Arba Minch Water Technology Institute

Faculty of Water Supply and Environmental Engineering

Course title; WaterTreatment

Course code; WSEE-3142

Target groups; 3rd year Water Supply and Environmental Engineering students

Academic year**; 2019/20**, Semester; **II**

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February, 2020

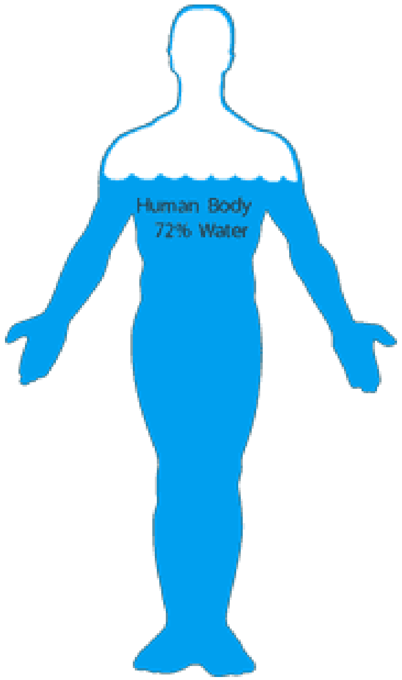
Outline

1. Introduction
2. Preliminary treatment
3. Sedimentation
4. Coagulation and flocculation
5. Filtration
6. Disinfection
7. Miscellaneous water treatment

INTRODUCTION

So what is it about water that makes it so important to us?

- Water is of major importance to all living things.
- Up to 70 percent of the human body is Water.
- Therefore the quality of Water we drink is very important.
- The Drinking Water should be clean, pure and free of any disease causing Microbes, and that's why it should be properly Treated and Disinfected before using it for drinking purpose.



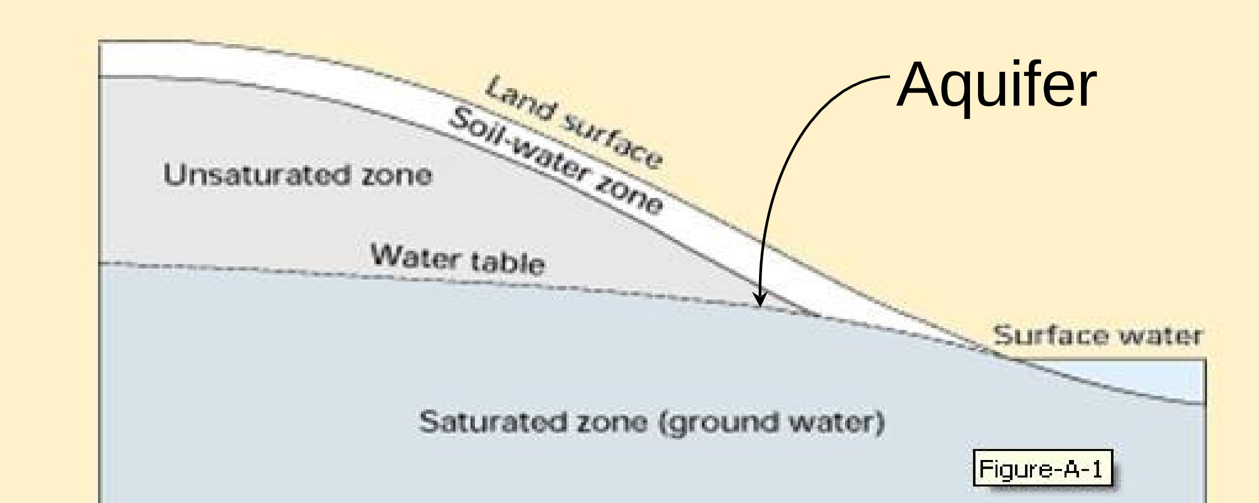
Uses of Water

- Bathing
- Toilets
- Cleaning
- Food preparation
- Cooling
- Fire protection
- Industrial purposes
- Drinking water = Potable water

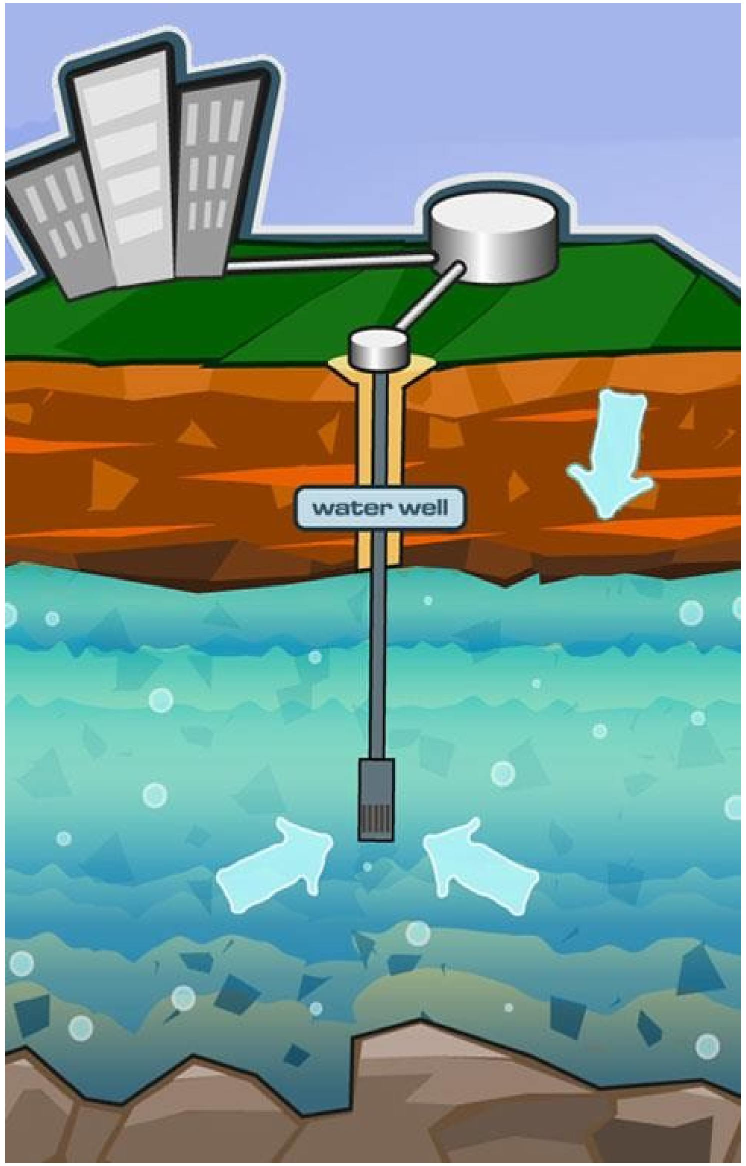
Sources of Water

Aquifers (Groundwater)

- Primary source of drinking water
- Porous consolidated rock or unconsolidated soil
- Groundwater fills spaces
- Wells and pumps used to remove water



Courtesy USGS at
http://pubs.usgs.gov/circ/circ1139/htdocs/boxa.htm



Sources of Water

Surface Water

- Lakes, reservoirs, rivers
- Rivers dammed to create reservoirs
- Reservoirs store water during heavy rain

Lake

Dam

River

Water Sources and their Quality

Sources for supplying water:

- Upland rivers
- Lowland rivers
- Lakes and reservoirs
- Groundwater aquifers

Which source to select?

Typical raw water quality

Parameter	Upland River	Lowland river
pH	6.0	7.5
Total solids, mg/L	50	400
Alkalinity	20	175
Hardness	10	200
Color	70	40
Turbidity	5	50
Coliforms, MPN/100mL	20	20×10^3

Comparison of surface water and groundwater quality

Parameter	Surface water	Groundwater
o Temperature	Varies with season	Relatively constant
o Turbidity and SS	Varies and is sometimes high	Usually low or nil
o Mineral content	Varies with soil, rainfall, effluents, etc	Relatively constant and high
o Iron and manganese	Some	Always high
o Carbon dioxide	None	Always high
o Dissolved oxygen	Often near saturation, if not polluted	Usually low
o Ammonia	Only in polluted water	Increasing trend
o Hydrogen sulfide	None	Usually some
o Nitrate	Generally none	Increasing trend
o Living organisms	May be high	Usually none

Source of Water Pollution and Water Impurities

Water Pollution

✓ Water pollution is any chemical, biological, or physical change in water quality that has a harmful effect on living organisms or makes water unsuitable for desired uses.

a) **Point source:** specific location (drain pipes, ditches, sewer lines).

b) **Non point source:** cannot be drawn to a single site of discharge (atmospheric deposition, agricultural / industrial / residential runoff)

Some raw water quality parameters

Physical

- Suspended solids
- TDS
- Color
- Turbidity
- Conductivity
- Taste
- Odor
- Absorbance/transmittance

Chemical

- Oxygen demanding organics
- Dissolved oxygen
- Principal inorganic ions
- Trace constituents
- Synthetic organic matters
- pH
- Alkalinity
- Hardness

Biological

- Total coliforms
- E.coli
- Plants and animals

Impurities in water

✓The impurities which are present in water may be classified in the following three categories.

a) Suspended impurities

b) Colloidal impurities

c) Dissolved impurities

a) Suspended impurities

- ✓ These impurities are dispersion of solid particles that are large enough to be removed by filtration or sedimentation.
- ✓ These impurities are normally remain in suspension
- ✓ They are microscopic and make turbid.
- ✓ Suspended impurities are:-
  - Bacteria –some cause diseases
  - Algae, protozoa –colour, odor, turbidity
  - Silt -muddiness or turbidity

b) Colloidal impurities

- ✓ The finely divided dispersion of solid particles
- ✓ Colloidal impurities are electrically charged. Due to this, the colloidal particles usually very small in size, remain in constant motion and do not settle.
- ✓ They are chief source of epidemic because they are associated with bacteria. It is removed by coagulation.

c) Dissolved impurities

- ✓ Which are not visible to the naked eye cannot be removed by ordinary filters
- ✓ It includes organic compound, inorganic salt and metals and gases etc.

Water analysis

- Various types of impurities present in water can be determined by water analysis.
- The analysis of raw water is used to determine the processes of water purification
- The analysis of purified water is done to know whether the degree of purification has reached the required standards or not.

The examination of water may be divided in to three classes:

1. Physical Examination
2. Chemical Examination
3. Microbiological Examination

1. Physical Examination

i. **Colour tests-** Water must be free from objectionable colour.

- Colour is indicative of decayed vegetation and bacteria or chemical, petrol- chemical, textile, paper and pulp etc.

ii. **Taste and odour test-** Odour in water indicates the presence of dissolved gases. Such situation gives rise to taste.

- Odour is measured in terms of thresh hold number

iii. **Temperature test-** This could destroy the biological and biochemical configuration of a water body.

- Aquatic organisms are sensitive to thermal changes.
- The temperature of water to be supplied should be between 10^0C to 20^0C

iv. **Turbidity test-** This refers to a state of unclear, muddy and thick water. It is an important measure of effluent quality standard.

- Common methods of measurement is Nephelometers, turbidity rod, Jackson/ Baylis turbidimeter.
- The permissible turbidity of domestic water may be between 5 to 10 p.p.m.

2. Chemical Examination

i. **Total solids-** the suspended, dissolved and colloidal solids are determined separately and then added together to get Total solids.

- High TDS causes corrosion and dehydration of organic tissues within the ecosystem.
- The amount of total solids should preferably be less than 500ppm.

ii. **Chlorides-** the test is carried out to determine the content of sodium chloride in water.

iii. **Hardness-** it is due to presence of certain salts of calcium and magnesium dissolved in it.

- Calcium and magnesium salts are soap destroying and are prime constituents concerned with hardness.
- Total hardness is composed of two components: Temporary hardness and permanent hardness

iv. **PH value-** This is a measure of acidity and alkalinity. pH for water body should fall within range 6 – 9

v. **Metals and other chemical substances**

- Iron in water causes hardness, bad taste, discolouration of clothes and flumbing fixtures and incrustation in water mains.
- Lead is a well known cumulative poison. Under normal condition, the concentration of lead should be less than 0.05mg/l.
- Iodine upto 1ppm keep away goiter while fluoride upto 1.2ppm will prevent dental caries of the children. Excess concentrations (>3ppm) can cause goiter and dental fluorosis or mottled enamel in childrens.
- Sodium and potassium Excess quantities are excreted, primarily in the urine.

- some patients of Heart, Kidney or Lever diseases are unable to rid themselves of sodium resulting substances.

3. Microbiological Examination

- The water used should be free from fecal or sewage contamination.
- The following are the purposes of bacteriological examination of water:
  - To detect and assess the degree of pollution in the source.
  - To assess the amount of treatment required.
  - To determine the efficiency of purification
  - To locate any sudden deterioration in quality
  - To establish the final water purity from bacteria
- **Test for E-coli (Escherichia coli)-** are bacteria found in the environment, food and intestines of humans and animals.

- **E.coli** are large and diverse group of bacteria
- E-coli in water supply indicates pollution by faecal contamination.

Diseases in Drinking water

- Diseases in drinking water can be classified in to:-

1. **Water born disease:** if pathogens that originates in Fecal material and are transmitted by drinking water. Like diarrhea, fatigue, abdominal cramps etc…
2. **Water Washed disease:** if organisms that originates in feces and are transmitted through contact because of inadequate sanitation or hygiene.
3. **Water based disease:** if organisms that spend part of their life cycle in aquatic animals and come in direct contact with humans in water, often through skins.
4. **Water related disease:** if organisms with life cycles associated with insects that live or breed in water and bite susceptible individuals.

Diseases in Drinking water

- Water born diseases are caused by pathogenic organisms carried by water containing fecal or sewage contamination.
- The most common water born diseases are grouped in to four heads:-

a. Bacterial diseases
b. Protozoal diseases
c. Virus diseases and
d. Helminthic(worm) diseases

a. Bacterial diseases

- **Typhoid fever**; water born disease where water supplies are drawn from surface source contaminated by human faeces or urine.
- **Paratyphoid fever;** mostly due to ingestion of contaminated food, especially milk, dried or frozen eggs and other products
- **Cholera;** by ingestion of water contaminated by infected human fecal material
  - It may be contracted by contaminated food or personal contact
- **Bacillary dysentery;** Mostly contracted due to ingestion of food contaminated by flies or by unhygienic food handlers.

b. Protozoal disease

- Caused by the protozoon Entamoeba histolytica, they live in the human large intestine forming cyst which are excreted in the bowel discharge of infected persons
- Infection takes place due to ingestion of these cyst which are carried by water or flies or even human fingers.

c. Virus diseases

- Any virus extracted and capable of causing infection when ingested could be transmitted by water.
- Those viruses that can multiply in the intestine wall and that are discharged in large numbers in faeces are of more concern.

d. Helminthic(worm) diseases

- Occurs only under grossly insanitary conditions or through gross mis management of sewage disposal system.

Water quality standards

- ✓ **Water quality standard** is limits on the amount of impurities in water for the intended use and which is legally enforced.
- ✓ It includes rules and regulations for sampling, testing and reporting procedures.
- ✓ There are three water quality standards:

1. Stream standards: this can set limits on pollutants discharge in surface water
2. Effluent standards: this can set limits on pollutants from different sewage treatment plants which discharged in to rivers.
3. Drinking water standard: this can set limits on contaminants in public water supply.

Basic quality requirements of drinking water

- Free from diseases causing pathogenic organisms
- Contain no compounds that have adverse effect acute or in long term on human health
- Fairly clear (i.e., of low turbidity, little color)
- No saline
- Contain no compounds that cause offensive taste and odor
- Free of substances and organisms that cause corrosion or deposit of the water supply system, staining of clothes washed in it or food items cooked with it.

- **Primary drinking water standards :** Protect public health and their maximum permissible levels was enforced by law.
- **Secondary drinking water standards:** this is about aesthetic qualities, color, odor, and taste
  - Can be recommended but not enforced by law
- **Water quality for any construction** should be as much as possible in the standards of drinking quality

Drinking water quality standards

Parameter	WHO guideline (2018)	Recommended for Ethiopia(2017)
pH	6.5-8.5	6.5-8.5
Total solids, mg/L	1000	1000
Total hardness, mg/L	500	300
Chloride, mg/L	250	250
Sulphate, mg/L	250	250
Fluoride, mg/L	1.5	1.5
Iron, mg/L	0.3	0.3
E. Coli, MPN/100 ml	10	30
Nitrate , mg/L	50	40
Arsenic and lead, mg/l	0.01	0.01

Water quality monitoring and surveillance

- This means basically administering, managing and close observation of water issues for public satisfaction.
  - ❑ **Quality of water:-** the microbiological quality is given highest priority
  - ❑ **quantity of water:-** the quantity of water should be enough for basic requirements
  - ❑ **Reliability of supply :-** should be reliable and available at a short distance as possible
  - ❑ **Cost of water:-** payment of the use of water
  - ❑ **Coverage of the population:-** % of the population that has access to a recognizable water supply

Introduction to Water Treatment processes

Common words

- **Palatable -** Water having no unpleasant taste or good taste.
- **Safe -** Water free from pathogenic micro organisms & chemicals which could be a harmful for consumer
- **Clean -** Water free from suspended solids and turbidity
- **Colorless and odorless –** Water aesthetic to drink
- **Reasonably soft –** Water allowing easy wash of cloths, dishes with less soap
- **Lower organic content -** To avoid unwanted biological growth in pipes & smell
- **Non corrosive -** Devoid of gases e.g. O_2, Co_2 , H_2S
- **Potable -** Water suitable for drinking i.e. Safe and pleasant to taste
- **Wholesome -** Potable water having sufficient minerals of natural origin which are must for life.
- **Contaminated -** Water having micro organisms, chemicals or substances making the water unsafe and dirty.

Some facts

- According to WHO, the water source has to be within **1,000 metres** of the home and collection time should **not exceed 30 minutes.** But the average distance that women in Africa and Asia walk to collect water is **6 kilometres**.
- 27% of the urban population in the developing world does not have piped water in their homes. *Source:UNESCO*
- Long-term exposure to high level of arsenic in drinking water can cause thickening and pigment spots in the skin, and cancer of the skin, lungs, bladder or kidney.
- An estimated 1000 children die every day in India due to polluted water.

- Now a day globally, 844 million people lack access to clean water, more than 1 of every 10 people on the planet. (world vision 2018)
- Woman and girls spend an estimated 200 million hours hauling water every day. (world vision 2018)
- 62 million people living without basic access to safe drinking water.
- 31 percent of the Ethiopian population relies on unprotected water for their daily needs.
- Every day, more than 800 children under age 5 die from diarrhea attributed to poor water and sanitation. (world vision 2018)
- One in every 17 children does not live to see their fifth birthday, and diarrheal disease is the leading cause of death in Ethiopia.

Water Treatment

- ✓ Water available in various sources may contain various types of impurities and cannot be directly used by the public for various purposes, before removing the impurities
- ✓ Therefore, removing these impurities up to certain extent so that it may not be harmful to the public health is necessary.
- ✓ The process of removing the impurities from water is called **water treatment** and the treated water is called *wholesome water.*

- ✓The degree and methods of treatment depend upon nature of the source, quality of the source and purpose for which the water is supplied.
- ✓The various treatment methods and the nature of source of impurities removed by employing them are given in table:-

Process	**Impurity Removal**
Aeration	Taste and Odour removal, oxygen deficiency
Screening	Floating matter
Plain sedimentation	Large suspended solids
Coagulation	Fine particle
Filtration	Colloidal particles, microorganisms
Activated Carbon	Elements causing tastes and odor
Softening	Hardness
Disinfection	Living organism including pathogen

Objective of treatment

- The main objective of the treatment process is to remove the impurities of raw water and bring the quality of water to the required standard
- The objective may be summarized as follow:-

(i) Preventing Disease Transmission

- Organisms that cause disease must be removed or inactivated to make the water safe

(ii) Making the Water Acceptable

- If the consumers regard the water as unsatisfactory they may use an alternative source which is hazardous

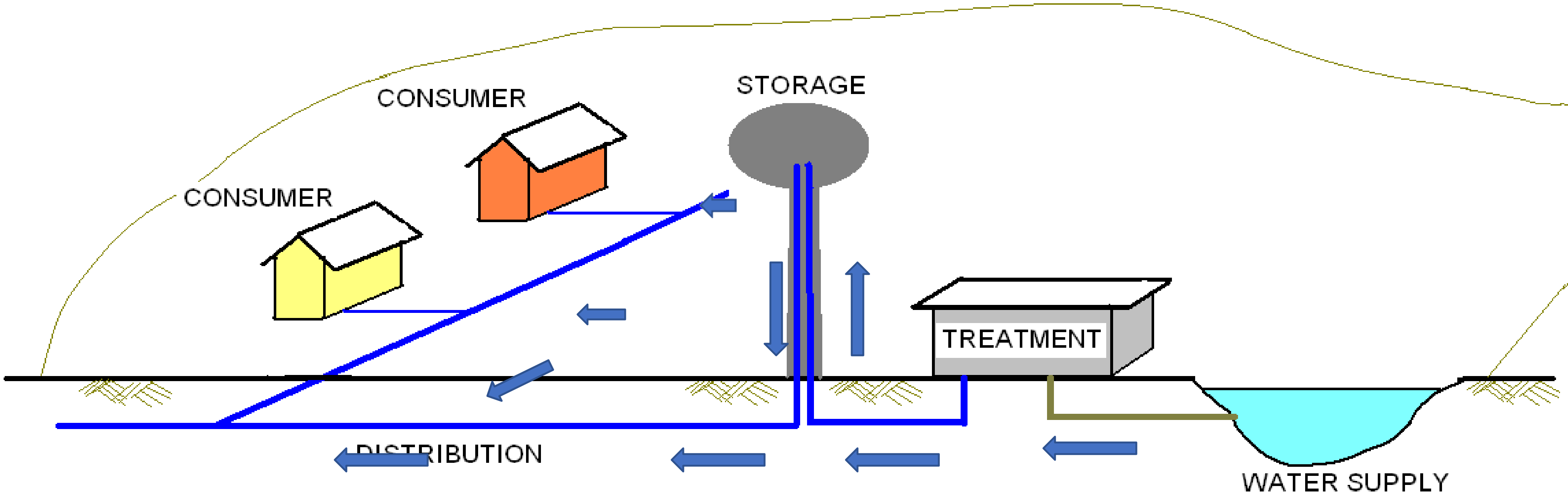
(iii) Protecting the distribution System

- Corrosion reduces the life of the pipes, reduces their carrying capacity, and forms deposits which may color the water.

Location of treatment plant

- The treatment plant should be located
  - ✓ Near to the town to which water is to be supplied and near to the source of supply. This will prevent the water quality to depreciate after treatment.
  - ✓ Away from any source of pollution.
  - ✓ Away from the border of other countries and should be announced as a protected area. During war time, a neighbor country may play foul game by damaging the plant, poisoning the water.
  - ✓ At higher elevation if the natural topography permit.

Location of Treatment Plant



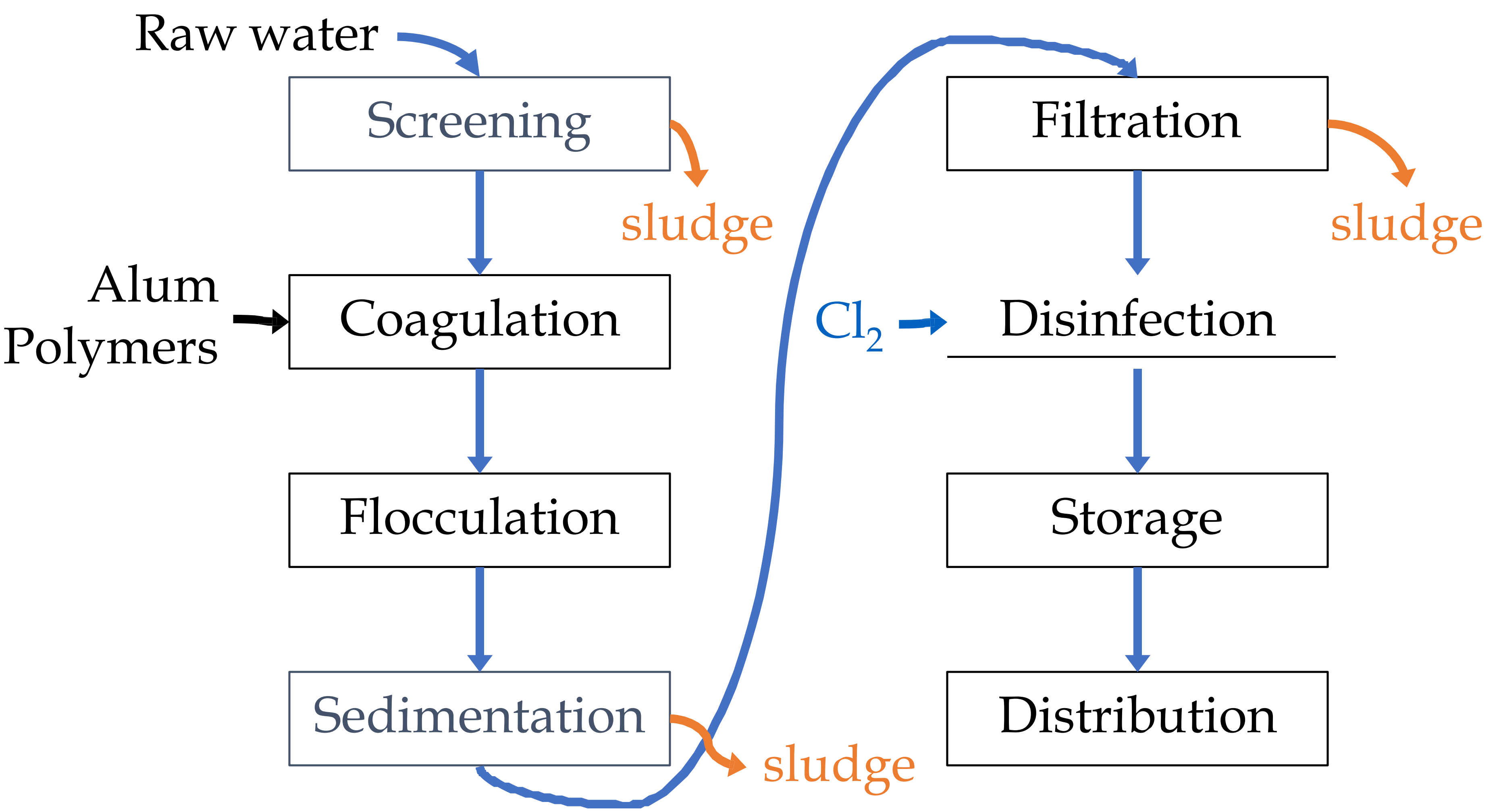
Treatment Schemes

a) Slow Sand Filters

b) Conventional Treatment

c) Treatment of Ground Water

Conventional Surface Water Treatment



Factors Affecting the Choice of Treatment Schemes

a) Limitation of capital

b) Availability of skilled and unskilled labor

c) Availability of equipment, construction material, and water treatment chemicals

d) Local codes, drinking water standards and material specifications

e) Local traditions, customs and cultural standards

f) National sanitation and pollution policies.

Consideration for Treatment units in developing country

- ✓ Use hydraulic devices instead of mechanical equipment’s
  e.g. for mixing of chemicals
- ✓ Use indigenous materials & manufacturing to reduce the cost
- ✓ Lower peak and per capital consumption
- ✓ Lower design period
- ✓ Organizational capacity to recruits and retrain
- ✓ Head lose should be conserved possible

Preliminary Treatment Systems

- High turbidity water which may occur particularly during the rainy season requires pre treatment in the form of screening, sedimentation, storage or roughing filtration to reduce much of the suspended solids.
- This is an advantage otherwise a very large amount of chemicals may have to be employed for chemical coagulation which can be expensive

Types of preliminary treatment

- Intakes
- Screens
- Plain sedimentation
- Storage
- Roughing filter
- Infiltration galleries
- Silt trap

Intakes

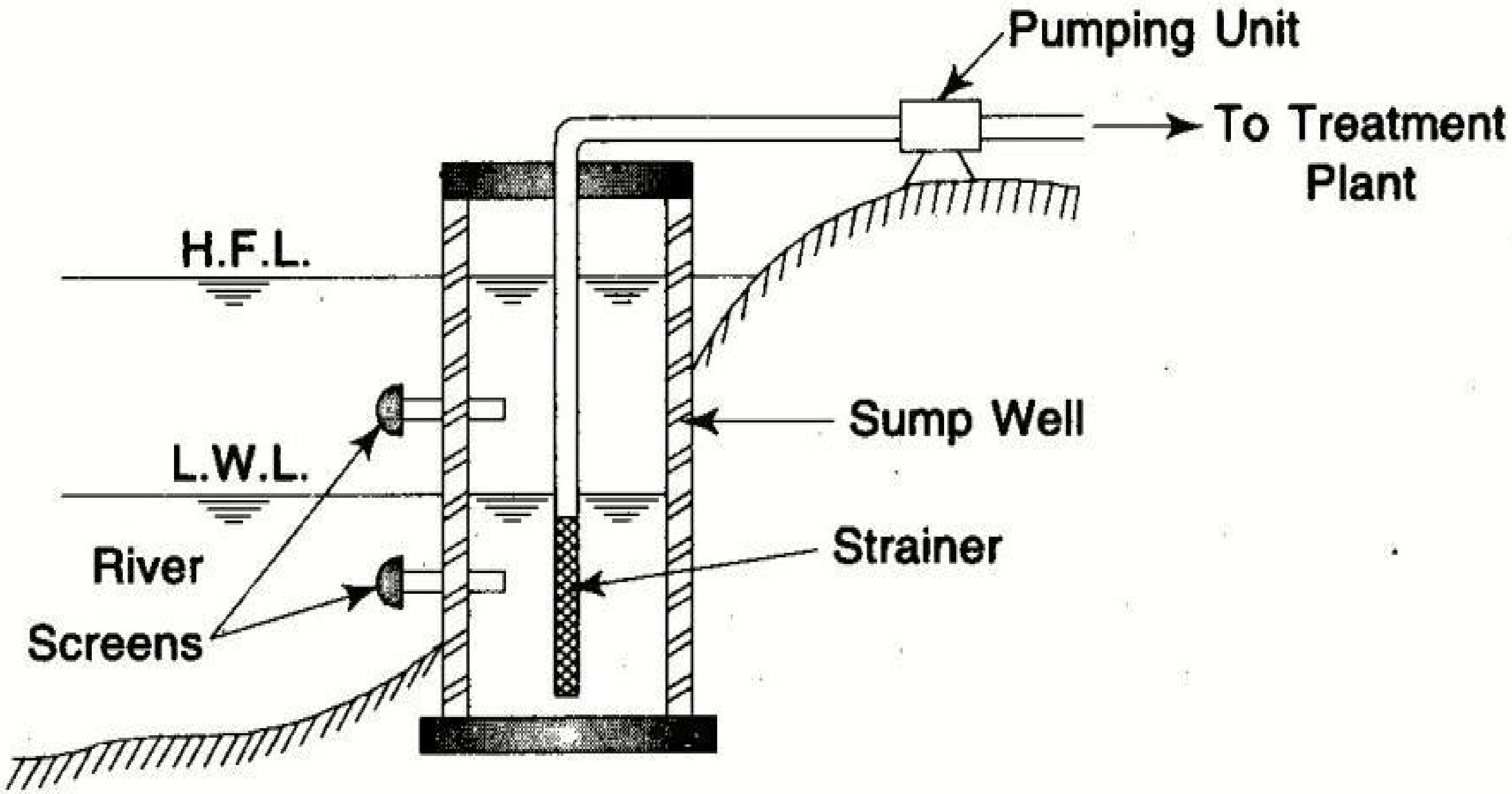
- Proper design of the intake structure is one way of achieving preliminary treatment
- The intakes should be located in such a way that rolling debris at the bottom is prevented from entering via the intake
- Bar Screens are provided to screen out larger size floating and suspended materials
- Sometimes two filters are provided successively for coarse and fine screening

