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FILTRATION: A MECHANICAL OR PHYSICAL OPERATION TO REMOVE DEBRIS *IN–VITRO/IN–VIVO*

[*1]Prodipta Bhattacharyya, [1]Kushal Nandi, [1]Dr. Dhrubo Jyoti Sen and [2]Dr. Dhananjoy Saha

[1]Department of Pharmaceutical Chemistry, School of Pharmacy, Techno India University, Salt Lake City, Sector–V, EM–4, Kolkata–700091, West Bengal, India.
[2]Deputy Director, Directorate of Technical Education, Bikash Bhavan, Salt Lake City, Kolkata–700091, West Bengal, India.

Corresponding Author: Prodipta Bhattacharyya
Department of Pharmaceutical Chemistry, School of Pharmacy, Techno India University, Salt Lake City, Sector–V, EM–4, Kolkata–700091, West Bengal, India.

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ABSTRACT

Filtration is a mechanical or physical operation which is used for the separation of solids from fluids (liquids or gases) by interposing a porous medium through which only the fluid can pass. The suspension of solid and liquid to be filtered is known as **the feed or slurry.** 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**. The term **clarification** is used when the amount of solid in liquid is not more than 1%w/v. The surface upon which solids are deposited in a filter is called the filter medium. Filter aid is used to prevent the medium from becoming blocked and helps to form an open, porous cake, hence reducing the resistance to flow of the filtrate. Rate of filtration is defined as volume of filtrate collected in unit time.

KEYWORDS: Filter bed, Filter medium, Filter cake, Filtrate, Filtration time, Dialysis, Ultrafiltration.

INTRODUCTION

Examples of filtration include:

1. The coffee filter to keep the coffee separate from the grounds
2. HEPA filters in air conditioning to remove particles from air
3. Belt filters to extract precious metals in mining
4. Horizontal plate filter, also known as Sparkler filter
5. Vertical plate filter such as those used in Merrill-Crowe process
6. Nutsche filters typically used in pharmaceutical applications or batch processes that need to capture solids

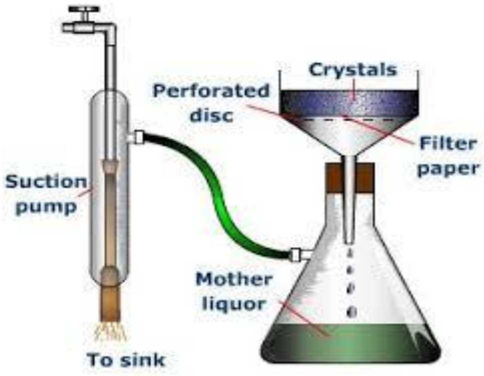
7. Furnaces use filtration to prevent the furnace elements from fouling with particulates
8. Pneumatic conveying systems often employ filtration to stop or slow the flow of material that is transported, through the use of a baghouse
9. In the laboratory, a Büchner funnel is often used, with a filter paper serving as the porous barrier
10. Air filters are commonly used to remove airborne particulate matter in building ventilation systems, combustion engines, and industrial processes
11. Oil filter in automobiles, often as a canister or cartridge
12. Aquarium filter

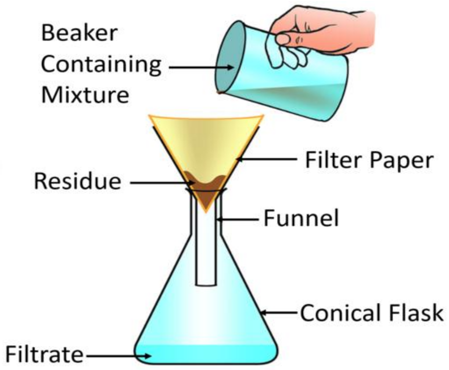
An experiment to prove the existence of microscopic organisms involves the comparison of water passed through unglazed porcelain and unfiltered water. When left in sealed containers the filtered water takes longer to go foul, demonstrating that very small items (such as bacteria) can be removed from fluids by filtration. In the kidney, renal filtration is the filtration of blood in the glomerulus, followed by selective reabsorption of many substances essential for the body to maintain homeostasis. Filtration is used to separate solid particles and fluid in a suspension. One of the most important techniques used by chemists to purify compounds is by dissolving the mixture in the chosen solvent, which dissolves one component of the mixture, and will go into the solution and hence pass through the filter, while the other component will be retained.

Rate of filtration is defined as volume of filtrate collected in unit time. The factors affecting rate of filtration is known **as Darcy's law** and may be expressed as: Henry Philibert Gaspard Darcy (10 June 1803 – 3 January 1858) was a French engineer who made several important contributions to hydraulics including Darcy's law for flow in porous media.[1]

$$dV/dt = KA \times \Delta P/\mu l$$

Where; V = volume of filtrate, t = time of filtration, K = constant for the filter medium and filter cake, A = area of filter medium, ΔP = pressure drop across the filter medium and filter cake, μ = viscosity of the filtrate, and l = thickness of cake.





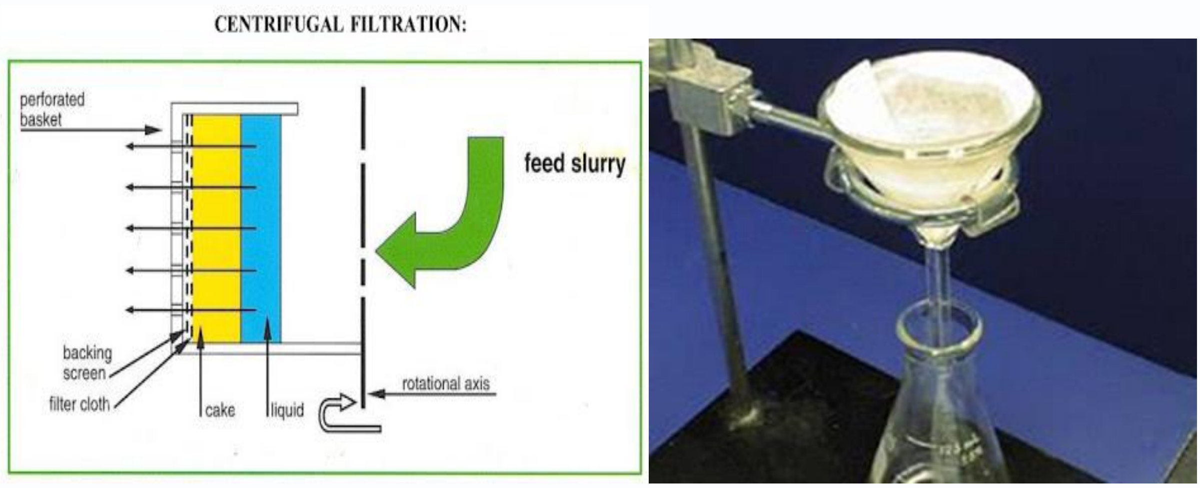
Figure–1: Filtration.

