Lecture 10
Filtration
FILTRATION

Water filtration is a mechanical or physical process of separating suspended and colloidal particles from fluids (liquids or gases) by interposing a medium through which only the fluid can pass. Medium used is generally a granular material through which water is passed. In the conventional water treatment process, filtration usually follows coagulation, flocculation, and sedimentation.

Filtration process

- During filtration in a conventional down-flow depth filter, wastewater containing suspended matter is applied to the top of the filter bed.
- As the water passes through the filter bed, the suspended matter in the wastewater is removed by a variety of removal mechanisms.
- With passage of time, as material accumulates within the interstices of the granular medium, the head-loss through the filter starts to build up beyond the initial value.
- After some period of time, the operating head-loss or effluent turbidity reaches a predetermined head loss or turbidity value, and the filter must be cleaned (backwashed) to remove the material (suspended solids) that has accumulated within the granular filter bed.
- Backwashing is accomplished by reversing the flow through the filter. A sufficient flow of wash water is applied until the granular filtering medium is fluidized (expanded), causing the particles of the filtering medium to abrade against each other.

Filtration is classified into following three types [1]:

1) Depth filtration
   a) Slow sand filtration
   b) Rapid porous and compressible medium filtration
   c) Intermittent porous medium filtration
   d) Recirculating porous medium filtration

2) Surface filtration
   a) Laboratory filters used for TSS test
   b) Diatomaceous earth filtration
   c) Cloth or screen filtration

3) Membrane filtration
DEPTH FILTRATION

In this method, the removal of suspended particulate material from liquid slurry is done by passing the liquid through a filter bed composed of granular or compressible filter medium.

- Depth filtration is the solid/liquid separation process in which a dilute suspension or wastewater is passed through a packed bed of sand, anthracite, or other granular media.
- Solids (particles) get attached to the media or to the previously retained particles and are removed from the fluid [2].
- This method is virtually used everywhere in the treatment of surface waters for potable water supply.
- Depth filtration is also often successfully used as a tertiary treatment for wastewater.
- Failure of depth filtration affects the other downstream processes significantly and most of the times results in overall plant failure.
- Performance of a filter is quantified by particle removal efficiency and head loss across the packed bed.
- The duration of a filter run is limited by numerous constraints: available head, effluent quality or flow requirement.
- The head loss and removal efficiency of a filter are complicated functions of suspension qualities (particle size distribution and concentration, particle surface chemistry, and solution chemistry), filter design parameters (media size, type, and depth), and operating conditions (filtration rate and filter runtime) [2].

**Slow sand filtration (SSF):**

- It is very effective for removing flocs containing microorganisms such as algae, bacteria, virus, etc.
- Slow sand filtration (SSF), with flow rates ranging between 0.1 and 0.2 m$^3$ h$^{-1}$, has been a standard biofiltration treatment for decades in the wastewater industry [3].

**Rapid sand filtration (RSF)**

- The major difference between SSF and RSF is in the principle of operation; that is, in the speed or rate at which water passes through the media.
- In Rapid sand filtration (RSF), water passes downward through a sand bed that removes the suspended particles [4].
• RSF is used today as an effective pretreatment procedure to enhance water quality prior to reverse osmosis (RO) membranes in desalination plants [3].

SURFACE FILTRATION
• Surface filtration involves removal of suspended material in a liquid by mechanical sieving. In this method, the liquid is passed through a thin septum (i.e., filter material).
• Materials that have been used as filter septum include woven metal fabrics, cloth fabrics of different weaves, and a variety of synthetic materials [4].

MEMBRANE FILTRATION
• Membrane filtration can be broadly defined as a separation process that uses semi-permeable membrane to divide the feed stream into two portions: a permeate that contains the material passing through the membranes, and a retentate consisting of the species being left behind [5].
• Membrane filtration can be further classified in terms of the size range of permeating species, the mechanisms of rejection, the driving forces employed, the chemical structure and composition of membranes, and the geometry of construction [6].
• The most important types of membrane filtration are pressure driven processes including microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO).

