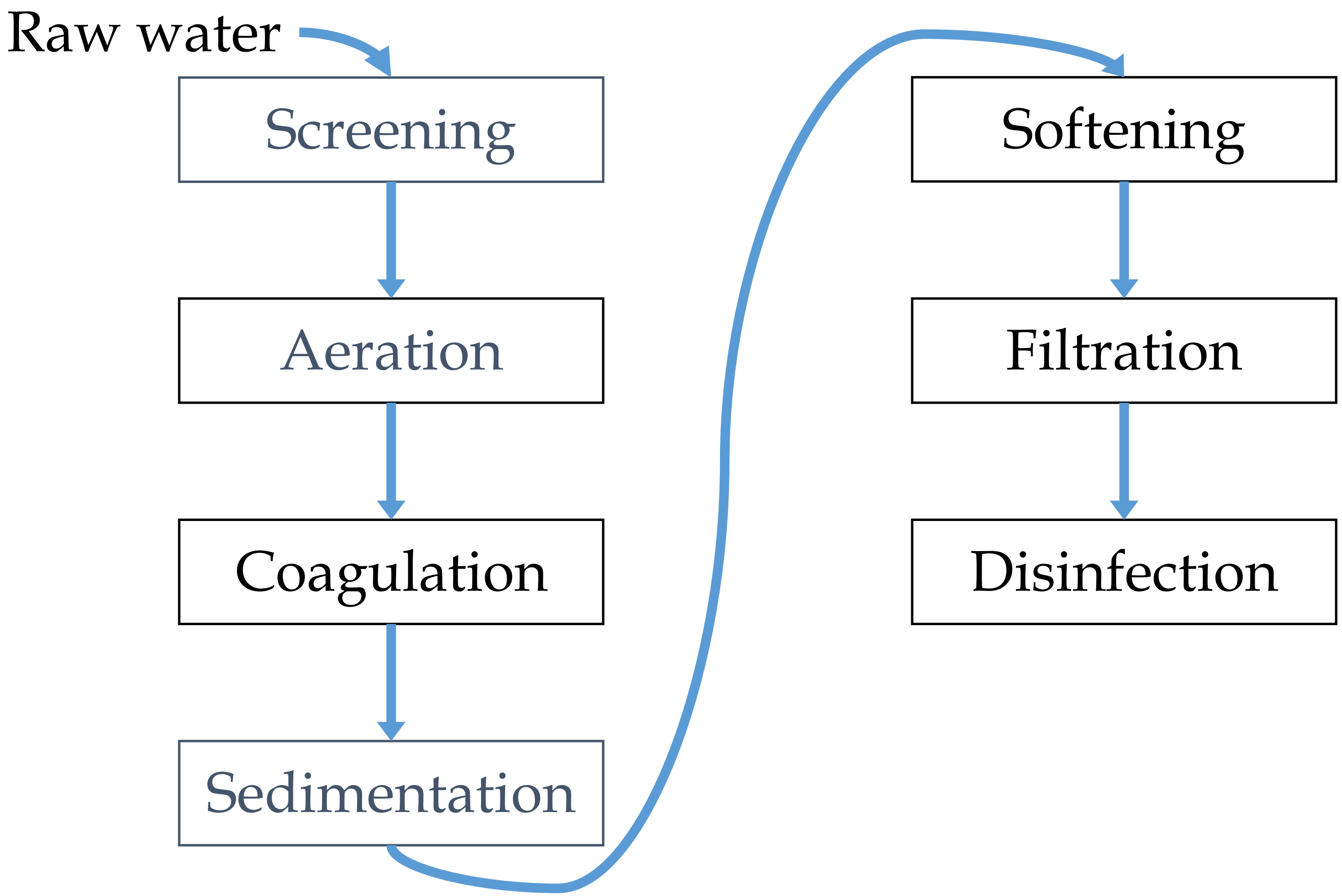
-File water Cess Return by May 15
-Provide Water Meters
-Access to Relevant Information/Inspection

Rights

-25% Rebate on Cess (i) Consume less than specified water
(ii) Complying with all standards
- Right to Appeal