- Two types of intakes are there:
  - ➢ Dry intake
  - ➢ Wet intake

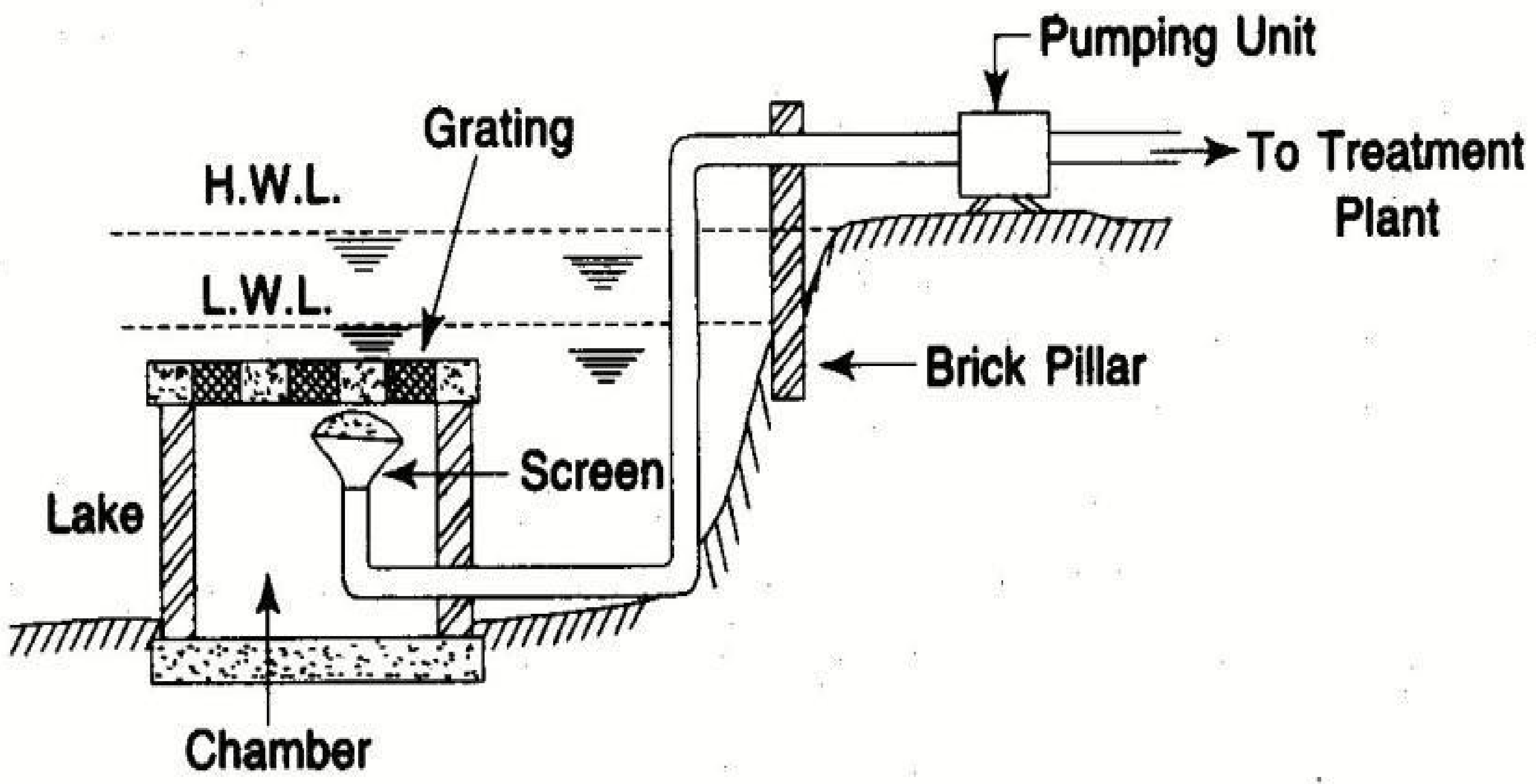
✓ Low level intake in the dry season, to avoid algae at the top and

✓ High level intake in the wet season to avoid suspended solids at the bottom

River intake

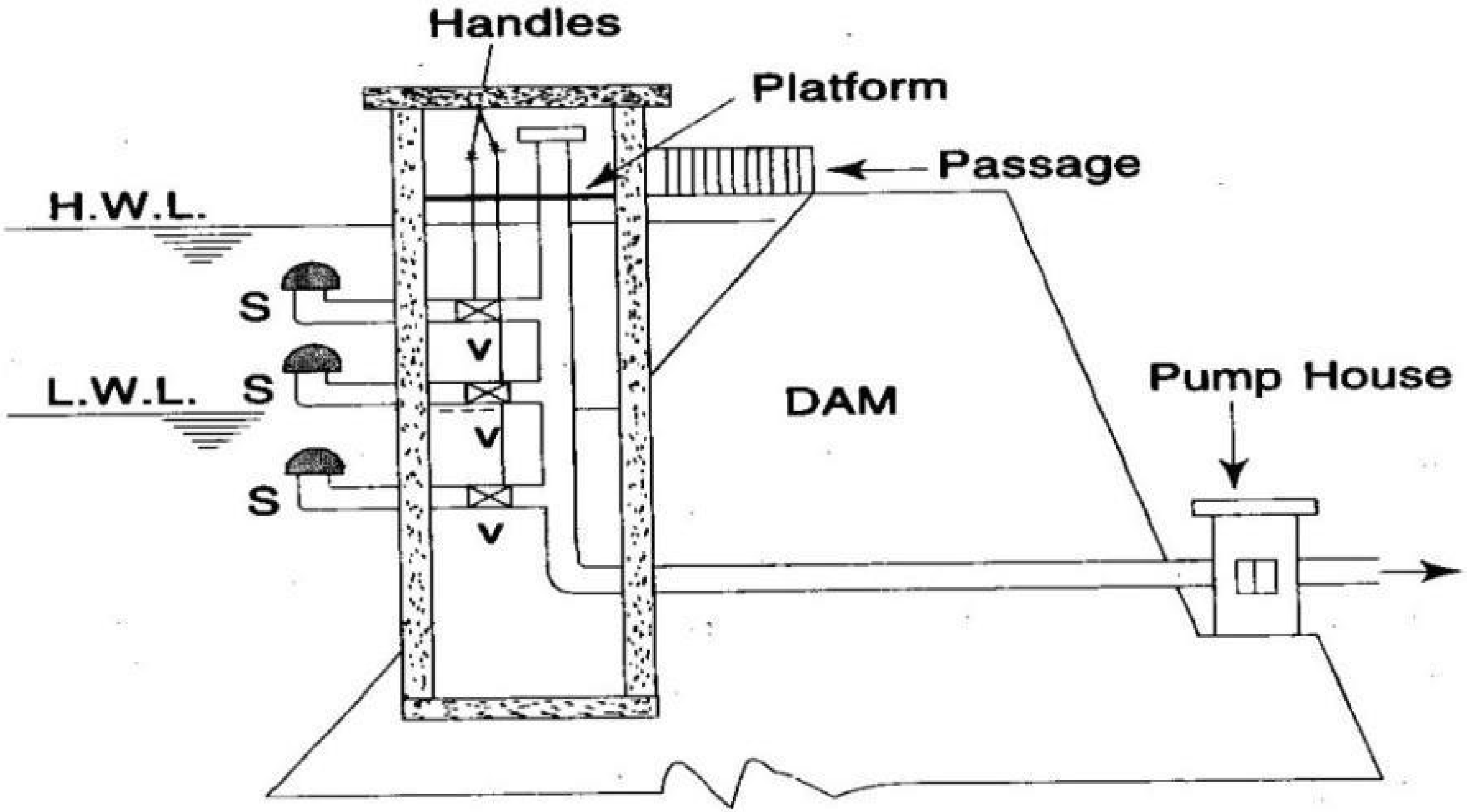


Lake intake

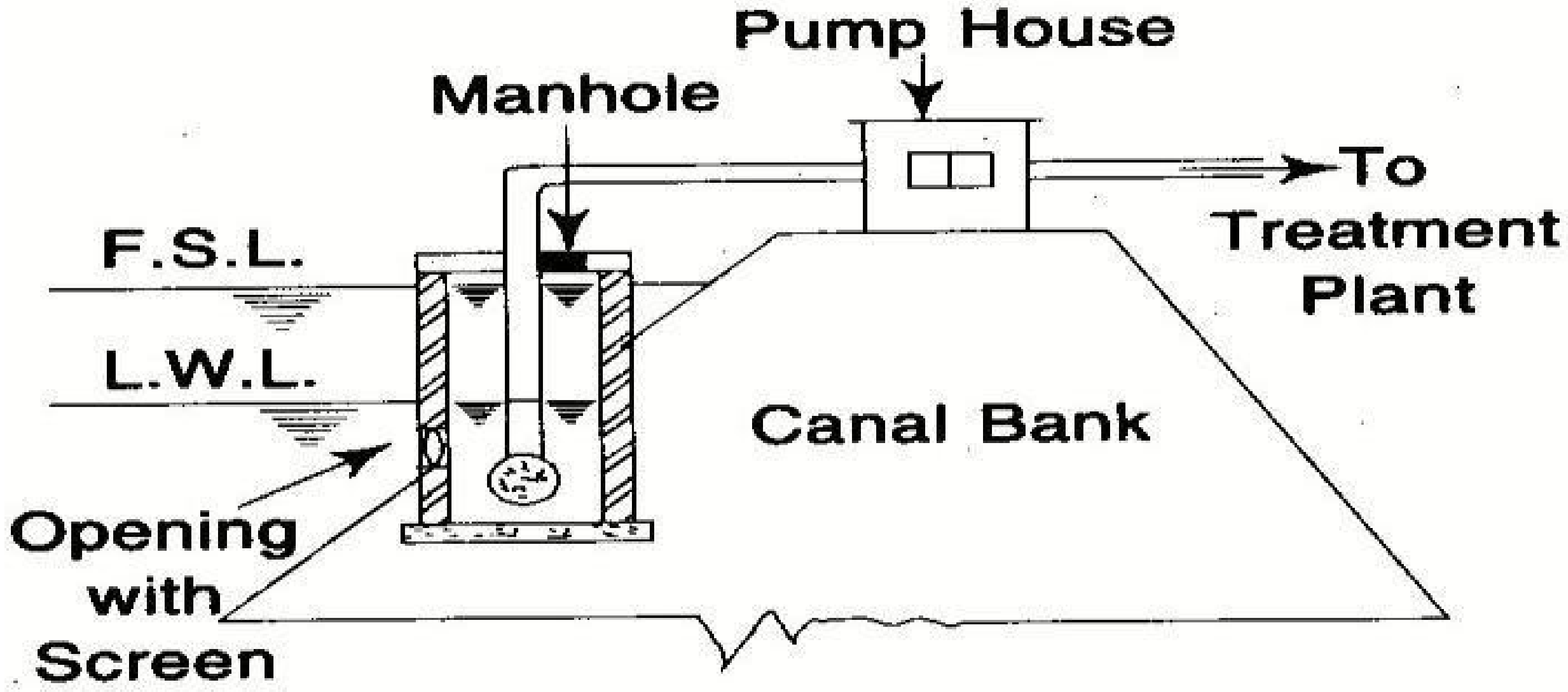


Pumping Unit
Grating
H.W.L.
To Treatment Plant
L.W.L.
Brick Pillar
Screen
Lake
Chamber

Reservoir Intake



Channel Intake



Example 1

- Design a bell mouth intake for a city of 80,000 persons drawing water from a channel which runs for 10hrs in a day with depth of 1.8m. Also calculate the head loss in intake conduit if the treatment plant is ½ km away. Draw a net sketch of the canal intake assume average consumption per person =150l/d.
- Assume the velocity through the screen & the bell mouth to be less than 16cm/s & 32cm/s respectively.

Solution:

1) Q through intake

Daily discharge = 150*80,000 = 12,000,000l/d

Since the Channel runs only for 10 hrs

Intake load/hour = (12,000,000l/d))/(10hr/d)

= 1200m^3/hr=0.3333m^3/s

2) Area of Coarse Screen in Front of intake

$$A_s = (\frac{Q}{V}) = (\frac{0.3333\ \mathrm{m}^3/s}{0.16 m/s}) = 2.083\mathrm{m}2$$

Let the area occupied by the solid bar be 30% of the total area

The actual area for the screen ($\frac{2.083\ m2}{0.7}$) = 2.98m2

- Let assume the minimum water level @ 0.3m below the normal water level.
- Let as keep the bottom of the screen @ 0.2m above the channel bed.
- Available height of screen =1.8-0.3-0.2=1.3m
- Required length of screen =2.98m/1.3m=2.29m2.3m
- Hence provide a screen size=1.3m*2.3m

3) Design a bell mouth entry

$A_b = (\frac{Q}{Vb}) = (\frac{0.3333 \text{ m}^3/s}{0.32 m/s}) = 1.042\text{m2}$

Diameter of bell mouth $D_b = \sqrt{(\frac{1.042*4}{\Pi})} = 1.15\text{m}$

Hence provide a bell mouth of 1.2m

4) Design of intake conduit

Let us assume a velocity of 1.5m/s in the conduit

$$D_i = \sqrt{(\frac{0.3333*4}{1.5*\Pi})} = 0.532\text{m}$$

Provide=0.5m diameter intake conduit

Therefore the actual Velocity V =($\frac{0.3333*4}{\Pi*0.5^2}$)=1.7m/s

- 5) Head loss through the conduit

$$V= 0.849CR^{0.63}S^{0.54}$$

But C=130 for cast iron

R=D/4=0.5/4=0.125

Substitute to the above Equation

$$1.7= 0.849130 * 0.125^{0.63}S^{0.54}$$

S=4.98*10^-3

S=Hl/L

Hl=S*L ➡ 4.98*10^-3 *0.5*1000 = 2.49m

Screens

- ✓Screening of water which is one form of pre-treatment is done by passing the water through closely spaced bars, gratings or perforated plates.
- ✓Screening does not change the chemical or bacteriological quality of the water
- ✓It serves to retain the coarse material and suspended matter that are larger than the screen openings.

Purposes of screen

(i) Removal of floating and suspended matter which clogs pipes, damages pumps, etc.

(ii) Clarification by removal of suspended matter to lighten the load on subsequent treatment processes.

Types of screen

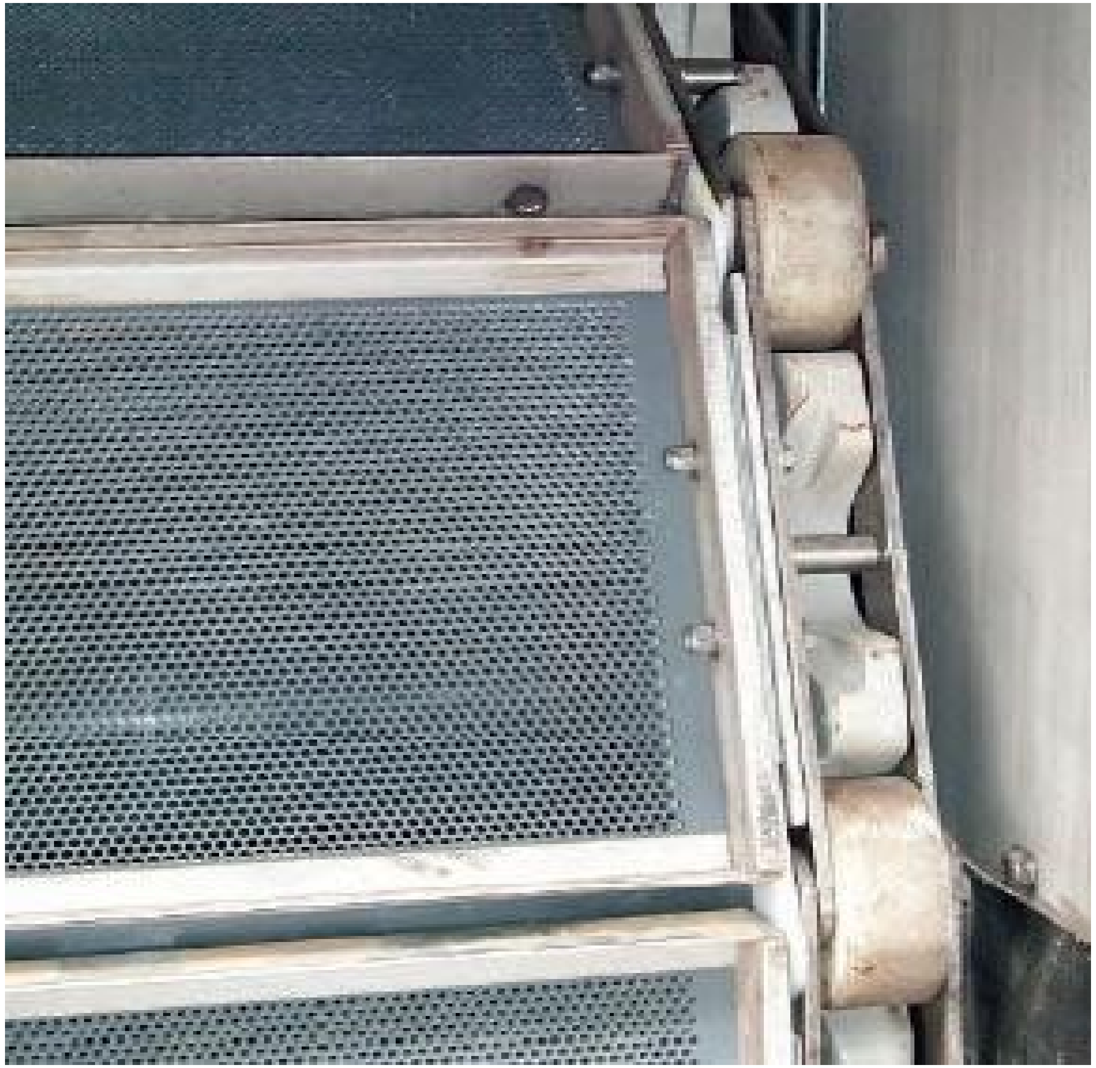
1. Coarse screen
2. Fine screen
3. Micro strainer

- Bar screen spacing is typically between 0.5 and 5cm
- Angle of inclination of bars is 60^0-75^0 if screening are very small and 30^0-45^0 if larger amount is retained over the screen bar.
- Between the openings the velocity should be restricted to up to 0.7m/sec
- If regular cleaning is done an allowance for loss of heads of up to 0.1 to 0.2m is made

Coarse screen

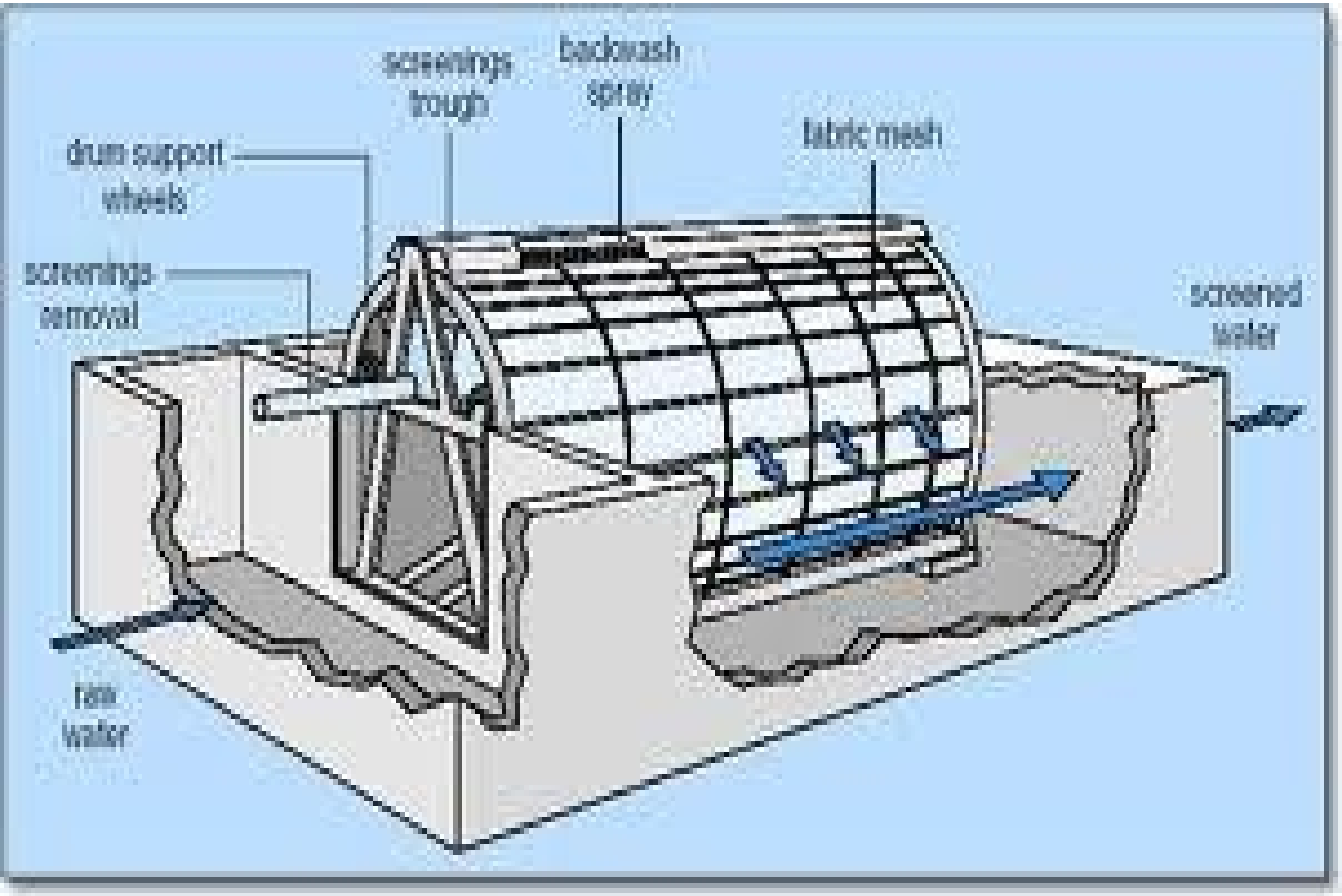
- Purpose: To prevent large objects from entering the conveyance system
- Design considerations
  - Design flow: $Q_{\text{max-day}}$
  - Layout: located slightly projected away from intake ports, on the water side.
  - Bar arrangement: 5-8 cm of clear opening
  - Velocity of flow: < 8.0 cm/s

Fine screen

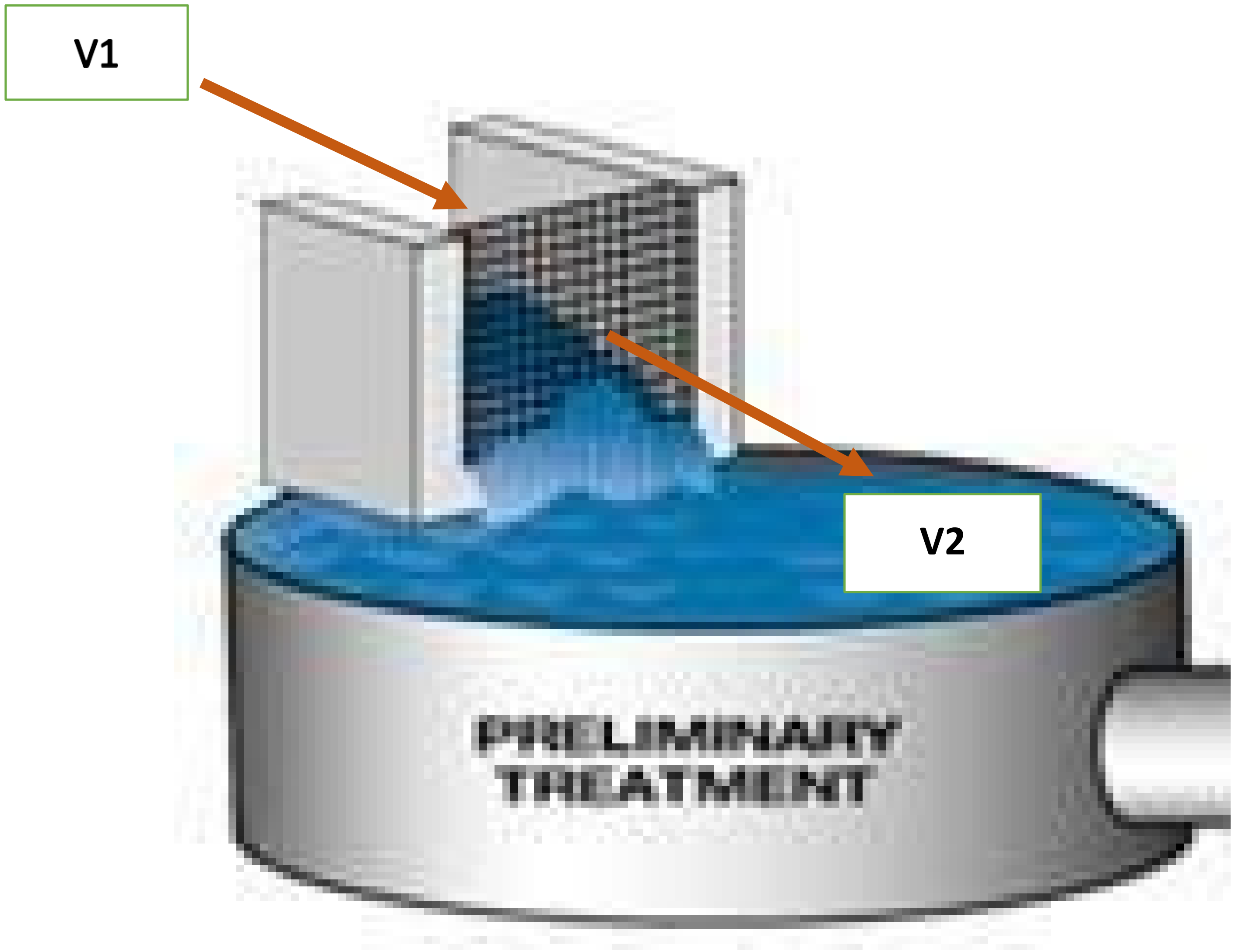


- Purpose: To remove smaller objects that may damage pumps or other equipment
- Heavy wire mesh with 0.5 cm openings
- Design velocity 0.4-0.8 m/s
- Automatic cleaning may be required

Micro strainer



- Purpose: To remove plankton and algae
- Before pre-chlorination and coagulation
- Consists of a rotating cylinder covered with fine wire mesh
- Operational problems due to biofilms


V1
V2
PRELIMINARY
TREATMENT

Head Loss Through Bar Screen

$$hl = \frac{1}{C} * (\frac{V2^2 - V1^2}{2g})$$

Where

c=empirical discharge coefficient to account for turbulence and eddy motion. (c=0.7 for clean bar and 0.6 for clogged bar screen)

V2=velocity of flow through openings

V1= approaching velocity of upstream channel

g= gravitational acceleration (9.81m/s2)

Head Loss Through fine Screen

$$hl=\frac{1}{C*2g}*(\frac{Q}{A})^2$$

Where

c=empirical discharge coefficient to account for turbulence and eddy motion. (c=0.6)

g= gravitational acceleration (9.81m/s2)

Q= discharge (m3/s)

A=effective opening area of the screen

Example

Determine the building up of head loss through a bar screen. when 35% of the flow area is blocked off by the accumulation of coarse solids assume the following conditions are applied.

Approach velocity =0.6m/s

Velocity through a clean bar screen =0.9m/s

Open area for flow through clean bar screen =0.19m2

Solution:

i. Compute the Head Loss Through a clean Bar Screen

$$hl = \frac{1}{C} * \left(\frac{V2^2 - V1^2}{2g}\right)$$

$$hl = \frac{1}{0.7} * \left(\frac{0.9^2 - 0.6^2}{2(9.81)}\right) = 0.0327\text{m}$$

ii. Compute the Head Loss Through a clogged Bar Screen

$V_i = \left(\frac{Q}{Ai}\right)$ and $V_f = \left(\frac{Q}{Af}\right)$ but 50% of Ai is only open

Therefore, Af =50%Ai

$$A_f = \left(\frac{50Ai}{100}\right) = \frac{Ai}{2}$$

$$Vf = \left(\frac{Q}{Af}\right) = 2 * \left(\frac{Q}{Ai}\right) = 2Vi$$

From this the velocity through a clogged bar screen is doubled

$$V=0.9*2=1.8m/s$$

$$hl = \frac{1}{0.6} * \left(\frac{1.8^2 - 0.6^2}{2(9.81)}\right) = 0.2m$$

Plain Sedimentation

- ✓ Plain sedimentation is a form of pre treatment that provides a low velocity of flow through a tank preferably excavated in the ground
- ✓ The purpose is to settle some solids because of this low velocity by gravity sedimentation
- ✓ Significant by reducing the turbidity below 30 NTU
- ✓ The tank may be rectangular, or, to minimize the need for thicker walls trapezoidal shape (which also facilitates settlement to the bottom) tank can be used.

- ✓ Baffle walls are provided at the inlet to dissipate the kinetic energy of the incoming water and provide quiescent settlement.
- ✓ Less importantly, they are also provided at the outlet to prevent turbulence in the outlet zone.

Storage

- ✓ Storage is very effective for high turbidity water
- ✓ The detention time is greater than for plain sedimentation tanks

Advantages:

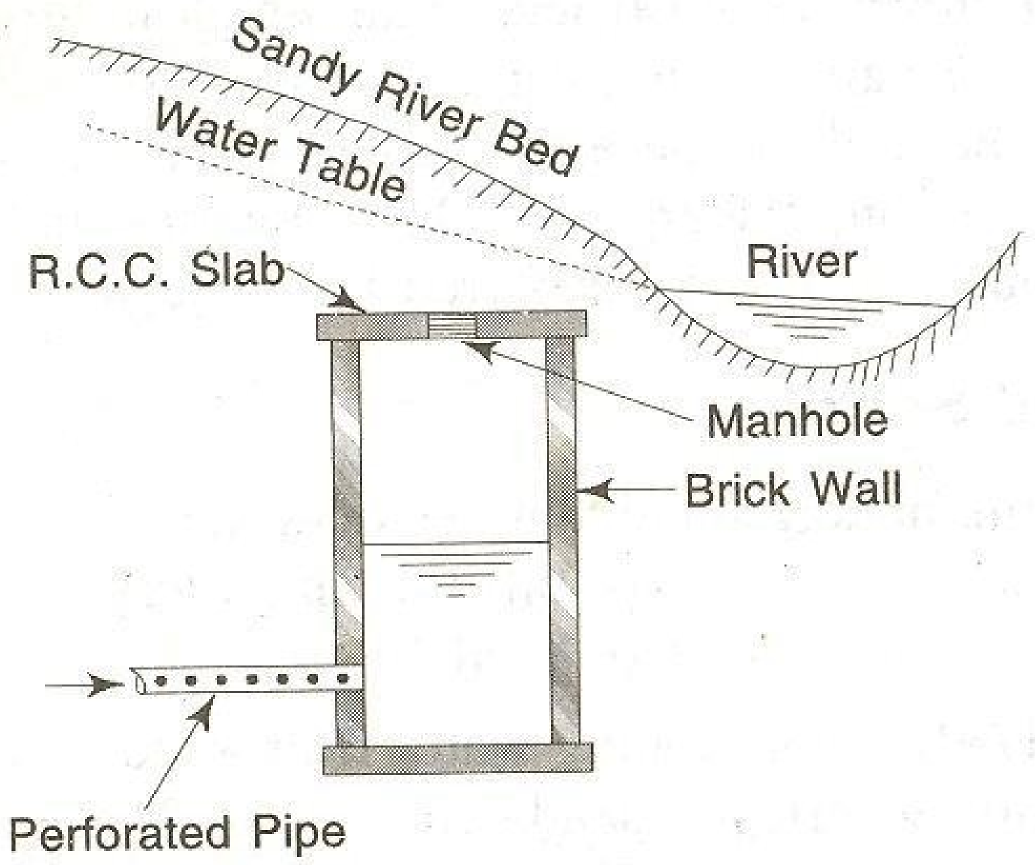
- Natural sedimentation
- Reduction of sudden water quality fluctuation.
- Reduction in the number of pathogenic bacteria
- Improved reliability of supply
- Excessively turbid water can be diverted away.

Roughing Filtration

- ✓ Roughing filtration allows a deep penetration of the filter layer and holds a large silt storage capacity
- ✓ Used by removing suspended solids from water that could rapidly clog a slow sand filter.
- ✓ Pathogen removal is between 60 and 90% without using any disinfectant
- ✓ Considerably reduce the amount of iron and manganese.
- ✓ Capable of reducing turbidity to as low as 5NTU from a raw water turbidity of 150NTU.

Infiltration Gallery

- ✓ It is underground tunnel which have holes on its sides, used for tapping underground water near river, lakes and stream.
- ✓ Sedimentation of silt is the main problem.



Silt trap

- This is a box like structure to remove any kind of silt, soil, sediment, metals or pesticides from entering your water storage system by containing water in the trap for some times.
- It allows these unwanted materials to settle to the bottom of the bucket and separate from the water
- It is essentially works like a filter

CONVENTIONAL METHODS OFWATER TREATMENT

Coagulation & Flocculation

What is Coagulation?

- **Coagulation** is the process by which colloidal particles and very fine solid suspensions initially present in a wastewater are combined into larger agglomerates.
- Commonly achieved by adding different types of chemicals (coagulants) to the waste water to promote destabilization of the colloid dispersion and agglomeration of the resulting individual colloidal particles.
- The chemicals are known as Coagulants, usually higher valence cationic salts (Al^{3+}, Fe^{3+} etc.)
- Coagulation is essentially a chemical process

Purpose

- The primary purpose of the coagulation/ flocculation process is the removal of turbidity from the water.
- **Turbidity** is a cloudy appearance of water caused by small particles suspended therein.
    - o Water with little or no turbidity will be clear.

