The Islamic University of Gaza
Faculty of Engineering
Civil Engineering Department

Environmental Engineering
(ECIV 4324)

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Lect. 20

Water treatment –
Filtration Theory
Filtration
The resultant water after sedimentation will not be pure, and may contain some very fine suspended particles and bacteria in it. To remove or to reduce the remaining impurities still further, the water is filtered through the beds of fine granular material, such as sand, etc. The process of passing the water through the beds of such granular materials is known as Filtration.
Filtration Mechanisms

There are four basic filtration mechanisms:

**SEDIMENTATION**: The mechanism of sedimentation is due to force of gravity and the associate settling velocity of the particle, which causes it to cross the streamlines and reach the collector.

**INTERCEPTION**: Interception of particles is common for large particles. If a large enough particle follows the streamline, that lies very close to the media surface it will hit the media grain and be captured into media grains.
Filtration Mechanisms

**BROWNIAN DIFFUSION** : Diffusion towards media granules occurs for very small particles, such as viruses. Particles move randomly about within the fluid, due to thermal gradients. This mechanism is only important for particles with diameters < 1 micron.

**INERTIA** : Attachment by inertia occurs when larger particles move fast enough to travel off their streamlines and bump into media grains.
Filter Materials

**Sand**: Sand, either fine or coarse, is generally used as filter media. The size of the sand is measured and expressed by the term called effective size. *The effective size*, i.e. $D_{10}$ may be defined as the size of the sieve in mm through which ten percent of the sample of sand by weight will pass. The uniformity in size or degree of variations in sizes of particles is measured and expressed by the term called *uniformity coefficient*. The uniformity coefficient, i.e. $(D_{60}/D_{10})$ may be defined as the ratio of the sieve size in mm through which 60 percent of the sample of sand will pass, to the effective size of the sand.
Filter Materials

**Gravel:** The layers of sand may be supported on gravel, which permits the filtered water to move freely to the under drains, and allows the wash water to move uniformly upwards.

**Other materials:** Instead of using sand, sometimes, anthrafilt is used as filter media. Anthrafilt is made from anthracite, which is a type of coal-stone that burns without smoke or flames. It is cheaper and has been able to give a high rate of filtration.
Types of Filter

*Slow sand filter:* They consist of fine sand, supported by gravel. They capture particles near the surface of the bed and are usually cleaned by scraping away the top layer of sand that contains the particles.

*Rapid-sand filter:* They consist of larger sand grains supported by gravel and capture particles throughout the bed. They are cleaned by backwashing water through the bed to 'lift out' the particles.
Cross sectional view of a Rapid Sand Filter

- Wash water troughs
- Sand
- Gravel
- Perforated laterals
- Filter floor
- Cast iron manifold with strainers
Principles of Slow Sand Filtration

• In a slow sand filter impurities in the water are removed by a combination of processes: sedimentation, straining, adsorption, and chemical and bacteriological action.

• During the first few days, water is purified mainly by mechanical and physical-chemical processes. The resulting accumulation of sediment and organic matter forms a thin layer on the sand surface, which remains permeable and retains particles even smaller than the spaces between the sand grains.
Principles of Slow Sand Filtration

• As this layer (referred to as “Schmutzdecke”) develops, it becomes living quarters of vast numbers of micro-organisms which break down organic material retained from the water, converting it into water, carbon dioxide and other oxides.

• Most impurities, including bacteria and viruses, are removed from the raw water as it passes through the filter skin and the layer of filter bed sand just below. The purification mechanisms extend from the filter skin to approx. 0.3-0.4 m below the surface of the filter bed.
Principles of Slow Sand Filtration

• When the micro-organisms become well established, the filter will work efficiently and produce high quality effluent which is virtually free of disease carrying organisms and biodegradable organic matter.

They are suitable for treating waters with low colors, low turbidities and low bacterial contents.
Sand Filters vs. Rapid Sand Filters

**Base material:** In SSF it varies from 3 to 65 mm in size and 30 to 75 cm in depth while in RSF it varies from 3 to 40 mm in size and its depth is slightly more, i.e. about 60 to 90 cm.

**Filter sand:** In SSF the effective size ranges between 0.2 to 0.4 mm and uniformity coefficient between 1.8 to 2.5 or 3.0. In RSF the effective size ranges between 0.35 to 0.55 and uniformity coefficient between 1.2 to 1.8.
Sand Filters vs. Rapid Sand Filters

Rate of filtration: In SSF it is small, such as 100 to 200 L/h/sq.m. of filter area while in RSF it is large, such as 3000 to 6000 L/h/sq.m. of filter area.

Flexibility: SSF are not flexible for meeting variation in demand whereas RSF are quite flexible for meeting reasonable variations in demand.
Sand Filters vs. Rapid Sand Filters

Post treatment required: Almost pure water is obtained from SSF. However, water may be disinfected slightly to make it completely safe. Disinfection is a must after RSF.

Method of cleaning: Scrapping and removing of the top 1.5 to 3 cm thick layer is done to clean SSF. To clean RSF, sand is agitated and backwashed with or without compressed air.
Sand Filters vs. Rapid Sand Filters

**Loss of head:** In case of SSF approx. 10 cm is the initial loss, and 0.8 to 1.2m is the final limit when cleaning is required. For RSF 0.3m is the initial loss, and 2.5 to 3.5m is the final limit when cleaning is required.