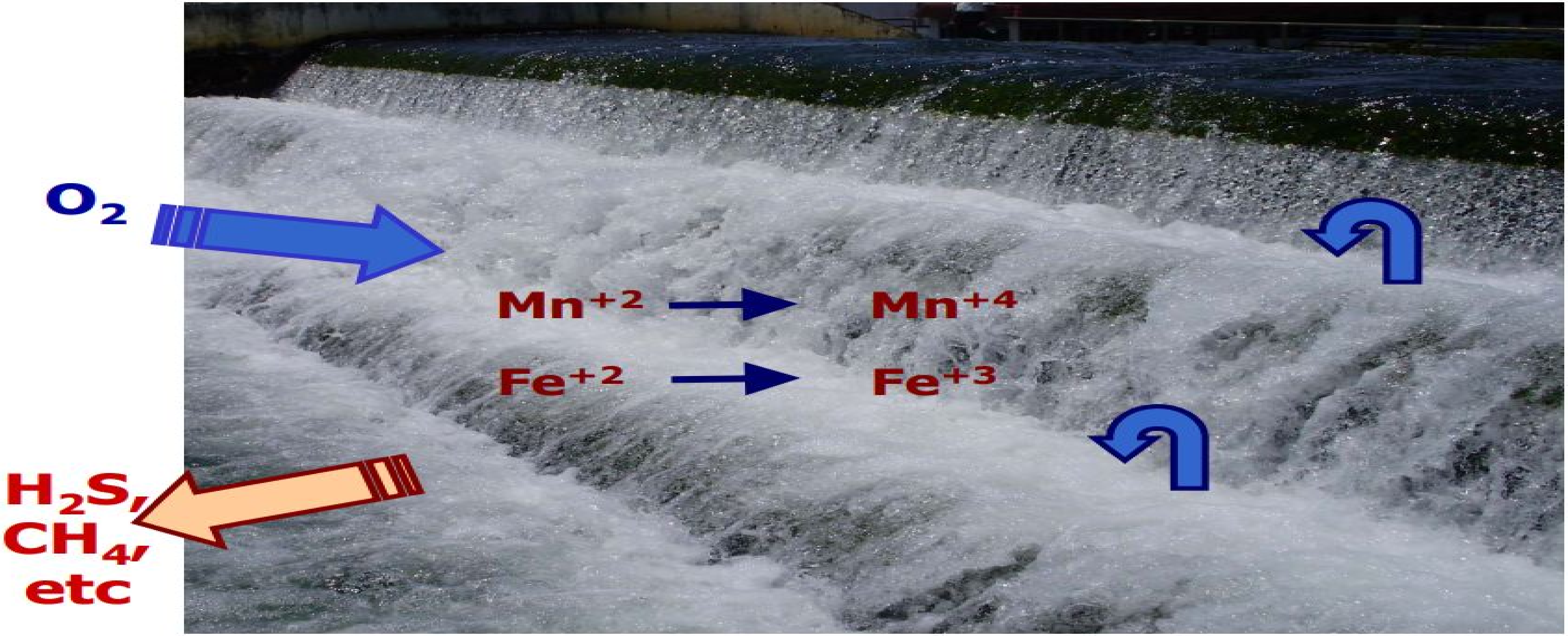
Water Treatment Process

Processes involved in treatment of Conventional Groundwater Treatment



Aeration

- Aeration brings water and air in close contact in order to remove **dissolved gases** (such as carbon dioxide) and oxidizes **dissolved metals** such as iron, hydrogen sulphide, and volatile organic chemicals (VOCs).



Types of Aerators

1. **Gravity/Cascade Aerators :** water is allowed to **fall by gravity** such that a large area of water is exposed to atmosphere.

2. **Fountain Aerators** : These are also known as spray aerators with special **nozzles** to produce a fine spray.