Location in the Treatment Plant

- After the source water has been screened and has passed through the optional steps of pre-chlorination and aeration, it is ready for coagulation and flocculation

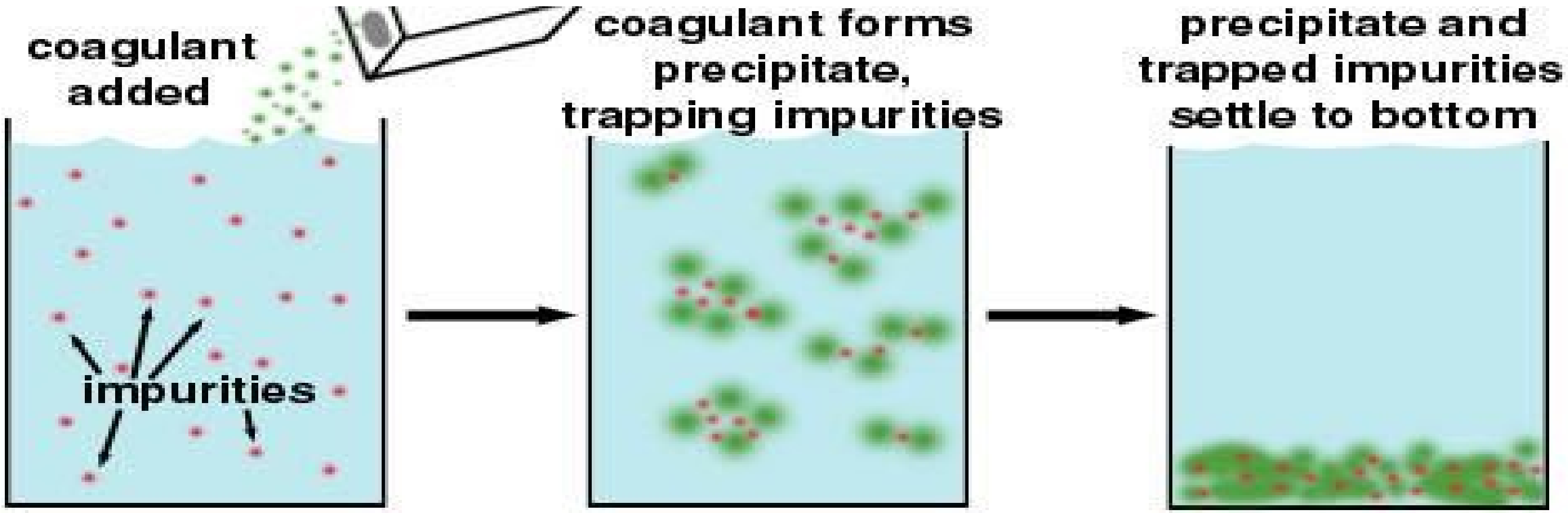
What is Flocculation?

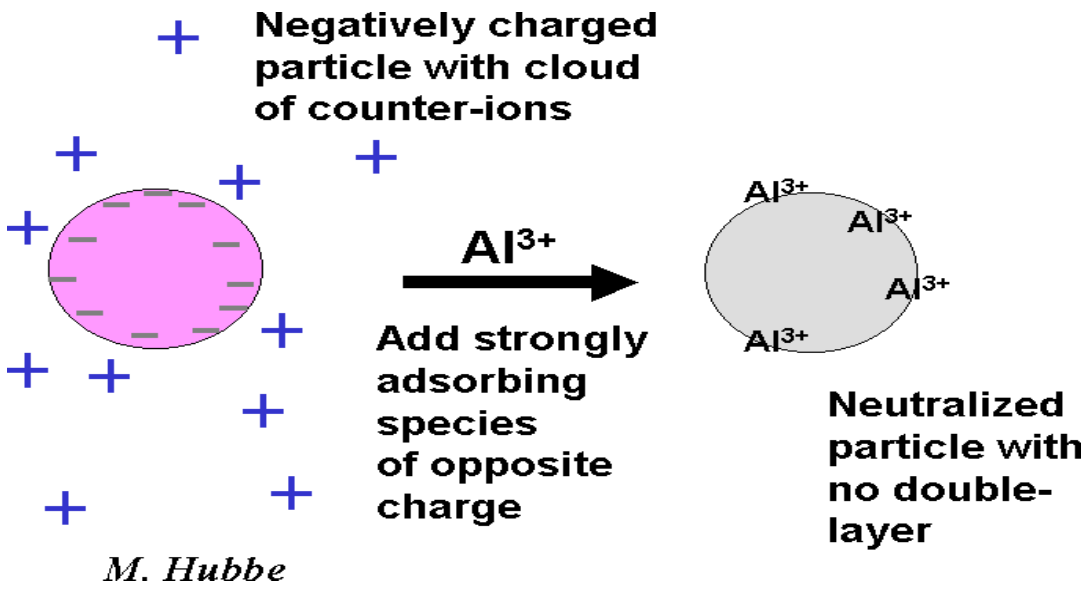
Flocculation is the agglomeration of destabilized particles into a large size particles known as flocs which can be effectively removed by sedimentation or flotation.

Principle of coagulation

- ✓ When certain chemicals are added to water an insoluble gelatinous flocculent is formed
- ✓ The gelatinous precipitate therefore has the property of removing fine and colloidal particle quickly and completely than by plain sedimentation
- ✓ These coagulants further the advantage of removing color, odor and taste from the water
- ✓ First the coagulant are mixed in the water to produce the required precipitate ,then the water is sent in the sedimentation basins

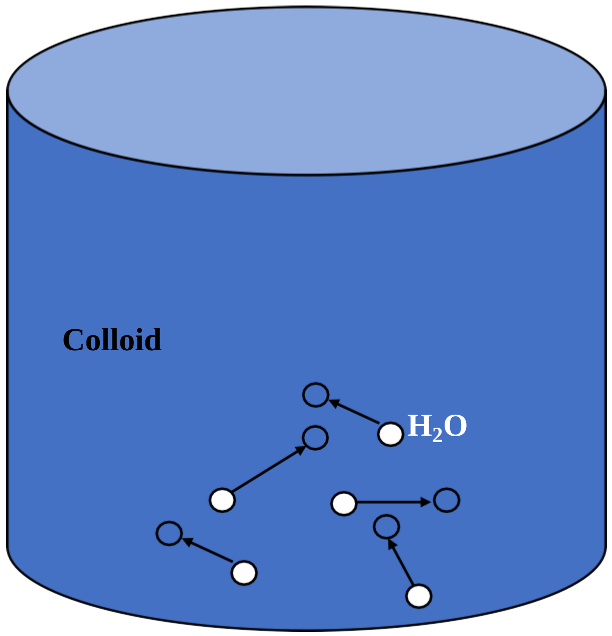
Coagulation aim

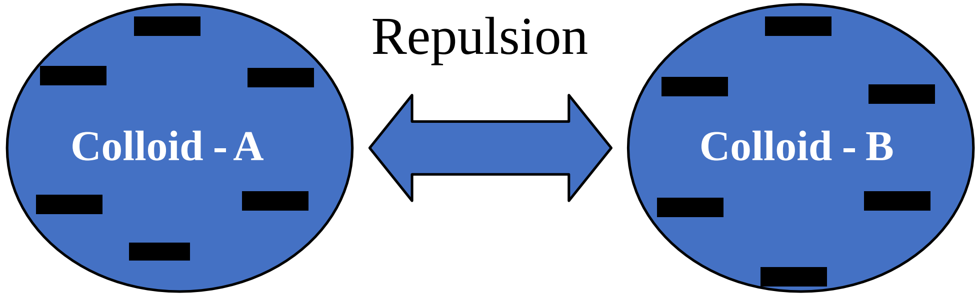




Colloid Stability

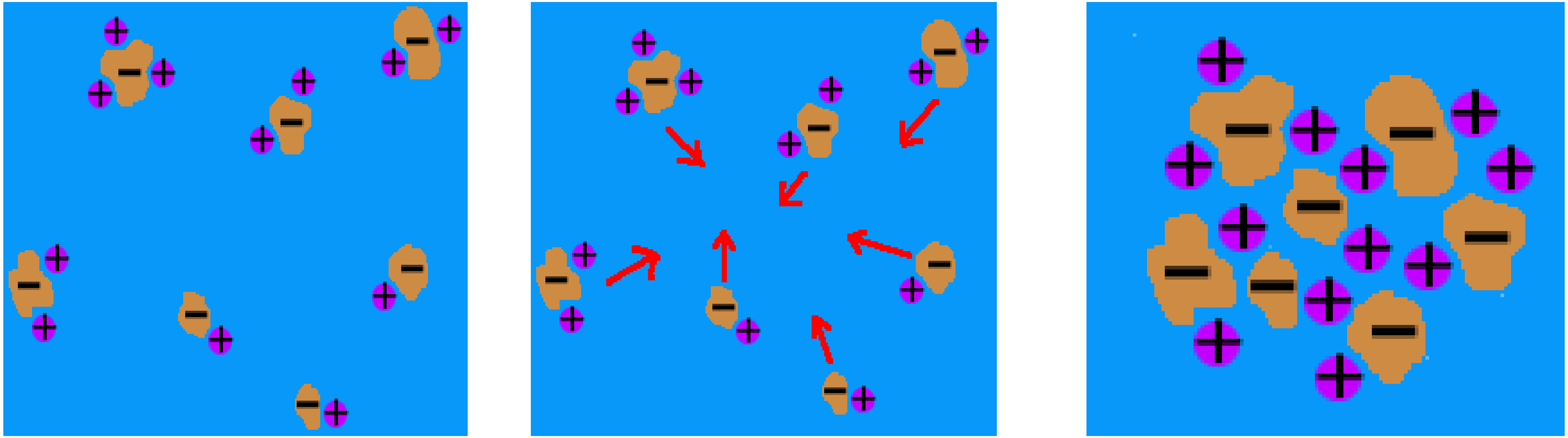
- ✓ Colloids have a net negative surface charge
- ✓ Electrostatic force prevents them from agglomeration





- ✓ Brownian motion keeps the colloids in suspension
- ✓ Impossible to remove colloids by gravity settling

- ✓ Colloids can be destabilized by charge neutralization
- ✓ Positively charged ions (Na^+ , Mg^{2+} , Al^{3+} , Fe^{3+} etc.) neutralize the colloidal negative charges and thus destabilize them
- ✓ With destabilization, colloids aggregate in size and start to settle

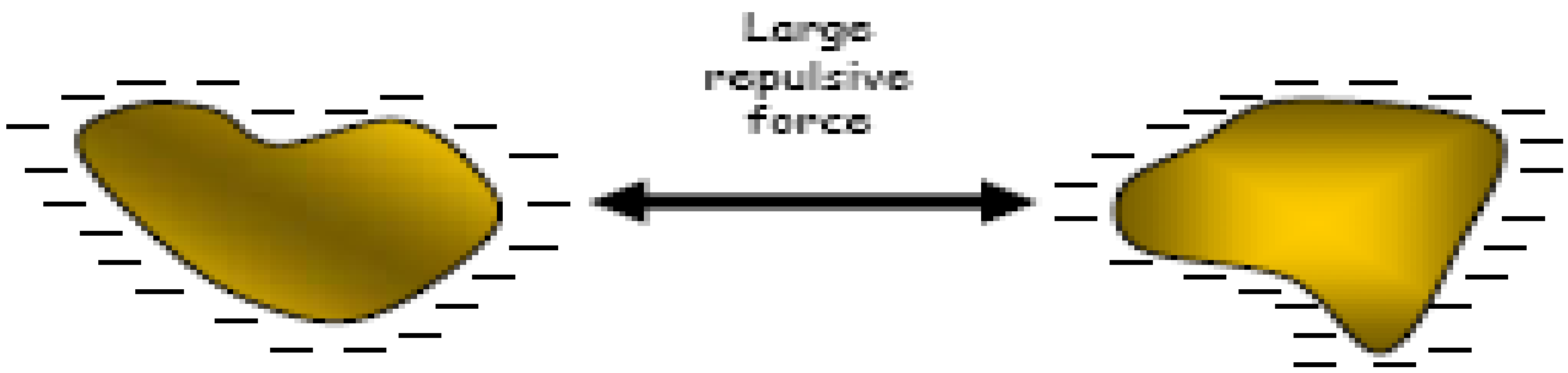


Colloidal interaction

- There are two major forces acting on colloids:

1) electrostatic repulsion

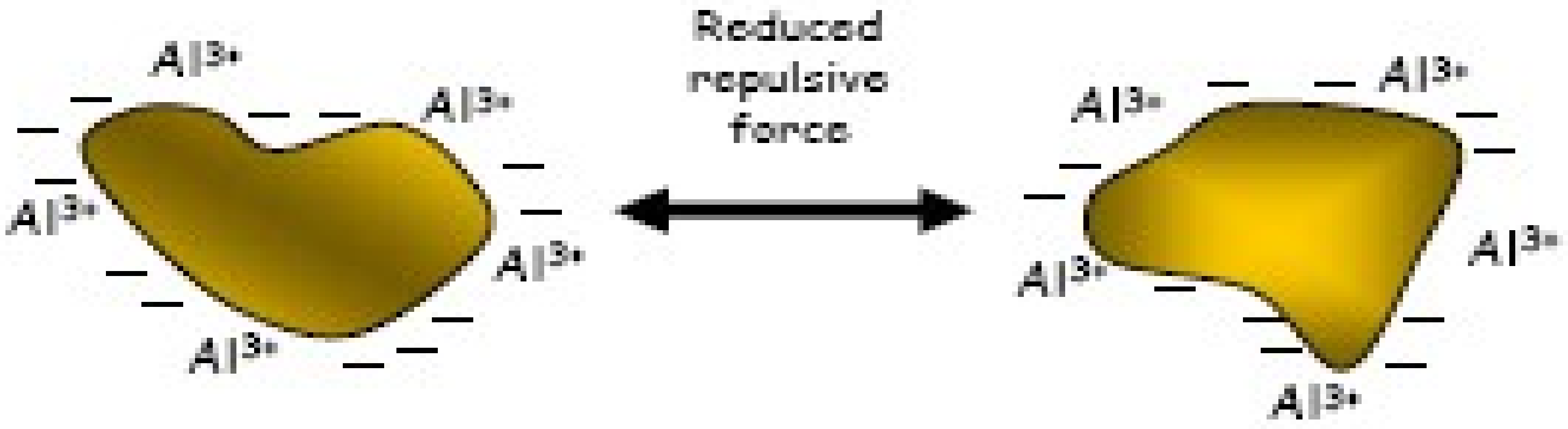
(simply, negative colloids repel other negatively charged colloids)



2) intermolecular, or van der Waals, attraction.

Charge reduction

- Coagulants can be used to reduce the electrostatic repulsive forces
- The electrostatic repulsion reduced by the addition of countercharged ions [Al^{3+}]



Jar Tests

- The jar test – a laboratory procedure to determine the **optimum pH** and the **optimum coagulant dose**
- A jar test simulates the coagulation and flocculation processes

Determination of optimum pH

- Fill the jars with raw water sample (500 or 1000 mL)
  – usually 6 jars
- Adjust pH of the jars while mixing using H_2SO_4 or NaOH/lime
  (pH: 5.0; 5.5; 6.0; 6.5; 7.0; 7.5)
- Add same dose of the selected coagulant (alum or iron) to each jar
  (Coagulant dose: 5 or 10 mg/L)

Jar Test

Jar Tests – determining optimum pH

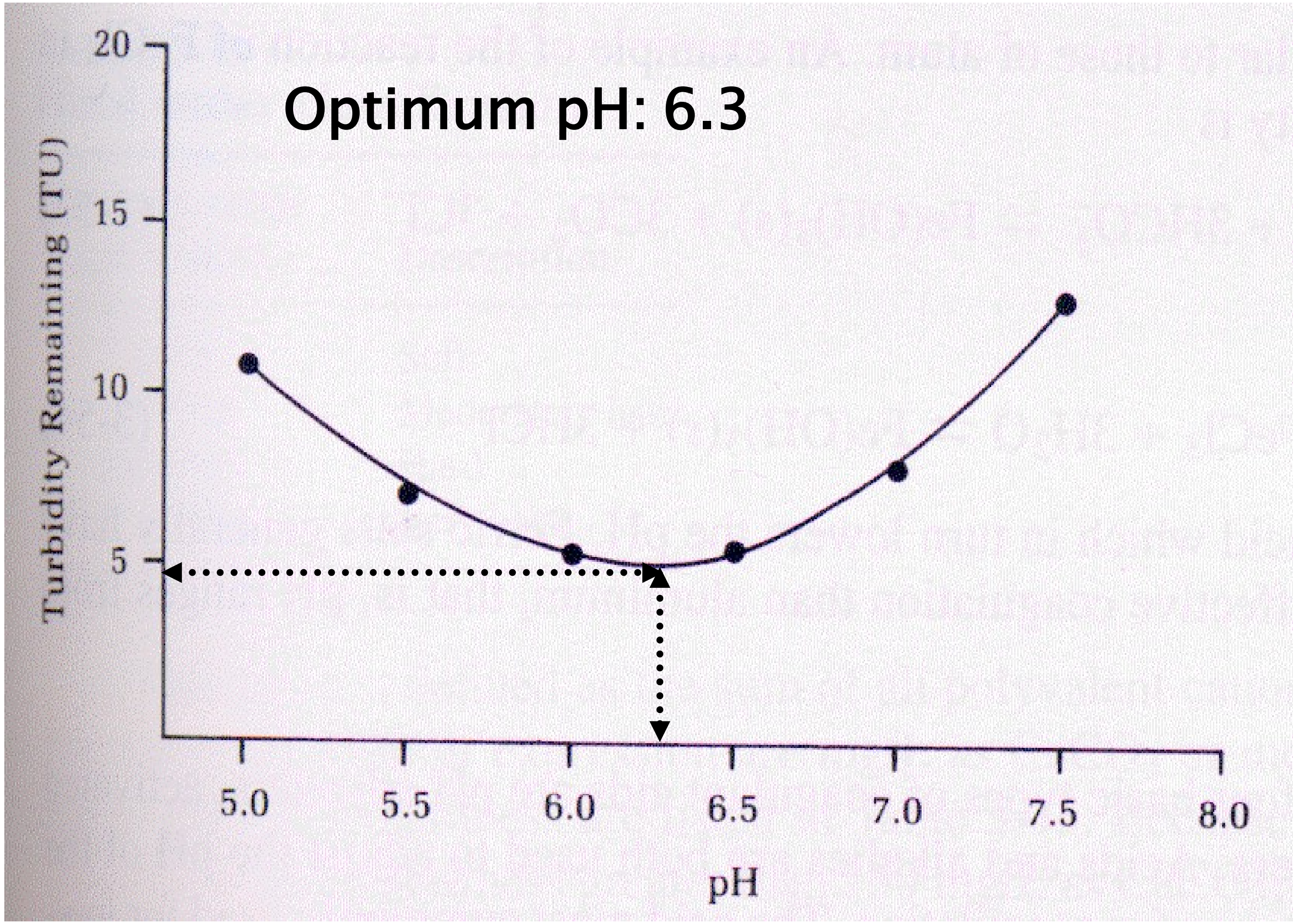
- ❑ Rapid mix each jar at 100 to 150 rpm for 1 minute. The rapid mix helps to disperse the coagulant throughout each container
- ❑ Reduce the stirring speed to 25 to 30 rpm and continue mixing for 15 to 20 mins.

This slower mixing speed helps promote floc formation by enhancing particle collisions, which lead to larger flocs

Jar Test set-up

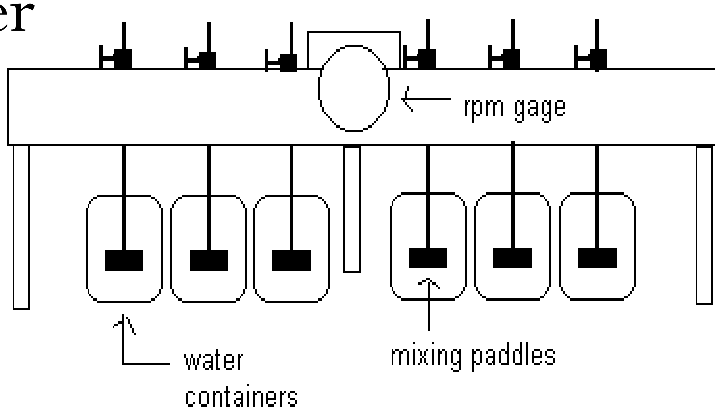
- ❑ Turn off the mixers and allow flocs to settle for 30 to 45 mins
- ❑ Measure the final residual turbidity in each jar
- ❑ Plot residual turbidity against pH

Jar Tests – optimum pH



Optimum coagulant dose

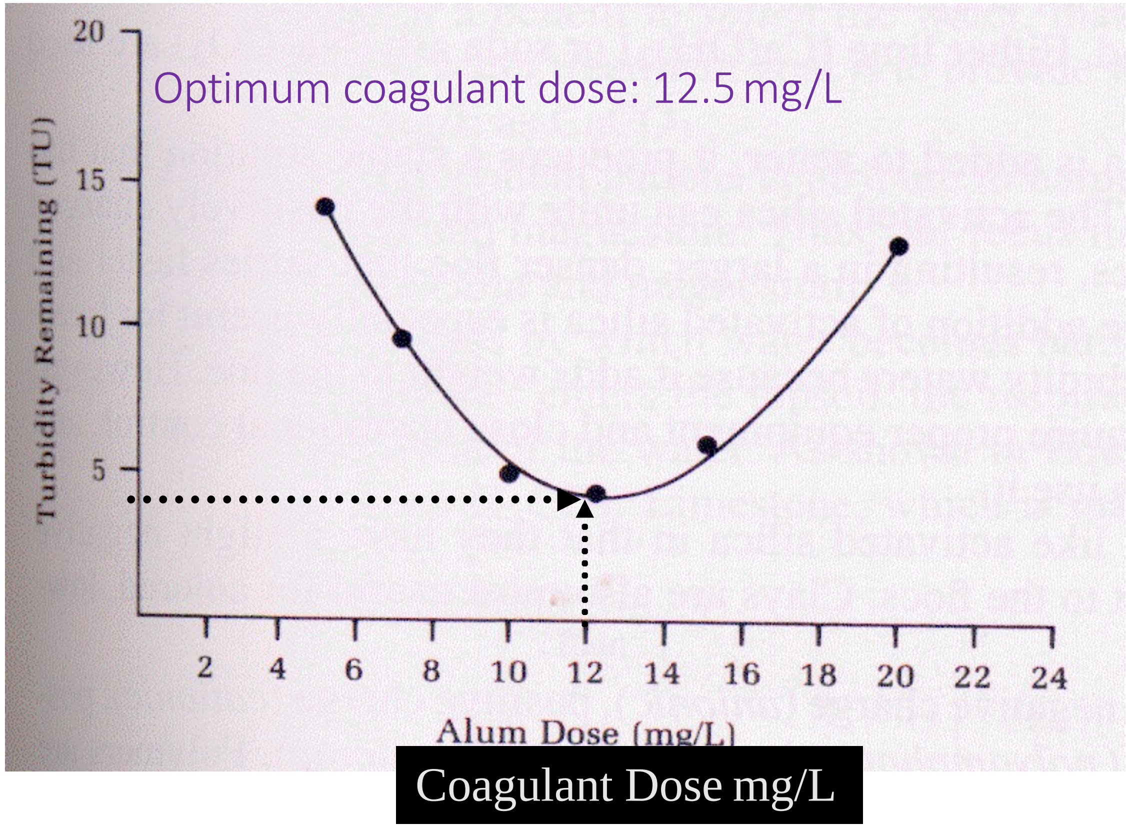
- Repeat all the previous steps
- This time adjust pH of all jars at optimum (6.3 found from first test) while mixing using H_2SO_4 or NaOH/lime
- Add different doses of the selected coagulant (alum or iron) to each jar (Coagulant dose: 5; 7; 10; 12; 15; 20 mg/L)
- Rapid mix each jar at 100 to 150 rpm for 1 minute. The rapid mix helps to disperse the coagulant throughout each container
- Reduce the stirring speed to 25 to 30 rpm for 15 to 20 mins



Optimum coagulant dose

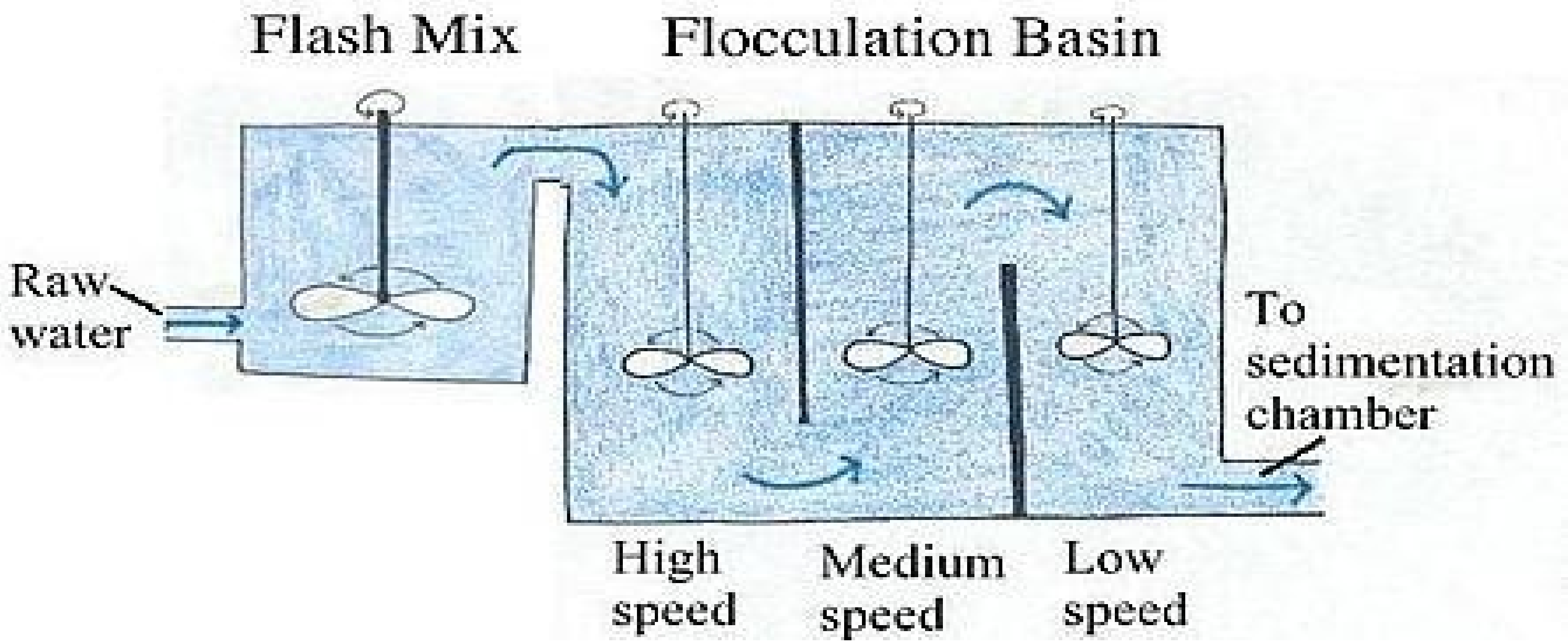
- ❑ Turn off the mixers and allow flocs to settle for 30 to 45 mins
- ❑ Then measure the final residual turbidity in each jar
- ❑ Plot residual turbidity against coagulant dose

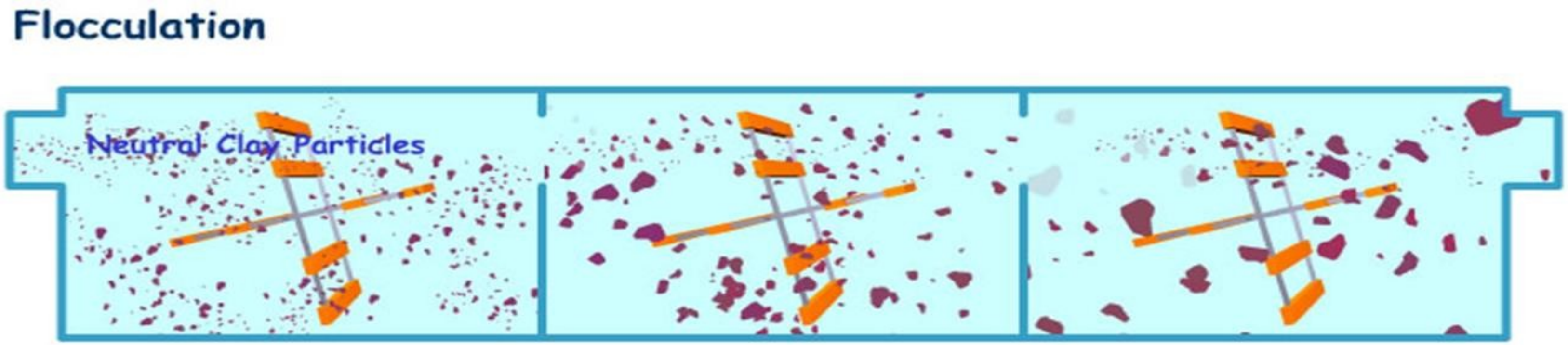
- The coagulant dose with the lowest residual turbidity will be the optimum coagulant dose



Factors affecting coagulation

1. Type of coagulant
2. Dose of coagulant
3. Characteristic of water
    - Type and quantity of suspended matter
    - Temperature of water
    - pH of water
4. Time and method of mixing


Flash Mix
Flocculation Basin
Raw water
To sedimentation chamber
High speed
Medium speed
Low speed


Flocculation
Neutral Clay Particles

Common Coagulants

- Coagulant chemicals come in two main types - primary coagulants and coagulant aids
- **Primary coagulants** neutralize the electrical charges of particles in the water which causes the particles to clump together
- **Coagulant aids** add density to slow-settling flocs and add toughness to the flocs so that they will not break up during the mixing and settling processes.

The following are the coagulants most commonly used:

i. Aluminum sulfate [$Al_2(SO4)_3.18H_2O$].

- ✓ It is also called Alum
- ✓ It is the most widely used chemical coagulant in water purification work
- ✓ Alum reacts with water only in the presence of alkalinity. If natural alkalinity is not present, lime may be added to develop alkalinity
- ✓ The chemical is found to be most effective between pH range of 6.5 to 8.5.
- ✓ Its dose may vary from 5 to 30mg/lit, for normal water usually dose being 14mg/l.

❖ **Due to the following reason, Alum is the most widely used chemical coagulant:-**

1. It is very cheap
2. It removes taste and color in addition to turbidity
3. It is very efficient
4. Flocs formed are more stable and heavy
5. It is not harmful to health
6. It is simple in working, doesn't require skilled supervision for dosing

ii. Sodium aluminates ($Na_2Al_2O_4$)

- ✓ In the process of coagulation, it can remove carbonate and non-carbonate hardness
- ✓ It reacts with calcium and magnesium salts to form flocculent aluminates of these elements.

iii. Chlorinated Copperas ($FeSO_4 . Cl$)

- ✓ Combination of Ferric Sulphate and Ferric chloride.
- ✓ When solution of Ferrous Sulphate is mixed with chlorine, both Ferric Sulphate and Ferric chloride are produced

- ✓ Ferric Sulphate and Ferric chloride each is an effective floc and so also their combination
- ✓ Ferric chloride effective in pH range 3.5 – 6.5 or above 8.5

iv. Poly electrolytes

v. Hydrated lime

vi. Copperas ($FeSO_4 . 7H_2O$)

Example

- Find out the quantity of alum required to treat 18 million liters of water per day. The dosage of alum is 14mg/lit. Also work out the amount of CO_2 released per liter of treated water.

