Filtration

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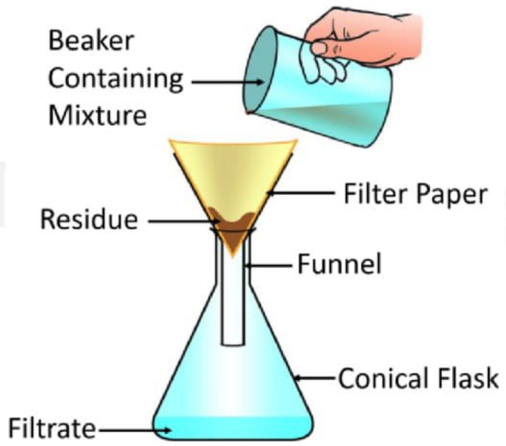


Filtration

1. Filtration is a common operation widely employed in the production of sterile products, bulk drugs, and in liquid oral formulation.
2. The suspension of solid and liquid to be filtered is known as the slurry.
3. The porous medium used to retain the solids is described as the filter medium; the accumulation of solids on the filter is referred to as the filter cake, while the clear liquid passing through the filter is the filtrate.
4. The pores of the filter medium are smaller than the size of particles to be separated.

Definition

"Filtration is a unique unit 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."

Objectives

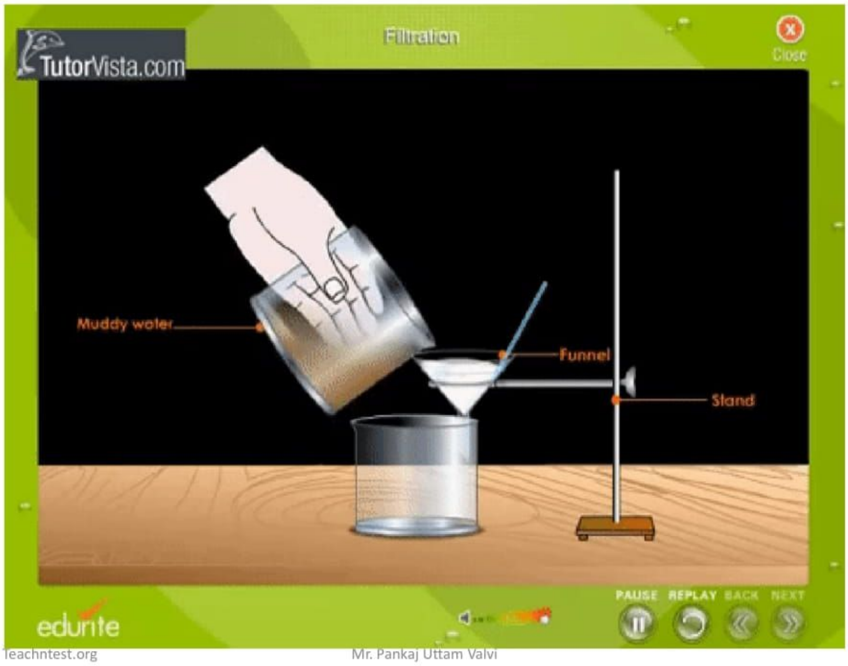
1. The main learning objective of filtration is to separate solids from liquid or gas medium The other objectives include:
2. To eliminate the contaminant particles so as to recover dispersing fluid.
3. To recover solid particles by eliminating the dispersing fluid.
4. To produce high-quality solvents and solids.
5. To purify air and pharmaceutically useful gases by removing particulate matter.
6. To sterilize thermolabile parenteral products.

Theory of Filtration

1. The flow of any liquid through any porous medium offers a resistance to its flow. The rate of filtration in such cases is expressed as:

   Filtration Rate= Driving force/Resistance by filter medium

2. The net driving force in filtration is pressure =(above the medium-pressure below the medium.)
3. The resistance offered by filter medium is not constant over the period of filtration as it goes on increasing with time due to particle deposition on filter medium.
4. Rate is expressed as volume of filtrate per unit time (dv/dt). Depending on dispersing (fluid) medium, Filtration theory is divided in two parts.