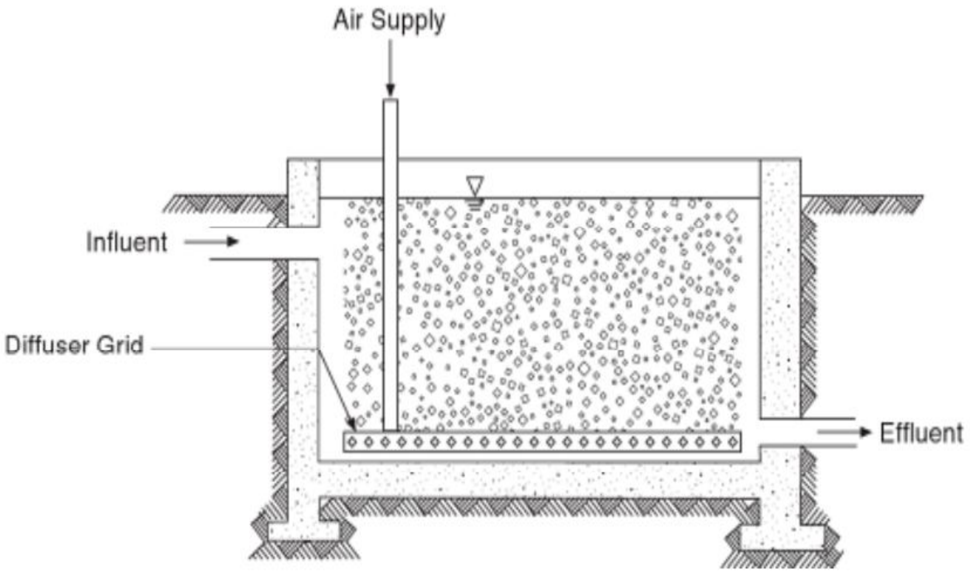
Cascade Aerator

Spray Aerators: Nozzles

Types of Aerators

3. **Diffused Aerators** : It consists of a tank with perforated pipes, tubes or diffuser plates, fixed at the bottom to release fine air bubbles from compressor unit.

4. **Mechanical Aerators** : Mixing Paddles may be either submerged or at the surface.



Diffused Air System

Mechanical Aerators

Sedimentation (Settling)

- Solids settle based on their gravitational force. Settling depends on its physical characteristics (diameter, density) and medium temperature, viscosity, density, etc.

- Types of settling

1. **Discrete settling (Type1 settling)**

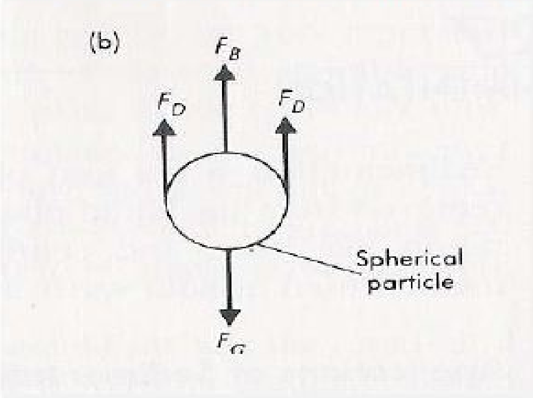
Some solids do not interact with each other during settling (i.e., discrete particles which show no change in their size and shape).Ex: settling of sand.

2. **Flocculent settling (Type2 settling)**

Some solids interact during their settling and **change their size and shape** (i.e., flocculent particles) (Type 2 settling). Ex: settling of clay; bacteria.

Type 1 – Discrete Settling

If a particle is suspended in water , it initially has 2 forces acting upon it.



ρ_p = density of particle

$\forall_p$ = volume of particle

ρ_w = density of water

$\forall_p$ = volume of particle

C_D = drag coeff.

A_p = cross sectional area of particle perpendicular to the direction of movement

1. The forces of gravity $\boxed{f_g = \rho_p g \forall_p}$
2. The buoyant force quantified by Archimedes. $\boxed{f_b = \rho_w g \forall_p}$

Once motion has been initiated, a third force is created due to viscous friction

ρ_w = density of water

υ_s =settling velocity of particle

5

1. Drag force $\boxed{f_D = C_D A_p \rho_w \frac{\upsilon_s^2}{2}}$

Force balance for a discrete particle that is settling

$$\boxed{\underbrace{m_p \frac{d\vartheta_s}{dt}}_{\text{Downward acceleration of particle}} = F_G - F_B - F_D}$$

After an initial transient period, the acceleration $\frac{d\upsilon_s}{dt}$ becomes zero and the settling velocity becomes constant.

$$0 = g\forall_p(\rho_p - \rho_w) - \left(C_D A_p \rho_w \frac{\vartheta_s^2}{2}\right)$$

$$g\forall_p(\rho_p - \rho_w) = \left(C_D A_p \rho_w \frac{\vartheta_s^2}{2}\right)$$

$$\boxed{\vartheta_s = \sqrt{\frac{2g(\rho_p - \rho_w)}{C_D \rho_w}\frac{\forall_p}{A_p}}}$$

SETTLING VELOCITY OF DISCRETE PARTICLE IN ANY SHAPE

(Eqn. 1)

