# ENVIRONMENTAL ENGINEERING -1

## Lecture 16 – Filtration

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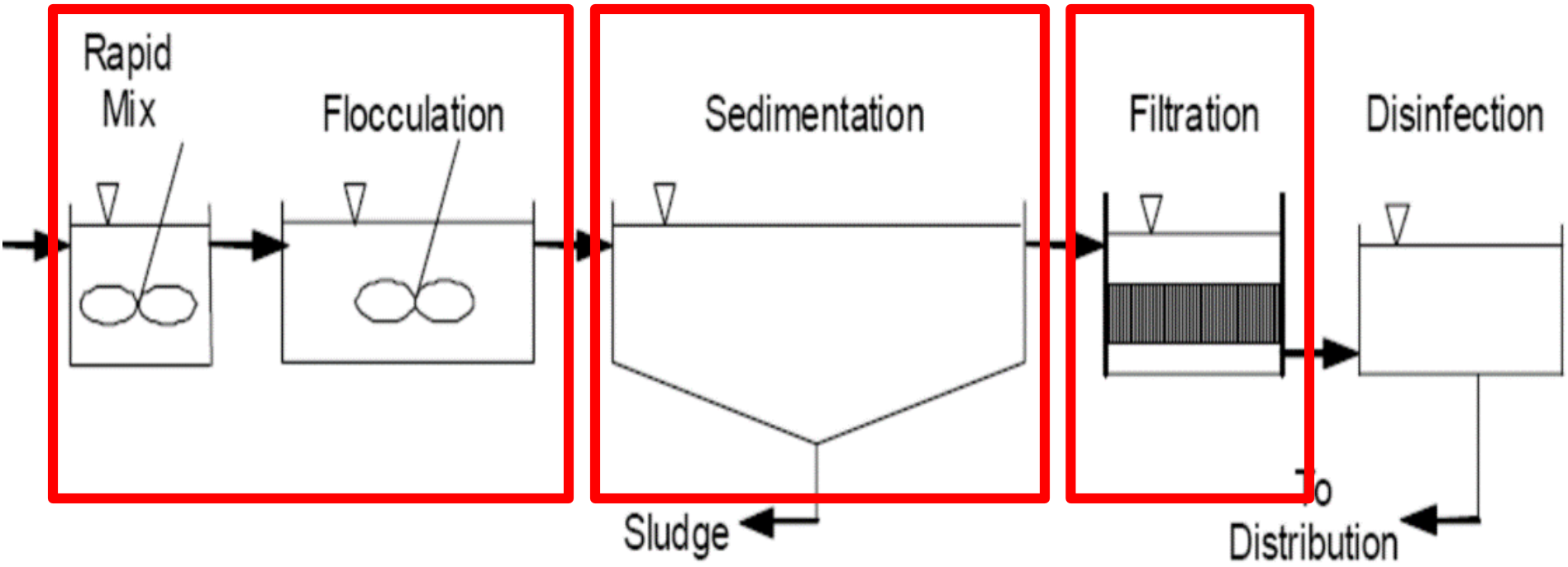

Rapid
Mix
Flocculation
Sedimentation
Filtration
Disinfection
Sludge
To
Distribution

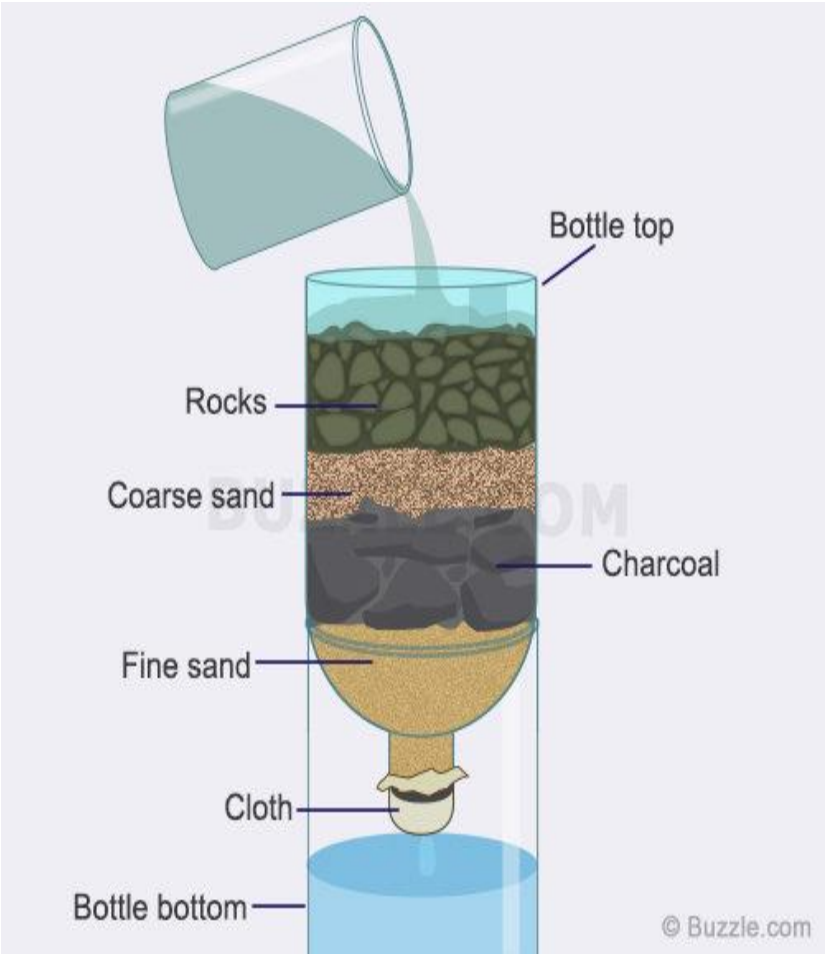
# Definition

*"It is the process in which suspended matter is removed from the water by passing the water through granular media".*

# Filter Media

- Granular media includes:

1. Sand
2. Crushed anthracite coal
3. Crushed stones




- A combinations of these media can also be used these days .