(A) Gas Filtration Theory:

Gas filtration includes filtration of aerosol. Membrane filters and nucleopore filters are used for gas filtration which works on the following mechanisms:

1) Diffusion deposition:

In this mechanism the trajectories of individual small particles do not coincide with the streamlines of the fluid because of Brownian motion. With decreasing particle size, the intensity of Brownian motion increases and thus as a consequence, the intensity of diffusion deposition also increases.

2) Direct interception:

This mechanism involves finite size particles. These particles are intercepted as they approach the collecting surface to a distance equal to its radius.

3) Inertial deposition:

The presence of particles in the flowing fluid results in a curvature of the streamlines in the neighborhood of the body. Because of their inertia, the individual particles do not follow the curved streamlines but are projected against the body and may deposit there. It is obvious that the intensity of this mechanism increases with increasing particle size and velocity of flow.

4) Gravitational deposition:

Individual particles have a certain sedimentation velocity due to gravity. As a consequence, the particles deviate from the streamlines of the fluid and, owing to this deviation; the particles may touch a fiber.

5. Electrostatic deposition:

   Both the particles and the fibers in the filter may carry electric charges. Deposition of particles on the fibers may take place because of the forces acting between charges or induced forces.

(B) Liquid Filtration Theory:

1. The term filtration covers all processes in which a liquid containing suspended solid is freed of some or the entire solid when the suspension is drawn through a porous medium.

2. Filtration is of two types namely: '***Cake filtration***' where the proportion of solids in suspension is large and most of the particles are collected in the filter cake which can subsequently be detached from the medium and '***Deep bed filtration***' where the proportion of solids is very small.

Kozeny-Carman Equation:

1. In the filtration as particles forming the cake are small and the flow through bed is slow, streamline conditions are almost invariably obtained.

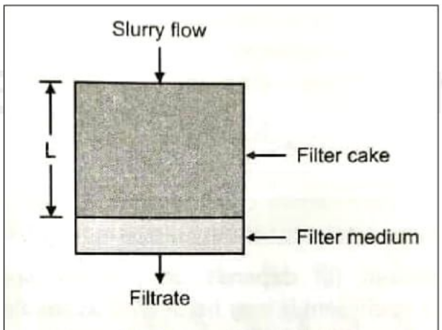


Fig. 4.14: Schematic of Filtration

2. At any instant it may be explained by Kozeny-Carman equation as:

$$U = \frac{1}{A}\frac{dv}{dt} = \frac{\Delta P}{r\mu\,(l + L)}$$

3. Where,
   - 'U' is flow rate,
   - 'A' is filter area,
   - 'v' is total volume of filtrate delivered,
   - 't' is filtration time,
   - 'ΔP' is pressure drop across cake and medium,
   - 'r' is specific cake resistance,
   - 'μ' is filtrate viscosity,
   - '*l*' cake thickness and
   - 'L' is thickness of cake equivalent to medium resistance.

Limitations:

1. Kozeny-Carman equation has certain limitations that it does not take into account the fact that depth of the granular bed is lesser than the actual path travelled by the fluid.
2. The actual path is not straight throughout the bed, but it is sinuous or tortuous.

Poiseuille's Law

1. Ìf flow of the filtrate under pressure through capillaries is laminar, then Poiseuille's equation could be used.

$$V = \frac{\pi \Delta P r^4}{8 L \eta}$$

2. Where;
   - V is rate of flow
   - ΔP is pressure difference across the filter,
   - r is radius of capillary in filter bed
   - L is Thickness of filter cake
   - η is the viscosity of the filtrate

Darcy's Equation

1. When using Poiseulle equation for filtration it is considered that capillaries in filter medium are highly irregular and non-uniform.
2. In order to approximate the flow rate the height of cake is taken as length of capillaries and a correction factors is introduced for the radius of capillaries.
3. This makes rate more simplified and is expressed as;

$$U = \frac{KA\,\Delta P}{\eta L}$$

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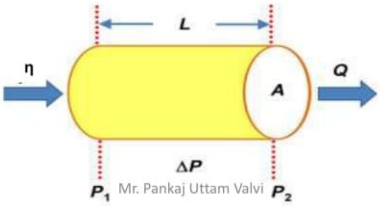
- Where,
  - U is flow rate,
  - K is permeability coefficient,
  - A is surface area of filter medium,
  - ΔP is pressure difference across the filter,
  - η is the viscosity of the fluid,
  - L is capillary length.
  - The permeability coefficient (K) depends on porosity, specific surface area and compressibility of cake.