Factors affecting rate of filtration:

1. **Permeability coefficient:** The constant (K) represents the resistance of both the filter medium and the filter cake. As the thickness of the cake increase, the rate of filtration will decrease. The permeability coefficient depends on the porosity, compressibility, and specific surface area of the filter cake.
2. **Area of filter medium:** Rate of filtration is directly proportional to the surface area of the filter which can be increased by using larger filters.
3. **Pressure drop:** The rate of filtration is directly proportional to the pressure difference across both the filter medium and filter cake.
4. **Viscosity of filtrate**: An increase in the viscosity of the filtrate will increase the resistance of flow, so that the rate of filtration is inversely proportional to the viscosity of the fluid.
5. **Thickness of filter cake:** The rate of flow of the filtrate through the filter cake is inversely proportional to thickness of the cake.

Types of filtration

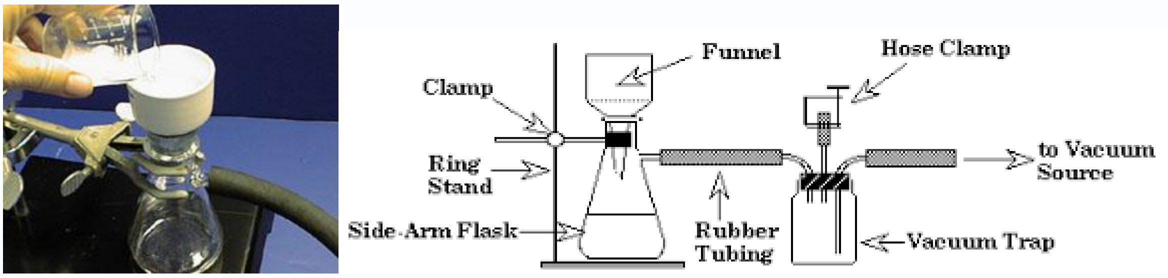
1. **Centrifugal Filtration:** It is a type of filtration in which filtration is performed through rotational movement of the filter body. There is no arrangement of any medium to get the filtration. During defined rotational speed of equipment, the high–density solids or liquids are separated from the low–density fluid. This is effective for liquid or semi–liquid fluid.



Figure–2: Centrifugal filtration & Gravity filtration.

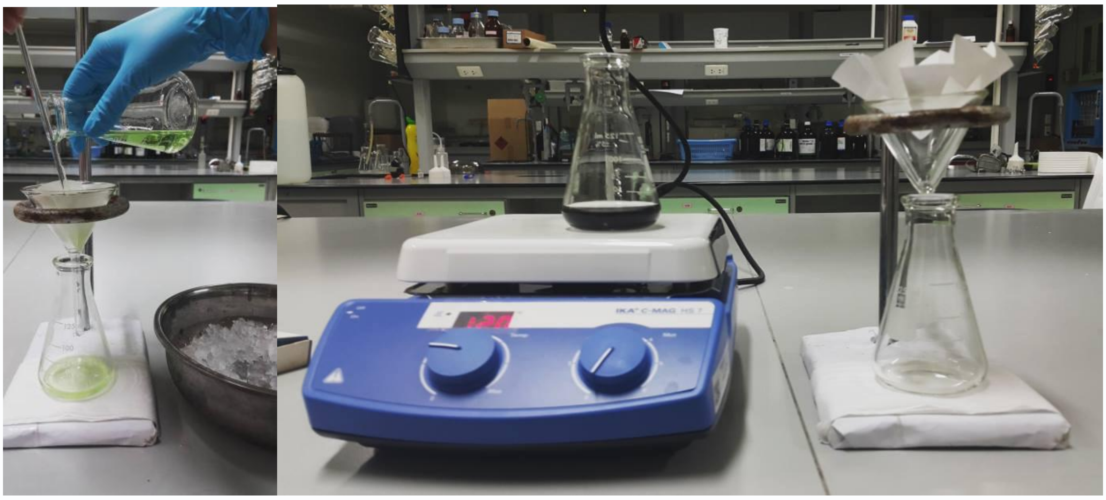
2. **Gravity Filtration:** When the suspended solid is removed from the **liquid applications** through the flow direction from top level to lower surface, the filtration is called as Gravity Filtration. This filtration is performed at atmospheric pressure.

3. **Vacuum Filtration:** Removal of the suspended dust particle from atmospheric air through suction or at static pressure level, the filtration is called as Vacuum Filtration.



Figure–3: Vacuum filtration.

4. **Chill / Cold Filtration:** This filtration process is performed after maintaining a required lower temp. (May be in negative temperature also) of fluid. This filtration is useful to remove available fatty acids, proteins or esters which can be mixed / created in fluid during preceding process. After maintaining a required lower temperature fluid has been passed through a filter medium to remove the chilled suspended particles. This filtration is useful to avoid sedimentation during final use of filtrate at lower temperature.



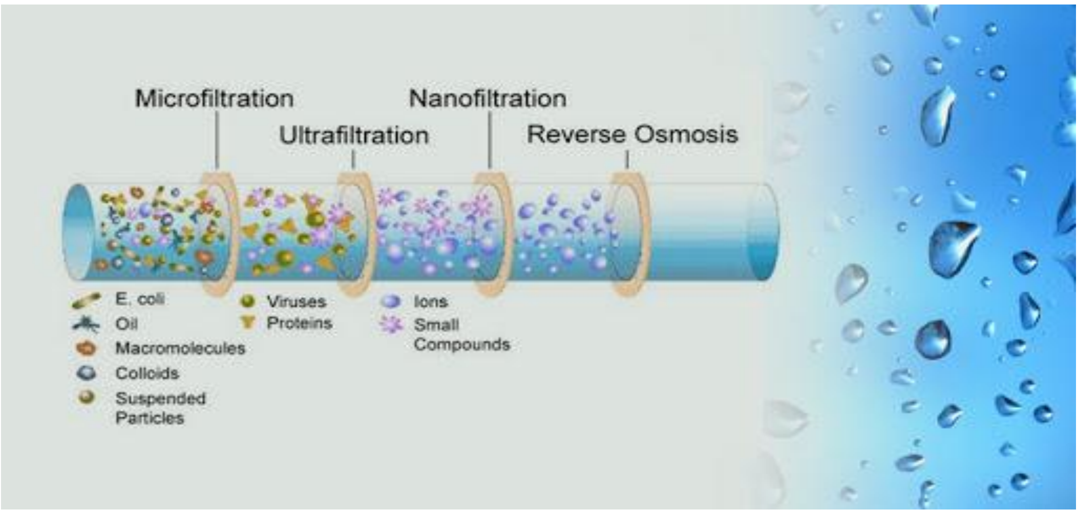
Figure–4: Cold filtration & Hot filtration.