# Factors

The choice of filter media is totally depends on some factors :

1. Durability Required
2. Desired degree of treatment
3. Length of filter run
4. Ease of backwash

## Properties of Ideal Medium

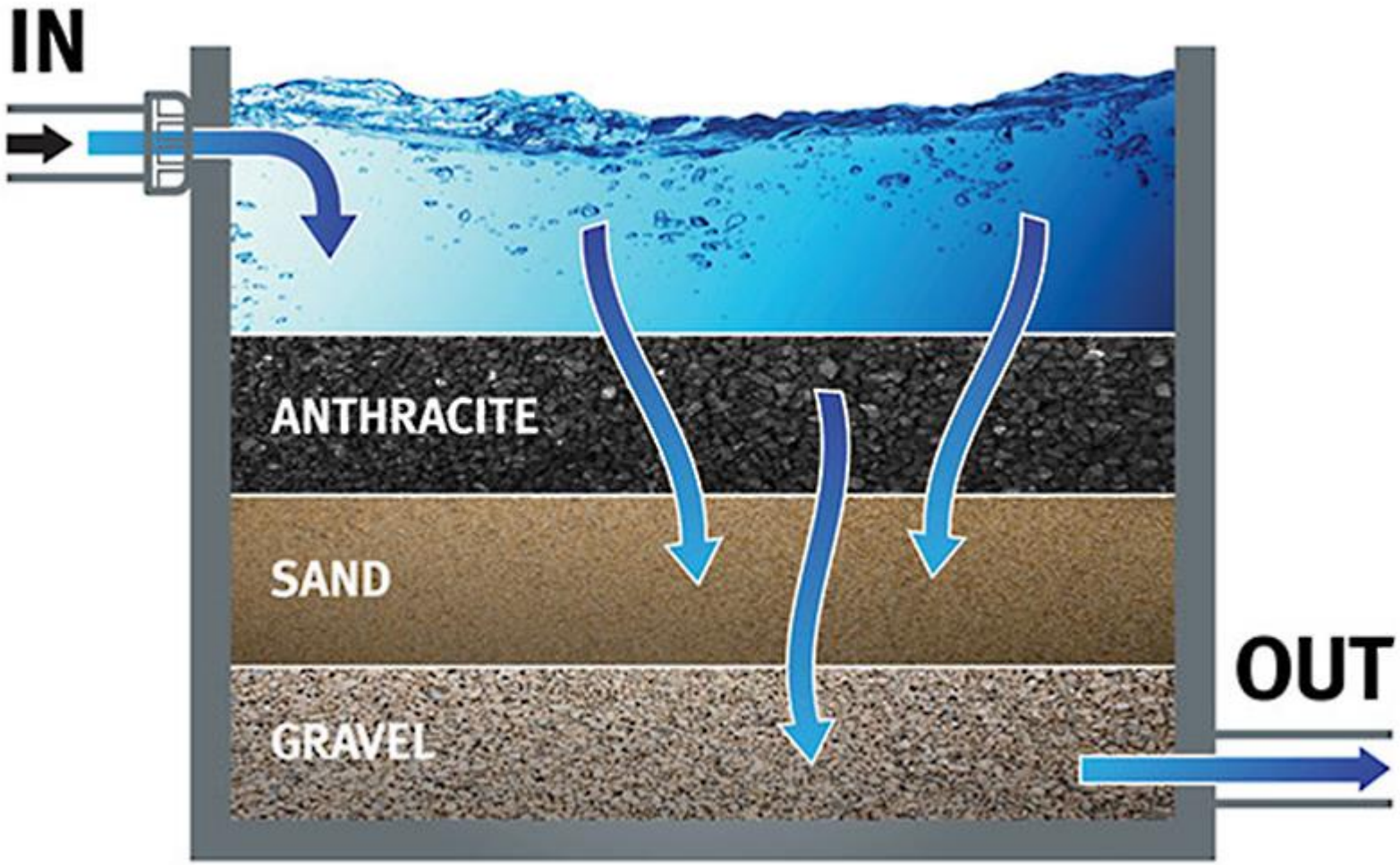
- It should provide satisfactory effluent
- Retain max. quantity of solids
- Readily cleaned with a minimum of wash water

# Different Types of Media

1. Sand (cheapest media)
2. Anthracite (specific gravity less than sand)
3. Other materials(Crushed glass, shredded coconut husk)
4. Mixed Media w.r.t Rapid sand filter
5. Gravel

# Anthracite

# Mixed media



# Theory of Filtration

- Filtration take place in 2 stage process:

1. **Filtration stage** (during which particles accumulate on or within filter media)

2. **Backwash stage** (during which the particles are removed from the filter)

- The removal of particles is brought by various mechanisms. These include:

1. **Physicochemical Process**
2. **Biological Purification Process**

- The **physicochemical process** consists of two steps:

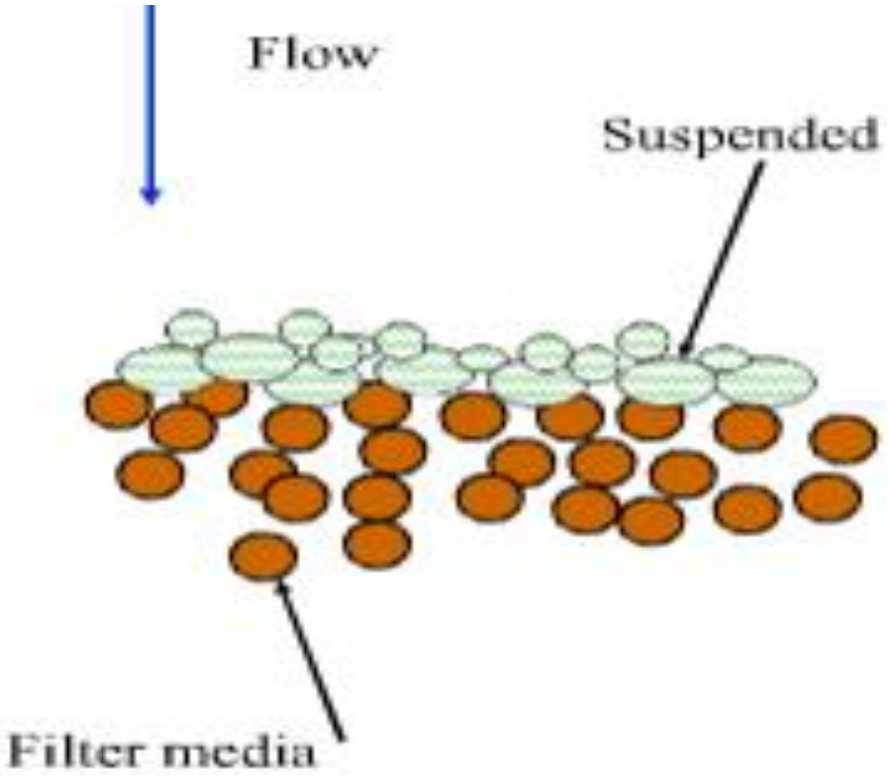
1. **Particle transport**
2. **Particle attachment**

# Particle Transport

The main mechanisms for transport are;

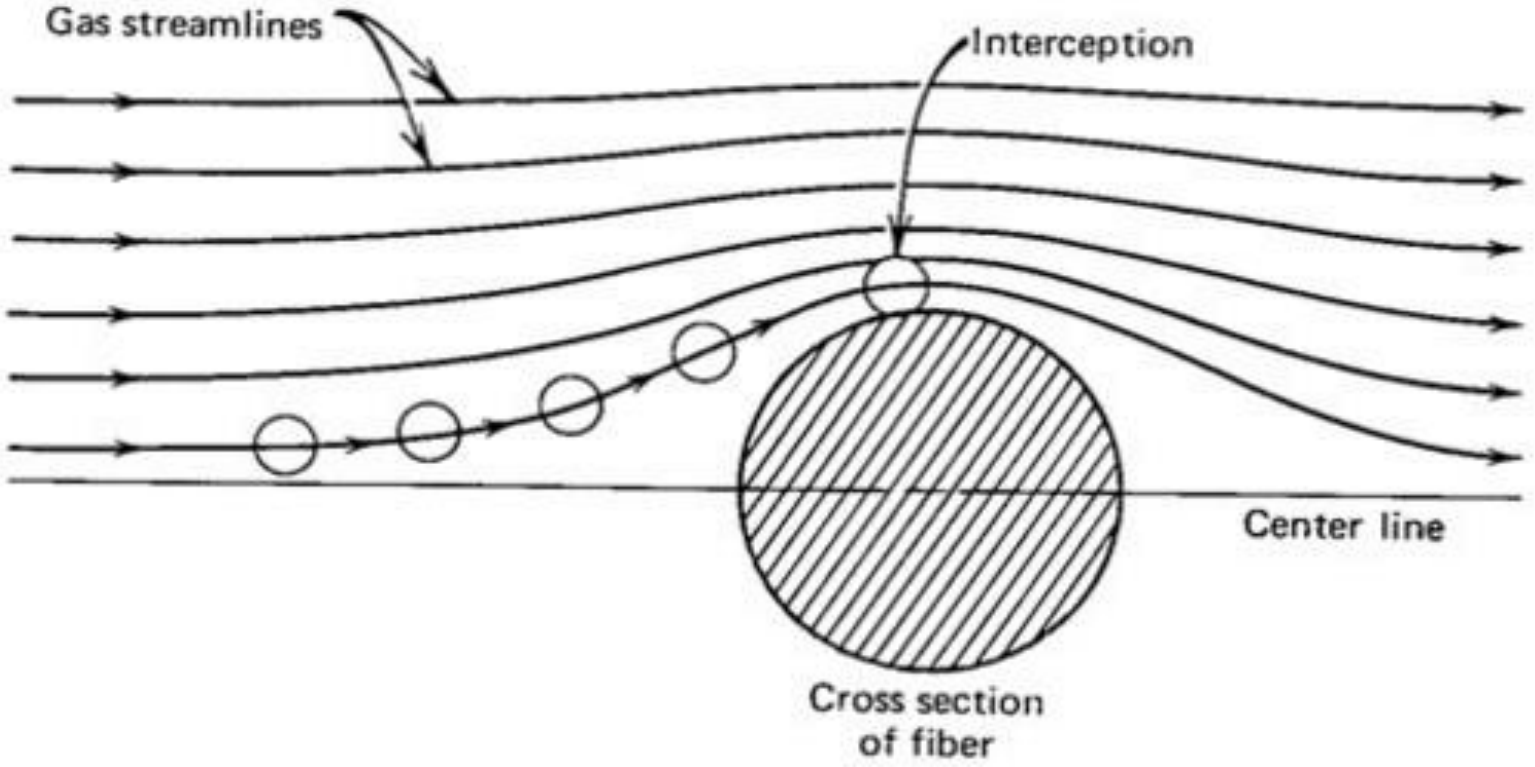
1. Mechanical Straining
2. Interception
3. Gravitational Settling
4. Diffusion