  The reaction is as follow:-

$$Al_2(SO_4)_3.18H_2O + 3Ca(HCO_3)_2 \longrightarrow 2Al(OH)_3 + 3CaSO_4 + 18H_2O + 6CO_2$$

Solution

Quantity of alum per day = $(14*18*10^6)/ 10^6$ = 252kg

The chemical reaction as follow:

$Al_2 (SO_4)_3.18H_2O+3Ca (HCO_3)_2 \longrightarrow 2Al(OH)_3+3CaSO_4+18H_2O+6CO_2$

Molecular weight of alum:

=2*26.97+3*32.066+36*1.008+30*16

=666

Molecular weight of CO_2 = (1*12.0) + 2*16) = 44

Thus

666mg of alum release 6*44mg of CO_2

14mg of alum will releases = (14*6*44)/666

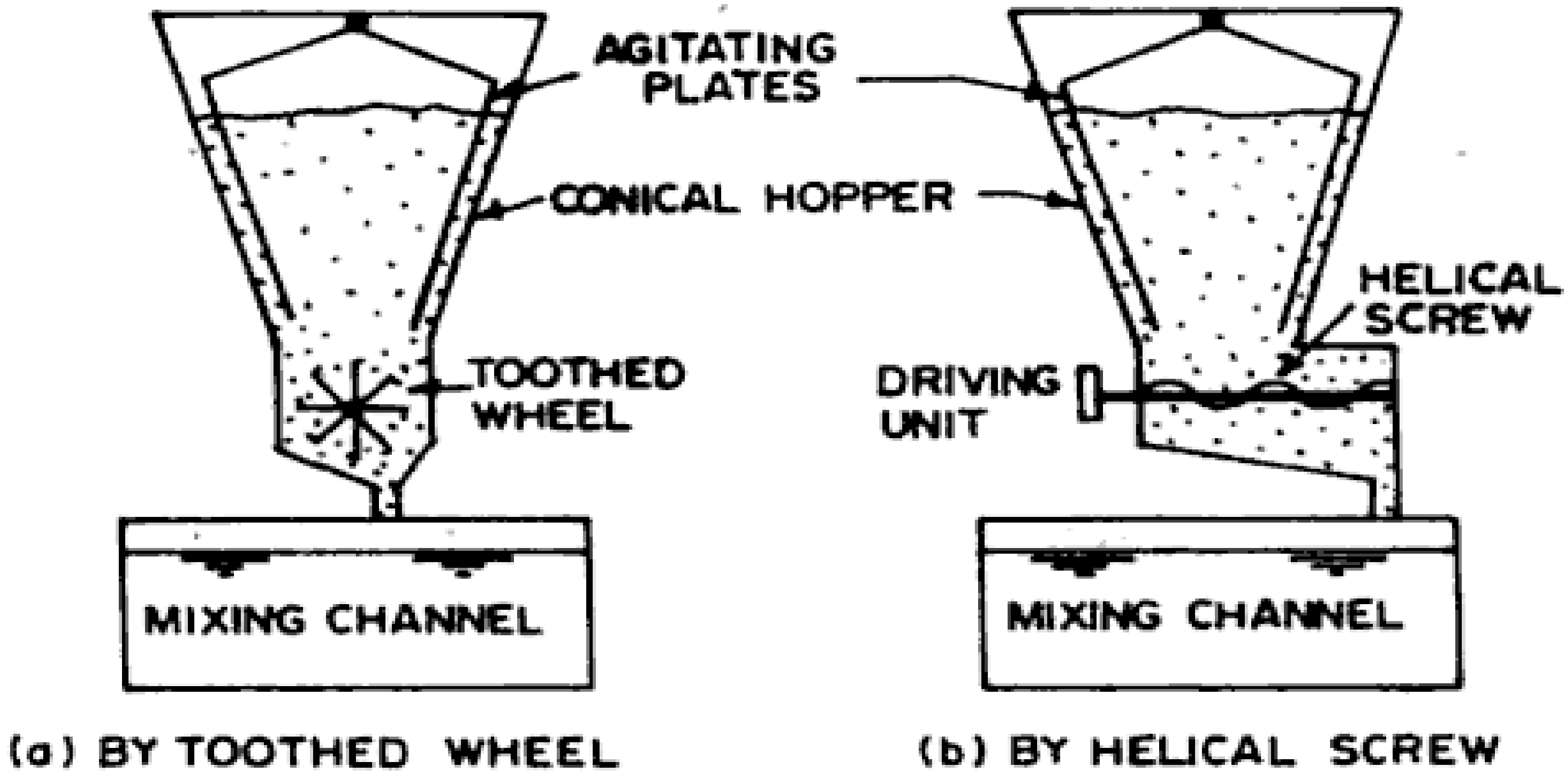
=5.55mg of CO_2

Feeding of coagulant

- ✓ Coagulants may be put in raw water either in powder form or in solution form
- ✓ In order to feed chemicals to the water regularly and accurately, some type of feeding equipment must be used.

I. Dry-feed Type

- ✓ Dry powder of coagulant is filled in the conical hopper
- ✓ The hoppers are fitted with agitating plates which prevent the chemical from being stabilized.



Dry feeding devices

II.Wet feeding type

- ✓ First, solution of required strength of coagulant is prepared
- ✓ The solution is filled in the tank and allowed to mix in the mixing channel in required proportion to the quantity of water
- ✓ It can be easily controlled with automatic devices.

Recommended values for coagulants

- Dosage
  - Alum: 10-150 mg/L
  - Ferric sulfate: 10-250 mg/L
  - Ferric chloride: 5-150 mg/L
- pH
  - Alum: 5.5-7.7
  - Fe3+: 5-8.5
- Initial mixing time (Al^{3+} and Fe^{3+})
  - Rapid mixing of 10 s and preferably less than 1m.

Mixing devices

- ✓The process of floc formation greatly depends upon the effective mixing (rapid mixing) of coagulant with the raw water
- ✓Rapid mixing of the mixture of coagulant and raw water is used to:
  - Disperse chemicals uniformly throughout the mixing basin
  - Allow adequate contact between the coagulant and particles
  - Formation of micro flocs

The mixing is done by mixing device.

1. Hydraulic jump - flume with considerable slope is developed
2. Pump method - centrifugal pump is used to raise raw water
3. Compressed air method – compressed air is diffused from bottom of the mixing tank
4. Mixing channels

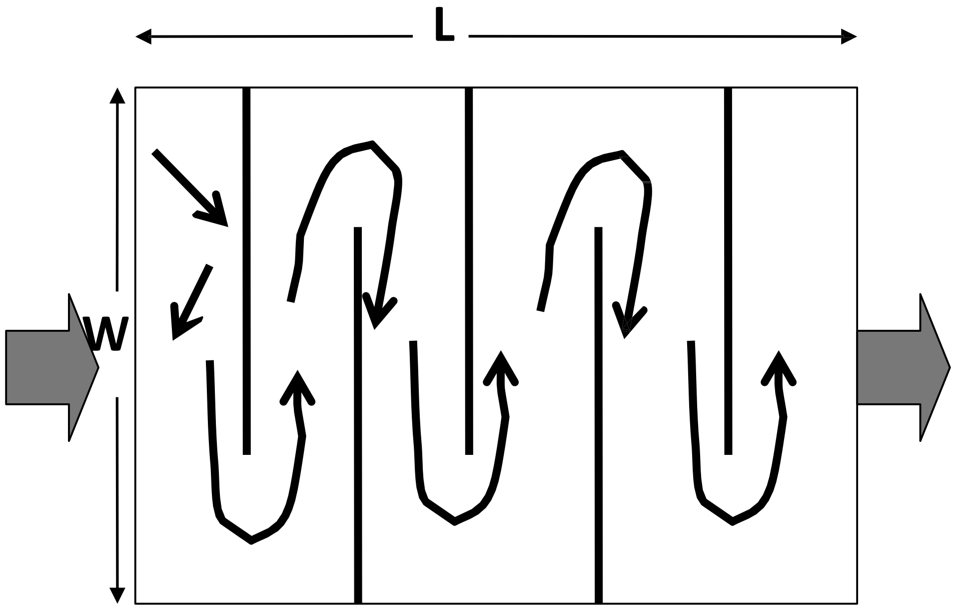
5. Mixing basin with baffle wall

6. Mechanical mixing basins

Mechanical means are used to agitate the mixture to achieve the objective of thorough mixing.

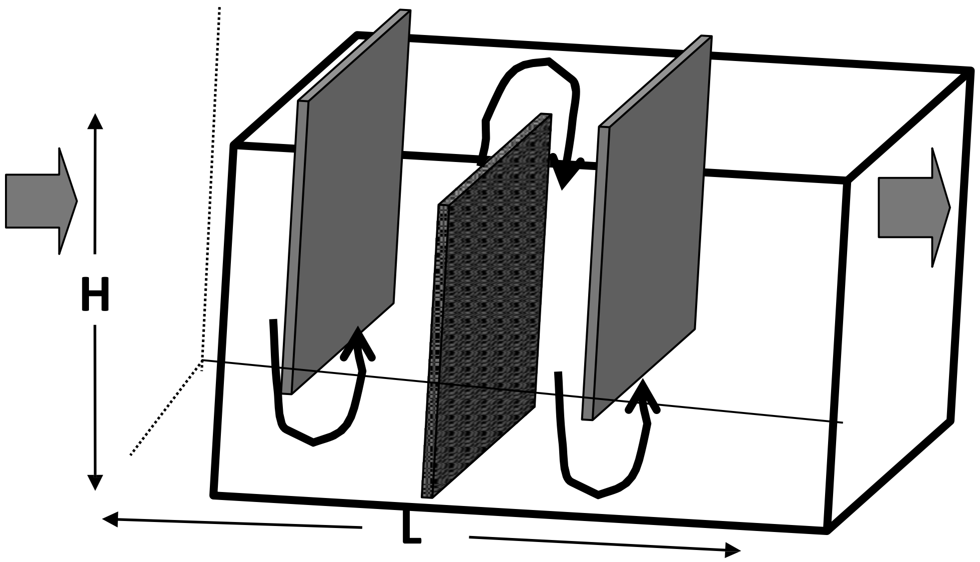
Baffled channel basin

Horizontal baffled tank



Plan view (horizontal flow)

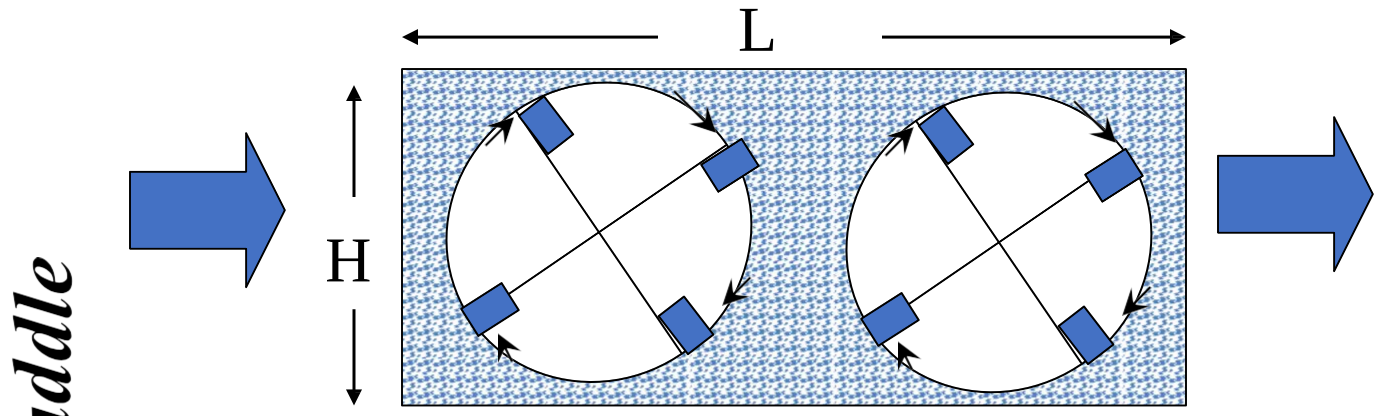
Vertical baffled tank



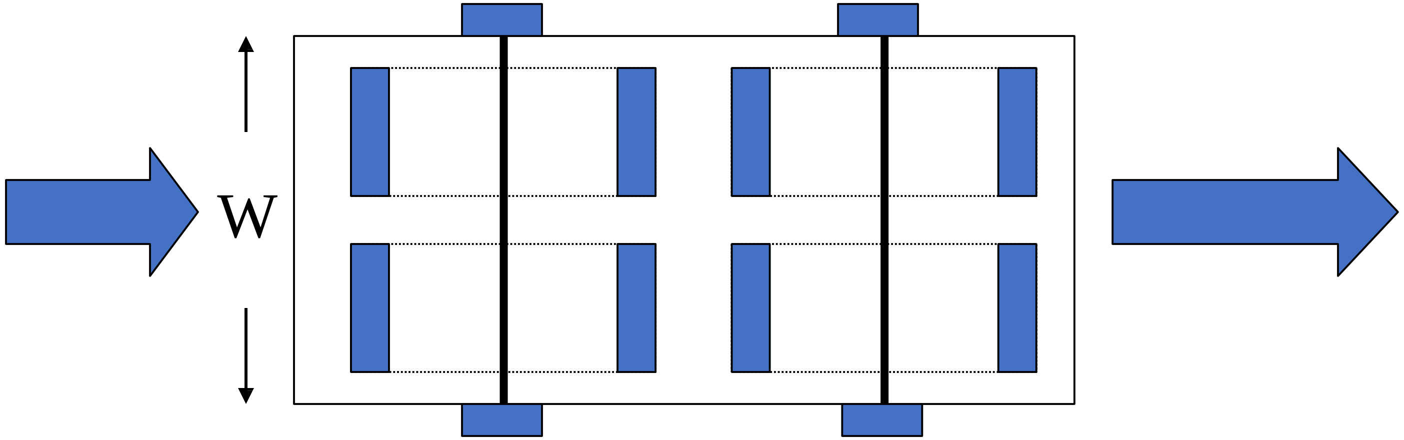
Isometric View (vertical flow)


Hydraulic flocculators: simple technology

Mechanical Flocculator- Paddle

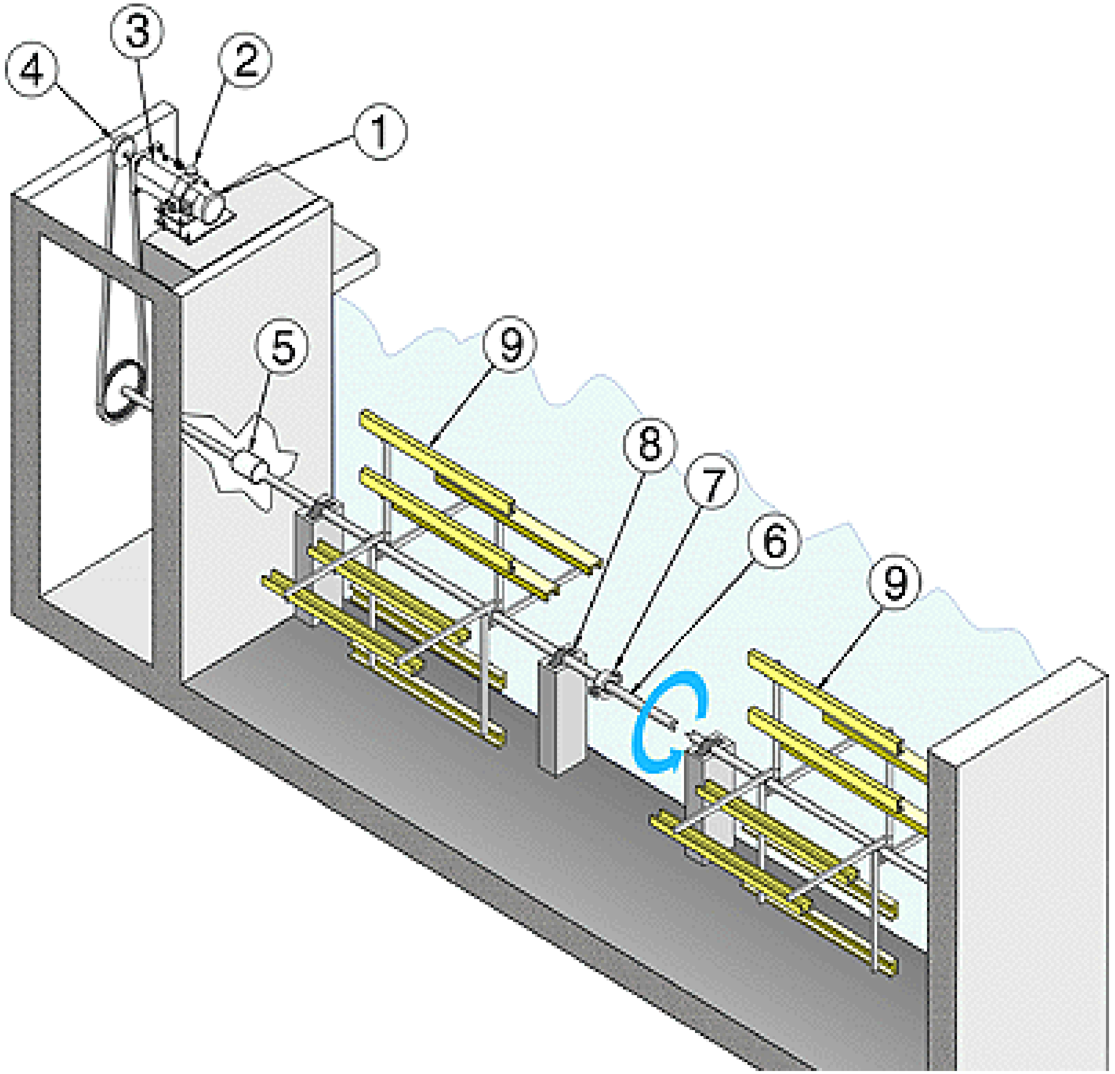


Cross flow Flocculator (sectional view)

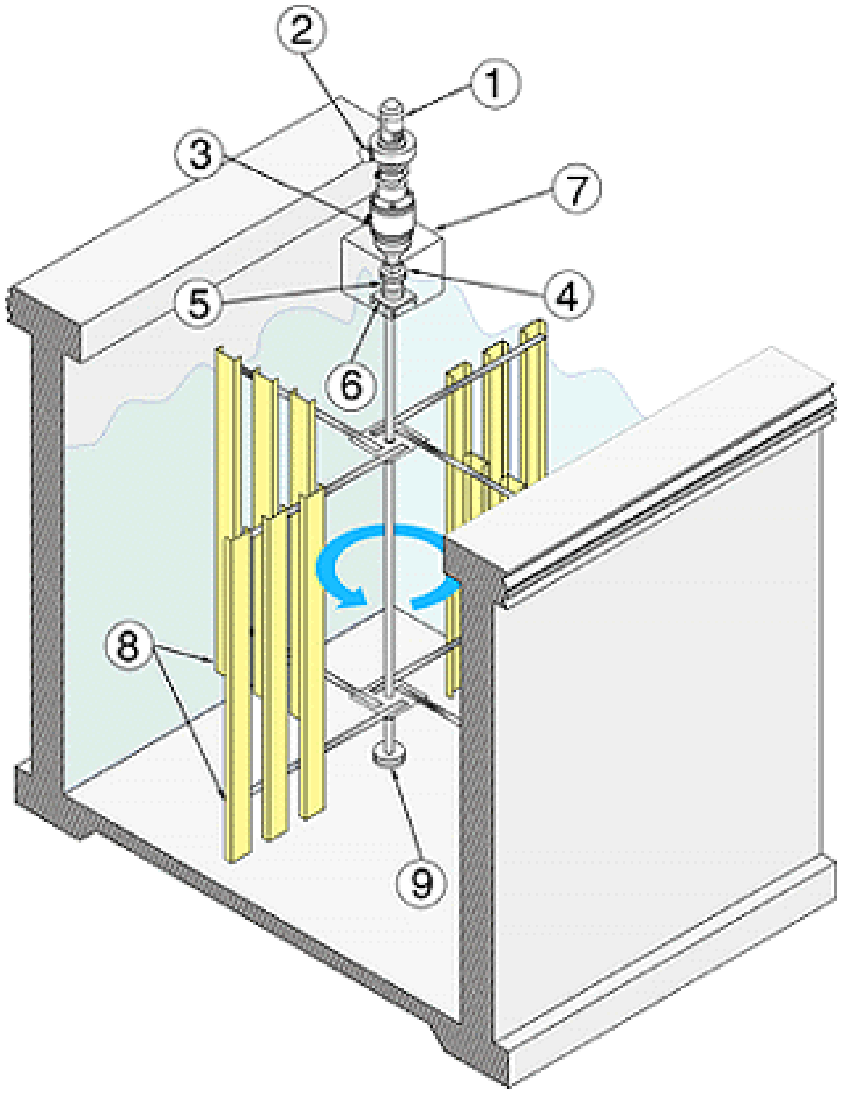


Plan (top view)

Paddle- horizontal shaft



Paddle- vertical shaft



Flocculation

- ✓ Next to rapid mixing, mixture is kept slowly agitated for about 30 to 60min.
- ✓ Slow mixing process in which particles are brought into contact in order to promote their agglomeration is called *flocculation*.
- ✓ The tank or basin in which flocculation process is carried out is called *flocculation chamber.*
- ✓ The velocity of flow in the chamber is kept between 12 – 18cm/sec.
- ✓ Activated carbon in powder form can be used to speed up the flocculation

The rate of agglomeration or flocculation is dependent upon

- ✓ Type and concentration of turbidity
- ✓ Type of coagulant and its dose
- ✓ Temporal mean velocity gradient – G in the basin

- In the system of stirring, the velocity of fluid varies both **spatially** (from point to point) and **temporally** (from time to time). The spatial changes in velocity are identified by **velocity gradient**, **G.**
- The mean velocity gradient is the rate of change of velocity per unit distance normal to the section - (meter per second per meter) (T^{-1}).

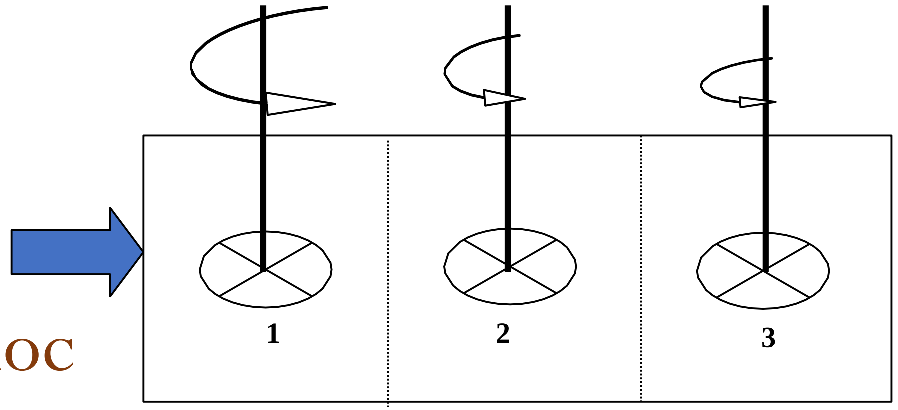
$$G = \left[\frac{P}{V * \mu}\right]^{1/2}$$

G= velocity gradient, s^{-1};
P = Power input, W
V = Tank volume, m^3;
μ = Dynamic viscosity, (Pa.s)

- G value for flocculation: 20 to 80 S^{-1};
  Mixing time: 20 to 60 min

In the flocculator design, Gt (also known Camp No.); a product of G and t is commonly used as a design parameter

Typical Gt for flocculation is 2 x 10^4 - 10^5

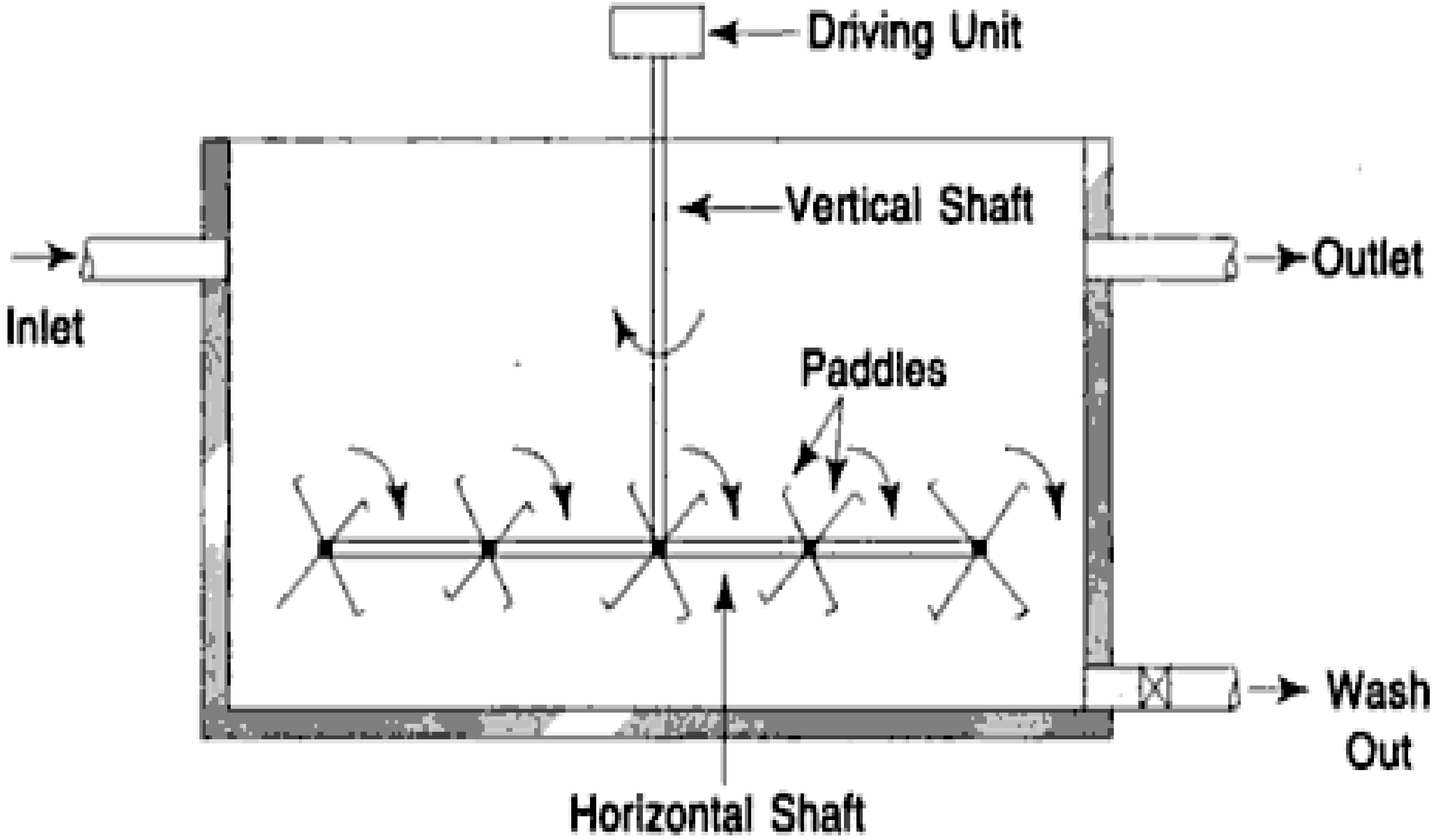


- **Large G and small T** gives small but dense floc
- **Small G and large T** gives big but light flocs (adequate collision will not occur and proper floc will not formed)

- We need big as well as dense flocs, which can be obtained by designing flocculator with different G values.

The design criteria of a horizontal continuous flow rectangular basin flocculator:

(*i*)	Depth of tank	: 3 to 4.5 m
(*ii*)	Detention time	: 10 to 40 min. ; normal : 30 min.
(*iii*)	Velocity of flow	: 0.2 to 0.8 m/s ; normal 0.4 m/s
(*iv*)	Total area of paddles	: 10 to 25% of the cross-sectional area of the tank
(*v*)	Peripheral velocity of blades	: 0.2–0.6 m/s ; normal 0.3 to 0.4 m/s
(*vi*)	Velocity gradient (*G*)	: 10 to 75 s^{-1}
(*vii*)	Factor *G.t*	: 10^4 to 10^5
(*viii*)	Power consumption	: 10.0 to 36.0 kW/mld
(*ix*)	Outlet flow velocity	: 0.15 to 0.25 m/s.



Flocculator

Power Calculation

What horsepower level do we need to supply to a flocculation basin to provide a G value of $100s^{-1}$ and a Gt of 100,000 for 10 MGD flow? **(Given:** $\mu = 0.89 \times 10^{-3}$ Pa.s; 1 hp = 745.7 watts)

Solution:

Retention time, $t = Gt/G = 100{,}000/100 = 1000$ sec

Volume of Flocculation basin, $V = (0.438\ m^3/sec) \times (1000\ sec)$

$= 438\ m^3$

$$G = \left[\frac{P}{V * \mu}\right]^{1/2}$$

$P = G^2 V \times \mu$

$= 100^2 \times 438 \times 0.89 \times 10^{-3} = 3900$ W

$= 3900/746 = 5.2$ hp

Example 1

Design a conventional vertical-shaft rapid mix tank unit for uniformly dispersing coagulant in 10 MLD of settled raw water as per design parameters given below:

- Detention time (t): 20 – 60 s
- Ratio of tank height (H) to diameter (D): (1:1 to 1:3)
- Ratio of impeller diameter (DI) to tank diameter (D): (0.2:1 to 0.4:1)
- Velocity gradient (G): >300 /s
- Gt: 10000 – 20000

- Tank diameter (D): < 3 m
- Paddle tip speed (vp): 1.75 – 2.0 m/s
- Velocity of paddle relative to water (v): 0.75 x paddle tip speed
- Paddle area (Ap)/Tank section area (AT): 10:100 – 20:100
- Coefficient of drag on impeller blade (CD): 1.8
- Maximum length of each impeller blade (L): 0.25 x impeller diameter
- Maximum width of impeller blade (B): 0.20 x impeller diameter
- Impeller height from bottom (HB): 1.0 x impeller diameter
- Kinematic viscosity : 1.003 x 10-6 m2/s
- Dynamic viscosity of water : 1.002 x 10-3 N.s/m2

Determine tank dimensions (provide a freeboard of 0.5 m), impeller diameter, paddle dimensions, number of paddles, clearance of the impeller from tank bottom, paddle rotation speed and power input requirement.

Examples 2

A water treatment plant of design capacity 378500 m^3/d requires 100 mg/L of alum to remove 25 mg/L suspended solids. Estimate the mass of alum required every day (kg/day) and the maximum mass of dry solids (in kg/day) that are removed from the plant.

Examples 3

Design a mechanical rapid mix tank used for treating 75700 m^3/d of water that has a temperature of 10^oC. The items you need to determine are: 1) tank volume 2) tank dimensions and 3) power consumption. Use a detention time of 2 minutes, velocity gradient of 850 s^{-1} and cubic tank geometry.

Examples 4

A water treatment plant is designed to process 100 x 10 ^{6} L/d. The flocculator is 30 m long, 15 m wide, and 5 m deep. Revolving paddles are attached to four horizontal shafts that rotate at 1.5 rpm. Each shaft supports four paddles that are 200 mm wide, 15 m long and centered 2 m from the shaft. Assume the mean water velocity to be 70% less than paddle velocity and C_D = 1.8. All paddles remain submerged all the time. Find:

a) the difference in velocity between paddles and water

b) the value of G and

c) the Camp number.