5. **Hot Filtration:** Hot Filtration is useful to remove the small amount of impurities from crystalline compounds. Dissolve the crystalline compound in a suitable solvent at suitable high temperature, remove the impurities from liquid compound through a medium and slowly cool down to get the clear recrystallized compounds. Filter the solution to isolate the purified solid compounds. This is the process of Hot Filtration.
6. **Multi–Layer Filtration (Sand/Gravel/Carbon Filtration):** An ancient days' innovation and specifically useful for water filtration in old days is sand filter. A filter tank has been arranged by different types and sizes of gravels which filter the avoidable particles between arrangement spaces. Coal carbon arranged in Carbon bed are useful to remove the unwanted application colour and odor.

Figure–5: Multi–Layer Filtration.

7. **Mechanical Filtration:** It is modern innovation and useful to cater the industrial filtration requirements at operating pressure higher than atmospheric one.This is the filtration which can be performed through an arrangement of medium within the main filter body. This can be bifurcated in two different types –

- Surface Filtration: It involves the removal of the particles from the liquid by means of sieving. The liquid passes through a thin septum i.e filter material.



Figure–6: Mechanical Filtration.

- Depth Filtration: It retains the larger particles at the surface and finer particles block the inside layers of the filter. It is primarily used for clarification of solutions. More efficient than surface filters and lasts longer.

8. Membrane Filtration: Separation process that uses a semi–permeable membrane. It consists of two parts: (i) permeate–containing the filtrate and (ii) retentate–containing the left–over particles.

Types of membrane filtration include (a) Microfiltration (b) Ultrafiltration (c) Nanofiltration (d) Reverse Osmosis.

Mechanism of filtration:

1. Straining: It is similar to sieving, means the particles of larger size cannot pass through the smaller pore size of filter medium.
2. Impingement: Solids move with streamline flow and strike the filter medium.
3. Entanglement: Particle becomes entangled in mass of fiber due to small size of particle than pore size.
4. Attractive force: Solids are retaining due to attractive forces between particles and filter medium.

Classification of the filtration equipment

Equipment's are classified based on the application of external force.

1. Pressure filters: plate and frame filter press and meta filter.
2. Vacuum filters: filter leaf
3. Centrifugal filters

Classification based on the operation of the filtration

1. Continuous filtration: discharge and filtrate are separated steadily and uninterrupted
2. Discontinuous filtration: discharge of filtered solids is intermittent. Filtrate is removed continuously. The operation must be stopped to collect the solids.

Classification based on the nature of filtration:

1. Cake filters: remove large amounts of solids (sludge or crystals)
2. Clarifying filters: remove small amounts of solids
3. Cross–flow filters: feed of suspension flows under pressure at a fairly high velocity across the filter medium.

Filter aids: Filter Aids is a group of inert materials that can be used in filtration pretreatment. The objective of the filter aid is to prevent the medium from becoming blocked and to form an open, porous cake, so reducing the resistance to flow of the filtrate. The particles must be inert, insoluble, incompressible, and irregular shaped.
Example– Purified talc, siliceous earth (kieselgurh), clays, charcoal, paper pulp, magnesium carbonate, bentonite, silica gel

Filter aids may be added in two ways

- 1–Pre–coating technique: By forming a pre–coat over the filter medium by filtering a suspension of the filter aid
- 2–Body–mix technique: A small proportion of the filter aid (0.1–0.5 %) is added to the slurry to be filtered. This slurry is re circulated through the filter until a clear filtrate is obtained, filtration then proceeds to completion.

Filter media: The surface upon which solids are deposited in a filter is called the Filter medium. An ideal filter media should be chemically inert, physically stable, should have sufficient mechanical strength to withstand filtration pressure, and must effectively retain the solid particles.

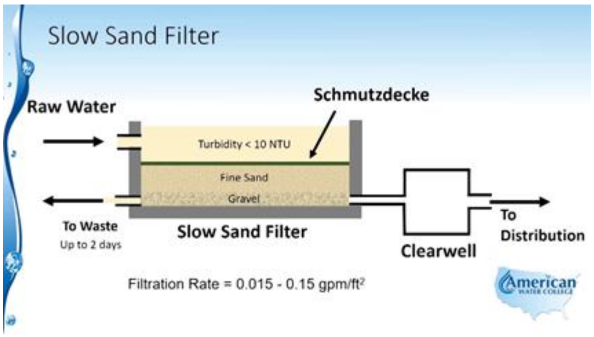
Classification of filter media

1. Woven filters: these include
(a) wire screening.
(b) fabrics of cotton, wool, nylon.

2. Non–woven filters: These include materials in which fabrics are joined to form a porous network. It is designed to remove ultrafine dust, aerosols, and viable organisms to maintain cleanliness in a wide range of application. **Filter paper** is a common filter medium since it offers controlled porosity, limited absorption characteristic, and low cost.
3. Membrane filters: These are basic tools for **micro–filtration**, useful in the preparation of sterile solutions. These filters are **made by casting** of various esters of cellulose, or from nylon, Teflon, polyvinyl chloride. The filter is a thin membrane with millions of pores per square centimeter of filter surface.
4. Porous plates: These include perforated metal or rubber plates, natural porous materials such as stone, porcelain or ceramics, and sintered glass.

Equipment's of pharmaceutical interest
1. Sand filters:
2. Filter presses: chamber, plate and frame filters (non–washing/washing; closed delivery/open delivery)
3. Leaf filters
4. Edge filters: stream line and meta filters
5. Rotary continuous filters
6. Membrane filters

1. Sand filters: These are used mainly when relatively small amounts of solid are to be removed from the liquid and when relatively large volumes of liquid must be handled at minimum cost. This operation consists of introducing water through the strainers, so that it may flow up through the sand bed and–out through the connection that is normally the inlet.

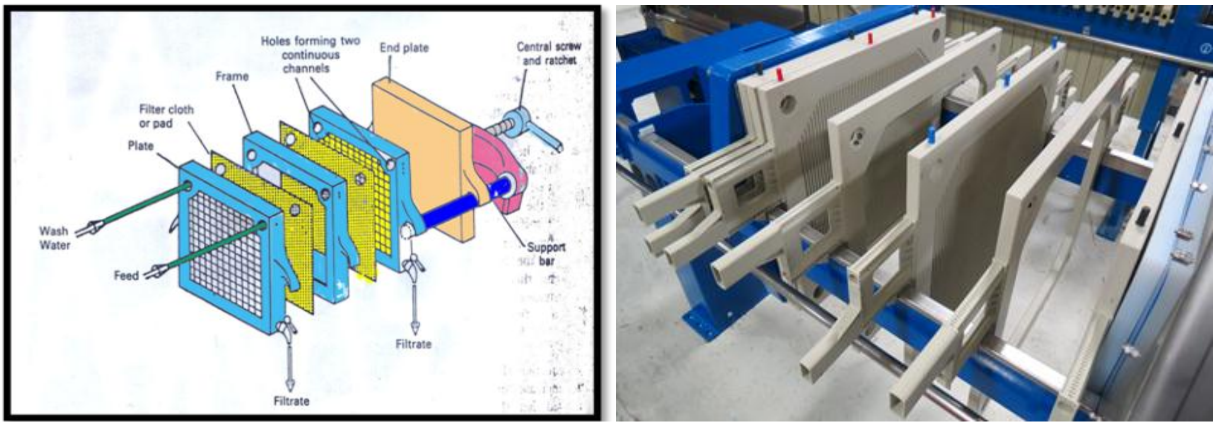


Figure–7: Sand filtration.

