FILTRATION
• **Purpose of filtration**

  ◦ To remove colloids turbid particles
  ◦ To reduce organic content.
  ◦ To remove micro-organisms (bacteria, protozoa & virus)
  ◦ To oxidize Fe\(^{++}\) to Fe\(^{+++}\), Mn\(^{++}\) to Mn\(^{++++}\)
  ◦ To oxidize NH\(_4^+\) bacteriologically to nitrates
  ◦ To remove colors.

• **Mechanism involved:**

  ◦ 1. Mechanical straining
  ◦ 2. Sedimentation
  ◦ 3. Adsorption
  ◦ 4. Centrifugal separation
  ◦ 5. Chemical oxidation of Fe\(^{++}\), Mn\(^{++}\) and NH\(_4^+\)
  ◦ 6. Surface electrolyte action
Filtration

- Filtration is the process of passing water through material to remove particulate and other impurities consist of suspended particles (fine silts and clays), biological matter (bacteria, plankton, spores, cysts or other matter) and floc.
The material used in filters

- Bed of sand, coal, or other granular substance.

Sand should contain the following properties:
- Free from dust and other impurities
- Uniform in nature and size
- Hard and resistant
- Not to lose more than 5% of its weight after being placed in \( \text{H}_2\text{SO}_4 \) for 24 hr
Size of sand is measured and expressed by the term called **effective size**.

**Effective Size (ES)** is defined as the size of a sieve opening through which 10 percent (by weight) of the particles (sand) will pass and is given the symbol $D_{10}$.

In a similar way, the size of a sieve opening through which 60 percent (by weight) of the particles (sand) will pass is given the symbol $D_{60}$.

**Uniformity Coefficient (UC)** which is a measure of the grading of the material, is the ratio of $D_{60}$ and $D_{10}$. Ratio of sieve size in mm through which 60 percent of the sample of sand will pass, to the effective size of the sand.
**Mechanism**

- **Coagulation – Sedimentation**
  Particle of size smaller than the size of the voids are also removed. Void spaces act like tiny coagulation come sedimentation tank. The colloidal matter arrested in these voids is a gelatinous mass and therefore attract other finer particle to settle down in the voids and get removed.

- **Adsorption**
  Adsorption is the process of particles sticking onto the surface of the individual filter grains or onto the previously deposited materials. The forces that attract and hold the particles to the grains are the same as those that work in coagulation and flocculation.
• Biological action
  microorganism and bacteria are generally present in the voids of the filters organic impurities utilize by microorganism and convert into harmless compound by biological metabolism
  harmless compound generally form a layer on the top which is called schmutzdecke or dirty skin. This layer further helps in absorbing and straining out the impurities
• Straining.
  The suspended particles present in water and bigger than the size of the voids in sand layer of the filter cannot pass through these voids and get arrested
• Absorption
  The soaking up of one substance into the body of another substance.
Classification of filters on

- filtration rate,
- Type of filter media
- Type of operation
Type of filter

- Slow sand filter
- Rapid gravity filter
- Pressure filter

Classification of filter

- Filter
  - Slow sand filters
  - Rapid sand filters
    - Rapid gravity filters
    - Pressure filters
Filter

- Filter tank or filter box
- Filter sand or mixed-media
- Gravel support bed
- Under drain system
- Wash water troughs
- Filter bed agitators
The filter will exhibit head loss and "clog" after a given time period (varies from several hours to several days).

Clogging may be defined as a buildup of head loss (pressure drop) across the filter media until it reaches some predetermined design limit. Total design head loss in gravity filters generally ranges from about 1.8 to 3.0 m depending on the depth of the water over the media.
Backwash mode of operation

How filter operates
1. Open valve A. (This allows influent to flow to filter.)
2. Open valve B. (This allows water to flow through filter.)
3. During filter operation all other valves are closed.

How filter is backwashed
1. Close valve A.
2. Close valve B when water in filter drops down to top of overflow.
3. Open valves C and D. (This allows water from wash-water tank to flow up through the filtering medium, loosening up the sand and washing the accumulated solids from the surface of the sand, out of the filter. Filter backwash water is returned to head end of treatment plant.

How to filter to waste (if used)
1. Open valves A and E. All other valves closed. Effluent is sometimes filtered to waste for a few minutes after filter has been washed to condition the filter before it is put into service.

Figure 4-28 Typical gravity flow filter operation. (From Metcalf & Eddy, Inc. [440].)
### Difference between