SEDIMENTATION

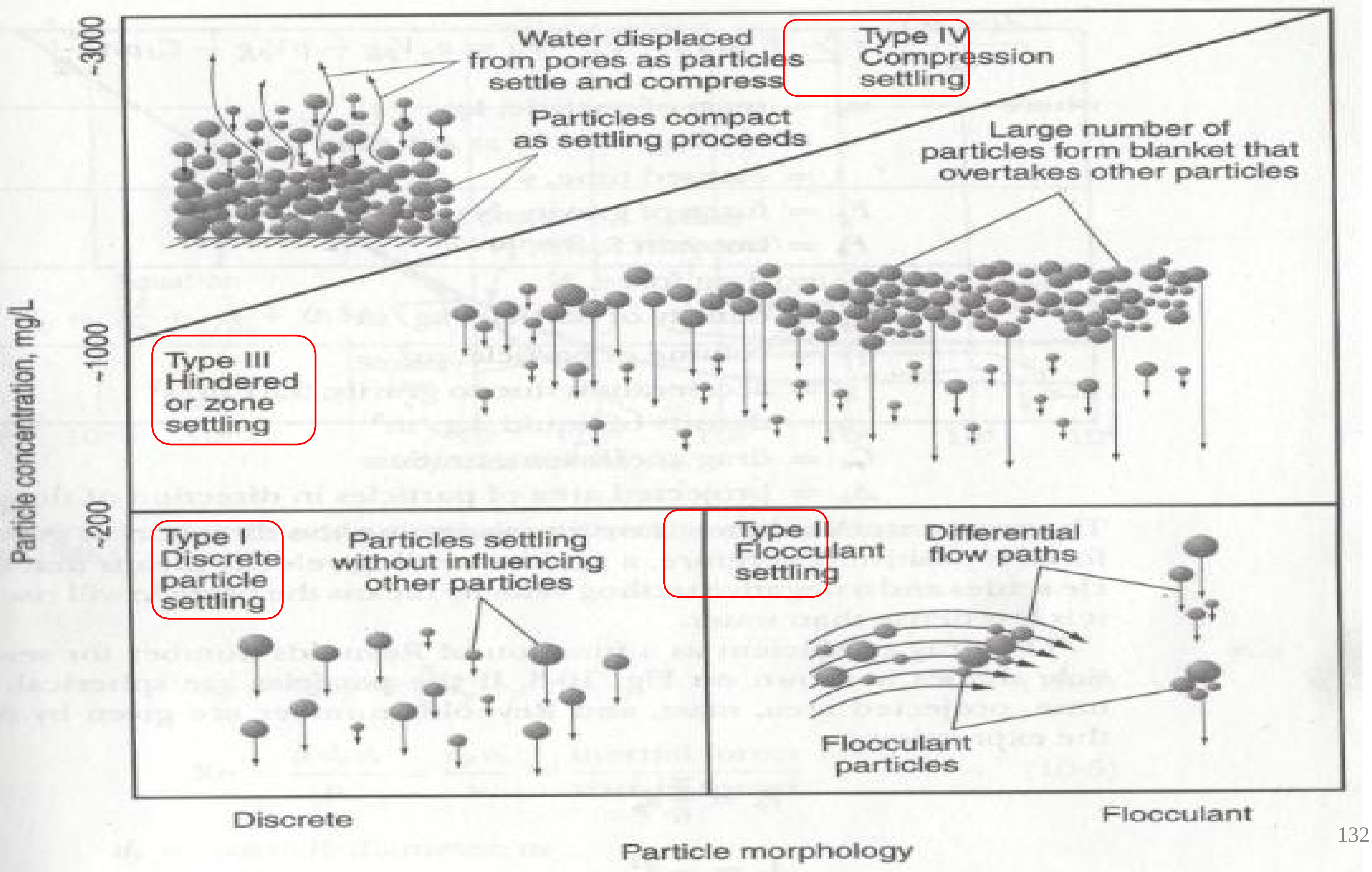
Definition and Use

- ✓Sedimentation is a treatment process in which the velocity of the water is lowered below the suspension velocity and the suspended particles settle out of the water due to gravity. The process is also known as settling or clarification
- ✓It is a commonly used unit operation in water and wastewater treatment plants.
- ✓This type of sedimentation requires chemical addition (in the coagulation/flocculation step) and removes the resulting floc from the water.
- ✓It is not be necessary in low turbidity water of less than 10 NTU

- ✓The purpose is to decrease the concentration of suspended particles and reducing the load on the filters.
- ✓Sedimentation at this stage in the treatment process should remove 90% of the suspended particles from the water, including bacteria

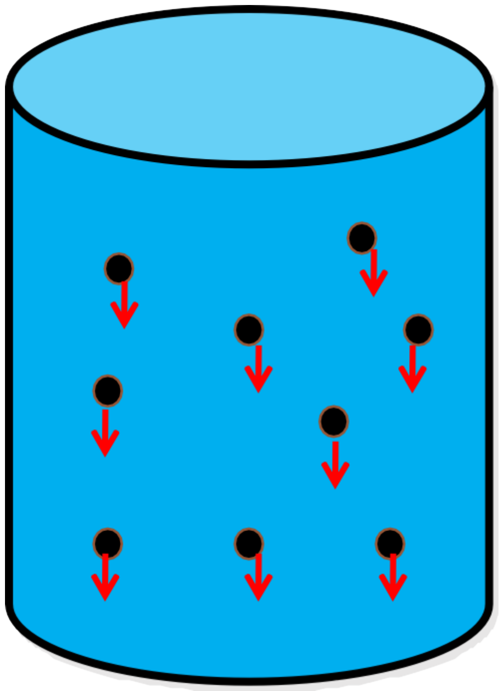
- *Water Treatment:*
  - Plain Sedimentation (Pre-sedimentation)
  - Sedimentation after Flocculation
  - Sedimentation after Softening

Types of Sedimentation



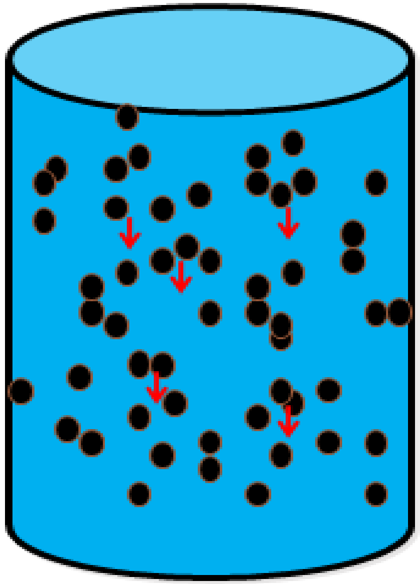
Type I: Discrete particle settling

- ✓Particles settle individually without interaction with neighboring particles.
- ✓Any particle which does not change its size, shape, and weight while rising or settling in any fluid is called discrete particle
- ✓It occurs under low solids concentration.
- ✓Settling velocity is constant for individual particles

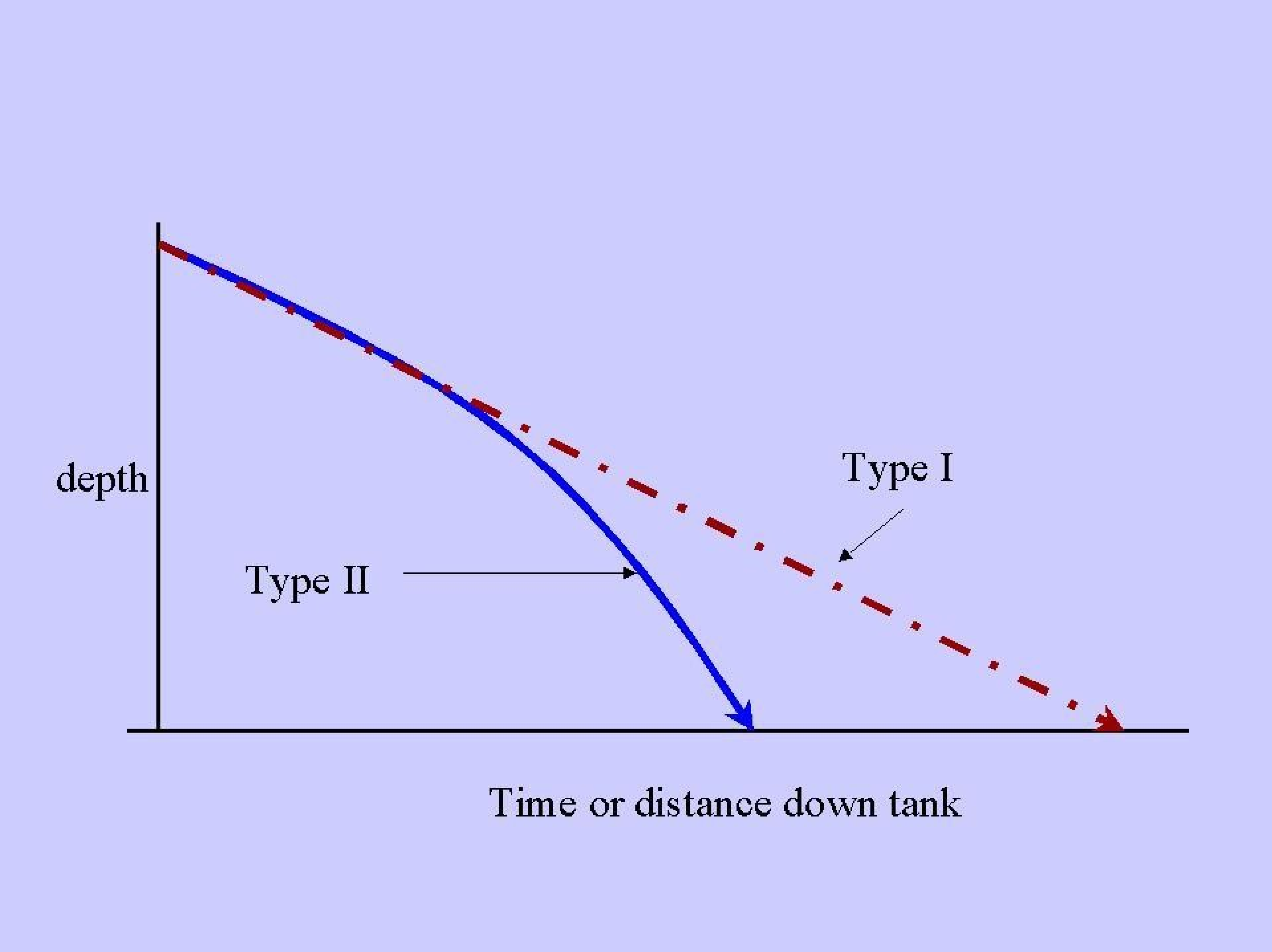


Type II: Flocculent particles

- ✓Flocculation causes the particles to increases in mass and settle at a faster rate.
- ✓Particles collide and adhere to each other resulting in particle growth
- ✓Examples: coagulation/flocculation settling in water treatment and primary sedimentation in wastewater treatment



Comparison of Type I and II sedimentation



Type III: Hindered or Zone settling

- The mass of particles tends to settle as a unity with individual particles remaining in fixed positions with respect to each other.
- Particles are so close together movement is restricted
- Solids move as a block rather than individual particles
- Fluidic interference causes a reduction in settling velocity
- Example: settling of secondary effluents

Type IV: Compression settling

- ✓ The concentration of particles is so high that sedimentation can only occur through compaction of structure.
- ✓ Particles physically in contact
- ✓ Volume of water may decrease
- ✓ High concentration of solids (sludge)

Modeling Discrete Settling

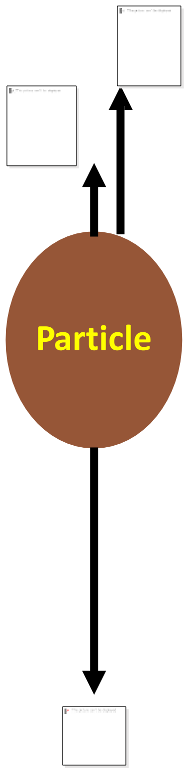
$$\sum F = ma$$

$$F_d + F_b - W = 0$$

$$F_b = \rho_w \forall_p g$$

$$W = \rho_p \forall_p g$$

$$F_d = C_d \rho A_p \frac{v_t^2}{2}$$



W = force of gravity, N

F_b = bouyant force, N

F_d = drag force, N

$\forall_p$ = Volume of particle, m^3

ρ_p = density of particle

ρ_w = density of water

g= acceleration due to gravity, m/s^2

C_d = drag coefficent, unitless

A_p = Projected area of particle in the direction of flow, m^2

v_t = settling velocity at any time, m/s

Terminal settling velocity

When forces are in equilibrium

$$F_d = W - F_b$$

$$C_D A_P \rho_w \frac{V_t^2}{2} = \forall_p (\rho_p - \rho_w) g$$

$$V_t^2 = \frac{2\forall_p (\rho_p - \rho_w) g}{C_D A_P \rho_w}$$

for a speherical particle

$$\forall_p = \frac{4}{3}\pi r^3 \qquad A_p = \pi r^2$$

$$V_t^2 = \frac{4}{3}\frac{gd}{C_D}\frac{(\rho_p - \rho_w)}{\rho_w}$$

$$V_t = \sqrt{\frac{4}{3}\frac{gd}{C_D}\frac{(\rho_p - \rho_w)}{\rho_w}}$$

- d = particle diameter
- C_D is a function of Reynolds number, R_e

$$\mathbf{Re} = \frac{V_t d\rho}{\mu} \quad \mathbf{OR} \quad \mathbf{Re} = \frac{V_t d}{\upsilon}$$

$$\mathbf{Re} < 1, C_D = \frac{24}{\mathbf{Re}} \qquad \textbf{laminar}$$

$$1 < \mathbf{Re} < 10^4, C_D = \frac{24}{\mathbf{Re}} + \frac{3}{\sqrt{\mathbf{Re}}} + 0.34 \qquad \textbf{transition}$$

$$\mathbf{Re} > 10^4, C_D \approx 0.4 \qquad \textbf{turbulent}$$

Stokes Law

- Using $C_d = 24/R_e$:

$$V_t = \frac{d^2 g(\rho_p - \rho_w)}{18\mu}$$

$$V_t = \frac{d^2 g(sg_p - 1)}{18\upsilon}$$

sg_p: Specific gravity of particle

υ: Kinematic viscosity, m^2/s

- Stokes law has limited applications in water treatment
- V_t should be calculated using the general formula by trial and error

$$V_t = \sqrt{\frac{4}{3}\frac{gd}{C_D}\frac{(\rho_p - \rho_w)}{\rho_w}}$$

Example

Find the terminal settling velocity for spherical particle with diameter 0.45 mm and density of 2650 kg/m^3 settling through water at 20 ^oC. Take dynamic viscosity as $1.002*10^{-3}$ at 20 ^oC

Classification of Sedimentation Tank

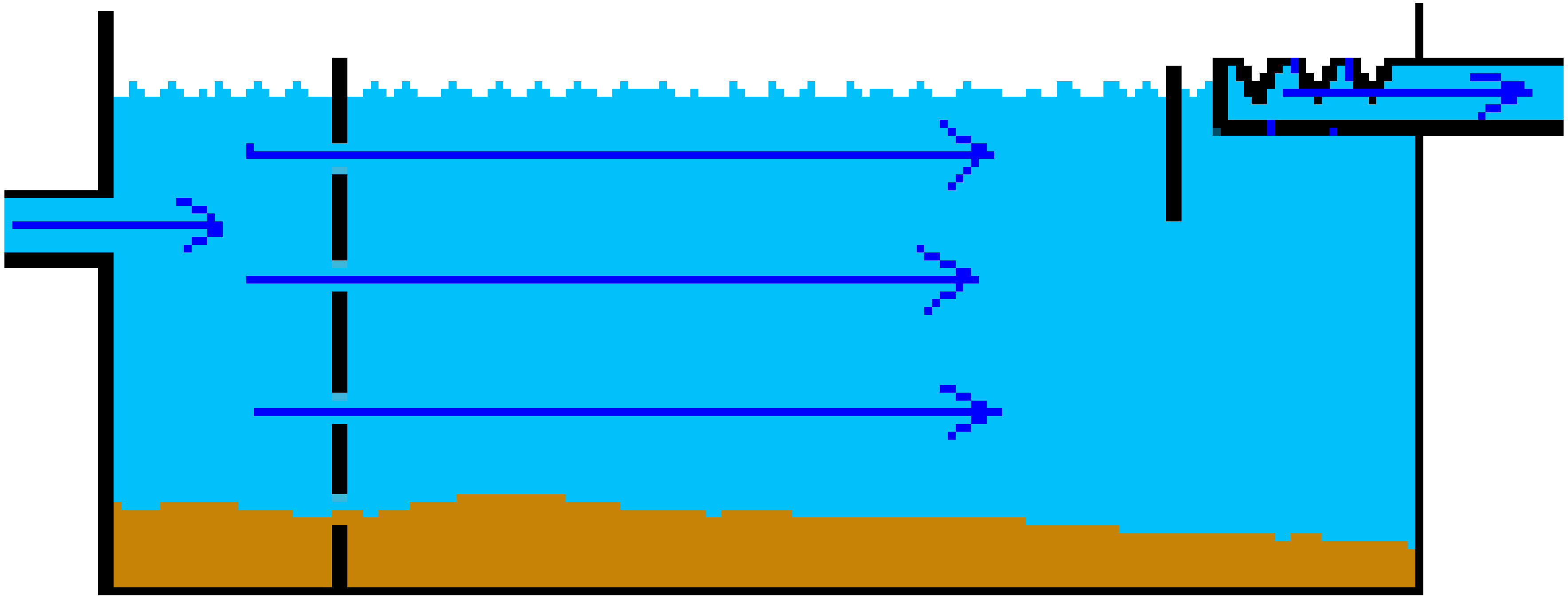
- ✓ Sedimentation tank are classified as continuous flow or intermittent flow
- ✓ The continuous flow types are mostly used now a days
- ✓ Tanks also classified as horizontal flow, when the liquid passes through in the horizontal direction and as vertical flow, when the liquid enters near the bottom of the tank and is withdrawn at the surface.
- ✓ The vertical flow type is generally used for sewage treatment.

COMMON TYPES OF SEDIMENTATION BASINS

1. RECTANGULAR BASINS

- ✓ Are the simplest design, allowing water to flow horizontally through a long tank.
- ✓ This type of basin is usually found in large-scale water treatment plants.
- ✓ Rectangular basins have a variety of advantages - predictability, cost-effectiveness, and low maintenance.
- ✓ In addition, rectangular basins are the least likely to short-circuit, especially if the length is at least twice the width.
- ✓ A disadvantage of rectangular basins is the large amount of land area required.

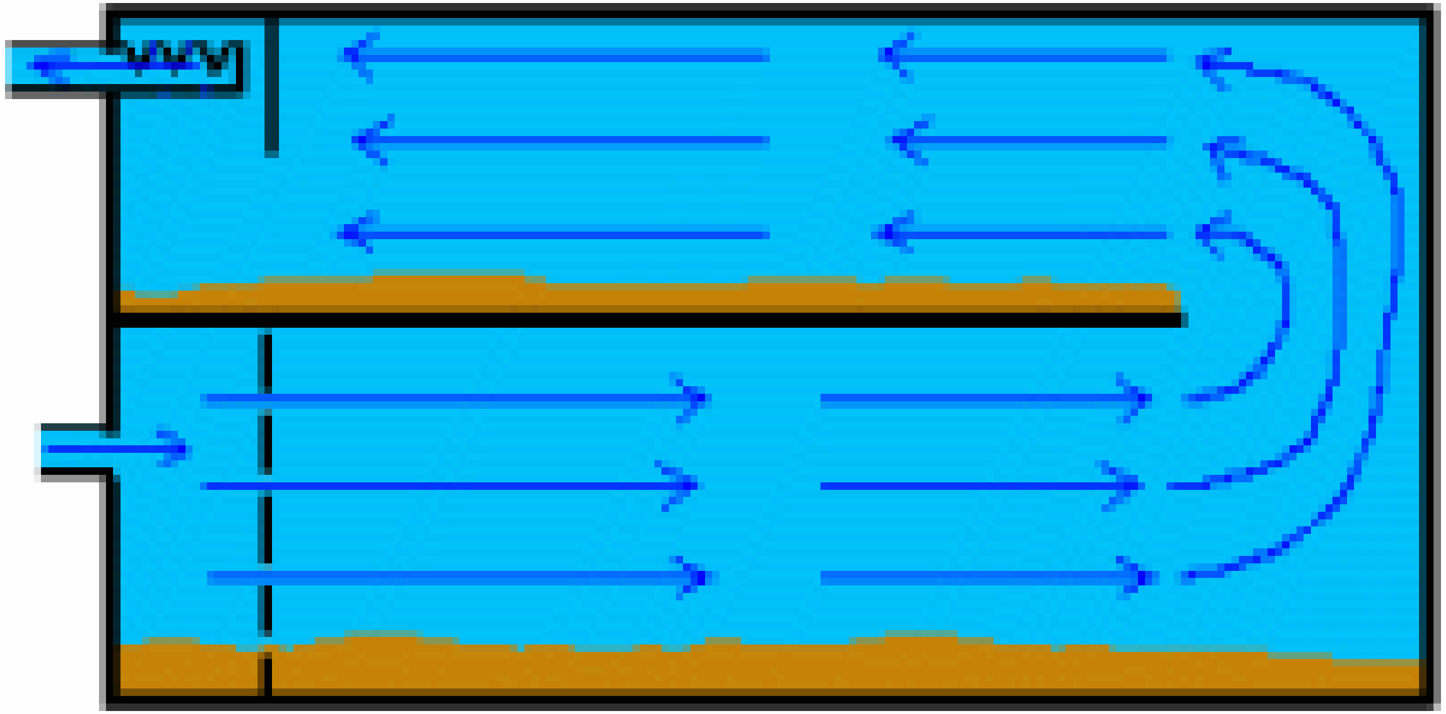
RECTANGULAR BASINS



2. DOUBLE-DECK RECTANGULAR BASINS

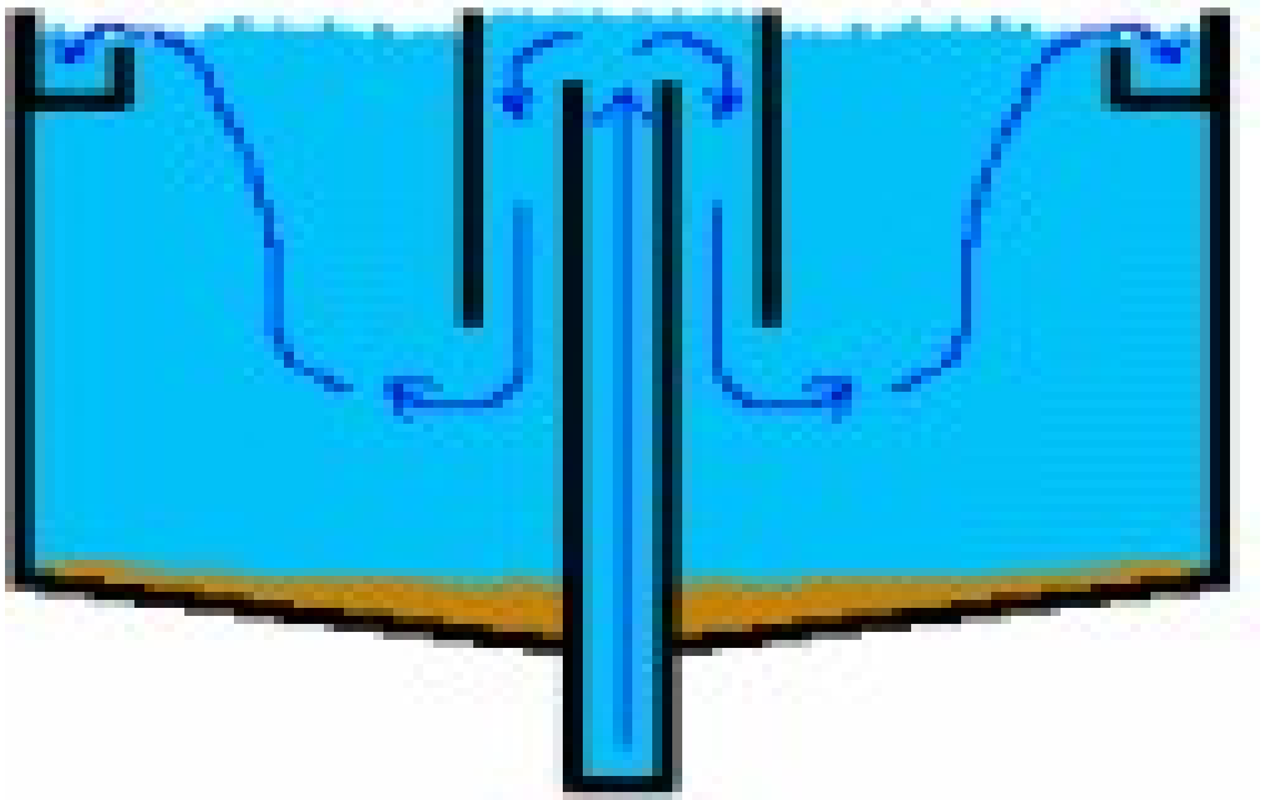
- Double-deck rectangular basins are essentially two rectangular sedimentation basins stacked one atop the other.
- This type of basin conserves land area, but has higher operation and maintenance costs than a one-level rectangular basin.

DOUBLE-DECK RECTANGULAR BASINS

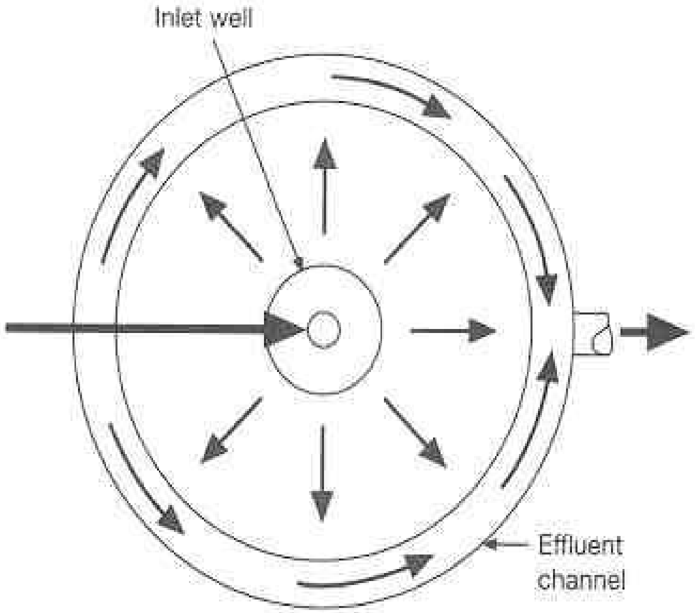


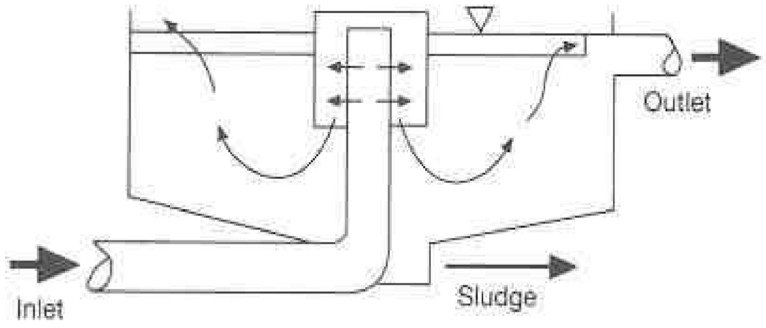
3. SQUARE OR CIRCULAR SEDIMENTATION BASINS

- ✓ Square or circular sedimentation basins with horizontal flow are often known as **clarifiers.**
- ✓ This type of basin is likely to have short-circuiting problems.

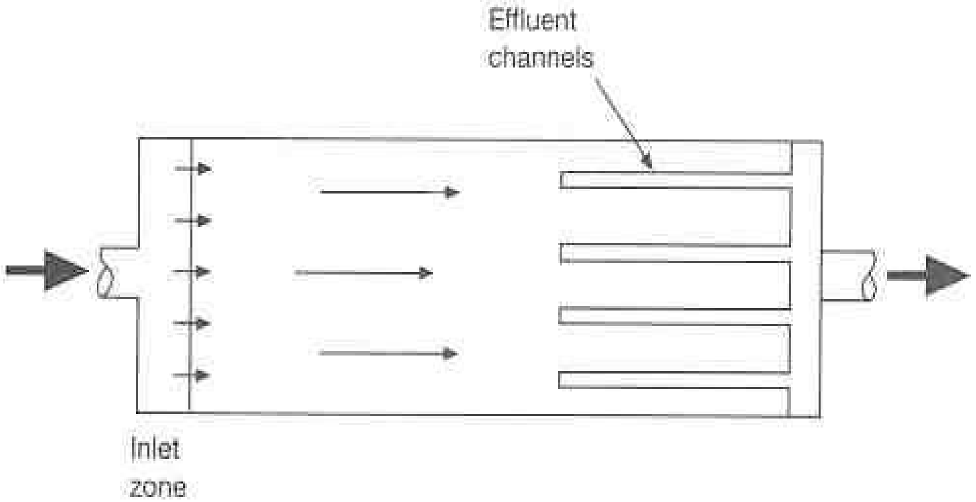


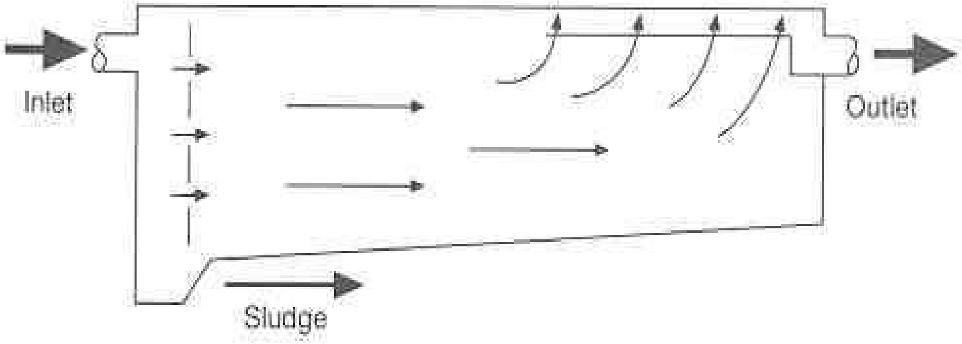
Circular Basin

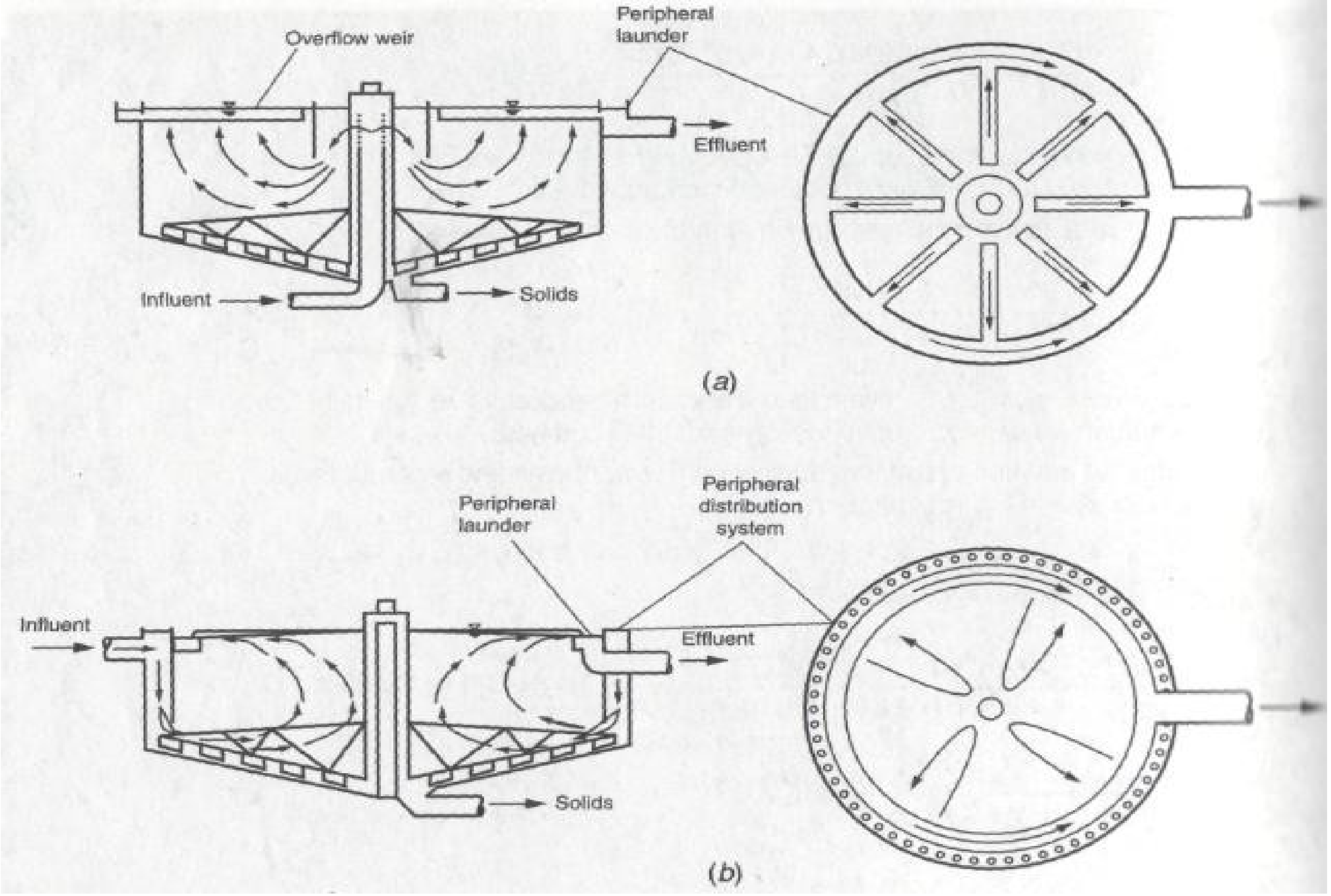




Rectangular Basin






Overflow weir
Peripheral launder
Effluent
Influent
Solids
(a)
Peripheral launder
Peripheral distribution system
Influent
Effluent
Solids
(b)

4. Solids-contact clarifiers

- ✓It is more complex than the others.
- ✓It is also known as up flow solids-contact clarifiers
- ✓Up flow sludge-blanket clarifiers combine coagulation, flocculation and sedimentation within a single basin.
- ✓Solids-contact clarifiers are often found in packaged plants and in cold climates where sedimentation must occur in odor.
- ✓This type of clarifier is also often used in softening operation.