Factors Affecting Rate of Filtration

- ***Pressure:*** the rate of filtration is directly proportional to the pressure difference between the filter medium and filter cake.
- ***Viscosity:*** the rate of filtration is inversely proportional to the viscosity of the liquid undergoing filtration.
- ***Surface area of filter medium:*** the rate of filtration is directly proportional to the surface are of filter media.
- ***Temperature*** of liquid to filtered.
- ***Particle size***
- ***Pore size*** of filter media
- ***Thickness*** of cake
- ***Nature*** of solid material

Membrane Filter

1. A membrane is a thin layer of semi-permeable material that separates substances when a driving force is applied across the membrane.
2. It works on the principle of physical separation. These are used for removal of bacteria, micro-organisms, particulates, and natural organic material.
3. The membrane processes includes microfiltration, ultrafiltration, nanofiltration and reverse osmosis.

Principle:

1. The principle is quite simple that the membrane acts as a very specific filter that allows water to flow through, while it catches suspended solids and other substances.
2. Membrane filter uses the sieving mechanism of the microfiltration membrane, driven by pressure, to trap particles with a diameter between 0.1-1 um such as suspended solids, bacteria, some viruses, and large-sized colloids.
3. Water flow through the membrane is not very fast, so in order to pass the required amount of water, the monomer area of the membrane device is large, and many thin membrane tubes are filled in a small space.

Construction:

1. Membrane filters are plastic membranes based on cellulose acetate, cellulose nitrate or mixed cellulose esters with pore sizes in the micron or submicron range.
2. Filters with pore sizes from 0.010 to 0.10 μ can remove virus particles from water or air.
3. Filters with pore sizes from 0.30 to 0.65 μ are employed for removing bacteria.
4. Filters with the larger pore sizes, viz. 0.8, 1.2 and 3.0 to 5.0 μ are employed, for example, in aerosol, radio activity and particle sizing applications.

5. Membrane filters are manufactured as flat sheet stock or as hollow fibers and formed into several different types of membrane modules.
6. Module construction involves potting or sealing the membrane material into an assembly, such as with hollow-fiber module.
7. These types of modules are designed for long-term use over the course of a number of years.

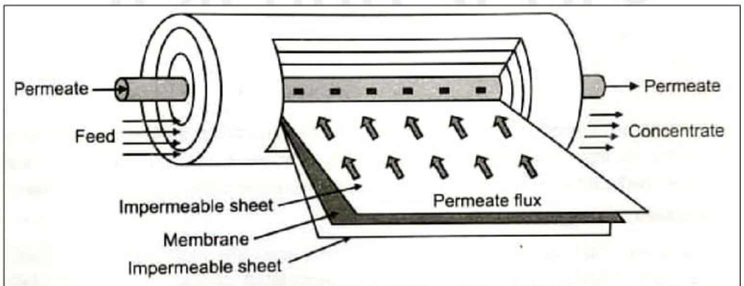


Fig. 4.15: Spiral Wound Membrane Filter

Working:

1. The membrane separation process is based on the presence of semi-permeable membranes.
2. The principle is membrane acts as a very specific filter that will let water flow through, while it catches suspended solids and other substances.
3. During use membrane filters are supported on a rigid base of perforated metal, plastic or coarse sintered glass.
4. If the solution to be filtered contains a considerable quantity of suspended matter, preliminary filtration through a suitable depth filter avoids clogging of the membrane filter during sterile filtration.
5. They are brittle when dry and can be stored indefinitely in the dry state but are fairly tough when wet.

Advantages:

1. It allows the filtration of any volumes of non-turbid water through the disk.
2. This method is inexpensive and effective.
3. There is no requirement of any chemicals.
4. This method is more energy efficient.