<table>
<thead>
<tr>
<th></th>
<th>Low Sand Filter</th>
<th>Rapid Sand Filter</th>
<th>Pressure Filter</th>
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<tbody>
<tr>
<td><strong>Filtration Mechanism</strong></td>
<td>Biological action, straining, and adsorption.</td>
<td>Primarily adsorption. Also some straining.</td>
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</tr>
<tr>
<td><strong>Rate of filtration</strong></td>
<td>100-200 L/h/m²</td>
<td>3000-6000 L/h/m²</td>
<td>6000-15000 L/h/m²</td>
</tr>
<tr>
<td><strong>Primarily straining.</strong></td>
<td>Manually removing the top 2 inches of sand.</td>
<td>Backwashing.</td>
<td>Backwashing.</td>
</tr>
<tr>
<td><strong>Area</strong></td>
<td>100-2000 m²</td>
<td>10-80 m²</td>
<td>Dia 1.5-3 m length 3.5-8 m</td>
</tr>
<tr>
<td><strong>Depth</strong></td>
<td>2.5- 3.5 m</td>
<td>2.5-3.5 m</td>
<td>-</td>
</tr>
<tr>
<td><strong>Effective size</strong></td>
<td>0.2 -0.4 mm</td>
<td>0.35-0.55mm</td>
<td>-</td>
</tr>
<tr>
<td><strong>Uniformity coefficient</strong></td>
<td>1.8-3</td>
<td>1.3-1.7</td>
<td>-</td>
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<tr>
<td><strong>Removal efficiency</strong></td>
<td>Bacteria 98-99 %</td>
<td>Bacteria 80-90</td>
<td>Turbidity &lt; 50 mg/ L</td>
</tr>
<tr>
<td></td>
<td>Turbidity 50 mg/ L</td>
<td>Turbidity 50 mg/ L</td>
<td>Removal efficiency of bacteria and turbidity more but the quality of the effluent is poorer</td>
</tr>
<tr>
<td><strong>Common Applications</strong></td>
<td>Small groundwater systems.</td>
<td>Most commonly used type of filter for surface water treatment.</td>
<td>Iron and manganese removal in small groundwater systems.</td>
</tr>
</tbody>
</table>
Operational troubles in Rapid gravity filters

- Mud balls in filter media
- Media cracking or shrinkage
- Media boils during backwash
- Excessive media loss or visible disturbance
- Filters that will not come clean during backwash
- Algae on walls and media
Problem:

Water is treated by rapid sand filter at a rate of 9 m/hour. The filter bed has a thickness of 1.2 m and is composed of crushed anthracite with a mass density of 1500 kg/m³, a pore size of 40%, a grain size of 1.2 mm and a coefficient of permeability equal to 15 m/h. The water depth to be 1.6 m while at the end of the filter run the minimum water pressure occur at a depth of 0.4 m below the top of filter bed. As under drain perforated laterals are used having per square meters 50 openings of 8 mm diameter. Calculate

(a) the resistance of the filter bed at the beginning and end of filter run when a negative pressure of 0.5 m water column is allowed.

(b) the resistance of the filter bed during back washing at 20% expansion.

(c) The resistance of the filter bottom during back washing at the rate of 30 m/hour.
Data:

- Rate of Filtration
  - $q = 9 \text{ m/hour} = 2.5 \times 10^{-3} \text{ m/sec.}$
- Thickness of filter bed $L = 1.2 \text{ m}$.
  - $\rho_f = 1500 \text{ kg/m}^3$
  - $\rho_w = 1000 \text{ kg/m}^3$
- $K = \text{Coefficient of Permeability} = 15 \text{ m/h}$
  - $= 4.16 \times 10^{-3} \text{ m/sec.}$
- Water depth $= 1.6 \text{ m}$
- U/D System $N = 50$, $d_0 = 0.008 \text{ m}$
- $I = \text{Slope of piezometric surface in filter bed or resistance offered in m/m.}$
The resistance of filter bed at the beginning of filter run $t = 0$

By Darcy’s equation $q = K I_0$
$I_0 = (q/K) = (2.5 \times 10^{-3} / (4.16 \times 10^{-3})) = 0.6 \text{ m/m}$.

Loss of head at $t = 0$
$H_a = I_0 \times L = 0.6 \times 1.2 = 0.72 \text{ m}$.

Maximum head loss at the end of filter run $(x / 0.4) = (0.72 / 1.2)$
Therefore, $x = 0.6 \times 0.4 = 0.24 \text{ m} + 0.5 = 0.74 \text{ m}$. 
Resistence during back wash:

- **E** – Percentage increase in filter bed thickness by expansion during backwashing.
- **L** – Filter bed thickness in m.
- **Le** – Thickness of expanded filter bed during back washing (m).
- **P** – Porosity in filter bed
- **Pe** – Porosity of expanded filter bed during back washing.

\[
E = 100\times \frac{(Le-L)}{L} = 100\times \frac{(Pe-P)}{1-P}
\]

- **E** – 20% 
  \[
20 = 100\times \frac{(Le-1.2)}{1.2}
\]
  \[
Le = 1.44m.
\]
- **E** – 20% 
  \[
20 = 100\times \frac{(Pe-0.4)}{1-Pe}
\]
  \[
Pe = 0.5
\]
The resistance of expanded filter bed (Loss of head at filter bed) = The submerged wt. of filter bed.

\[ H_{\text{bed}} = (1 - Pe) \times Le \times \left( \frac{\rho_f - \rho_w}{\rho_w} \right) \]

\[ = (1 - 0.5) \times 1.44 \times \left( \frac{1500 - 1000}{1000} \right) \]

Resistance to filter bottom during backwashing.

Rate of backwashing = 30 m/h = 8.33 \times 10^{-3} m/sec.

The resistance of filter bottom equals to velocity head of the jets issuing from the openings.

\[ H_{\text{bottom}} = \frac{V_0^2}{2g} = \frac{8\times V^2}{(\pi^2 \times g \times \mu^2 \times \eta^2 \times D_0^4)} \]
- $V_0$ = Velocity of the jet at the exit.
- $V$ = Rate of backwashing m/sec ($m^3/ (m^2sec)$
- $\mu$ = Discharge coefficient of openings = Coefficient of contraction.
- $\eta$ = No. of openings per $m^2$ of filter bed
- $D_0$ = Diameter of each opening.
- $H_{bottom}$
  
  $$= \frac{(8*(8.33*10^{-3})^2)}{(3.14^2*9.81*0.65^2*50^2*0.008^4)} = 1.33m.$$