This wash water is wasted. These sand filters are applicable only to the separation of precipitates that can be removed from the sand in this manner and that are to be discarded. Gelatinous precipitates or precipitates that coat the sand so that they cannot be removed by back washing or precipitates that are to be recovered cannot be handled in the sand filter.[2]

Capacity is usually 2 to 4 gpm/sq.ft of surface of filtering area.
For filtering excessively large quantities of very clean water, an open or rapid sand filter is used. It is similar to the pressure sand filter except that the sand is contained in large, open concrete boxes instead of in a closed pressure tank. Sand filter used in this way becomes a gravity filter (also called hydrostatic head filter).

Advantages: Gravity filters have advantages of extreme simplicity, needing only simple accessories, low first cost and can be made of almost any material.



Figure–8: Filter press.

Disadvantages
(1) Relatively low rate of filtration.
(2) Excessive floor area needed and high labour charges
(3) If the amount of particulate matter to be removed is too small or it is finely divided, sand filter will not remove the suspended solids.
(4) In processes involving organic materials there may be danger of bacterial infection from an infected process–water supply and the sand filter cannot remove the bacteria as such. In these cases, a coagulant like ferrous sulphate or aluminium sulphate is added to the water before filtration. These are hydrolysed by the alkalinity of most normal waters with the formation of a flocculant precipitate of iron or aluminium hydroxide. This precipitate adsorbs finely divided suspended matter and even bacteria, even if added to the water in very small amounts. The resultant flocs, though fine, are removed by the sand filters.

2. Plate and frame filter press

Principle: The mechanism is surface filtration. The slurry enters the frame by pressure and flows through the filter medium: The filtrate is collected on the plates and sent to the outlet. A number of frames and plates are used so that surface area increases and consequently large volumes of slurry can be processed simultaneously with or without washing.

Construction: The construction of a plate and frame filter press is shown in the figure. The filter press is made of two types of units, plates and frames.
(a) Frame–Maintains the slurry reservoir, inlet (eye) for slurry.
(b) Filter medium.
(c) Plate along with section–supports the filter medium, receiving the filtrate and outlet (eye).
(d) Assembly of plate and frame filter press.

These are usually made of aluminium alloy. Sometimes these are also lacquered for protection against corrosive chemicals and made suitable for steam sterilisation. Frame contains an open space inside wherein the slurry reservoir is maintained for filtration and an inlet to receive the slurry. The plate has a studded or grooved surface to support the filter cloth and an outlet. The filter medium (usually cloth) is interposed between plate and frame. Frames of different thicknesses are available. It is selected based on the thickness of the cake formed during filtration. Optimum thickness of the frame should be chosen. Plate, filter medium, frame, filter medium and plate are arranged in the sequence and clamped to a supporting structure. A number of plates and frames are employed so that filtration area is a large as necessary. In other words, a number of filtration units are operated in parallel. Channels for the **slurry inlet** and **filtrate outlet** can be arranged by fitting eyes to the plates and frames, these join together to form a channel. In some types, only one inlet channel is formed, while each plate is having individual outlets controlled by valves.

Working: The working of the frame and plate process can be described in two steps, namely filtration and washing of the cake (if desirable).

Filtration operation: Slurry enters the frame from the feed channel and passes through the filter medium on to the surface of the plate. The solids form a filter cake and remain in the frame. The thickness of the cake is half of the frame thickness, because on each side of the frame filtration occur. Thus, two filter cakes are formed, which meet eventually in the centre of the frame. In general, there will be an optimum thickness of filter cake for any slurry, depending on the solid content in the slurry and the resistance –of the filter cake.

The filtrate drains between the projections on the surface of the plate and escapes from the outlet. **As filtration proceeds, the resistance of the cake increases and the filtration rate decreases**. At a certain point, is preferable to stop the process rather than continuing at very low flow rates. The press is emptied and the cycle is restarted.

Washing operation: If it is necessary to wash the filter cake, the ordinary plate and frame press is unsatisfactory. Two cakes are built up in the frame meeting eventually in the middle. This means that flow is brought virtually to a standstill. Hence, water wash using the same channels of the filtrate is very inefficient, if not impossible. The steps are as follows.

(1) Filtration proceeds in the ordinary way until the frames are filled with cake.
(2) To wash the filter cake, the outlets of the washing plates are closed.
(3) Wash water is pumped into the washing channel. The water enters through the inlets on to the surface of the washing plates.
(4) Water passes through the filter cloth and enters frame which contains the cake. Then water washes the cake, passes through the filter cloth and enters the plate down the surface.
(5) Finally washed water escapes through the outlet of that plate.

Thus, with the help of special washing plates, it is possible for the wash–water to flow over the entire surface of washing plate, so that the flow resistance of the cake is equal to all points. Hence, the entire cake is washed with equal efficiency.

It should be noted that water– wash is efficient only if the frames are full with filter cake. If the solids do not fill the frame completely, the wash water causes the cake to break (on the washing plate side of the frame) then washing will be less effective. Hence, it is essential to allow the frames become completely filled with the cake. This helps not only in emptying the frames but also helps in washing the cake correctly.[3]

Uses: Filter sheets composed of asbestos and cellulose are capable of retaining bacteria, so that sterile filtrate can be obtained, provided that the whole filter press and filter medium have been previously sterilized. Usually, steam is passed through the assembled unit for sterilization.

Examples include collection of precipitated antitoxin, removal of precipitated proteins from insulin liquors and removal of cell broth from the fermentation medium.
Heating/cooling coils are incorporated in the press so as to make it suitable for the filtration of viscous liquids.

Advantages

(1) Construction of filter press is very simple and a variety of materials can be used.
(a) Cast iron for handling common substances.
(b) Bronze for smaller units.
(c) Stainless steel is used there by contamination can be avoided.

(d) Hard rubber or plastics where metal must be avoided.
(e) Wood for lightness though it must be kept wet.
(2) It provides a large filtering area in a relatively small floor space. It is versatile, the capacity being variable according to the thickness of frames and the number used. Surface area can be increased by employing chambers up to 60.
(3) The sturdy construction permits the use of considerable pressure difference. About 2000 kilopascals can' be normally used.
(4) Efficient washing of the cake is possible.
(5) Operation and maintenance is straight forward, because there are no moving parts, filter cloths are easily renewable. Since all joints are external, a plate can be disconnected if any leaks are visible. Thus contamination of the filtrate can be avoided.
(6) It produces dry cake in the form of slab.