Disadvantages:

1. The turbid water can not be used in membrane filtration.
2. Glass filters are breakable and can break quickly.
3. The membrane filters can crack easily.
4. Only liquids are sterilized by this method.

Applications:

1. Membrane filtration is used as an alternative to flocculation, sediment purification techniques, adsorption (sand filters and active carbon filters, ion exchangers) extraction and distillation.
2. It is used in dehydration, concentration/separation of substances or the treatment of residual liquids.
3. It is in concentration of dissolved or suspended solids, and for obtaining a rejected liquid that contains a very low concentration of dissolved solids.
4. It allows the isolation and enumeration of micro-organisms.

5. It is used in removal of ammonium ions from potable water.
6. It can also be used in the manufacture of dairy ingredients such as milk, whey and clarified cheese brine.
7. It is used in starch and sweetener industry to clarify corn syrups, concentrate rinse water from starch, the enrichment of dextrose, the depyrogenation of dextrose syrup, etc.
8. It is used in the industrial production lines for enzymes in concentrating them prior to other processes.

Sintered Glass Filter

1. Sintered glass is a glass mesh used for filtration. It is available in different pieces of glassware.
2. A suction funnel made of glass has its base made of very porous sintered glass.
3. Sintered glass filters are more convenient to use than Buchner funnels because there is no filter paper to worry about but they are harder to clean.

Principle:

1. The liquid to be filtered is poured into the sintered glass funnel and drawn through the perforations by vacuum suction.
2. These flasks are attached to vacuum pump to carry out filtration under reduced pressure to allow for the suction and collection of the filtrate.

Construction:

1. Sintered glass filter available in different pore size are made of borosilicate glass.
2. Borosilicate glass is finely powdered, sieved and particle of desired size are separated.
3. It is then packed into a disc mould and heated to a temperature at which adhesion takes place between the particles to form porous structure.
4. The disc is then fused to a funnel of suitable shape and size. Sintered filters are also made up of stainless steel which has a greater mechanical strength.

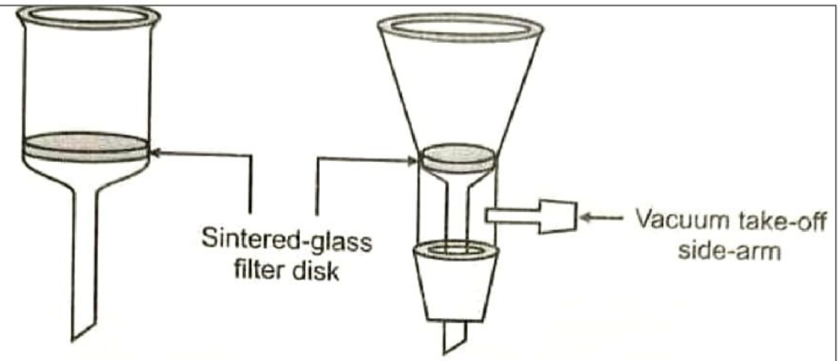


Fig. 4.16: Sintered glass filter and its assembly

5. However, these steel filters are very much liable to attack by the solutions passing through them.
6. The funnel with a sintered filter is numbered according to the pore size.
7. Porosity of sintered glass is labeled by integers from 0 - 5 (viz. 0, 1, 2, 3, 4, 5) where 0 has a pore size of 160-250 um and is considered coarse filtration, that is fluid willpass through it quickly and some finer solids will pass through.
8. Whereas, porosity 5 has a pore size of 4-10 um through which only liquids will drop through.

Working:

1. The porous fritted glass disc in the middle allows filtrate to drain through leaving solids behind.
2. The filtration may be carried out under reduced pressure.
3. The suction flask traps vacuum to ensure that no fluids are carried over from the vacuum pump to the evacuated apparatus or vice versa.

Applications:

1. It is used as an alternative to filter paper.
2. For separation of viruses from bacteria.
3. Sterilization of certain thermo-labile material.
4. Filtration of broth cultures of bacteria.

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