For spherical particle;

$$\left.\begin{aligned} \forall_p &= \frac{4}{3}\pi r^3 \\ A &= \pi r^2 \end{aligned}\right\} \quad \frac{\forall_p}{A_p} = \frac{\frac{4}{3}\pi r^3}{\pi r^2} = \frac{4}{3} r$$

$$= \frac{4}{3}\frac{d}{2} \longrightarrow$$

Subsitute into Eqn.1

$$\vartheta_s = \sqrt{\frac{2g(\rho_p - \rho_w)}{C_D \rho_w} \frac{4d}{32}}$$

$$\boxed{\vartheta_s = \sqrt{\frac{4}{3} \frac{(\rho_p - \rho_w) g d}{C_D \rho_w}}}$$

SETTLING VELOCITY OF SPHERICAL DICRETE PARTICLE
(Eqn 2)

Newton's drag coefficient (C_D) is a function of:

- Flow regime around the particle
- Particle shape

Drag coefficient (C_o) for spheres:

$$C_D = \frac{24}{R_e} + \frac{3}{\sqrt{R_e}} + 0.34$$

$R_e < 1$

$1 < R_e < 10^4$

$R_e > 10^4$

$R_e = \frac{\vartheta_s D}{\nu} \qquad \nu = \frac{\mu}{\rho_w}$ (kinetic visc.)

$R_e = \frac{\phi \vartheta_s D}{\nu}$ (for nonspheric al particles)

For laminar flow $\rightarrow$ $C_D = \dfrac{24}{R_e}$ where $R_e = \dfrac{\vartheta_s d}{\nu} = \dfrac{\vartheta_s d \rho}{\mu}$

$$C_D = \frac{24\mu}{\vartheta_s d \rho_w}$$ For laminar flow

$$\boxed{\vartheta_s = \frac{g}{18\mu}\left(\rho_p - \rho_w\right)d^2}$$

Settling velocity of spherical discrete particles under laminar flow conditions (STOKE'S LAW) (Eqn. 3)

9

- To Calculate settling velocity of turbulent and other types of flow put the value of Reynold's number in the drag coefficient formula and then put drag coefficient value in equation 2

Drag coefficient (C_D) for spheres:

$$C_D = \frac{24}{R_e} + \frac{3}{\sqrt{R_e}} + 0.34$$

$$\boxed{\vartheta_s = \sqrt{\frac{4\left(\rho_p - \rho_w\right)gd}{3 \quad C_D \rho_w}}}$$

SETTLING VELOCITY OF SPHERICAL DICRETE PARTICLE (Eqn 2)

Example : Find the terminal settling velocity of a spherical discrete particle with diameter 0.5 mm and specific gravity of 2.65 settling through water at 20⁰C

$$\rho_w = 998.2 kg/m^3$$

$$\mu = 1.002 . 10^{-3} Ns/m^2$$

SOLUTION

1. Assume laminar flow; from Eq. (4-8) with $\rho_w = 998.2\ \mathrm{kg/m^3}$ and $\mu = 1.002 \times 10^{-3}$ $\mathrm{N \cdot s/m^2}$ at 20°C

$$v_t = \frac{9.81\ \mathrm{m/s}(2650 - 998.2)\ \mathrm{kg/m^3} \times (5.0 \times 10^{-4})^2\ \mathrm{m^2}}{18 \times 1.002 \times 10^{-3}\ \mathrm{N \cdot s/m^2}}$$

(Recall that the units of N are $\mathrm{kg \cdot m/s^2}$.)

$$v_t = 0.22\ \mathrm{m/s}$$

2. Check Reynolds number:

$$\mathrm{Re} = \frac{0.22\ \mathrm{m/s} \times 5 \times 10^{-4}\ \mathrm{m} \times 998.2\ \mathrm{kg/m^3}}{1.002 \times 10^{-3}\ \mathrm{N \cdot s/m^2}}$$

$$= 112, \text{ which indicates transitional flow}$$

3.

$$C_D = \frac{24}{112} + \frac{3}{112^{1/2}} + 0.34$$

$$= 0.84$$

4.