Disadvantages
(1) It is a batch filters so there is a good deal of 'down–time', which is non–productive.
(2) The filter press is an expensive filter. The emptying time, the labour involved and the wear and tear of the cloth resulting in high costs.
(3) Operation is critical, as the frames should be full, otherwise washing is inefficient and the cake is difficult to remove.
(4) The filter press is used for slurries containing less than 5% solids. So high costs make it imperative that this filter press is used for expensive materials. Examples include the collection of precipitated antitoxin and removal of precipitated proteins from insulin liquors.

Figure–9: Leaf filter.

3. Filter leaf: The filter leaf is probably the simplest form, of filter, consisting of a frame enclosing a drainage screen or grooved plate, the whole unit being covered with filter cloth. The outlet for the filtrate connects to the inside of the frame. The frame may be of any shape, circular, square or rectangular shapes being used in practice. In use, the filter leaf is immersed in the slurry' and a receiver and vacuum system connected to the filtrate outlet. The method has the **advantage** that the slurry can be filtered from any vessel and the cake can be washed simply by immersing the filter, in a vessel of water. Removal of the cake is facilitated by the use of reverse air flow. An alternative method is to enclose the filter leaf in a special vessel into which the slurry is pumped under pressure.[4]

This form is commonest in filters where a number of leaves are connected to common outlet, to provide a larger area for filtration. A typical example is "the *Sweetland filters.*"

Figure–10: Rotary filter.

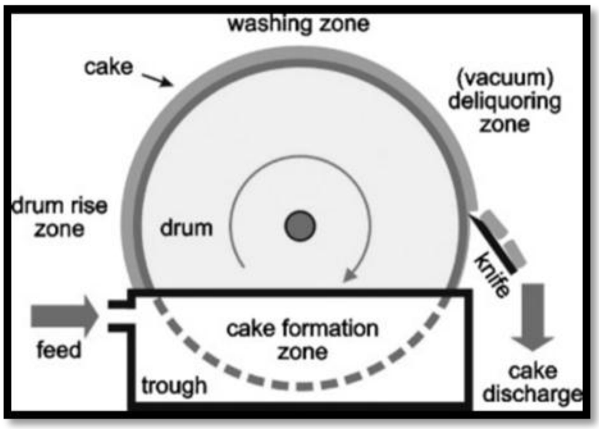
The filter leaf is a versatile piece of equipment. Area can be varied by employing a suitable number of units, and the pressure difference may be obtained with vacuum or by using pressures up to order of 8 bars. The leaf filter is most satisfactory if the solids content of slurry is not too high, **about 5 per cent being a suitable maximum.** A higher proportion, results in excessive non–productive time while the filter being emptied and, provided this is observed. The special feature of the leaf filter is the high efficiency of washing; in fact the cake can be dislodged and re–filtered from the wash water if desired.

4. Rotary filter: Filters such as the **filter leaf and filter press are batch operated** and can handle dilute suspensions only, if the process is to be economic. In large scale operation, continuous operation is sometimes desirable and it may be necessary to filter slurries containing a high proportion of solids.

The rotary filter is continuous in operation and has a system for removing the cake that is formed, hence it is **suitable for use with concentrated slurries.**

The rotary filter consists of a number of filter units (usually 16–20) arranged so that the units are passing in continuous succession through the various stages.

One form is the rotary disc filter in which the sectors shaped filter leafs form a disc with the outlet from the each leaf connected to the vacuum system, compressed air, and the appropriate receivers, in the correct sequence, by means of special rotating valve. It is the commonest form in use in the pharmaceutical industry. Each filter unit is rectangular in shape with a curved profile so that a number can be joined up to form a drum. Each unit has a perforated metal surface to the outer part of the drum and is covered with filter cloth. Appropriate connections are again made from each unit through a rotating valve at the centre of the drum. In operation, the drum rotates at low speed, so that cache unit passes through the various zones. Rotary filters may be up to 2m in diameter and 3.5m in length, giving areas of the order of $20m^2$. Special attachments may be included for special purposes; for example if the cake shrinks and cracks as it dries out, cake compression rollers can be fitted. These compress the cake to a homogenous mass to improve the efficiency of washing as the cake passes through the washing zone, or to aid drainage of wash water as the cake passes to the drying zone. Where the solids of the slurry are such that the filter cloth becomes blocked with the particles, a pre–coat filter may be used. This is variant in which a pre–coat of filter aid is deposited on the drum prior to the filtration process. The scraper knife then removes the solid filtered from the slurry together with a small amount of the pre–coat. If the removal of the cake presents the problems, alternative discharge methods can be used. The string discharge rotary filter, for example, is especially useful for certain pharmaceutical applications, particularly for filtering the fermentation liquor in the manufacture of antibiotics where the mould is difficult to filter by ordinary methods because it forms a felt–like cake.[5]



Figure–11: Various Zones of Rotary drum filter.

Advantages

(1) The rotary filter is automatic and is continuous in operation, so that labour costs are very low
(2) The filter has a large capacity.
(3) Variation of the speed of rotation enables the cake thickness to be controlled and for solids that form an impermeable cake, the thickness may be limited to less than 5mm. On the other hand, if the solids are coarse, forming a porous cake, the thickness may be 100mm or more.

Disadvantages

(1) The rotary filter is a complex piece of equipment with many moving parts and is very expensive and in addition to the filter itself, ancillary equipment's such as vacuum pumps and vacuum receivers and traps, slurry pumps and agitators are required.
(2) The cake tends to crack due to the air drawn through by the vacuum system so that washing and drying are not efficient.
(3) Being a vacuum filter the pressure difference is limited to 1 bar and hot filtrates may boil.
(4) The rotary filter is suitable only for straight forward slurries being less satisfactory if the solids formed an impermeable cake or will not separate cleanly from the cloth.

Uses of the rotary filters: The rotary filter is most suitable for continuous operation on large quantities of slurry, especially if the slurry contains considerable amounts of solids, i.e., in the range 15–30%.

Examples of pharmaceutical applications include the collection of calcium carbonate, magnesium carbonate and starch, and the separation of mycelium from the fermentation liquor in the manufacture of antibiotics.

5. Membrane filters: These are plastic membranes based on cellulose acetate, cellulose nitrate or mixed cellulose esters with pore sizes in the micron or submicron range. They are very thin (about 120 micron thick) and must be handled carefully. They act like a sieve trapping particulate matter on their surface. Several grades of filters are available with pore sizes ranging from 0.010 ± 0.002 micron to 5.0 ± 1.2 micron. Type codes VF and SM are given by Millipore Filter Corp. For these two extreme ranges respectively.

Figure–12: Filter Paper & Meta filter.