- **Mechanical Straining:**



# 2.Interception:

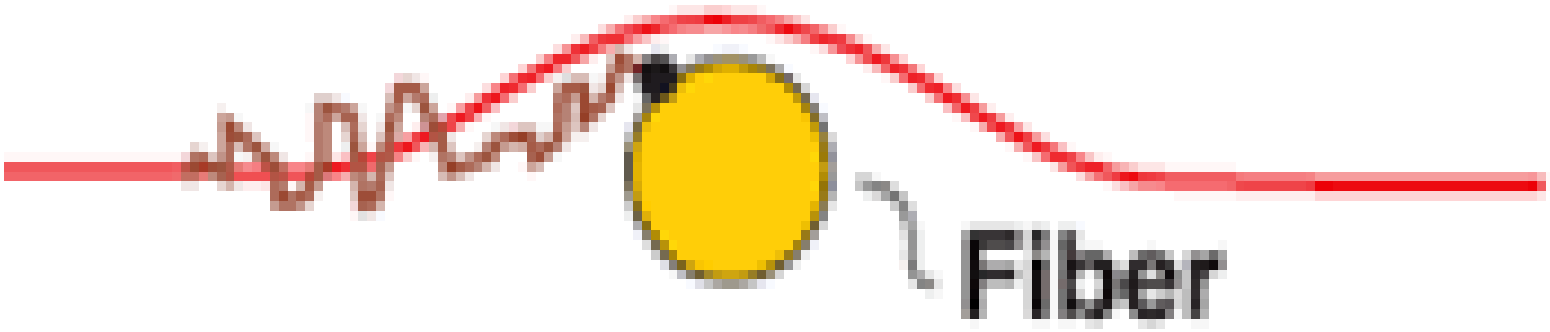
- Many particles that move along in the streamline are removed when they come in contact with the surface of the filter media.



# 3. Gravitational settling:

- Particles settles on filtering medium within the filter under gravitational force

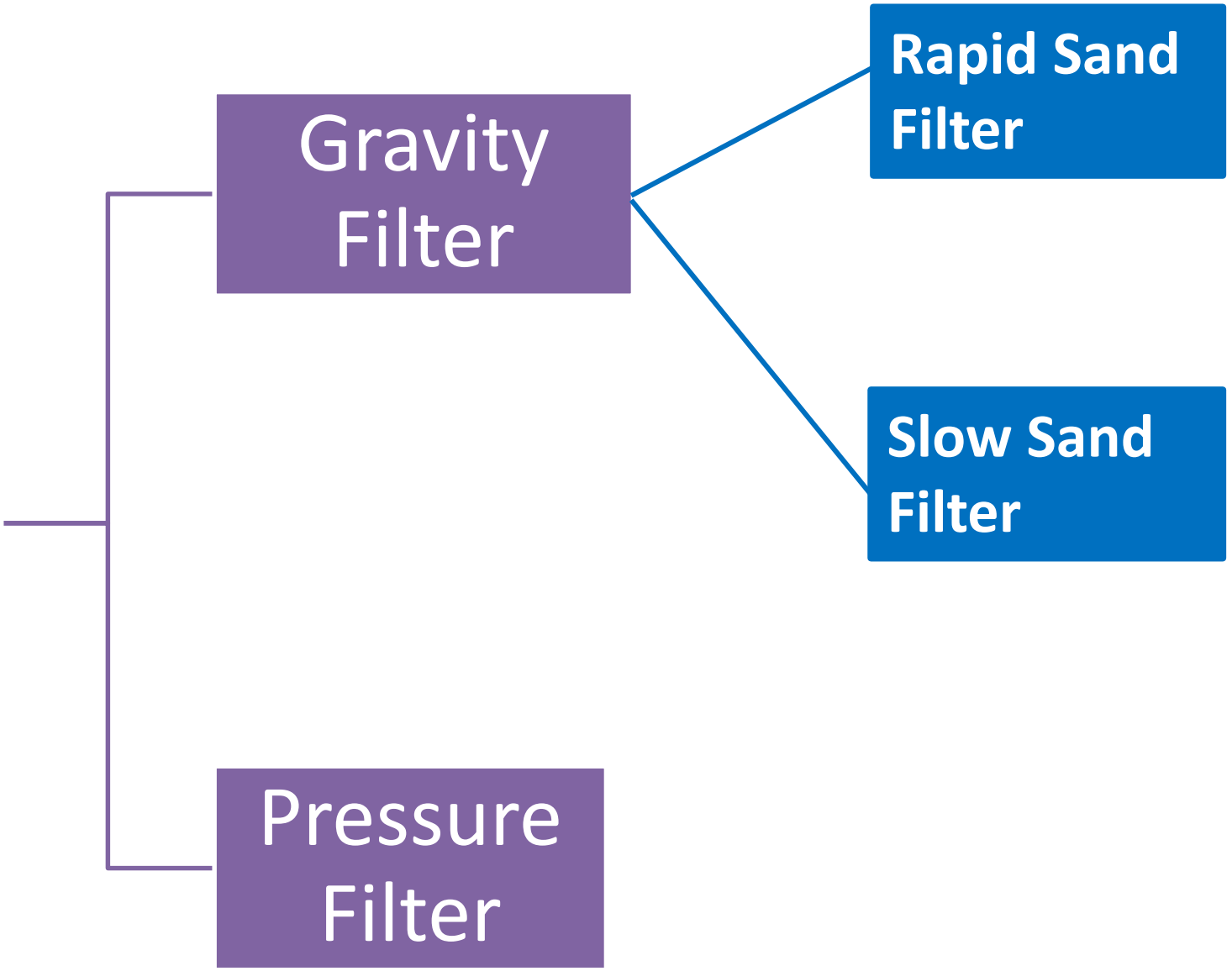
# 4. Diffusion



## 2.Biological Purification process

1. It is only applicable in slow sand filter
2. Formation of certain type of layer on the top of filter bed after a certain period of time
3. Formed layer carry out the oxidization of organic matter(if any)
4. Formed layer is called as **Schmutdzekh layer**
5. Due to this layer efficiency of slow sand filter increases