$$v_t^2 = \frac{4}{3} \times 9.81 \times \frac{(2650 - 998.2)}{0.84 \times 998.2} 5 \times 10^{-4}$$

$$v_t = 0.11\ \mathrm{m/s}$$

5. With $v_t = 0.11$, repeat steps 2, 3, and 4.

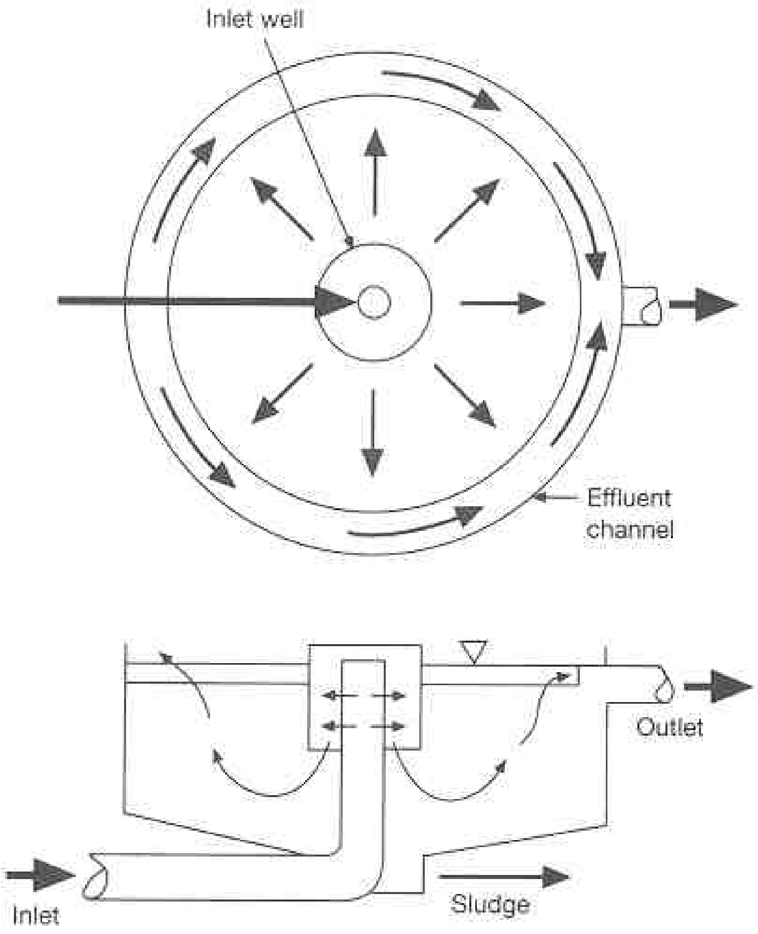
$\mathrm{Re} = 55$

$C_D = 1.18$

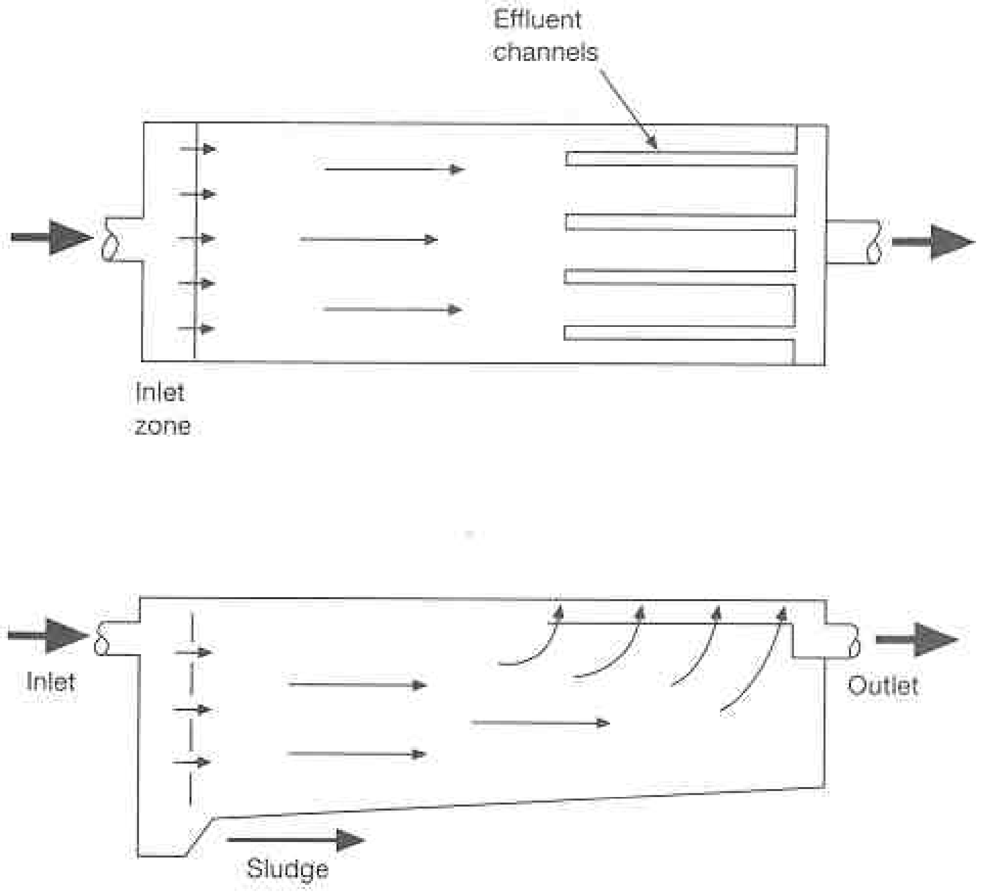
$v_t = 0.10\ \mathrm{m/s} \simeq 0.11\ \mathrm{m/s}$ (see step 4)