Filters with pore sizes from 0.010 to 0.10 micron can remove virus particles from water or air. Filters with pore sizes from 0.30 to 0.65 microns are employed for removing bacteria. Filters with the larger pore sizes, viz. 0.8, 1.2 and 3.0 to 5.0 microns are employed, for example, in aerosol, radio activity and particle sizing applications.

Advantages

(1) No bacterial growth through the filter takes place during prolonged filtration.
(2) They are disposable and hence no cross contamination take place.
(3) Adsorption is negligible they yield no fibres or alkali into the filtrate. Filtration rate is rapid.

Disadvantages

(1) They may clog though rarely.
(2) Ordinary types are less resistant to solvents like chloroform

6. Edge filters: Edge filters use a pack of the filter medium, so that filtration occurs on the edges. Forms using packs of media such as filter paper can be used but in the pharmaceutical industry greatest use is made of the Metafilter.

7. Meta–filter: The meta–filter, in its simplest form, consists of a grooved drainage rod on which is packed a series of metal rings. These rings, usually of stainless steel, are about 15mm inside diameter, and 0.8mm in thickness, with a number of semi–circular projections on one surface. The height of the projections and the shape of the section of the ring are such as that when the rings are packed together, all the same way up, and tightened on the drainage rod with a nut, channels are formed that taper from about 250µm down to 25µm. One or more of these packs is mounted in a vessel, and the filter may be operated by pumping in the slurry under pressure or, occasionally, by the application of reduced pressure to the outlet side. In this form, the meta–filter can be used as a strainer for coarse particles, but for finer particles a bed of a suitable material such kieselguhr is first built up. The pack of rings, therefore, serves essentially as a base on which the true filter medium is supported.

Advantages

(1) The meta–filter possesses considerable strength and high pressures can be used, with no danger of bursting the filter medium.
(2) As there is no filter medium as such, the running costs are low, and it is a very economical filter.
(3) The meta–filter can be made from materials that can provide excellent resistance to corrosion and avoid contamination of the most sensitive product.
(4) Removal of the cake is effectively carried out by back flushing with water. If further cleaning is required, it is normally necessary to do more than slacken the clamping nut on the end of the drainage rod on which the rings are packed.

Uses of the meta filter: The small surface of the meta–filter restricts the amount of the solids that can be collected. This, together with the ability to separate very fine particles, means that the meta–filter is used almost exclusively for clarification purposes. Furthermore, the strength of the meta–filter permits the use of high pressures (15 bars) making the method suitable for viscous liquids. Also, it can be constructed with material appropriate for corrosive materials. Specific examples of pharmaceutical uses include the clarification of syrups, injection and of products such as insulin liquors.

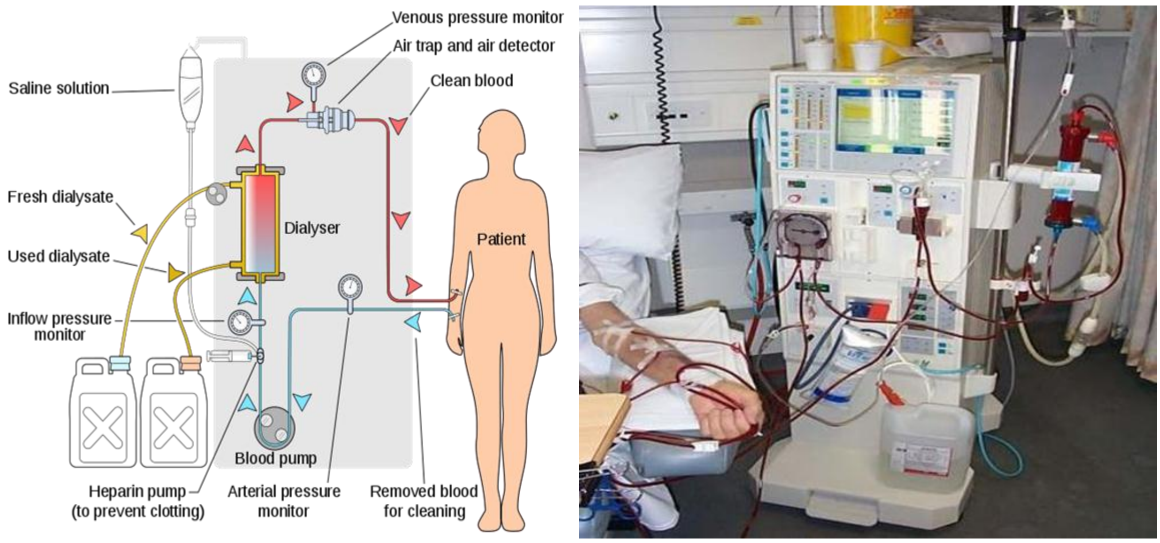
Filters used in Laboratories: It is important to study the filter papers that are used in laboratories. There are different grades of filter paper with different purposes, as detailed below:

● Qualitative filter paper is used for qualitative analytical purposes. There are 13 different grades of filter papers that are based on the pore size. The largest pore size is grade 4 and grade 602 has the smallest pore size.

Grade 1 with 11 µm pore size is utilized in agricultural analysis and air pollution monitoring.
Grade 2 has 8 µm pore size is utilized in monitoring contaminants in the atmosphere and soil testing.
Grade 3 has 6 µm pore size is suitable for carrying samples.
Grade 4 has 20–25 µm pore size is used to remove impurities in organic extracts.
Grade 602 – has 2 µm pore size is used for collecting fine particles.

- Quantitative filter paper is employed for gravimetric analysis.
- Glass fiber filters have 1 µm pore size and is used to filter highly contaminated solutions.
- Quartz fiber filters are highly resistant to chemicals, and do not absorb nitrogen or sulfur oxides. These filters are used for pollution analysis.
- PTFE filter has high air permeability and a wide operating temperature. It is used in autoclaves and to filter hot oils.