# Classification of Filter



# Filter Classification

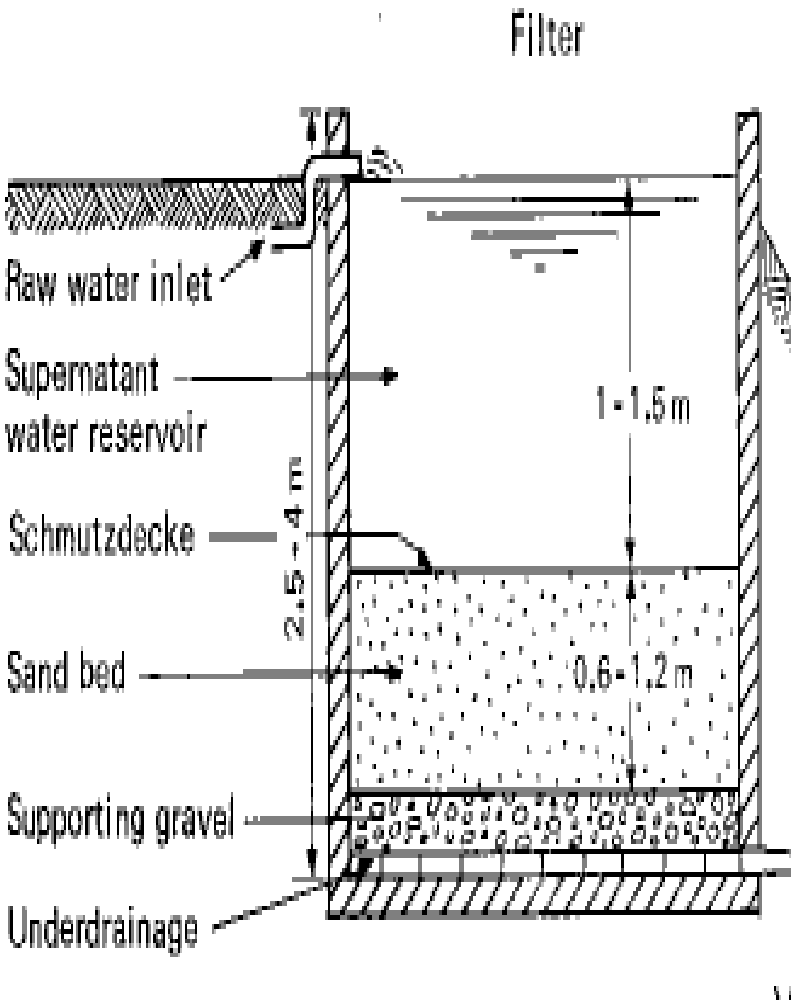
- In Rapid filtration water that has been pretreated with coagulants and flows downward by gravity through filter bed that is typically 0.6 to 1.8 m deep, particles are collected throughout the bed.
- Slow sand filtration has similarities to rapid filtration including gravity-driven downward flow through a bed of granular material but operated at a loading rate about 100 times lower the rapid filtration.