Settling operations

Circular Basin



Rectangular Basin



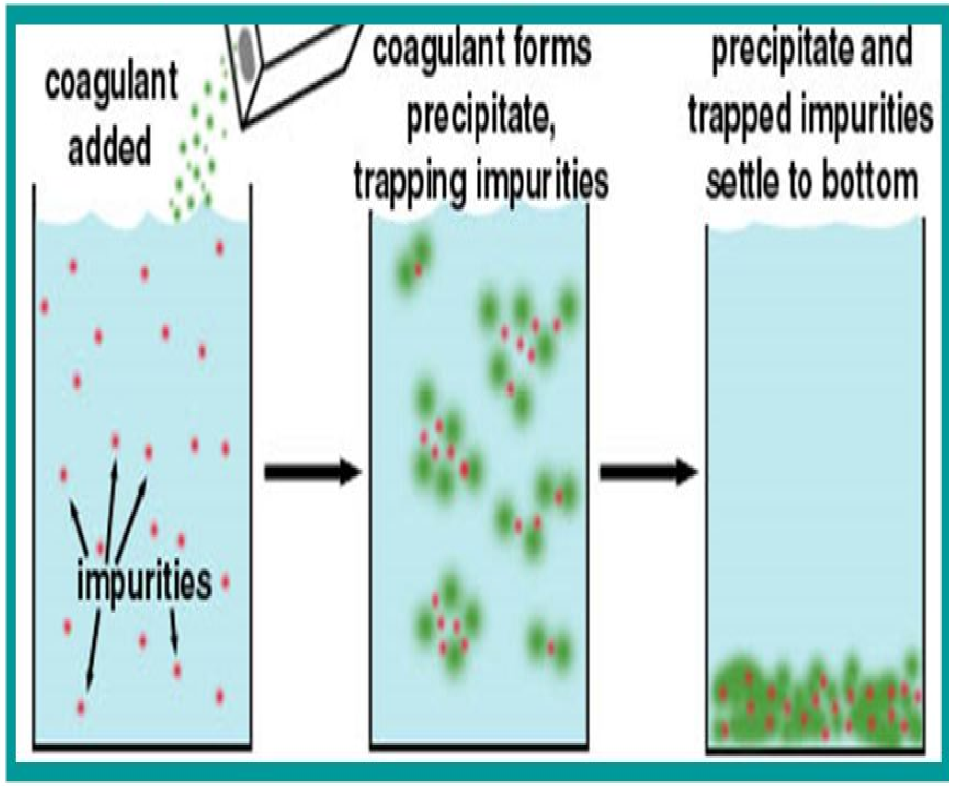
Coagulation

- Many of the contaminants in water and wastewater contain matter in the colloidal form. These colloids result in a stable "suspension". In general the suspension is stable enough so that gravity forces will not cause precipitation of these colloidal particles. So they need special treatment to remove them from the aqueous phase. This **destabilization of colloids** is called "coagulation".
- Coagulation is completed in 2 steps:

1. Rapid Mixing
2. Flocculation

Some coagulants:
aluminum sulfate,
ferric sulfate
ferric chloride

Some coagulant aids:
activated silica
clay
polymers



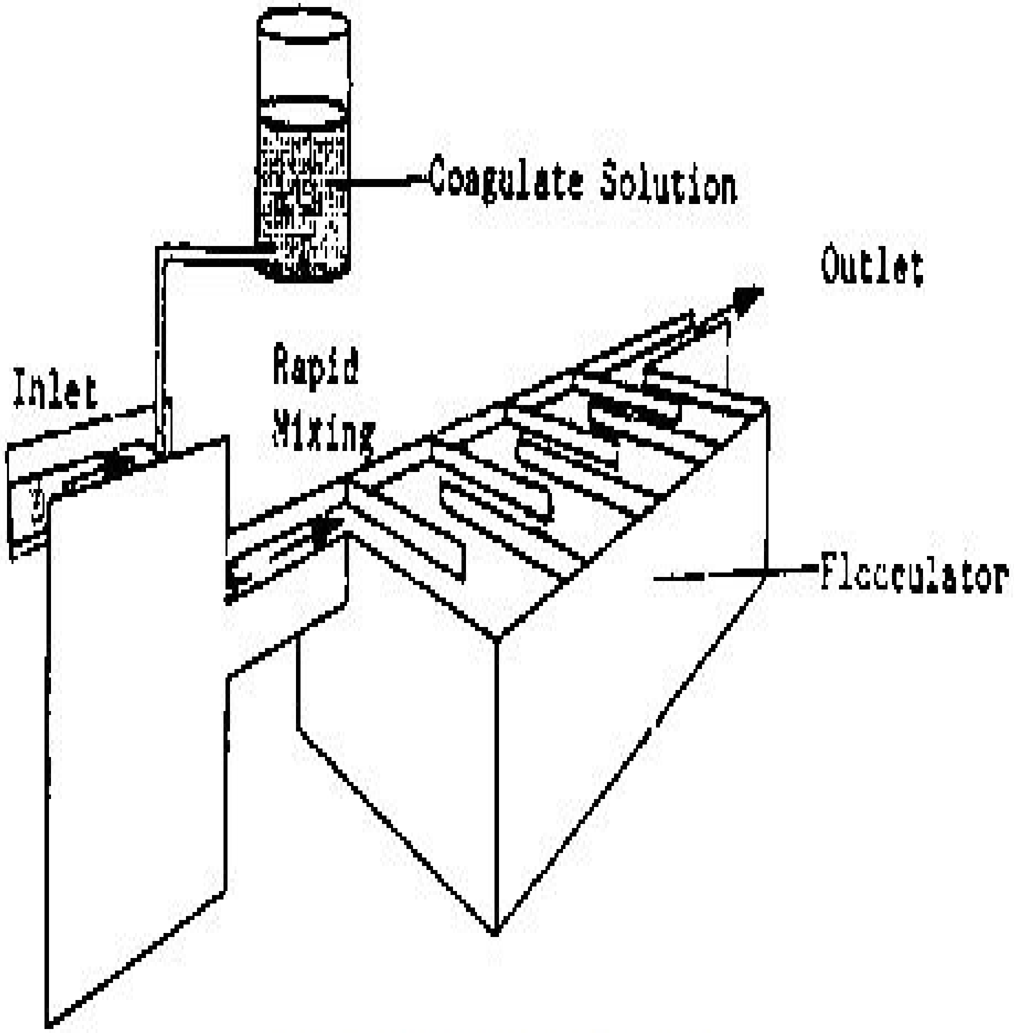
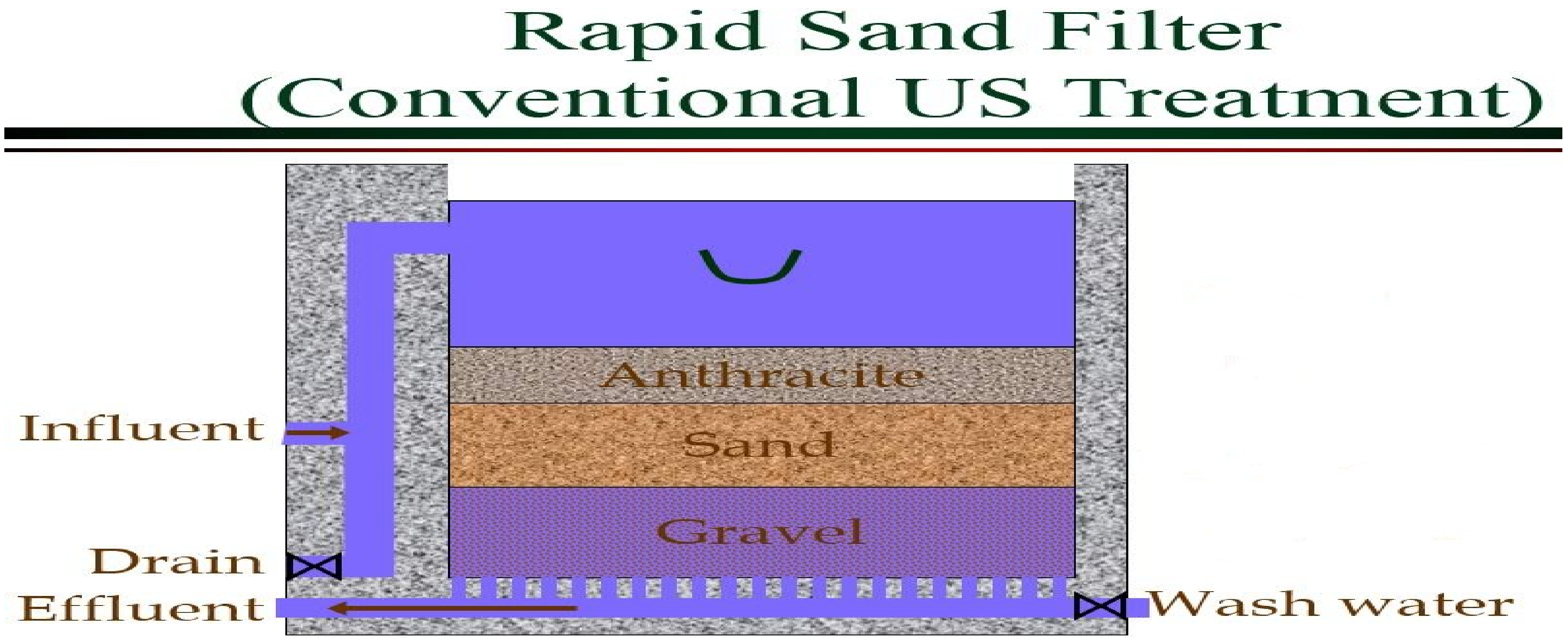