ZONES OF SEDIMENTATION BASIN

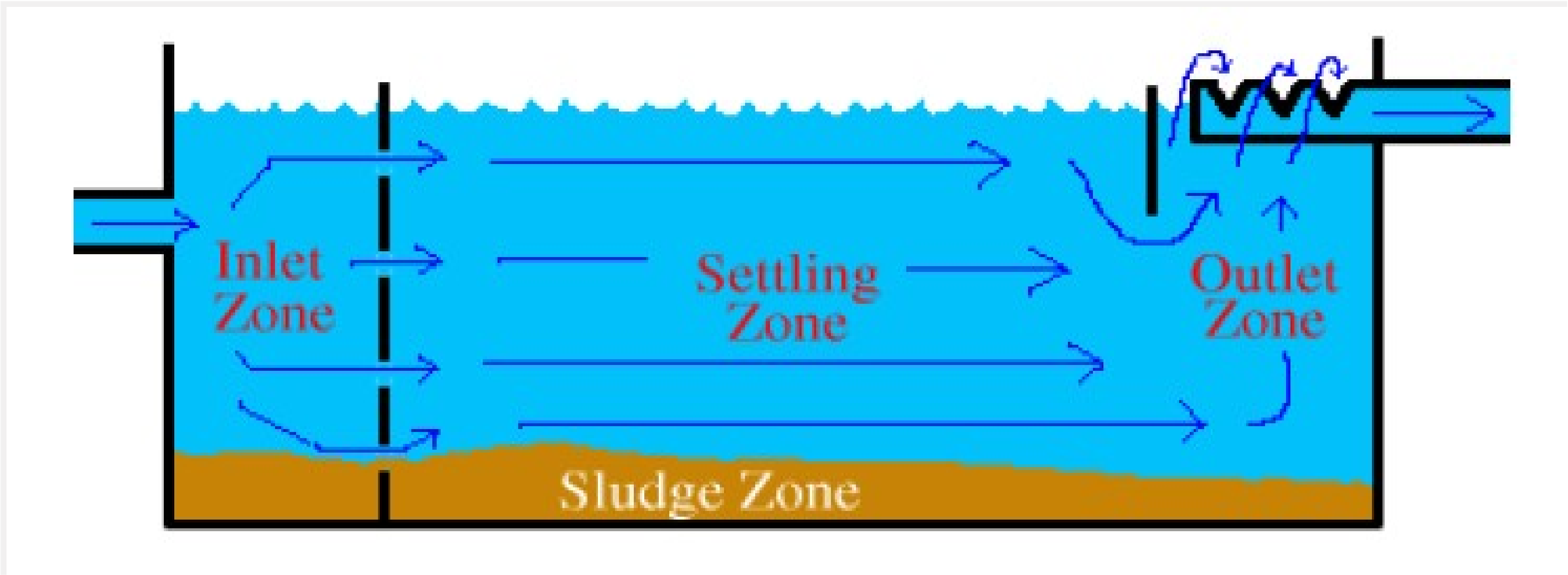
✓Sedimentation Basin has four Zones.

✓Each zone should provide a smooth transition between the zone before and the zone after.

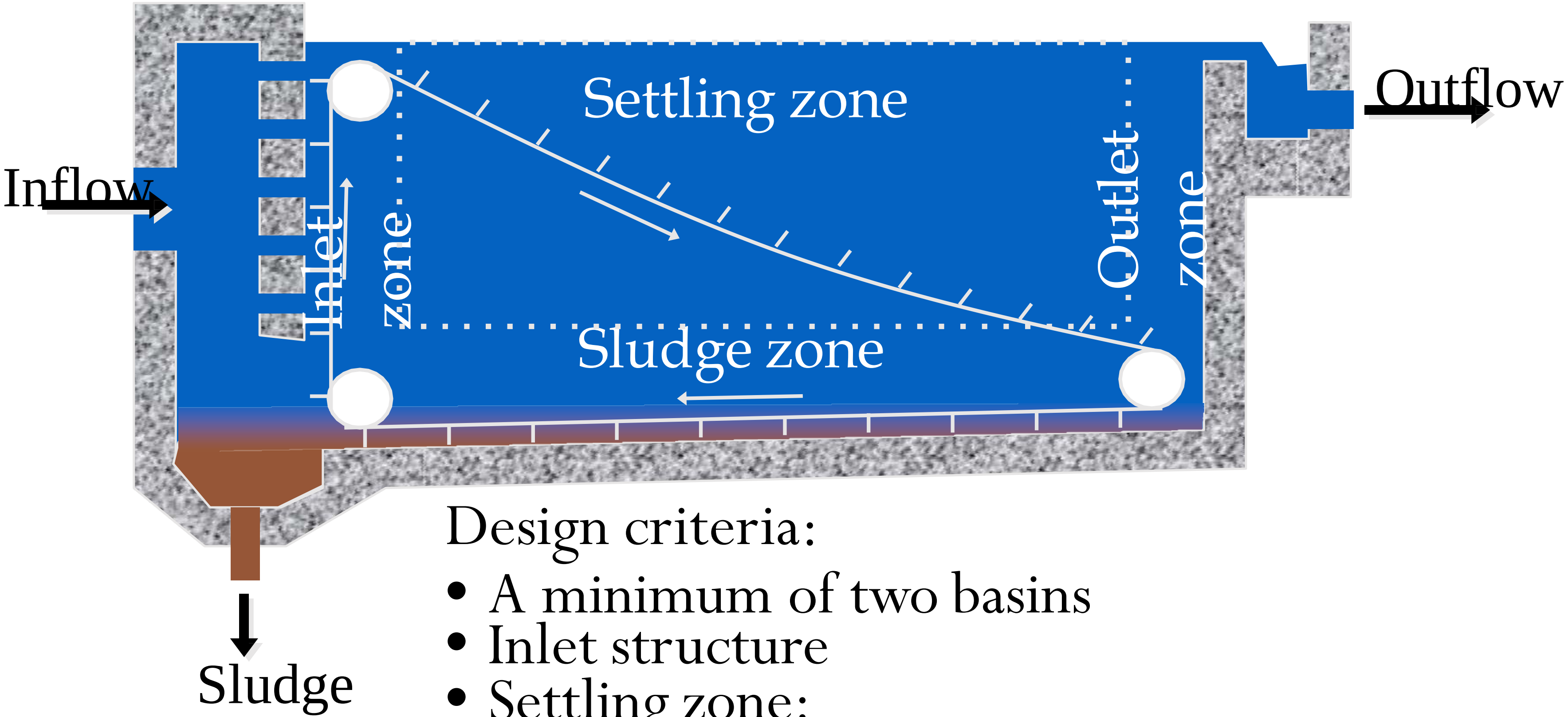
✓In addition, each zone has its own unique purpose

- *The inlet zone,*
- *The settling zone,*
- *The sludge zone, and*
- *The outlet zone*

ZONES OF SEDIMENTATION BASIN



Design of Rectangular Sedimentation Basin



Design criteria:

- A minimum of two basins
- Inlet structure
- Settling zone:
  - Surface overflow rate
  - Effective water depth
  - Horizontal flow velocity
  - Minimum length-to-width ratio
- Outlet structure
- Sludge zone

Typical design criteria for horizontal-flow rectangular tanks

Parameter	Value
Type	Horizontal flow rectangular
Minimum number of tank	2
Water depth, m	3-5
Minimum length-to-depth ratio	15:1
Width-to-depth ratio	3:1-6:1
Minimum length-to-width ratio	4:1-5:1
Surface overflow rate, m/h	1.25-2.5
Horizontal mean flow velocity (at $Q_{max\text{-}day}$), m/min	0.3-1.1
Detention time, h	1.5-4
Launder weir loading, $m^3/m.h$	9-13
Reynolds number	$<20,000$
Froude number	$>10^{-5}$
Bottom slope for manual sludge removal systems, m/m	1:600
Bottom slope for mechanical sludge scraper equipment	1:300
Sludge collector speed for collection path, m/min	0.3-0.9
Sludge collector speed for the return path, m/min	1.5-3

Inlet Zone

- ✓ The two primary purposes of the inlet zone of a sedimentation basin are to distribute the water and to control the water's velocity as it enters the basin.
- ✓ In addition, inlet devices act to prevent turbulence of the water.
- ✓ The incoming flow in a sedimentation basin must be evenly distributed across the width of the basin to prevent short-circuiting.
- ✓ Short-circuiting is a problematic circumstance in which water bypasses the normal flow path through the basin and reaches the outlet in less than the normal detention time.

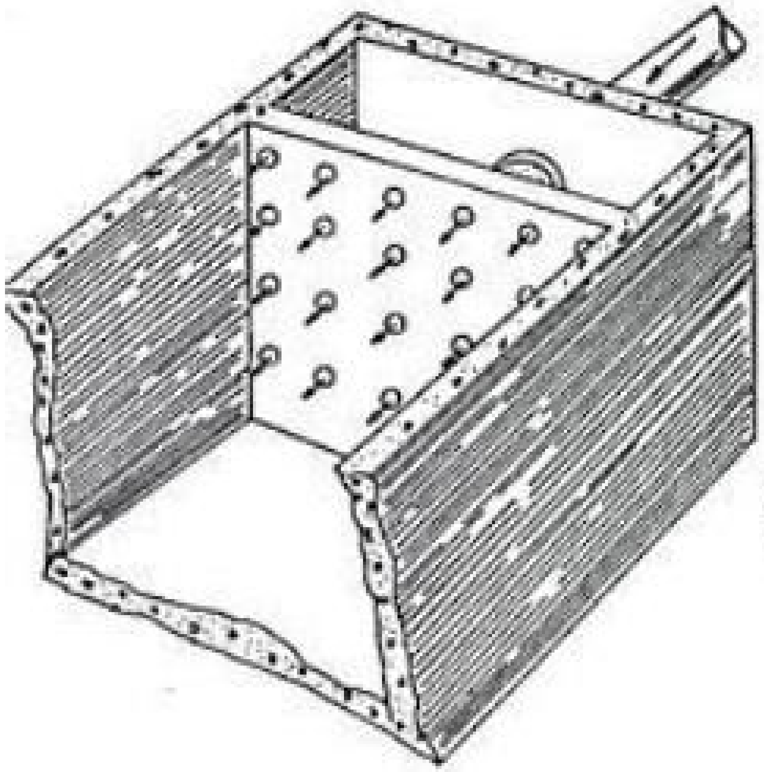
Inlet Zone

- ✓ In addition to preventing short-circuiting, inlets control the velocity of the incoming flow.
- ✓ If the water velocity is greater than 0.15 m/sec, then floc in the water will break up due to agitation of the water.
- ✓ Breakup of floc in the sedimentation basin will make settling much less efficient.

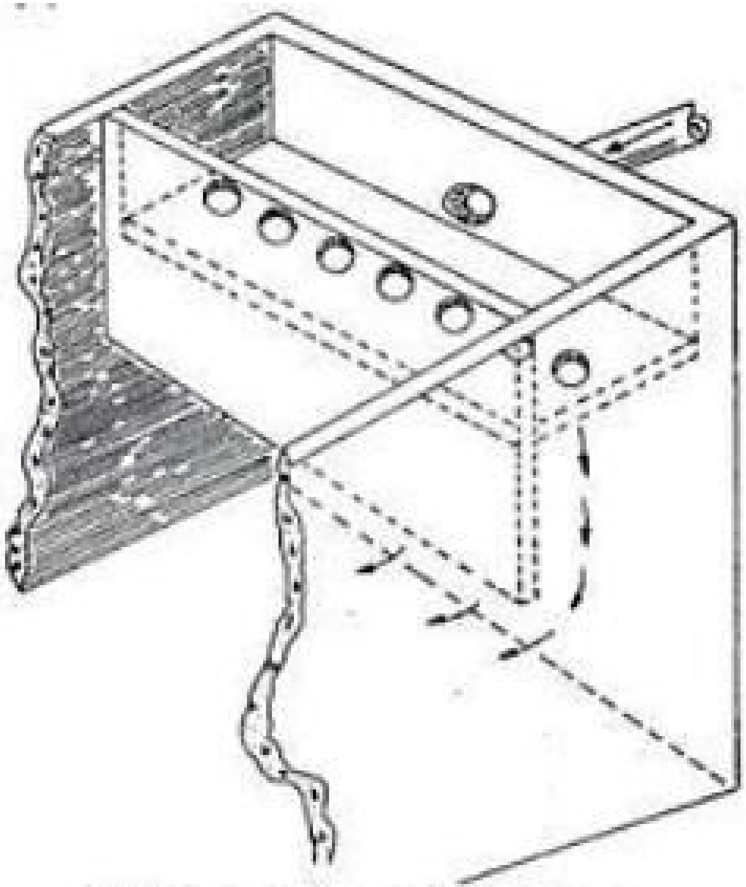
Inlet Zone

- Two types of inlets are shown below.

1. The stilling wall, also known as a perforated baffle wall, spans the entire basin from top to bottom and from side to side.
   - ✓ Water leaves the inlet and enters the settling zone of the sedimentation basin by flowing through the holes evenly spaced across the stilling wall.
2. The Channel or flume, allows water to enter the basin by first flowing through the holes evenly spaced across the bottom of the channel and then by flowing under the baffle in front of the channel.
   - ✓ The combination of channel and baffle serves to evenly distribute the incoming water.



Stilling Wall

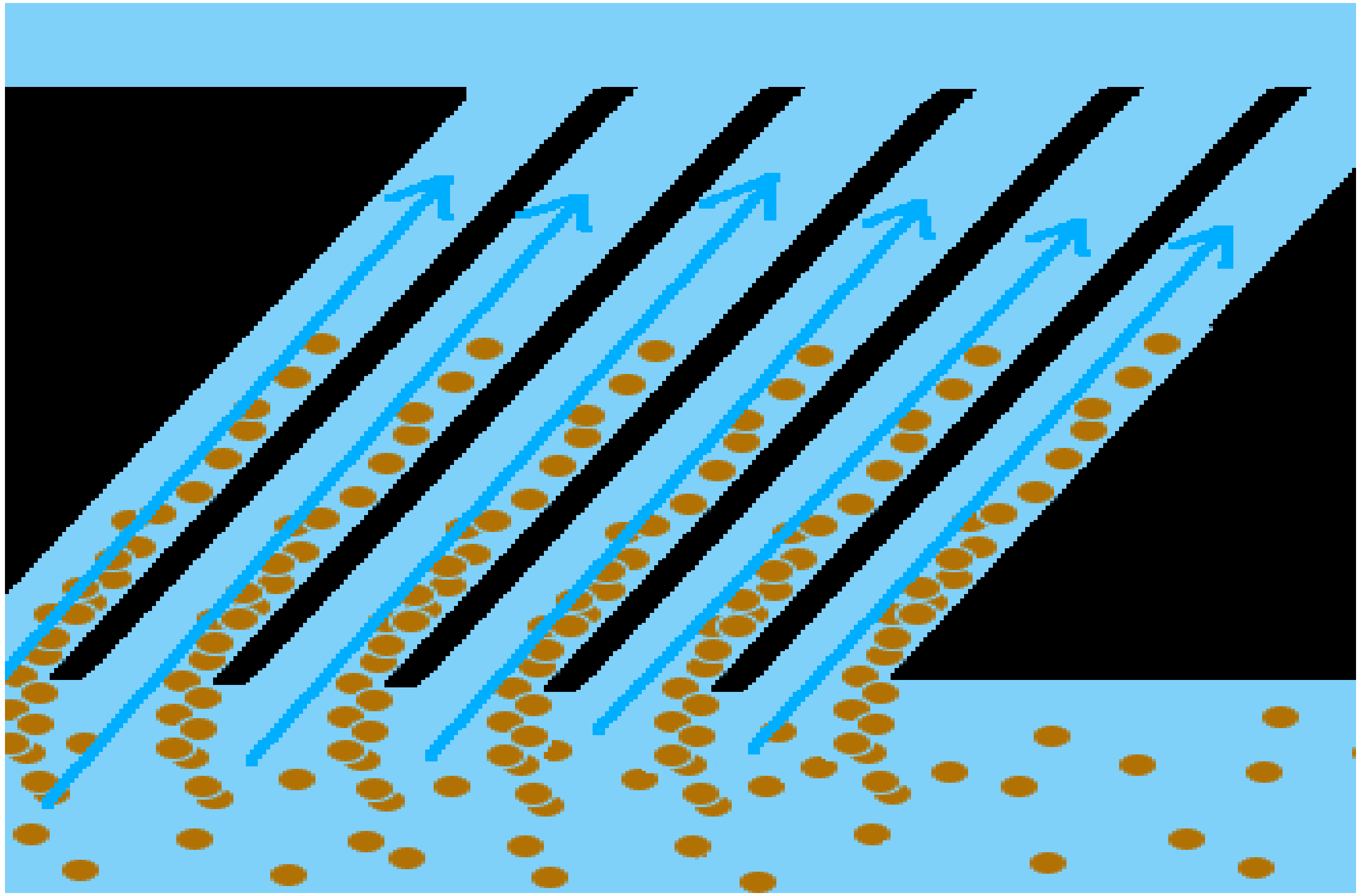


Channel or Flume

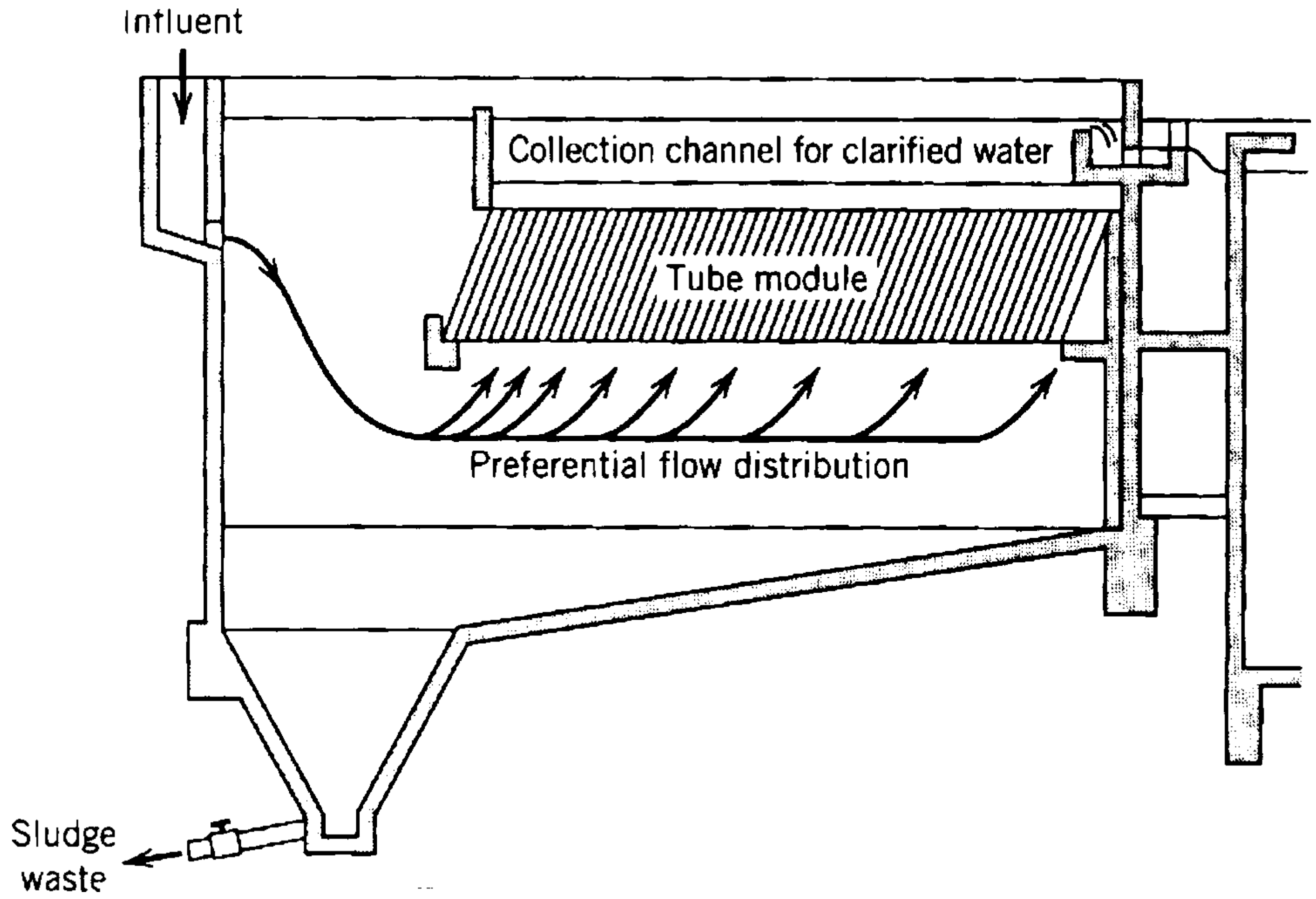
Settling zone

- ✓ After passing through the inlet zone, water enters the settling zone where water velocity is greatly reduced.
- ✓ This is where the bulk of floc settling occurs and this zone will make up the largest volume of the sedimentation basin.
- ✓ For optimal performance, the settling zone requires a slow and smooth flow of water.
- ✓ The settling zone may be simply a large area of open water.
- ✓ But in some cases, tube settlers and lamella plates, such as those shown below, are included in the settling zone

Tube settlers



Tube settlers



Lamella plates

Determining the capacity of the settling zone

- The capacity of the settling zone can be determined on the basis of over flow rate
- It is assumed that the settlement of a particle at the bottom of the tank does not depend on the depth, but on the surface area of the tank
- Let L= Length of the settling zone

  W=Width of the tank

  H=depth of the tank

  C=Capacity of the tank

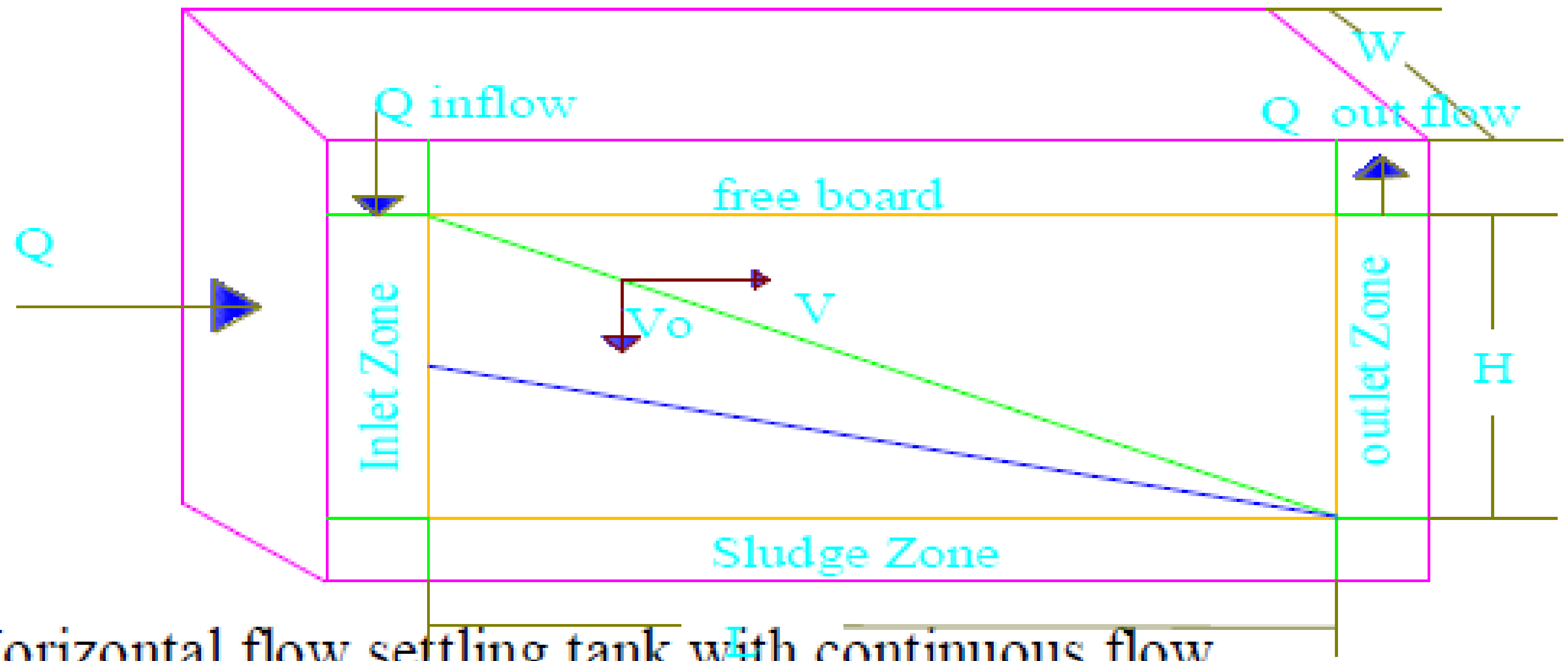
  T=time of horizontal flow(detention time)

  V=Horizontal velocity of flow

  Q=Discharge of flow

  v= velocity of settlement of a particular particle

Horizontal flow settling tank with continuous flow



Horizontal flow settling tank with continuous flow

Detention time, $T = L/V = \text{Capacity}/Q = L*W*H/Q$ ………….(1)

But T = Depth of the tank / velocity of the particle = H/v…… (2)

Equating (1) & (2), we get

$L/V = L*W*H/Q = H/v$

$v/V = H/L$ …………….(3)

$v = Q/L*W = Q/A$…… (4)

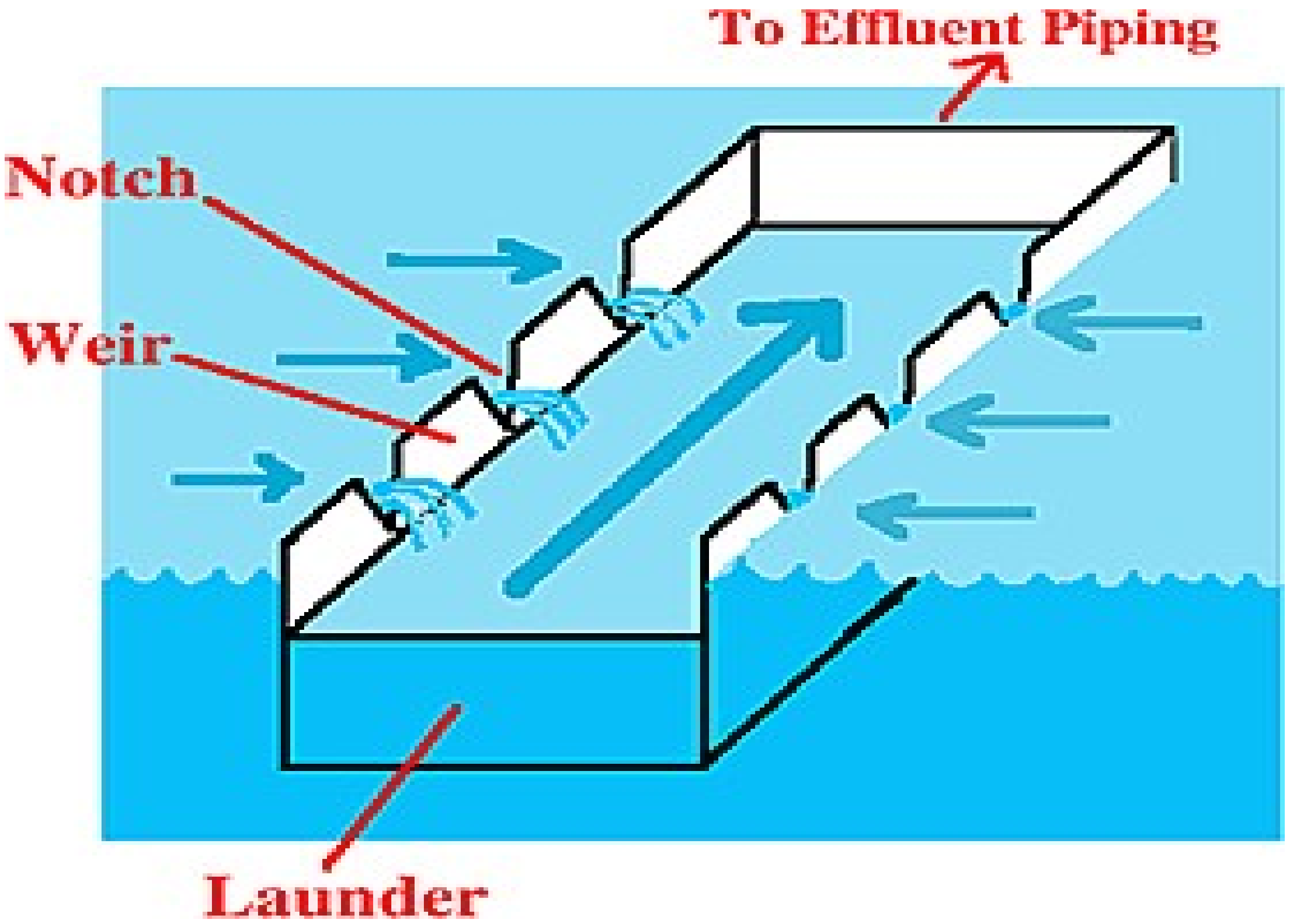
Outlet Zone

- The outlet zone controls the water flowing out of the sedimentation basin
- Like the inlet zone, the outlet zone is designed to prevent short-circuiting of water in the basin
- In addition, a good outlet will ensure that only well-settled water leaves the basin and enters the filter
- The outlet can also be used to control the water level in the basin

Outlet Zone

- Outlets are designed to ensure that the water flowing out of the sedimentation basin has the minimum amount of floc suspended in it.
- The best quality water is usually found at the very top of the sedimentation basin, so outlets are usually designed to skim this water off the sedimentation basin.
- A typical outlet zone begins with a baffle in front of the effluent.
- This baffle prevents floating material from escaping the sedimentation basin and clogging the filters.
- After the baffle comes the effluent structure, which usually consists of a launder, weirs, and effluent piping.

A typical effluent structure is shown below:



Outlet Zone

- The primary component of the effluent structure is the effluent launder, a trench which collects the water flowing out of the sedimentation basin and directs it to the effluent piping.
- The sides of a launder typically have weirs attached. Weirs are walls preventing water from flowing uncontrolled in to the launder.
- The weirs serve to skim the water evenly of the tank.

Outlet Zone

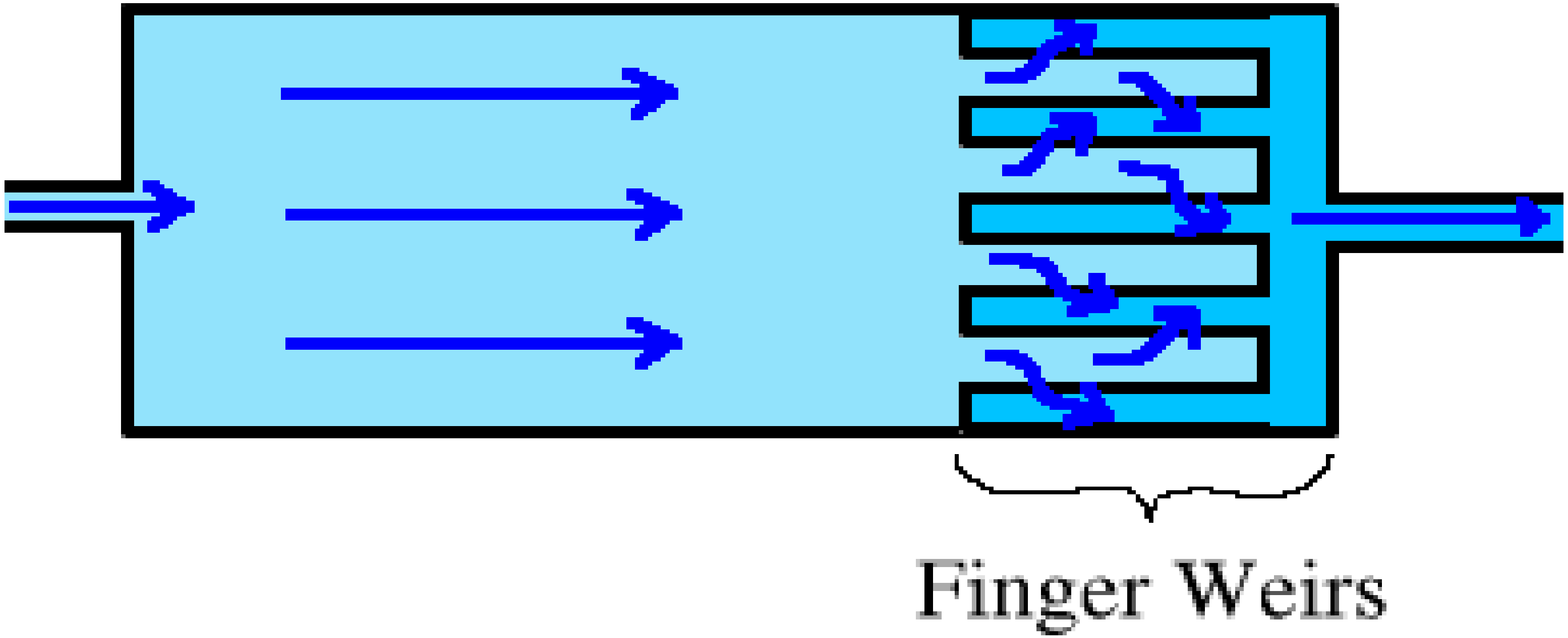
- A weir usually has notches, holes, or slits along its length.
- These holes allow water to flow in to the wire.
- The most common type of hole is the V-shaped notch Shown on the picture above which allows only the top inch or so of water to flow to out of the sedimentation basin

Outlet Zone

- Water flows over or through the holes in the weirs and in to the launder.
- This pipe carries water away from the sedimentation basin and to the next step in the treatment process.
- The effluent structure may be located at the end of a rectangular sedimentation basin or around the edges of the circular clarifier.