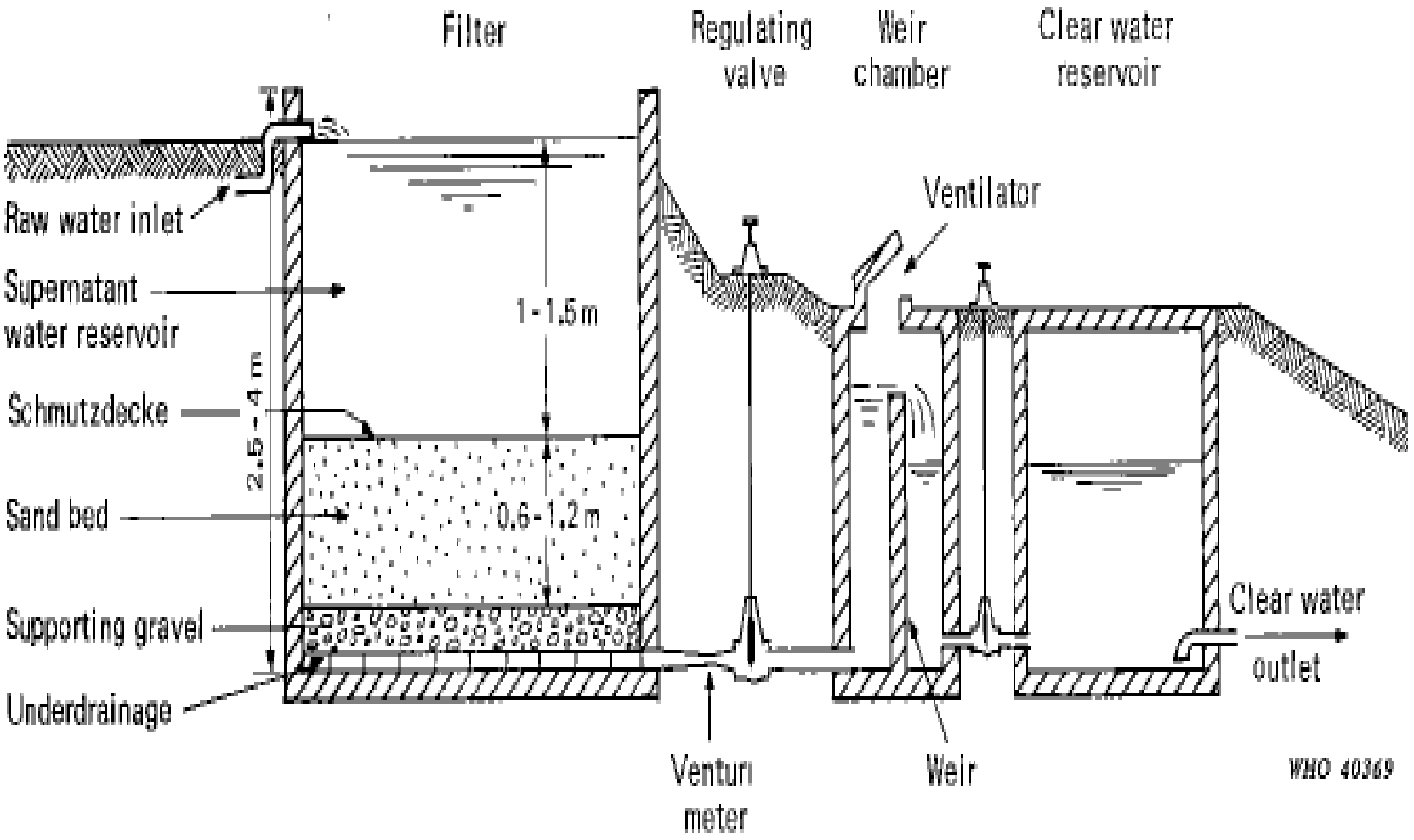
# Slow Sand Filtration

# Filter Design & Construction

- The essential parts of slow sand filter are:

1. The supernatant water reservoir
2. The filter bed
3. The filter bottom & under drainage system
4. The filter box
5. The filter control system




Filter
Regulating valve
Weir chamber
Clear water reservoir
Ventilator
Raw water inlet
Supernatant water reservoir
Schmutzdecke
Sand bed
Supporting gravel
Underdrainage
1 - 1.5 m
2.5 - 4 m
0.6 - 1.2 m
Clear water outlet
Venturi meter
Weir
WHO 40369

# Process Description

- Influent water seeps down by gravity through a submerged sand bed.
- In physicochemical process ,particles larger than bed are removed by straining & smaller particles are removed by combination of interception, gravitational settling etc.
- With the passage of time the surface of bed form a biological mat ,called a **Schmutzdecke**.
- The **Schmutzdecke** forms an additional filtration layer of biological community that degrades some organic matter

# Pre-treatment

- In the past slow sand filter were used only for **low turbidity ( < 10 NTU)**water and no treatment was required.
- Now they are also used for high turbidity water and pre-treatment is required,

# Performance

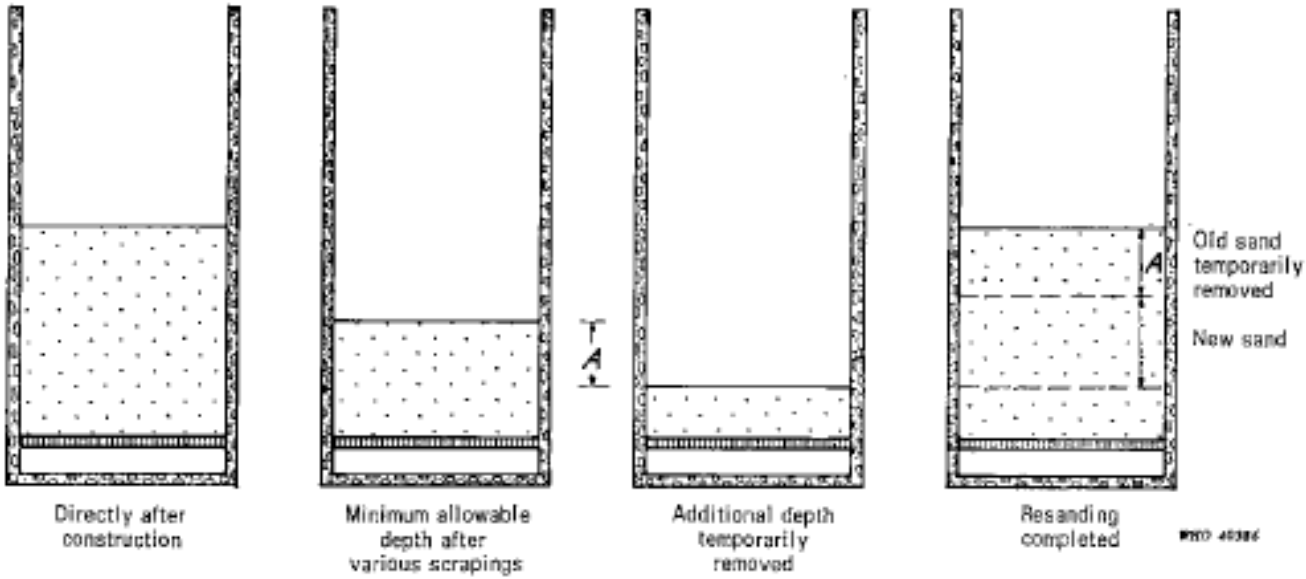
- The performance of the filter varies with time, first increasing and than decreasing with time as head loss increases with time. So filters required cleaning after certain time interval.

# Cleaning of filter( by “Scrapping  upper layer”)

- To clean filter-bed , the raw water inlet valve is first closed, allowing the filter to continue to discharge to the clear water well as long as possible.
- When the supernatant water has been drained off , the schmutzdecke is dry enough to handle, cleaning should start.
- The cleaning of the bed may be carried out by hand or with mechanical equipment.