MECHANISMS INVOLVED IN THE FILTRATION PROCESSES
The process of filtration involves several mechanisms listed in the table. Straining has been identified as the principal mechanism that is operative in the removal of suspended solids during the filtration of settled secondary effluent from biological treatment processes. Other mechanisms including impaction, interception, and adhesion are also operative even though their effects are small and, for the most part, masked by the straining action.
Table 3.10.1 Mechanisms involved in the filtration processes [1]

<table>
<thead>
<tr>
<th>Mechanism/phenomenon</th>
<th>Description</th>
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<tbody>
<tr>
<td>Straining</td>
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<tr>
<td>a) Mechanical</td>
<td>Particles larger than the pore space of the filtering medium are strained out mechanically.</td>
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<tr>
<td>b) Chance contact</td>
<td>Particles smaller than the pore space are trapped within the filter by chance contact</td>
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<tr>
<td>Sedimentation</td>
<td>Particles settle on the filtering medium within the filter</td>
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<td>Impaction</td>
<td>Heavy particles do not follow the flow streamlines</td>
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<tr>
<td>Interception</td>
<td>Particles get removed during contact with the surface of the filtering medium</td>
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<tr>
<td>Adhesion</td>
<td>Particles become attached to the surface of the filtering medium as they pass through.</td>
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<td>Flocculation</td>
<td>It can occur within the interstices of the filter medium.</td>
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<tr>
<td>Chemical adsorption</td>
<td>Once a particle has been brought in contact with the surface of the filtering medium or with other particles, either one of these mechanisms, chemical or physical adsorption or both, may occur.</td>
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<tr>
<td>a) Bonding</td>
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<tr>
<td>b) Chemical interaction</td>
<td></td>
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<tr>
<td>Physical adsorption</td>
<td></td>
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<tr>
<td>a) Electrostatic forces</td>
<td></td>
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<tr>
<td>b) Electrokinetic forces</td>
<td></td>
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<tr>
<td>c) Van der Waals forces</td>
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<tr>
<td>Biological growth</td>
<td>Biological growth within the filter reduces the pore volume and enhances the removal of particles with any of the above removal mechanisms</td>
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FILTER-MEDIUM CHARACTERISTICS

*Grain size* is the principle filter-medium characteristic that affects the filtration operation. Grain size affects both the clear-water head loss and the buildup of head loss during the filter run. If too small a filtering medium is selected, much of the driving force will be wasted in
overcoming the frictional resistance of the filter bed. On the other hand, if the size of the medium is too large, many of the small particles in the influent will pass directly through the bed. The size distribution of the filter material is usually determined by sieve analysis using a series of decreasing sieve sizes.

**CLASSIFICATION OF FILTERS**

Filters that must be taken off-line periodically to be backwashed are classified operationally as semi-continuous.

Filters in which filtration and backwash operations occur simultaneously are classified as continuous.

Within each of these two classifications, there are a number of different types of filters depending on bed depth (e.g., shallow, conventional, and deep bed), the type filtering medium used (mono-, dual-, and multi-medium), whether the filtering medium is stratified or unstratified, the type of operation (down-flow or upflow), and the method used for the management of solids (surface or internal storage). For the mono- and dual-medium semi-continuous filters, a further classification can be made based on the driving force (e.g., gravity or pressure) [7].

**TYPES OF DEPTH FILTERS**

The five types of depth filters used most commonly for wastewater filtration are

(a) **Conventional down-flow filters**: Single-, dual-, or multimedium filter materials are utilized in conventional down-flow depth filters. Typically sand or anthracite is used as the filtering material in single-medium filters. Dual-medium filters usually consist of a layer anthracite over a layer of sand. Dual- and multimedium and deep-bed mono-medium depth filters were developed to allow the suspended solids in the liquid to be filtered to penetrate farther into the filter bed, and thus use more of the solids-storage capacity available within the filter bed.

(b) **Deep-bed down-flow filters**: The deep-bed down-flow filter is similar to the conventional down-flow filter with the exception that the depth of the filter bed and the size of the filter medium are greater than corresponding values an conventional filter. Because of the greater depth and larger medium size, more solids can be stored within the filter bed and the run length can be extended.

(c) **Deep-bed upflow continuous-backwash filters**: In this filter the wastewater to be filtered is introduced into the bottom of the filter where it flows upward through a series of riser tubes and
is distributed evenly into the sand bed through the open bottom of an inlet distribution hood. The water then flows upward through the downward-moving sand. The clean filtrate exits from the sand bed, overflows a weir, and is discharged from the filter. Because the sand has higher settling velocity than the removed solids, the sand is not carried out of the filter.

(d) Pulsed-bed filter: The pulsed-bed filter is a proprietary down-flow gravity filter with an unstratified shallow layer of fine sand as the filtering medium. The shallow bed is used for solids storage, as opposed to other shallow-bed filters where solids are principally stored on the sand surface. An unusual feature of this filter is the use of an air pulse to disrupt the sand surface and thus allow penetration of suspended solids into the bed.

(e) Travelling-bridge filters: The travelling-bridge filter is a proprietary continuous down-flow, automatic backwash, low-head, granular medium depth filter. The bed of the filter is divided horizontally into long independent filter cells. Each filter cell contains approximately 280 mm of medium. Treated wastewater flows through the medium by gravity.

REFERENCES