Outlet Zone

- Alternatively, the effluent may consist of a finger weir, an arrangement of launders which extend out in to the settling basin as shown below.



Sludge Zone

- The sludge zone is found across the bottom of the sedimentation basin where the sludge collects temporarily.
- **Velocity** in this zone should be very slow to prevent re-suspension of sludge.
- A drain at the bottom of the basin allows the sludge to be easily removed from the tank.
- The tank bottom should slope toward the drains to further facilitate sludge removal.
- In some plants, sludge removal is achieved continuously using automated equipment.

Sludge Zone

- In other plants, sludge must be removed manually. If removed manually, the basin should be cleaned at least twice per year or more often if excessive sludge buildup occurs.
- It is best to clean the sedimentation basin when water demand is low, usually in April and October.
- Many plants have at least two sedimentation basins so that water can continue to be treated while one basin is being cleaned, maintained, and inspected

Sludge Zone

- If sludge is not removed from the sedimentation basin often enough, the effective (useable) volume of the tank will decrease, reducing the efficiency of sedimentation.
- In addition, the sludge built up on the bottom of the tank may become **septic**, meaning that it has begun to decay an aerobically.
- Septic sludge may result in taste and odor problems or may float to the top of the water and become scum.
- Sludge may also become re-suspended in the water and be carried over to the filters

Factors Influencing Efficiency of the basin

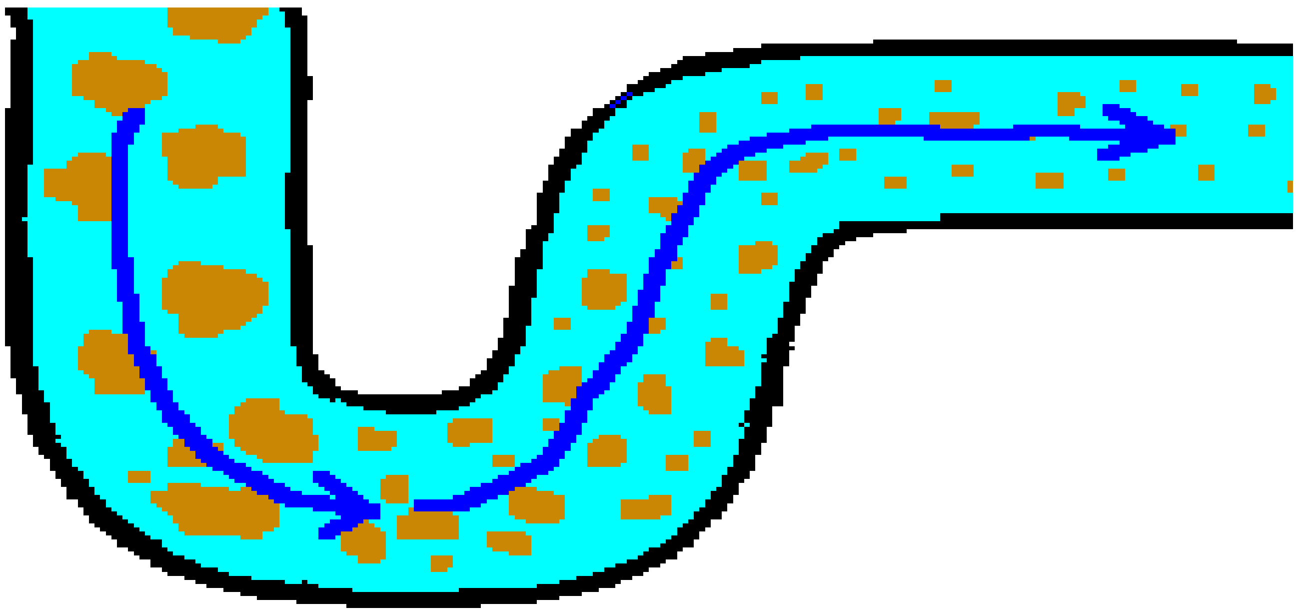
❖ **Floc Characteristics**

- ✓ To a large extent, a sedimentation basin's efficiency will depend on the efficiency of the preceding coagulation/flocculation process
- ✓ The size, shape, and density of the floc influence how well the floc settles out of the water
- ✓ Floc which is too small or too large, is irregularly shaped, or has a low density will not tend to settle out in the sedimentation basin

- Even if the coagulation/flocculation process is very efficient, floc can disintegrate on its way to or in the sedimentation basin.

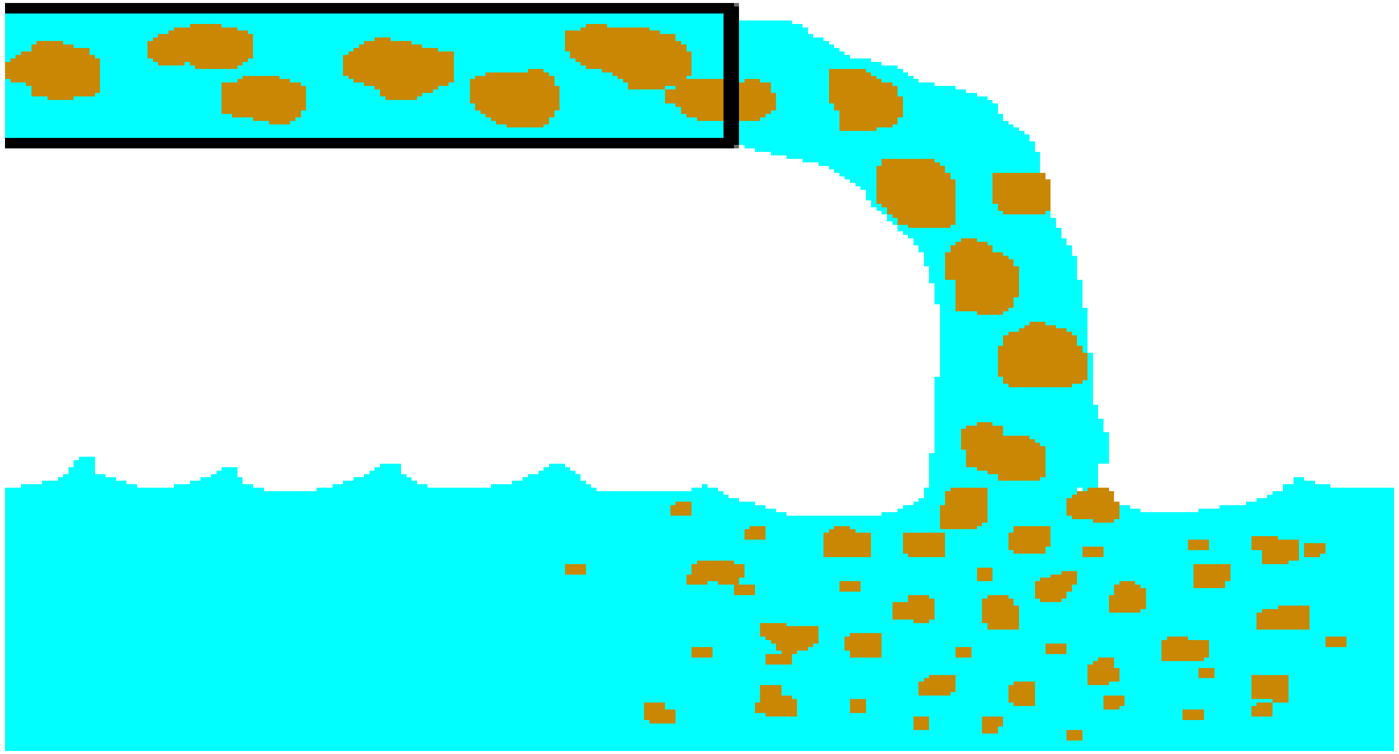
➢ **Previously formed floc will disintegrate**

  - ✓ If the water velocity is too high,
  - ✓ If there are sharp bends in the pipe at the inlet…



sharp bends in the pipe at the inlet

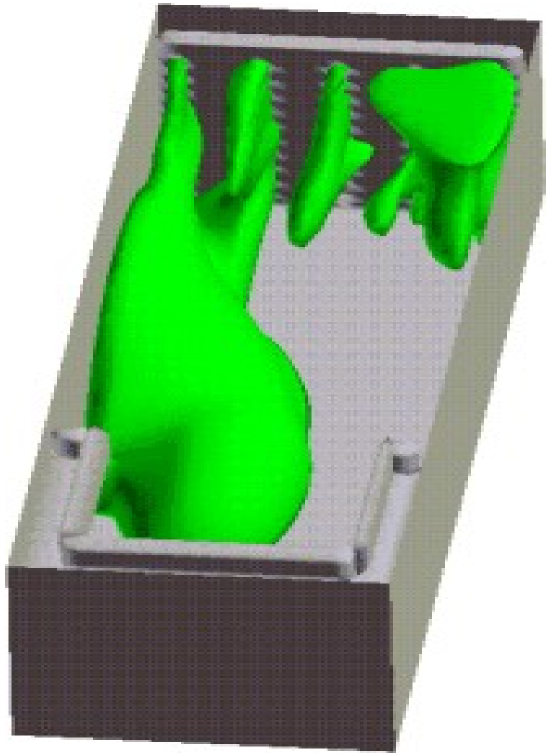
✓If water is discharged above the sedimentation basin water level or if throttle valves are used.



water is discharged above the sedimentation basin

❖ Short-circuiting

- An efficient sedimentation basin would have water flowing through the entire basin, rather than through just one area.



✓ When water in the sedimentation basin short-circuit, floc does not have enough time to settle out of the water, influencing the economy of the plant and the quality of the treated water.

➢ A variety of factors causes short-circuiting in a sedimentation basin

- ✓ Basin shape and design of the inlet and out-let
- ✓ Thin sedimentation basin is less likely to short-circuit than is a short broad one
- ✓ Uneven distribution of flow either at the inlet or out-let
- ✓ Weir at the out-let is not level or if some of the notches clog, flow will be uneven
- ✓ Difference in temperature

❖ Other Problems

- Gases in the water may cause floating scum,
- Algal growth.
- Intermittent operation of the basin can cause settling problems.

Designing a Rectangular Sedimentation Tank

- Designing a rectangular sedimentation tank is similar in many ways to design a flocculation chamber.
- Water in a sedimentation basin is not agitated, so the velocity gradient is not a factor in the calculation
- Two additional characteristics are important in designing a sedimentation basin
  - The **overflow rate** (also known as **surface loading** or the **surface overflow rate**)
  - **Weir loading**, also known as **weir overflow rate**

Design of Horizontal Flow Tanks

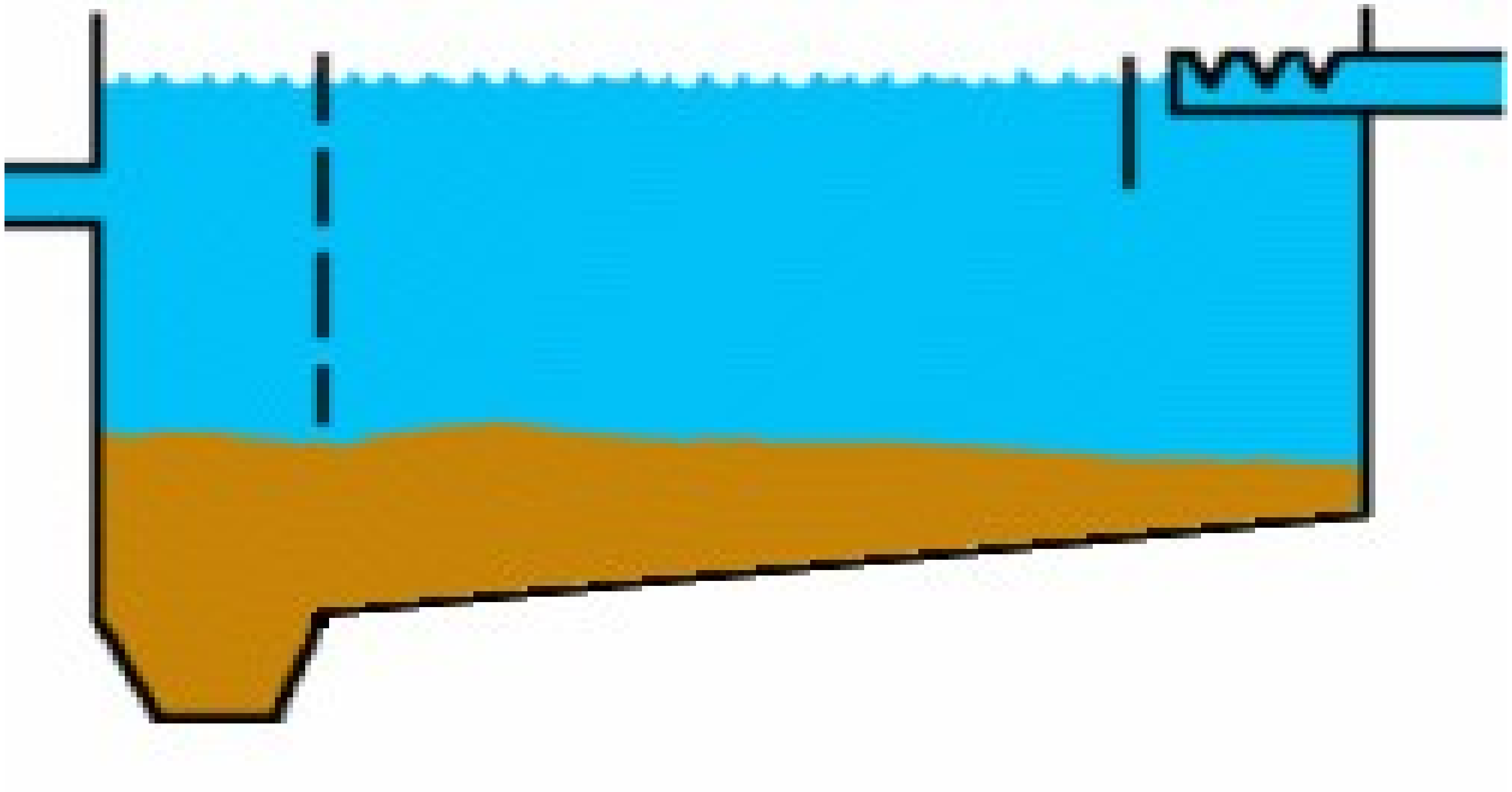
- A depth of at least 3m is provided to allow for sludge storage
- For a given flow rate, the remaining variable to determine will be either the plan area or the detention time

Specifications

✓The sedimentation basin we will design is a rectangular sedimentation basin with the following specifications

- Rectangular basin
- Depth:7-16 ft (2m-5m)
- Width:10-50ft (3m-15m)
- Length: 4mwidth

- Influent baffle to reduce the flow momentum
- Slope of bottom to ward sludge hopper >1%
- Continuous sludge removal with a scraper velocity <15ft/min
- Detention time:4-8 hr
- Flow through velocity :0.5ft/min (0.15m/min)
- Overflow rate:500-1,000gal/day-ft2 (1gal=0.00379m3)
- Weir loading:15,000-20,000gal/day-ft



Rectangular sedimentation basin

Over view of calculations

- ✓ We will determine the surface area, dimensions, and volume of the sedimentation tank as well as the weir length
- ✓ The calculations are as follows:
  - Divide flow in to at least two tanks.
  - Calculate the required surface area.
  - Calculate the required volume.
  - Calculate the tank depth.

- Calculate the tank width and length.
- Check flow through velocity.
- If velocity is too high, repeat calculations with more tanks.
- Calculate the weir length

Example 1

Find the dimension of a rectangular sedimentation basin for the following data

- ✓ Quantity of treated water $=3*10^6$ l/d
- ✓ td=4hr =240min
- ✓ velocity of flow = 10cm/min

Example2

Design a sedimentation basin for the following data

1. Flow rate
    - Maximum flow rate =10,000m3/day
    - Average flow rate 5790m3/day
2. Design parameters
    - td = 4hr
    - L/W=2
    - SOR=10m3/m2/d
    - Design flow rate to be 25% of maximum flow rate

FILTRATION

Theory of Filtration

- ✓ The effluent obtained after coagulation does not satisfy the drinking water standard and is not safe, So it requires further treatments
- ✓ Filtration is one of the water purification process in which water is allowed to pass through a porous medium to remove remaining flocs or suspended solids from the previous treatment processes
- ✓ Filtration process assist significantly by reducing the load on the disinfections process, increasing disinfection efficiency.

- ✓Filtration consists of passing water through a thick layer of sand
- ✓During the passage of water through sand, the following effects take place.

  i) Suspended matter and colloidal matter are removed

  ii) Chemical characteristic of water get changed

  iii) Number of bacteria considerably reduced.

Classification of filters

Slow sand filters

- Simplest and biological filters without any mechanical equipment
- It can use for Less than 20 NTU water treatment.
- Best suited for the filtration of water for small towns
- Fine sand with an effective size of 0.2 mm
- Filtration rate is 50 to 100 times slower than that of rapid sand filter (2.4 to 3.6m^3/m^2/day)
- A layer of dirt, debris, and microorganisms builds up on the top of the sand.
- This layer is known as **schmutzdecke**, which is German for "dirty skin."or "dirty cover".

- The **Schmutzdecke** breaks down organic particles in the water biologically, and is also very effective in straining out even very small inorganic particles
- Filtered water has <0.3NTU turbidity (the goal is <0.1NTU)
- Output water may requires chlorination (for quality improvement)

Essential features of slow sand filter

1. Enclosed tank
2. Filter media
3. Base material
4. Under drainage system
5. Appurtenances

1. Enclosed tank

- ✓SSF is open basin, rectangular shape and built below finished ground level.
- ✓Surface area of the tank varies from 50 to 1000sqm.
- ✓Filtration rate – 100 to 200 lit/ sqm/hr
- ✓Depth – 2.5 to 4m

2. Filter media : Sand

- ✓ Thickness of sand layer – 90 to 110cm.
- ✓Effective size – 0.20 to 0.35 (common value – 2.5)
- ✓Coefficient of uniformity – 2.0 to 3.0 (common value – 2.5)

3. Base material : Gravel

✓ Thickness of gravel bed – 30 to 75cm.

Layer	Depth	Size(mm)
Top most	15 cm	3 to 6
Intermediate	15 cm	6 to 20
Intermediate	15 cm	20 to 40
Bottom	15 cm	40 to 65

4. Under drainage system

✓ Base material and filter media are supported by under drainage system

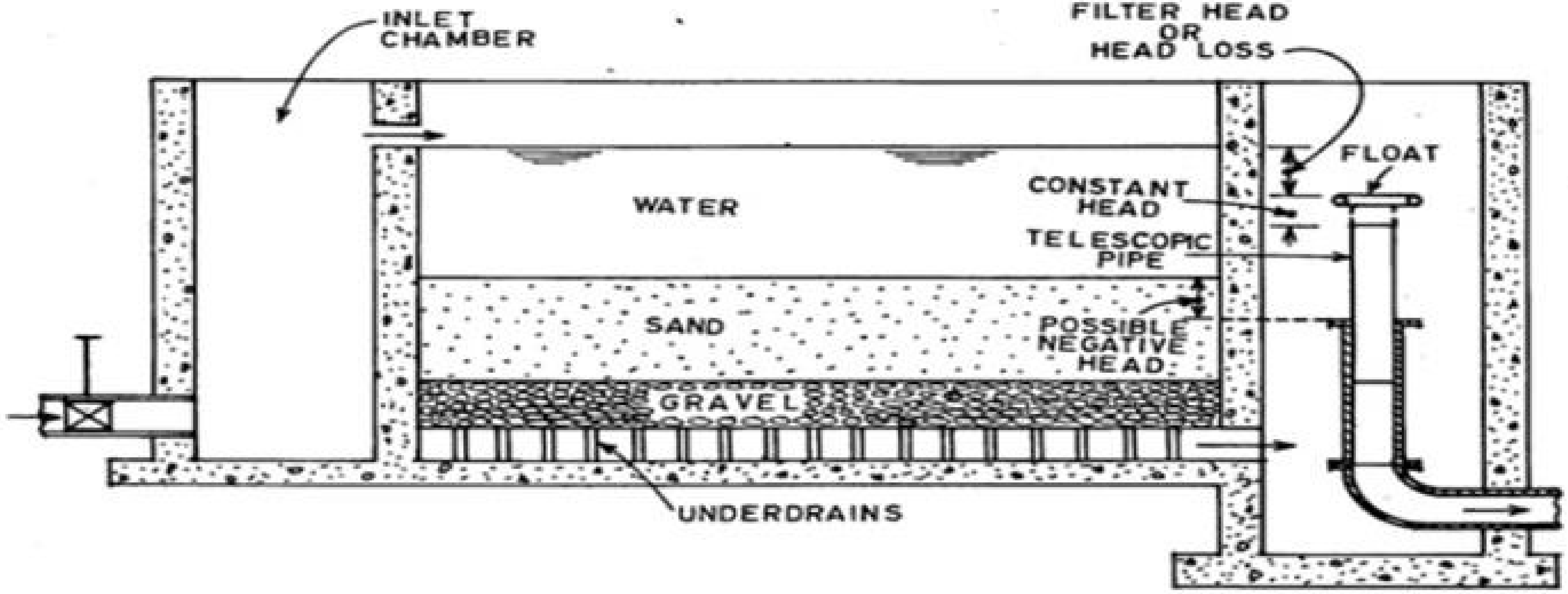
✓ Under drainage system collects filtered water and delivers it to the reservoir

5. Appurtenances

- ✓ Devices are required for
  - Gauge – to measure loss of head
  - Vertical air vent pipe – for proper functioning of filtering layer
  - Telescope tube – to maintain constant discharge
  - A meter – to measure flow

FILTER AND THEIR CLASSIFICATION

1. Slow sand filter (SSF)



Slow Sand Filter Cleaning

- ✓ Periodic raking and cleaning of the filter by removing the top two inches of sand. After a few cleanings, new sand must be added to replace the removed sand.
- ✓ After a cleaning the filter must be operated for two weeks, with the filtered water sent to waste, to allow the schmutzdecke layer to rebuild (formation of biofilm)
- ✓ Two slow sand filters should be provided for continuous operation.

Advantages and Disadvantages of SSF

- Advantages:
  - Long design life
  - Can use local material and labor
  - Cost of construction cheaper than rapid sand filter
  - Do not usually require coagulation/flocculation before filtration
  - Filters enough water for a community (up to 15,000gal/day)
  - Bacterial count reduction is 99.9% to 99.99% and E.coli reduction is 99% to 99.9%
- Disadvantages:
  - Initial cost is low but maintenance cost is much more than rapid sand filter
  - These filters requires extensive land area for a large municipal system.

Design criteria for slow sand filters

Parameter	Recommended level
Design life	10-15 year
Period of operation	24 h/day
Filtration rate	0.1 – 0.2 m/h
Filter bed area	5-200 m^2/filter
Height of filter bed	
Initial	0.8-0.9 m
Minimum	0.5-0.6 m
Effective size	0.15-0.3 mm
Uniformity coefficient	< 3
Height of under drains including gravel layer	0.3-0.5 m
Height of supernatant water	1 m

Rapid Sand Filter

- It is somewhat complex and expensive to operate and maintain and therefore less suitable for small communities.
- Much greater filtration rate ranging from 100 to 150m3/m2/day
- The ability to clean automatically using backwashing and require small filter area.
- Do not use biological filtration and depend primarily on adsorption and some straining

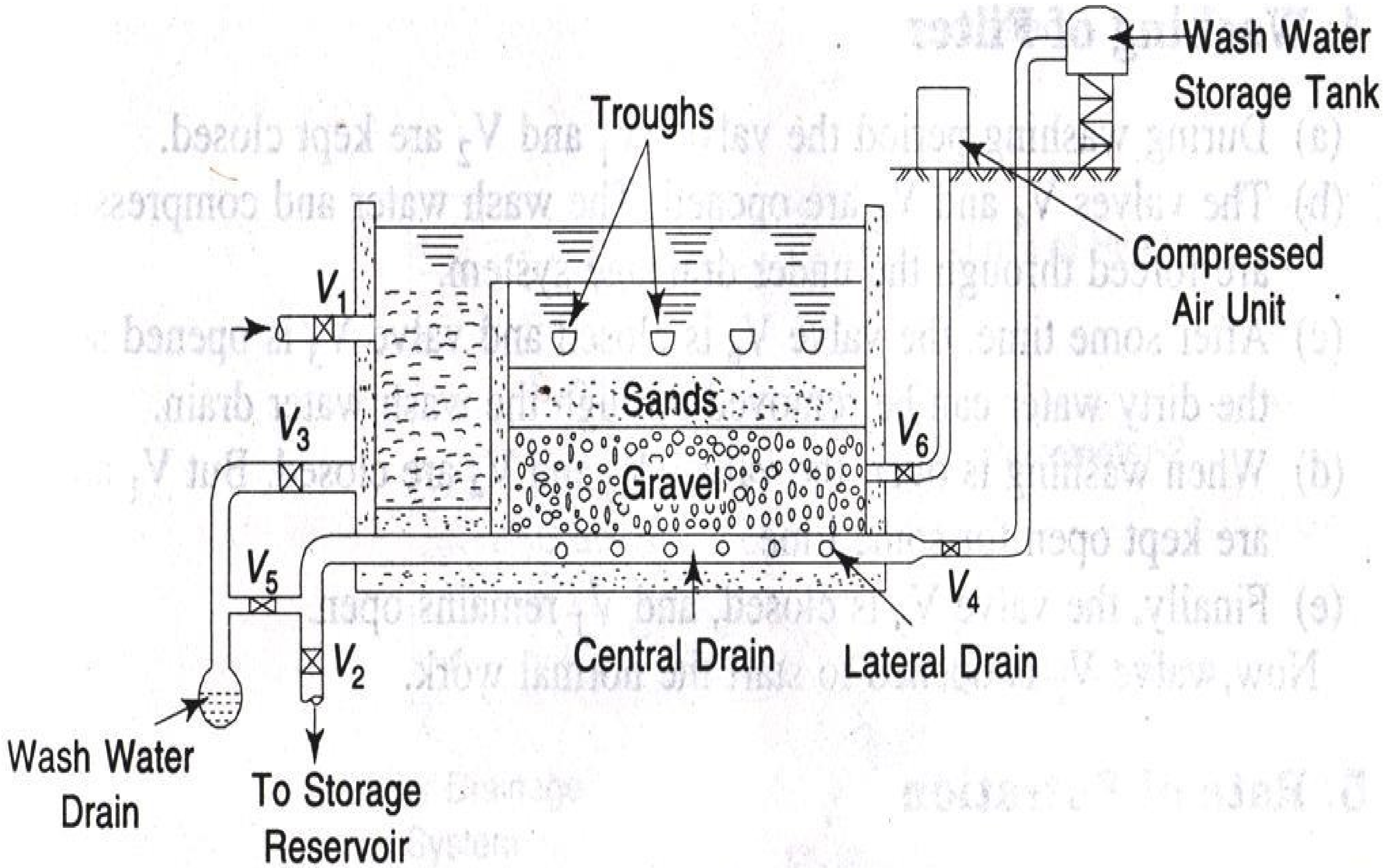
Rapid Filter

- The media is coarser compared to slow sand filters (0.4 to 0.6 mm or higher)
- Most common in water treatment plants
- Removal is with depth
- Have to clean the entire filter media usually by backwashing for the cleaning of rapid sand filter.
- Cleaning by back washing (head losses 1.2 – 2.5 m)
- Water must be pre-treated to destabilize negatively charged particles

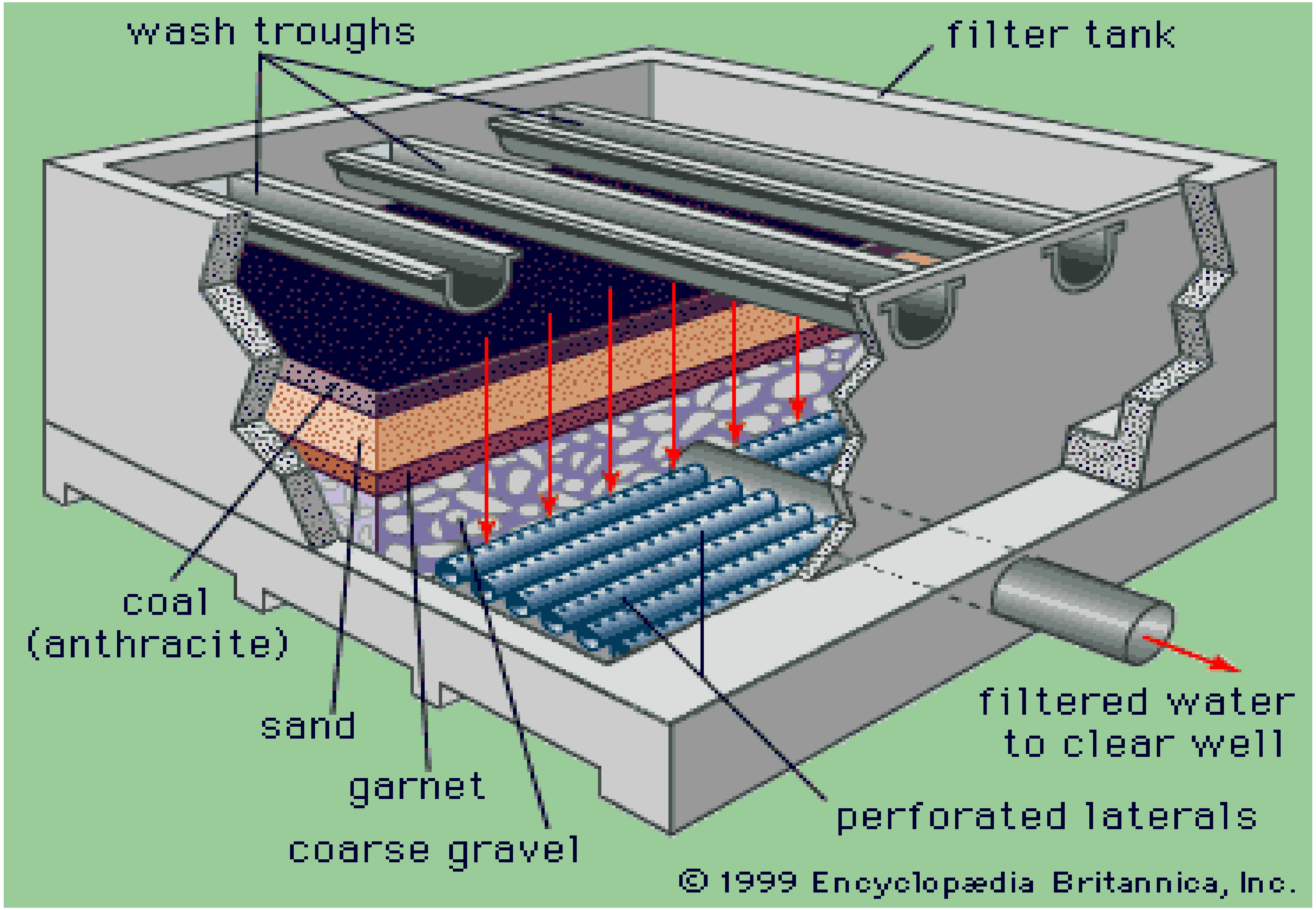
Rapid filter

- The most commonly used filter media is sand.
- Sometimes use coal, anthracite, coconut shell and ballistic stone etc.

Rapid Filter- Essential parts



Components of Rapid Filters



Operation

- ✓The water from coagulation sedimentation tank is uniformly distributed on the whole sand bed
- ✓Water after passing through the sand bed is collected through the under drainage system in the filtered water well
- ✓The outlet chamber in this filter is also equipped with filter rate controller
- ✓In the beginning the loss of head is very small
- ✓But as the bed gets clogged, the loss of head increases and the rate of filtration become very low
- ✓Therefore the filter bed requires its washing.

Washing of Filter

- ✓ Involves passing water upward through the filter media at a velocity sufficient to expand (fluidize) the bed and wash out the accumulated solids
- ✓ Done when:
  - The head loss through the filter exceeds the design value.
  - Turbidity breakthrough causes the effluent quality to be less than a minimum acceptable level
- ✓ Bed expansions are achieved in backwashing. The sand bed expands by about 50%.
- ✓ Washing process is continued till the sand bed appears clearly.
- ✓ Rapid sand filter bring down the turbidity of water to 1 N.T.U.

Sl.No.	ITEM	S.S.F	R.S.F
1.	Area	Need very large area	Needs small area
2.	Raw Water Turbidity	Not more than 30 NTU	Not more than 10NTU hence needs coagulation
3.	Sand Media	Effective size 0.2 to 0.3 mm uniformity coefficient 2 to 3 single layer of uniform size	Effective size 0.45 to 0.7 mm uniformity coefficient 1.3 to 1.7 multiple graded layers of sand.
4.	Rate of Filtration	2.4 to 3.6m^3/m^2/day	100-150 m^3/m^2/day
5.	Loss of Head	0.6m to 0.7 m	1.8m to 2.0m
6.	Supervision	No skilled supervision is required	Skilled supervision is required
7.	Cleaning of Filter	Scraping of 21/2cm thick layer washing and replacing. Cleaning interval that is replacement of sand at 1 to 2 months.	Back wash with clean water under pressure to detach the dirt on the sand. Backwashing daily or on alternate days.
8.	Efficiency	Bacterial removal, taste, odour, colour and turbidity removal.	There is no removal of bacteria. Removal colour taste, odour and turbidity is good.