# Re sanding

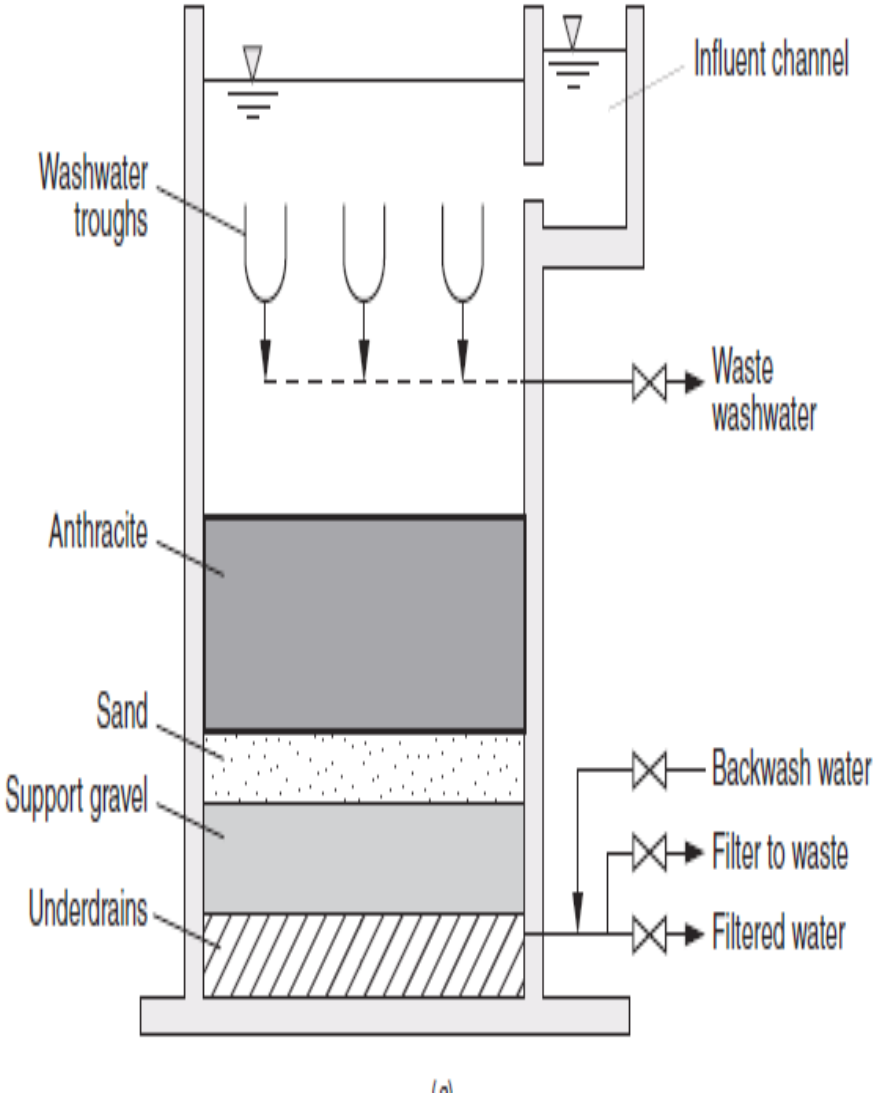
- After each cleaning the sand thickness decreases
- When the depth reaches to 600mm ,more sand is filled to make to original depth
- New sand is not applied  at the top but below the layer of the old sand by throwing over process



# Rapid Sand Filter

# Filter Design & Construction

- Supernatant reservoir
- Filter bed
- Under drainage system
- Filter control system
- Wash water trough



# Process flow description

- Filter bed is contained in a deep structure that is typically constructed of reinforced concrete and open to atmosphere.
- Rapid filtration operates over a cycle consisting of two stages :

1. Filtration stage
2. Backwash stage

# Pre-treatment

Pre treatment is required prior to rapid sand filtration, typical employs coagulation, flocculation and sedimentation.

# Cleaning of Filter bed( by Back Washing)

The physical steps that occur during the backwashing stage include the following:

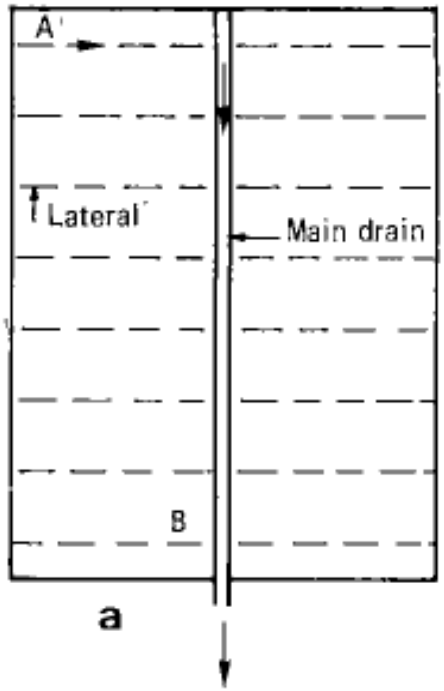
- The filter influent and effluent lines are isolated with valves and the backwash supply and wastewater valves are opened.
- Backwash water, which is potable water produced by the plant, is directed upward through the filter bed.
- The upward flow flushes captured particles up and away from the bed

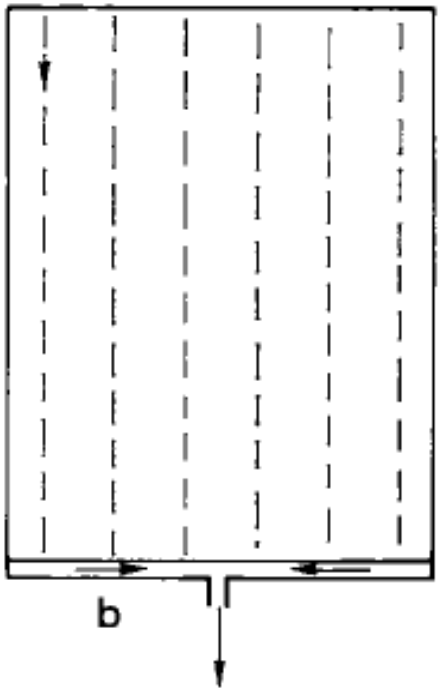
- Washing consists of passing filtered water upward through the bed at such a velocity that it causes the sand bed to expand until its thickness is 25-40% greater during filtration depending upon the media.
- The grains move through the rising water, rub against each other and are cleaned of deposits.
- The back wash velocity must be sufficient to carry off the suspended matter yet not so great to wash out the filter medium.
- After backwash , the valve positions are reversed and the filter is placed back in service
- Collected water after back washing goes through wash water troughs

# Under drainage System

## Purpose

- Collect filtered water from gravel
- Distribute wash water during washing
- Maximum velocity of flow in under drain should not more than 0.2 m/s
- Maximum spacing of under drain is 3 m
- Under drain usually consists of the title drains with open joints
- A network of pipes also used, made of cast iron is laid under the gravel. Laterals are generally 150 mm to 200mm apart.