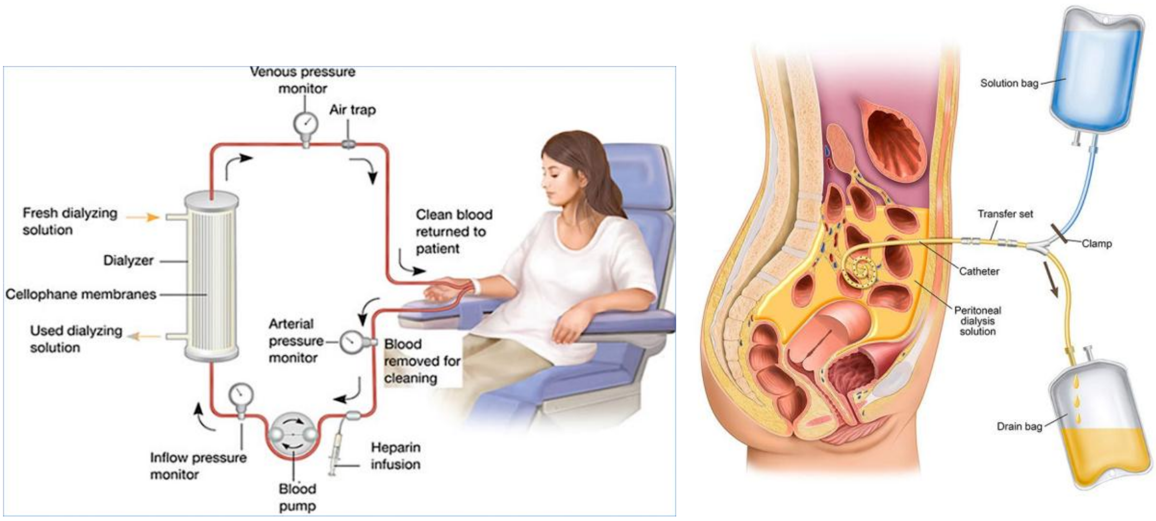
Dialysis: In medicine, dialysis (from Greek διάλυσις, dialysis, "dissolution"; from διά, dia, "through", and λύσις, lysis, "loosening or splitting") is the process of removing excess water, solutes, and toxins from the blood in people whose kidneys can no longer perform these functions naturally. This is referred to as renal replacement therapy. The first successful dialysis was performed in 1943. Dialysis may need to be initiated when there is a sudden rapid loss of kidney function, known as acute kidney injury (previously called acute renal failure), or when a gradual decline in kidney function –chronic kidney disease reaches stage 5. Stage 5 chronic renal failure is reached when the glomerular filtration rate is 10–15% of normal, creatinine clearance is less than 10mL per minute and uremia is present. Dialysis is used as a temporary measure in either acute kidney injury or in those awaiting kidney transplant and as a permanent measure in those for whom a transplant is not indicated or not possible. In Australia, Canada, the United Kingdom, and the United States, dialysis is paid for by the government for those who are eligible. In research laboratories, dialysis technique can also be used to separate molecules based on their size. Additionally, it can be used to balance buffer between a sample and the solution "dialysis bath" or "dialysate" that the sample is in. For dialysis in a laboratory, a tubular semipermeable membrane made of cellulose acetate or nitrocellulose is used. Pore size is varied according to the size separation required with larger pore sizes allowing larger molecules to pass through the membrane. Solvents, ions and buffer can diffuse easily across the semipermeable membrane, but larger molecules are unable to pass through the pores. This can be used to purify proteins of interest from a complex mixture by removing smaller proteins and molecules. Dialysis works on the principles of the diffusion of solutes and ultrafiltration of fluid across a semi–permeable membrane. Diffusion is a property of substances in water; substances in water tend to move from an area of high concentration to an area of low concentration. Blood flows by one side of a semi–permeable membrane, and a dialysate, or special dialysis fluid, flows by the opposite side. A semipermeable membrane is a thin layer of material that contains holes of various sizes, or pores. Smaller solutes and fluid pass through the membrane, but the membrane blocks the passage of larger substances (for example, red blood cells and large proteins). This replicates the filtering process that takes place in the kidneys when the blood enters the kidneys and the larger substances are separated from the smaller ones in the glomerulus. The two main types of dialysis, hemodialysis and peritoneal dialysis, remove wastes and excess water from the blood in different ways.



Figure–13: Dialysis.

Hemodialysis (MBST: Membrane Based Separation Technique) removes wastes and water by circulating blood outside the body through an external filter, called a dialyzer, that contains a semipermeable membrane. The blood flows in one direction and the dialysate flows in the opposite. The counter–current flow of the blood and dialysate maximizes the concentration gradient of solutes between the blood and dialysate, which helps to remove more urea and creatinine from the blood. The concentrations of solutes normally found in the urine (for example potassium, phosphorus and urea) are undesirably high in the blood, but low or absent in the dialysis solution, and constant replacement of the dialysate ensures that the concentration of undesired solutes is kept low on this side of the membrane. The dialysis solution has levels of minerals like potassium and calcium that are similar to their natural concentration in healthy blood. For another solute, bicarbonate, dialysis solution level is set at a slightly higher level than in normal blood, to encourage diffusion of bicarbonate into the blood, to act as a pH buffer to neutralize the metabolic acidosis that is often present in these patients. The levels of the components of dialysate are typically prescribed by a nephrologist according to the needs of the individual patient.[6]

In peritoneal dialysis, wastes and water are removed from the blood inside the body using the peritoneum as a natural semipermeable membrane. Wastes and excess water move from the blood, across the peritoneal membrane and into a special dialysis solution, called dialysate, in the abdominal cavity. There are three primary and two secondary types of dialysis: hemodialysis (primary), peritoneal dialysis (primary), hemofiltration (primary), hemodiafiltration (secondary) and intestinal dialysis (secondary). In hemodialysis, the patient's blood is pumped through the blood compartment of a dialyzer, exposing it to a partially permeable membrane. The dialyzer is composed of thousands of tiny hollow synthetic fibers. The fiber wall acts as the semipermeable membrane. Blood flows through the fibers, dialysis solution flows around the outside of the fibers, and water and wastes move between these two solutions. The cleansed blood is then returned via the circuit back to the body. Ultrafiltration occurs by increasing the hydrostatic pressure across the dialyzer membrane This usually is done by applying a negative pressure to the dialysate compartment of the dialyzer. This pressure gradient causes water and dissolved solutes to move from blood to dialysate and allows the removal of several litres of excess fluid during a typical 4–hour treatment. Studies have demonstrated the clinical benefits of dialyzing 5 to 7 times a week, for 6 to 8 hours. This type of hemodialysis is usually called nocturnal daily hemodialysis and a study has shown it provides a significant improvement in both small and large molecular weight clearance and decreases the need for phosphate binders. These frequent long treatments are often done at home while sleeping, but home dialysis is a flexible modality and schedules can be changed day to day, week to week. In general, studies show that both increased treatment length and frequency are clinically beneficial.



Figure–14: Hemodialysis & Peritoneal dialysis.

Peritoneal dialysis: In peritoneal dialysis, a sterile solution containing glucose (called dialysate) is run through a tube into the peritoneal cavity, the abdominal body cavity around the intestine, where the peritoneal membrane acts as a partially permeable membrane. This exchange is repeated 4–5 times per day; automatic systems can run more frequent exchange cycles overnight. Peritoneal dialysis is less efficient than hemodialysis, but because it is carried out for a longer period of time the net effect in terms of removal of waste products and of salt and water are similar to hemodialysis. Peritoneal dialysis is carried out at home by the patient, often without help. This frees patients from the routine of having to go to a dialysis clinic on a fixed schedule multiple times per week. Peritoneal dialysis can be performed with little to no specialized equipment (other than bags of fresh dialysate).