Figure . Rapid mixing of coagulant

Filtration

- Water filtration is a mechanical or physical process of **separating suspended and colloidal** particles from fluids (liquids or gases) by interposing a medium through which only the fluid can pass. Medium used is generally a granular material through which water is passed.



Types of Filtration

1. **Slow sand filtration (SSF):**
   - It is very effective for removing **flocs** containing microorganisms such as algae, bacteria, virus, etc.
   - Slow sand filtration (SSF), with flow rates ranging between 0.1 and 0.2 $m3h^{-1}$ has been a standard bio filtration treatment for decades in the wastewater industry.

2. **Rapid sand filtration (RSF)**
   - The major difference between SSF and RSF is in the principle of operation; that is, in the speed or rate at which water passes through the media.
   - In Rapid sand filtration (RSF), water passes downward through a sand bed that removes the **suspended particles**.

https://www.youtube.com/watch?v=uISgsZsXVdU

Disinfection

- Any process to destroy or prevent the growth of microbes and Intended to inactivate the microbes by physical, chemical or biological processes
- Inactivation is achieved by altering or destroying essential structures or functions within the microbe.
- **DIFFERENCE BETWEEN DISINFECTION & STERLIZATION**:
  disinfection is the process of eliminating or reducing ***harmful*** microorganisms while sterilization is the process of killing ***all*** microorganisms.
- **Some disinfectants are** : Free Chlorine, Monochloramine, Ozone, Chlorine Dioxide , Iodine , UV Light , Boiling (at household level in emergencies)

Some disinfectants

Chlorine

- Chlorine enters the cell walls of bacteria and kill the enzymes which are essential for the metabolic processes of living organisms.
- Typical dosage (1-5 mg/L)
    - variable, based on the chlorine demand
    - goal of 0.2 mg/L residual

Ozone

- O_3 is chemically unstable
- 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.

VIDEO FOR WATER TREATMENT

https://www.youtube.com/watch?v=CSPIxwQmGIQ