A
Lateral
Main drain
B
a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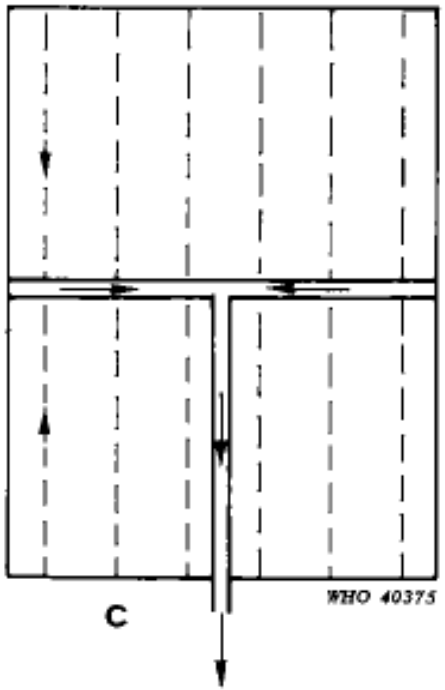
c
WHO 40375

# Wash water trough

- These are  small channel system and used to collect backwash water after it emerges from the sand and drain from where it is finally disposed off.

- Maximum space between two wash water trough should not more than 2 m.

- A free board of 50 to 100mm is provided at upper end.

- Trough bottom are usually horizontal, however, they may slope towards gullet

# Wash water trough

- The dimension of wash water troughs, when the bottom is horizontal and the flowing water can be allowed to assume its own slope can be obtained by using following formula

$$Y = 1.75 \sqrt[3]{\frac{Q^2}{gB^2}}$$

Where,

- Q= discharge received by the trough (m3/sec)
- B=width of trough(m)
- Y=Depth of water in trough (m)

(c) Rapid filter during the backwash cycle. Washwater flows up through the media, pours over into the troughs, and then runs into the central channel. The influent valve, visible at the far end of the central channel, is closed, and the waste washwater flows out through the open washwater valve.

# Washing Process

Rate of washing

- 0.15-0.9 m/min. This rate produce a sand expansion of 30-50%

Water required

- 1-5% of filtered water

Head required

- Wash water is supplied to give a **head of 10m** above wash water trough

Time required

- Washing takes 5 minutes but the bed may be out of operation for 10-20 minutes

Washing frequency

- Washing is done when head losses reach 2.5 m

Minimum No.: At least 2 or $N=0.5(A)^{1/3}$

# Comparison b/w slow sand & rapid sand filters

| Parameters | Slow sand filter | Rapid sand filter |
|---|---|---|
| Filtration rate | 3-6 m/day | 120-360m/day |
| Size of sand | 0.15-0.35 mm | > 0.45mm |
| Depth of sand | 1-1.2m | 0.6-0.75m |
| Depth of water over sand | 1-1.75m | 1-1.25m |
| Uniformity co efficient | 2-3 | 1.2-1.7 |
| Loss of head | 0.05 -1.25m | 0.3-3m |
| Length of run | 20-60 days | 12-72 hours |
| Impurities penetration | Mostly on upper surface | Deep |
| Cost of construction | High | Low |
| Operational cost | Low | High |
| Method of cleaning | Scrapping upper layer | Back washing |
| Pre treatment | Generally Nil | Coagulation |
| Bacterial removal | More effective | Less effective |
| Depth of gravel | 200-300 mm | 400-600mm |

# Filter Operational Difficulties

## 1. Air binding

It is caused by :

- Negative head
- High temperature
- Algal action

**Air binding may be prevented through:**

- Avoidance of excessive negative head
- Keeping the filters under shed
- Algal control i.e. $CuSO_4$ treatment

## 2. Mud Accumulation

- Mud may accumulate on the filter surface to form a dense mat. Sometimes lumps are also formed at the surface. These lumps sink sooner or later to the gravel surface where it will interfere with the rising wash water and cause excessive velocities around the edge of the mud balls.
- Use of surface wash and air scour had been very successfully used to reduce this problem.

## 3. Sand Incrustation

When heavy lime treatment of water is practiced, deposition of calcium carbonate on sand may occur and thus enlargement of sand grains occurs. This may result in troubles during filtration as well as back washing.

# Numerical 1(Slow sand filter)

- Calculate the size and number of slow sand filters to treat a flow of 8000 m3/day.

# Numericals ( Rapid sand filter)

- A rapid sand filter is to treat 23000m3/d at a rate of 120m/d. Find the size and no. of units req. if the filtration rate is not to exceed 180m/day with one filter being backwashed. Nor 240m/d when two units are out of operation. How much water would be req. to backwash one filter at a rate of 1m/min for 10min.
- Calculate the no. and size of the filter to serve design population of 30000 persons with avg. consumption of 400lpcd. The filtration is not to exceed 120m/day with all the filters in operation and one filter being backwashed it should be less than 156m/day.

- A filter bed is 4.5 x 9 m. After filtering 9450m3/d in 24hr. The filter is backwashed at a rate of 600mm/min for 15mins. Compute avg. filtration rate quantity and % of treated water used in washing.
- Calculate the no. and size of filters to serve a population of 30000 with an avg. water consumption of 400L/c/d. The filtration rate is not to exceed 5m/hr. with all filters in operation and 6.5m/hr when one filter is being back washed.

- Determine the depth of a rectangular wash water trough which is 300 mm wide. The trough has to receive the wash water from half of the surface of a rapid sand filter treating a flow of 1310 litre/min. The rate of filtration is 0.08 m/min and back wash is 0.6 m/min