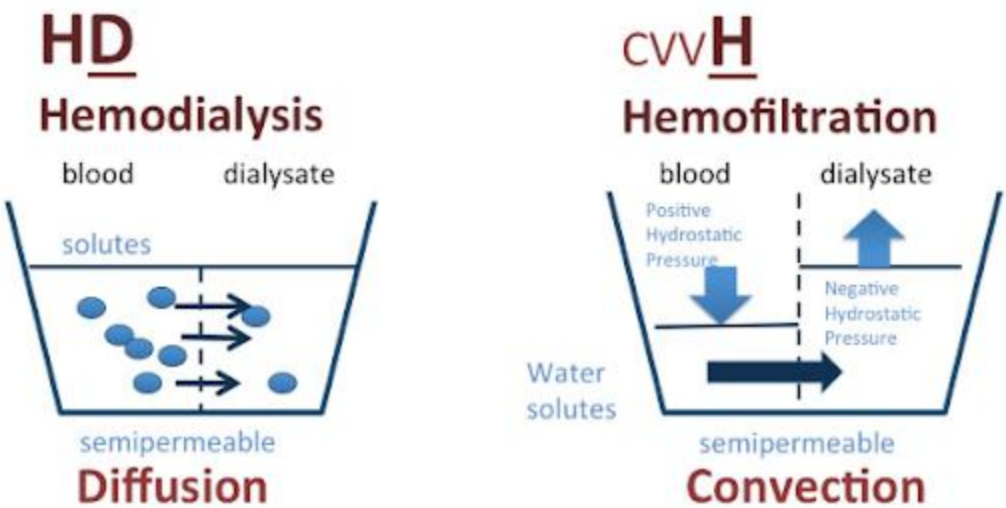


Figure-15: Difference between diffusion & convection.

Hemofiltration: Hemofiltration is a similar treatment to hemodialysis, but it makes use of a different principle. The blood is pumped through a dialyzer or "hemofilter" as in dialysis, but no dialysate is used. A pressure gradient is applied; as a result, water moves across the very permeable membrane rapidly, "dragging" along with it many dissolved substances, including ones with large molecular weights, which are not cleared as well by hemodialysis. Salts and water lost from the blood during this process are replaced with a "substitution fluid" that is infused into the extracorporeal circuit during the treatment.

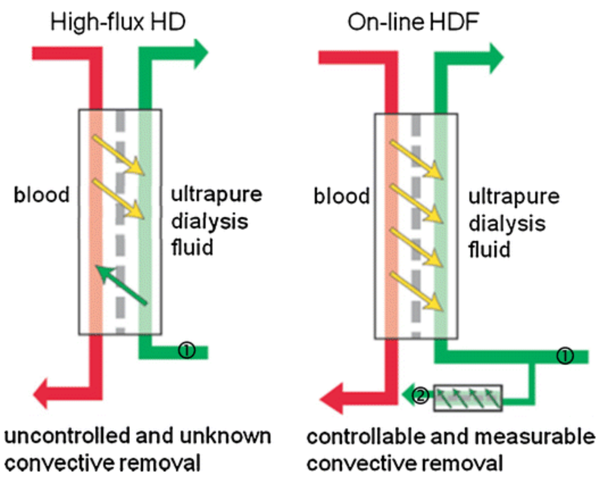


Figure-16: Haemodialysis & Hemodiafiltration.

Hemodiafiltration: Hemodiafiltration is a combination of hemodialysis and hemofiltration, thus used to purify the blood from toxins when the kidney is not working normally and also used to treat acute kidney injury (AKI).

Intestinal dialysis: In intestinal dialysis, the diet is supplemented with soluble fibres such as acacia fibre, which is digested by bacteria in the colon. This bacterial growth increases the amount of nitrogen that is eliminated in fecal waste. An alternative approach utilizes the ingestion of 1 to 1.5 liters of non–absorbable solutions of polyethylene glycol or mannitol every fourth hour.[7]

Depyrogenation refers to the removal of pyrogens from solution, most commonly from injectable pharmaceuticals. A pyrogen is defined as any substance that can cause a fever. Bacterial pyrogens include endotoxins and exotoxins, although many pyrogens are endogenous to the host. Endotoxins include lipopolysaccharide (LPS) molecules found as part of the cell wall of Gram-negative bacteria, and are released upon bacterial cell lysis. Endotoxins may become pyrogenic when released into the bloodstream or other tissue where they are not usually found. Although the colon contains Gram-negative bacteria in abundance, they do not cause a pyrogenic effect as the bacteria are not undergoing gross lysis, and the immune system is not exposed to free endotoxin while the colonic wall is intact. When LPS is released upon bacterial cell lysis, the lipid A component is first bound by serum LPS-Binding Protein (LBP) and then transferred to CD14 (either free CD14 in the serum or bound to the cell surface of macrophages or monocytes). This monomerises the aggregated LPS, as the LPS receptor Toll-like Receptor 4 (TLR4) cannot recognise LPS while aggregated. Monomeric LPS is then transferred to MD-2 pre-complexed with TLR4 on macrophages and monocytes. This leads to release of pro-inflammatory cytokines and nitric oxide, which may lead ultimately to septic shock depending on the strength of response. Vascular endothelial cells also express TLR4 and MD-2 and so respond to LPS directly, as well as via cytokines and nitric oxide. Bronchial epithelial cells and colonic epithelial cells also express TLR4, but as they do not express MD-2 they rely on LPS precomplexed with serum MD-2 in order to signal to LPS. Pyrogens can often be difficult to remove from solution due to the high variability of their molecular weight. Pyrogens are also relatively thermally stable and insensitive to pH changes. However, several removal techniques exist.

Ultrafiltration is used to remove pyrogens. Because the molecular weight of endotoxins is usually over 10 kD, ultrafiltration can sometimes be used to perform as a size-based separation. Due to the high variability of endotoxin size, it can be difficult to select the correct membrane, hence this method is best used only when all endotoxins present are larger than 300,000 Da. Commercially available ultra-filters have been shown to remove pyrogens to a level below 0.001 EU/ml.

CONCLUSION

Filtration is a unique unit operation. The separative process of filtration is widely used in the biopharmaceutical industry to remove contaminants from liquids, air, and gases, such as particulate matter, microorganisms. So, a thorough knowledge of filtration equipment and their integrity testing is essential. Filtration produce the outcome free from unwanted debris. Hemodialysis is one of the machines that we use to replace some of the functions of the kidney. The kidney performs many functions and a hemodialysis machine can replace some of those functions. Ultrafiltration is the removal of fluid volume from a patient. Ultrafiltration (fluid removal) is one of the functions of the kidney and the hemodialysis machine. The other function that a hemodialyis machine is capable of is to perform dialysis (cleaning) of the blood in order to remove the toxins and built up wastes from the body. Hence the combination of dialysis and ultrafiltration constitute hemodialysis.

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