Parts of a rapid filter

- **Filter tank:** A water tight tank is constructed either masonry or concrete
- **Filter sand:** specially manufactured or selected sand and other filter media. The depth of sand 60 to 75cm
- **Under drain system:** carries filtered water & distributes the backwash water uniformly
- **Wash water trough:** collects back wash water
- **Filter bed agitator:** agitates sand layer for cleansing (air-scour or surface wash systems)
- **Appurtenances** :Air compressors useful for washing of filter and wash water troughs for collection of dirty water after washing of filter.

Rapid Filter Media

- Filter media controls:
  - The solids holding capacity of the filter bed
  - The hydraulic loading rate of the filters
  - The finished water quality
- Types
  - Single media (usually sand)
  - Dual media (usually sand and anthracite)
  - Multi-media (usually sand, anthracite, garnet)

Typical Filter Media Design Values

Parameter	Single-medium	Dual-media	Multi-media
Anthracite layer			
Effective size, mm	0.50-1.5	0.70-2.0	1.0-2.0
Uniformity coeff.	1.2-1.7	1.3-1.8	1.4-1.8
Depth, cm	50-150	30-60	50-130
Sand layer			
Effective size, mm	0.45-1.0	0.45-0.60	0.40-0.80
Uniformity coeff.	1.2-1.7	1.2-1.7	1.2-1.7
Depth, cm	50-150	20-40	20-40
Garnet layer			
Effective size, mm			0.20-0.80
Uniformity coeff.			1.5-1.8
Depth, cm			5-15

Selection of Filter Media

- Methods
  - Pilot testing: takes long time and costly
  - Experience from past studies (e.g. use media depth to effective size ratio)

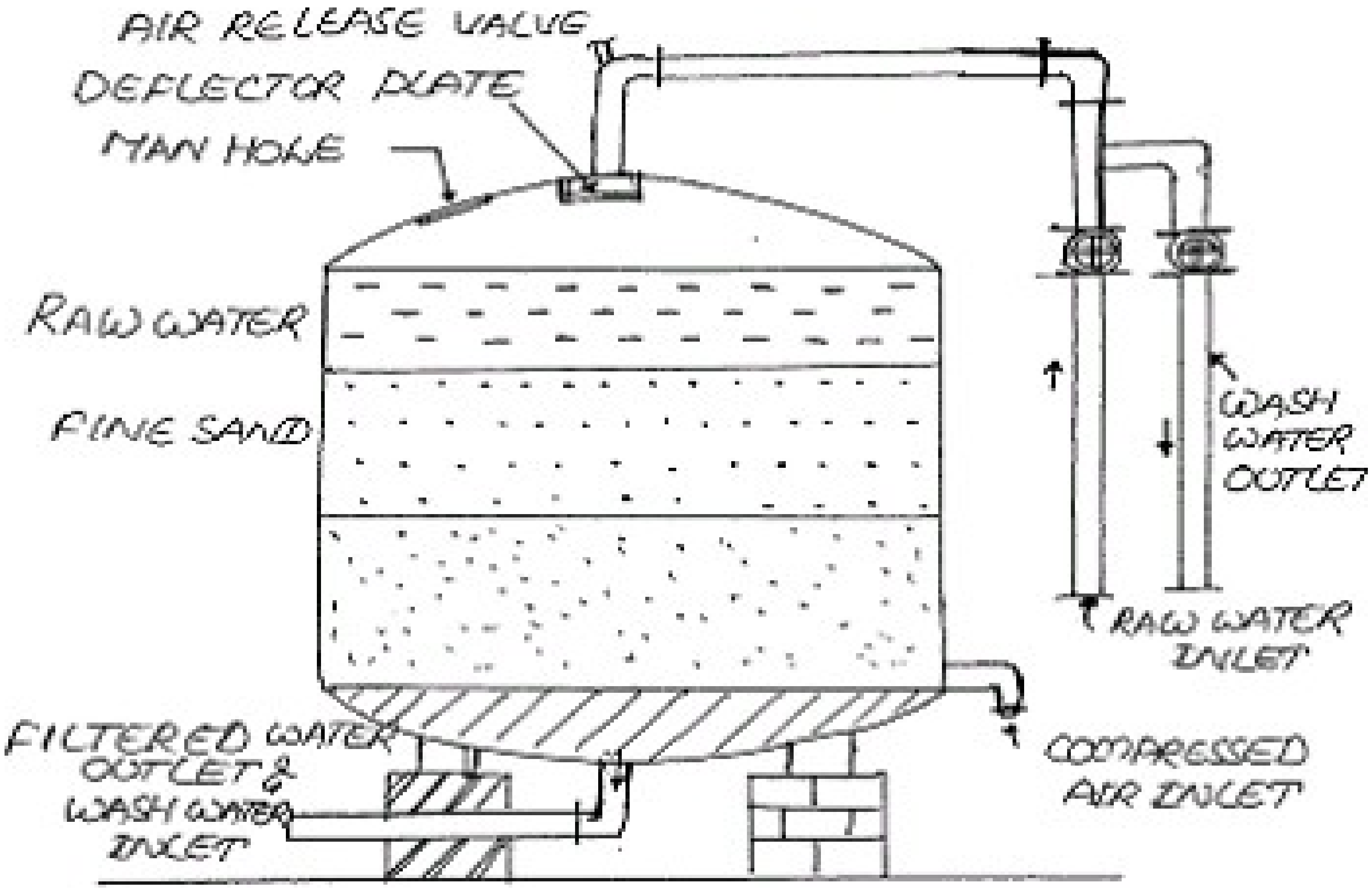
The main features of rapid sand filter are as follows

- ✓ Effective size of sand - 0.45 to 0.70mm
- ✓ Uniformity coefficient of sand - 1.2 to 1.7
- ✓ Depth of sand - 60 to 75cm
- ✓ Filter gravel - 2 to 50mm size (Increase size towards bottom)
- ✓ Depth of gravel - 45cm
- ✓ Depth of water over sand during filtration - 1 to 2m

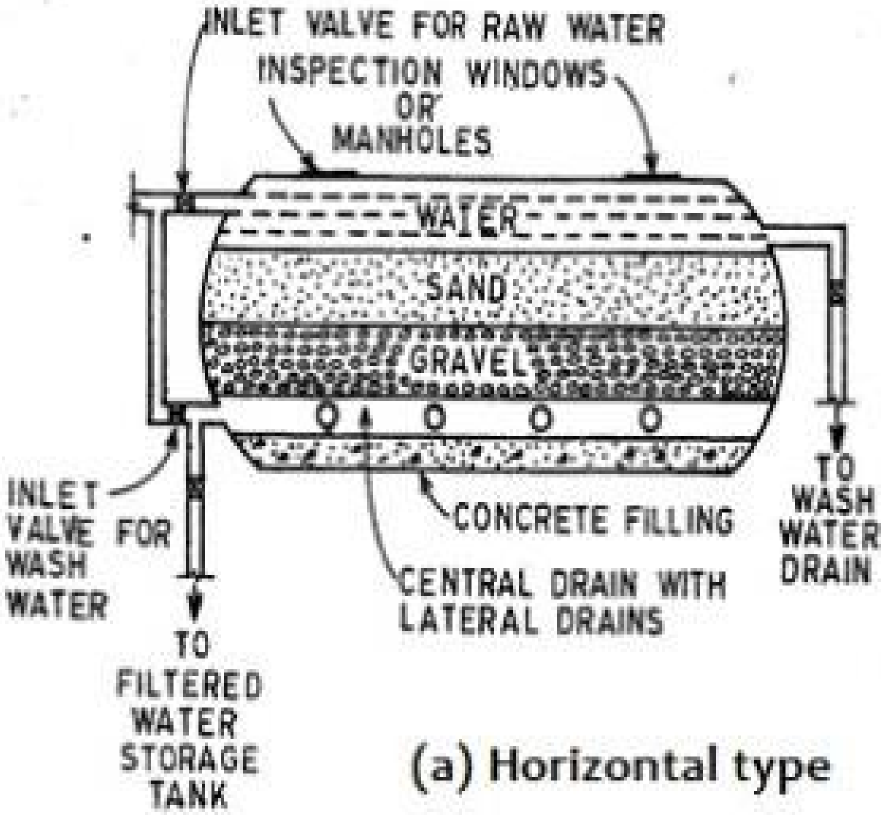
- ✓ Overall depth of filter including 0.5m free board - 2.5m
- ✓ Area of single filter unit - 100m2 in two parts of each 50m2
- ✓ Loss of head - Max 1.8 to 2.0m
- ✓ Turbidity of filtered water - 1 NTU
- ✓ Influent pipe to filters: 0.6-1.8 m/s
- ✓ Effluent pipe carrying filtered water: 0.9-1.8 m/s
- ✓ Drains carrying spent backwash water: 1.2-2.4 m/s
- ✓ Wash water line (influent): 2.4-3.7 m/s
- ✓ Filter to waste drain: 3.7-4.8 m/s

Pressure Filter

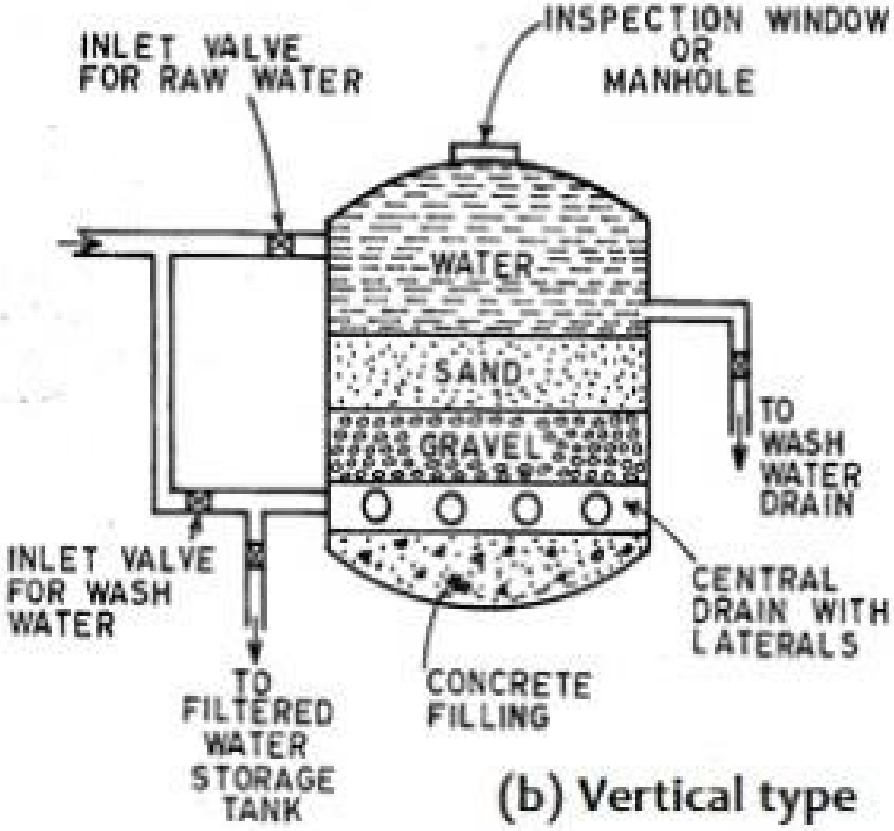
- Pressure filter is type of rapid sand filter in closed water tight cylinder through which the water passes through the sand bed under pressure
- All the operation of the filter is similar to rapid gravity filter; except that the coagulated water is directly applied to the filter without mixing and flocculation
- These filters are used for industrial plants but these are not economical on large scale
- Pressure filters may be vertical pressure filter and horizontal pressure filter
- Backwash is carried by reversing the flow
- The rate of flow is 120 to 300 $m^3/m^2/day$



Vertical Pressure filters



(a) Horizontal type



(b) Vertical type

Fig 6.23 Pressure filters *(Source: Modi, 1998)*

Example 1

Calculate the head loss through a clean bed of uniform sand that has a grain diameter of 0.5 mm, bed depth 0.3 m and porosity ratio of 0.4. The shape factor is 0.85 and the specific gravity of sand is 2.65. The water temperature is 20°C and the filter has a loading rate of 4.0 m3/m2-h. Use the Carmen-Kozeny equation.

Example 2

- A dual-media filter bed is being designed. The media used are sand and anthracite. The effective size and specific gravity of sand are 0.60 mm and 2.65. The specific gravity of anthracite is 1.5. Calculate
  - The effective size of the anthracite that has the same settling velocity as the sand

6. DISINFECTION

- The primary goal of water treatment is to ensure that the water is safe to drink and does not contain any disease-causing microorganisms.
- Pathogens can be removed from water through physical or chemical processes.
- **Disinfection**, which is the process of selectively destroying or inactivating pathogenic organisms in water, usually by chemical means.
- Disinfection is different from **sterilization**, which is the complete destruction of all organisms found in water and which is usually expensive and unnecessary.

Location in the Treatment Process

- During pre-chlorination, chlorine is usually added to raw water after screening and before flash mixing.
- Post-chlorination, is often the last stage in the treatment process.
- After flowing through the filter, water is chlorinated and then pumped to the clear well to allow a sufficient contact time for the chlorine to act.
- From the clear-well, the water may be pumped into a large, outdoor storage tank.
- Finally, the water is released to the customer.

Requirements of Good Disinfectant

1. Destroy bacteria/pathogens within a practicable period of time, over an expected range of water temperature.
2. Effective at variable compositions, concentration and conditions of water treated.
3. Neither toxic to humans and domestic animals nor unpalatable or otherwise offensive in required concentration.
4. Not change water properties

Requirements of Good Disinfectant

5. Have residual in a sufficient concentration to provide protection against recontamination
6. Can be determined easily, quickly, and preferably automatically.
7. Unnecessary at reasonable cost.
8. Safe and easy to store, transport, handle and supply.
9. Not form toxic by-products due to their reactions with any naturally occurring materials in water.

Methods of Disinfection

- The disinfection of water can be done by one of the following methods:

  a) Boiling of water

  b) Ultra–Violate rays

  c) Iodine and bromine

  d) Ozone O3

  e) Excess lime

  f) Potassium permanganate [KMnO4]

  g) Chlorine

- ✓ The most common method of disinfection is the use of chlorine i.e. ***chlorination.***
- ✓ The various chlorine compounds which are available in the market and used as disinfectants are:

1. Calcium hypo chlorite [Ca (OCl) 2] – **poweder form**
2. Sodium hypo chlorite [NaOCl] –**liquid form**
3. Free chlorine Cl2- **Gaseous form**

Chlorination

- ✓ Is the application of chlorine to water for the purpose of disinfection.
- ✓ Chlorination can also be used for taste and odor control, iron and manganese removal, and to remove some gases such as ammonia and hydrogen sulfide.

Chlorination Chemistry

- ✓When chlorine is added to water, a variety of chemical processes take place.
- ✓The chlorine reacts with compounds in the water and with the water itself.
- ✓Some of the results of these reactions (known as the **chlorine residual**) are able to kill microorganisms in the water.

- ✓ The total amount of chlorine which is used up in reactions with compounds in the water is known as the **chlorine demand.**
- ✓ A sufficient quantity of chlorine must be added to the water so that, after the chlorine demand is met, there is still some chlorine left to kill microorganisms in the water.

Reactions of Chlorine Gas with Water

- The reaction depends on the type of chlorine added to the water as well as on the pH of the water itself.
- The gas is difficult to handle since it is toxic, heavy, corrosive, and an irritant.
- At high concentrations, chlorine gas can even be fatal.
- The following reaction occurs:

$$Cl_2 + H_2O \longrightarrow HOCl + HCl$$

- Hypochlorous acid is the most effective form of **free chlorine residual**, meaning that it is chlorine available to kill microorganisms in the water.

Hypo-chlorites

- Instead of using chlorine gas, some plants apply chlorine to water as a ***hypochlorite***, also known as **a *bleach*.**
- There are three types of hypochlorite's - sodium hypochlorite, calcium hypochlorite, and commercial bleach.
- They react with water and form the disinfectant hypochlorous acid.

- The reactions of sodium hypochlorite and calcium hypochlorite with water are shown below:

Calcium hypochlorite + Water → Hypochlorous Acid + Calcium Hydroxide

$$Ca(OCl)_2 + 2H_2O \longrightarrow 2HOCl + Ca(OH)_2$$

Sodium hypochlorite + Water → Hypochlorous Acid + Sodium Hydroxide

$$NaOCl + H_2O \longrightarrow HOCl + NaOH$$

Chloramines

- Some plants use **chloramines** rather than hypochlorous acid to disinfect water.
- To produce **chloramines**, first chlorine gas or hypochlorite is added to the water to produce hypochlorous acid
- Then ammonia is added to the water to react with the hypochlorous acid and produce chloramine.
- Three types of chloramines can be formed in water
- Ammonia + Hypochlorous Acid $\longrightarrow$ Monochloramine + Water

$$\mathbf{NH_3 + HOCl \longrightarrow NH_2Cl + H_2O}$$

- Mono-chloramine + Hypochlorous Acid ⟶ Dichloramine + Water

$$NH_2Cl + HOCl \longrightarrow NHCl_2 + H_2O$$

- Dichloramine + Hypochlorous Acid ⟶ Trichloramine + Water

$$NHCl_2 + HOCl \longrightarrow NCl_3 + H_2O$$

✓Mono-chloramines and dichloramines can both be used as a disinfecting agent, called ***combined chlorine residual***

Plain Chlorination

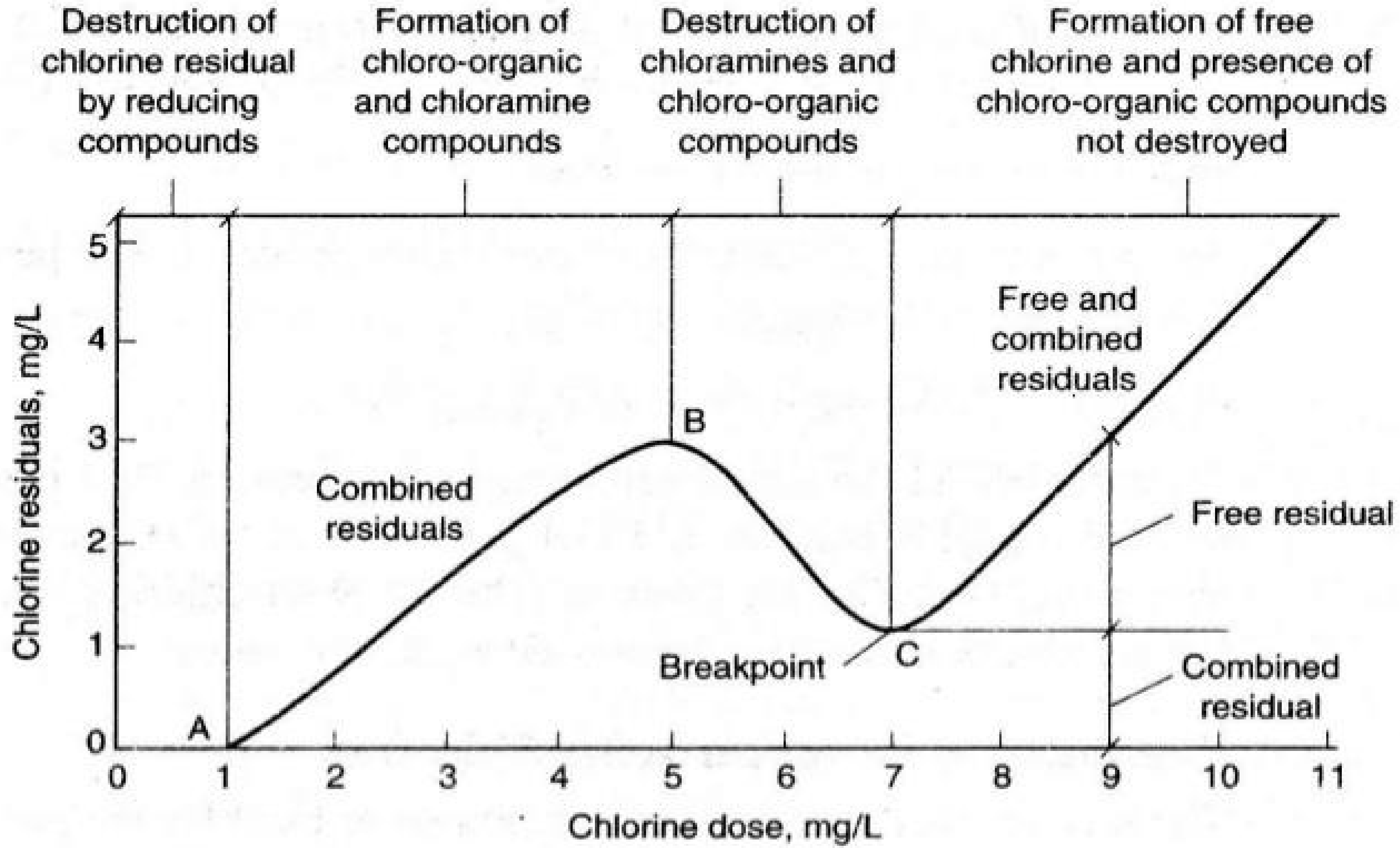
- ✓Plain chlorination is the process of addition of chlorine only when the surface water with no other treatment is required.
- ✓The water of lakes and springs is pure and can be used after plain chlorination.
- ✓A rate of 0.8mg/lit/hour at 15N/cm^2 pressure is the normal dosage so as to maintain in residual chlorine of 0.2 mg/lit.

Super Chlorination

- ✓Super chlorination is addition of excess amounts of chlorine to a water supply, to insure disinfection within a short contact time.
- ✓About 10 to 15 mg/lit is applied with a contact time of 10 to 30 minutes under the circumstances such as during epidemic breakout water is to be dechlorinated before supply to the distribution system.

Break Point Chlorination

- The **breakpoint** is the point at which the chlorine demand has been totally satisfied - the chlorine has reacted with all reducing agents, organics, and ammonia in the water.
- When more chlorine is added past the breakpoint, the chlorine reacts with water and forms hypochlorous acid in direct proportion to the amount of chlorine added.
- This process, known as ***breakpoint chlorination***, is the most common form of chlorination, in which enough chlorine is added to the water to bring it past the breakpoint and to create some free chlorine residual.



Chlorine reacts with reduced materials (Fe^{2+}, Mn^{2+}, H_2S, organics, NH_3, etc.)

Breakpoint Chlorination

De-chlorination

- ✓Removal of excess chlorine resulting from super chlorination in part or completely is called **De-chlorination.**
- ✓Excess chlorine in water gives pungent smell and corrodes the pipe lines.
- ✓Hence excess chlorine is to be removed before supply.
- ✓Physical methods like aeration, heating and absorption on charcoal may be adopted.
- ✓Chemical methods like Sulphur dioxide (SO_2), Sodium Bi-Sulphate ($NaHSO_3$), Sodium Thiosulphate ($Na_2S_2O_8$) are used.

Points of Chlorination

- Chlorine applied at various stages of treatment and distribution accordingly they are known as pre, post and re-chlorination.

a) Pre-Chlorination

- Chlorine applied prior to the sedimentation and filtration process is known as *Pre-chlorination*.
- This is practiced when the water is heavily polluted and to remove taste, odor, color and growth of algae on treatment units.
- Pre-chlorination improves coagulation.
- Always followed by post chlorination, so as to ensure the final safety of water.
- The normal dose required are as high as 5 to 10 mg/l.

b) Post Chlorination

- **Post chlorination** is the application of chlorine after water has been treated or after filtration but before the water reaches the distribution system.
- At this stage, chlorination is meant to kill pathogens and to provide a chlorine residual in the distribution system.
- The dosage should be such as to have a residual chlorine of about 0.1 to 0.2mg/l having a contact period of 30min.
- Post-chlorination is nearly always part of the treatment process, either used in combination with pre-chlorination or used as the sole disinfection process.

c) Re-Chlorination

- In long distribution systems, chlorine residual may fall tendering the water unsafe.
- Application of excess chlorine to compensate for this may lead to unpleasant smell to consumers at the points nearer to treatment plant, in such cases chlorine is applied again that is re-chlorinated at intermediate points generally at service reservoirs and booster pumping stations.

Ozonation / ozone water treatment

- ✓Oxygen rich molecule is pumped in to water system to eliminate biological contaminants.
- ✓It is also effective for oxidizing and removing iron, sulfur, manganese and other inorganic substances.
- ✓Ozone is significantly more effective than chlorine at inactivating and/or killing viruses and bacteria.
- ✓Since ozone quickly converts to oxygen and leaves no toxic residual.
  - Can increase the dissolved oxygen concentration of water.

The disadvantages of Ozonation is:

- The cost of treatment is relatively high, being both capital and power intensive.
- There is no measurable residual to indicate the efficiency of ozone disinfection.
- Very reactive, irritative, toxic and corrosive, thus requires corrosion resistance materials, such as stainless steel.
- Low dosages may not effectively inactivate some viruses, spores and cysts.

UV disinfection

- **Ultra violet(uv) light disinfection:** is one water treatment system that can be used to remove most forms of microbiological contamination from water.
- Uv light is normally effective against all viruses, bacteria and protozoa.
- Uv light enters a microorganism its energy will damage the microorganism's cellular function so that it will not be able to grow.

Advantages of UV

- ✓ Proven technology, environmentally friendly, safe.
- ✓ Cost saving in both initial construction and long-term operation.
- ✓ There is no residual effect that can be harmful to human and aquatic life.
- ✓ Effective disinfectant for chlorine- resistant protozoa's like giardia.
- ✓ UV disinfection has a short contact time when compared to other disinfectants.
- ✓ Requires less space than other methods.

Disadvantages of UV

- Low dosage may not effective inactivating some viruses, cyst and bacteria.
- Do not remove all impurities
- Water needs to be pre-filtered
- It has single application- producing microbiologically safe, it has no effect on chemicals, heavy metals, sediments, and any other such issues.
- Needs electricity to work

MISCELLANEOUS WATER TREATMENT

1. Removal of Taste and Odor Problem

- ✓The sense of odour is closely related to that of taste.
- ✓In fact it is normally correct to suggest that most 'tastes' in water are really a sensation of smell
- ✓The brackishness associated with relatively high concentrations of salts such as sodium chloride or magnesium sulphate

- Iron and manganese in water often produce an astringent taste.
- Surface waters deficient in dissolved oxygen are often 'flat' to the taste.
- Consumers identify and accept water as being pure as a result of its lack of colour, its clarity and its lack of taste and odour

Causes of Odor and Taste

- ✓ Concentrations of inorganic salts (brackishness)
- ✓ Hydrogen sulphide
- ✓ Contact with painted surfaces
- ✓ Industrial discharges _ pesticides, phenols etc
- ✓ Metabolites of actinomycete, algae etc
- ✓ Dead and decaying organic material including sewage and algae
- ✓ Chlorination

Prevention of odours and tastes from microorganisms

- ✓ Some bacteria reduce sulphate to sulphide (H_2S)
  - These are controlled by aeration and chlorination.
- ✓ Mold-like bacteria grow frequently in mains as a slime on the inside of the pipes
  - They may be controlled by treating reservoirs with copper sulphate or by ensuring there is residual chlorine throughout the mains

- ✓ Iron bacteria - grow in water containing high concentrations of iron and in which the D.O. is limited
- ✓ They produce objectionable odours and tastes as well as leading to the precipitation of iron
  - The remedies are removal of iron, chlorination or dosing with copper sulphate

Recommended method to remove test and odour problem

1. Aeration

- ✓ Slightly volatile odors resulting from the decomposition of vegetation.
- ✓ Due to aeration, concentrations of odoriferous metabolites emanating from living microorganisms can be decreased
- ✓ Thus, reducing the amount of activated carbon required at a later stage.

2. Chlorine

- ✓ Marginal chlorination is not sufficient to remove odoriferous compounds and also may add a noticeable smell of chlorine
- ✓ Super chlorination with more than a breakpoint dosage will destroy most malodorous compounds

3. Ozone

- ✓ Ozone reduces H_2S odors and tastes and also the odors from decaying vegetable matter.
- ✓ Algae must be removed prior to the addition of ozone

4. Hydrogen peroxide

✓This is occasionally used for odor control.

✓It is generally too costly.

5. Chlorine Dioxide

✓ClO_2 is particularly effective at removing phenolic odors from water.

✓It is most effective when mixed with an excess of chlorine

6. Potassium Permanganate

- ✓ It is one of the most effective chemical reagents for odour and taste control.
- ✓ In the USA it is widely used and is most effective between PH 8.0 and PH 8.3
- ✓ Although it is about three times as costly as activated Carbon it has been claimed to be up to five times as effective

7. Activated Carbon

- ✓Powdered activated carbon is a fine black powder applied either to the raw water, or the mixing basin, on the settling basin or directly before the filters
- ✓A normal dose might be 2.0 mg/1 to clarified water although it has been applied at rates up to 125 mg/1 to raw water
- ✓Granular activated carbon consists of relatively large grains and is held in filter towers through which the water is continually passed
- ✓At low levels of taste and odour powdered activated carbon is suggested as being more economic than the granular

2. Removal of Hydrogen sulphide

- ✓ The permissible concentration of H_2S in water, which are required for domestic purpose, is 0.5 mg/1 of H_2S
- ✓ It is offensive when its concentration greater than 1.0 mg/l
- ✓ The odours are less noticeable as the PH rises due to the formation of alkaline sulphides
- ✓ Hydrogen sulphide is removed by aeration and chlorination

- ✓ Aerators are normally of the natural-draft cascade-type but aeration has only a limited effect
- ✓ Removal by chlorination is highly effective but as much as 10 kg of chlorine may be required to remove 1.0 kg of hydrogen sulphide
- ✓ It is necessary to establish a cost balance between aeration and chlorination

3. Removal of Iron and Manganese

- ✓ Iron and manganese can be dissolved from sandy soils, laterite, shale, sandstone and other rocks by acid water which contains no dissolved oxygen (such water may have an organic content)
- ✓ Decomposition consumes the oxygen and produces carbon dioxide, which is acidic
- ✓ The iron is usually in the form of ferrous bicarbonate and the manganese in the form of manganese oxide or bicarbonate. These forms are soluble

- If the water is now exposed to air so that oxygen can enter into solution and carbon dioxide leaves, the ferrous form is oxidized to ferric, and the manganese to manganic
- These latter forms are insoluble and so visible precipitates are formed
- Therefore, iron bearing water may be clear when pumped up from a well, but may on standing, turn brown and turbid

- ✓Manganese problem in a distribution system may take years to appear because the reactions are slow until catalyzed by deposits
- ✓Iron and manganese problems most commonly occur with groundwater, but may also appear in water drawn from the bottom of a stratified reservoir or in acidic waters
- ✓Manganese may occur in significant quantities in river water, sometimes coming from acid mine drainage

Effects of Iron and Manganese

- These metals in potable water can have:

a) Colour in the water

b) Staining of plumbing fixtures and clothing (Fe -brown. Mn - black)

c) Astringent, metallic or medicinal taste in the water

d) Growth of iron bacteria

e) Brown stains on cooked vegetables and discoloured etc.

Method of Treatment

- Groundwater containing iron and/or manganese needs only treatment to remove these metals, and disinfection.
- Surface water containing iron or manganese will usually also require removal of the turbidity of clay colloids.
- Small quantities of iron can be removed by normal conventional treatment.
- If a higher PH is needed to remove iron or manganese then alum may not be suitable and ferric coagulants may be preferred if removal of turbidity and iron or manganese is effected simultaneously.

1. Aeration

- ✓ It is commonly used, but some processes require exclusion of air at the early stages.
- ✓ Aeration raises the PH by removing carbon dioxide, and adds oxygen.
- ✓ Only 0.14 mg/1 of dissolved oxygen is needed to oxidize 1 mg/1 of iron.

2. Sedimentation

- ✓ It is useful where large particles are formed in a short time

3. Filtration

- ✓ It is required in most processes as a means of capturing small suspended particles
- ✓ Also often to promote oxidation by the catalytic effect of deposits on the sand grains. Because the deposits are useful the filter will take time to mature and should not be back washed too thoroughly

4. Chlorination

- ✓ It is simple and cheap, but slow for manganese below PH 8.5 and in some cases may form very fine precipitates

5. Lime

- ✓ Raising the PH will cause oxidation, but this technique is not suitable for hard waters because it will cause deposition of calcium carbonate on the filter sand

6. Ion exchange

- ✓ When used for softening water will also remove soluble iron and manganese, it should therefore be done in the absence of air to prevent formation of the insoluble forms.

LET US PROVIDE QUALITY WATER FOR OUR COMMUNITY