SUBJECT NAME & CODE: PHARMACEUTICAL ENGINEERING(BP304T)

UNIT: IV **(FILTRATION)**

CLASS:29

TOPIC: OBJECTIVES, APPLICATIONS, THEORIES AND FACTORS EFFECTING, FILTRATION

FILTERATION

Filtration may be defined as a process of separation of solids from a fluid by passing the same through a porous medium that retains the solids, but allows the fluid to pass through.

The suspension to be filtered is known as *slurry*.

The porous medium used to retain the solids is known as *filter medium*.

The accumulated solids on the filter are referred to as *filter cake*, while the clear liquid passing through the filter is *filtrate.*

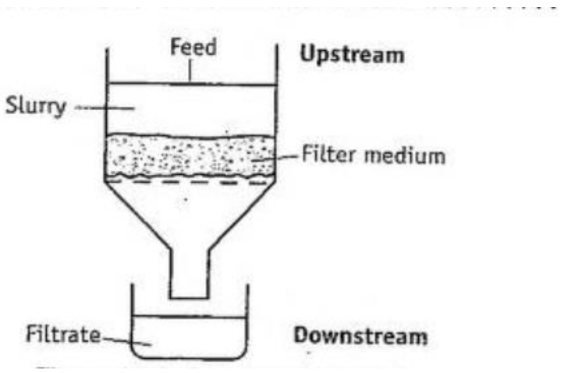
When solids are present in a very low concentration, i.e., not exceeding 1.0% w/v, the process of its separation from liquid is called *clarification.*

Clarification is generally employed when contaminating material is finely subdivided, amorphous or colloidal in nature. These solids tend to plug the filter medium. Several other processes having similar mechanisms are decolouration, decantation, collation, expression etc.

Process of Filtration

A typical filtration operation is shown in Figure. The pores of the filter medium are smaller than the size of particles to be separated. Filter medium (for example filter paper or muslin cloth) is placed on a support (a mesh). When slurry (feed) is passed over the filter medium, the fluid flows through the filter medium by virtue of a pressure difference across the filter. Gravity is acting on the liquid column. Therefore, solids are trapped on the surface of the filter medium.

Once the preliminary layer of particles is deposited, further filtration is brought about wherein the filter medium serves only as a support. The filter will work efficiently only after an initial deposit. In an industrial scale, large quantities of suspensions are mechanically handled. After a particular point of time, the resistance offered by the filter cake is so high that virtually filtration is stopped. For this reason, a positive pressure is applied on the filter cake (upstream) or negative pressure (suction) is applied below the filter medium (downstream),



Principle of filtration.

Objectives

- Separating solids from liquids and gases is the main goal of filtration. It also includes
- To remove contaminant particles from dispensing fluid so that it can be removed.
- By removing the dispensing fluid, solid particles can be recovered
- Solvents and solids must be of high quality
- Particles can be removed from the air to enable pharmaceutically useful gases to be purified
- It is used to sterilize parenteral thermolabile products
- To examine the basic technology and requirements for
    1. Water treatment systems
    2. Storage requirements
    3. Sampling and testing
    4. Different types of water used in pharmaceuticals
    5. Microbial limits, disinfection

Applications

Production of sterile products: Air is filtered through HEPA filters (high efficiency particulate air filters) or laminar air-bench to obtain sterile air, which maintains good environment prior to and during manufacture of sterile products.

A solution is passed through a bacteria proof filter in order to obtain sterile solution, particularly when heat sterilisation is not suitable on account of thermolabile nature of the contents. In case of sterile products, particles as small as 0.2 um should be removed, which includes the bio-burden of fungi, bacteria etc.

Similar facilities are required for the production of antibiotics by fermentation, recombinant technologies of biological products and vaccines.

Production of bulk drugs: Solids of intermediates and finished products are separated from the reaction mixture by filtration technique. By this method, impurities can be removed.

Production of liquid oral formulations: Filtration is an essential step in the production of liquid oral solutions for obtaining clear solutions (clarification).

a) Dewaxing of oils**.**
b) Removing suspended oils from aqueous solutions. Examples are aromatic waters, syrups, elixirs, eye drops etc.
c) Removing of undesirable solids, which interfere with the transparency of the liquids. Examples are honey and fruit juices,
d) Clarifying the potable water.

Effluent and waste water treatment: Waste solids must be separated from the waste liquid prior to its disposal. Sometimes, the soluble components are precipitated and then separated by filtration.

MECHANISMS OF FILTRATION

The mechanism whereby particles are retained by a cant only in the initial stages of filtration. Some of the mechanisms are:

Impingement: Solids having the momentum move along the path of streamline flow and strike (impinge) the filter medium. Thus, the solids are retained on the filter medium. Filter is significantly

Straining: Similar to sieving. i.e., the particles of larger size cannot pass through the smaller pore size of the filter medium.

Entanglement: Particles become entwined (entangled) in the mass of fibres (of cloth with a fine hairy surface or porous felt) due to smaller size of particles than the pore size. Thus, the solids are retained within the filter medium.

Attractive forces: Solids are retained on the filter medium as a result of attractive forces between particles and filter medium, as in case of electrostatic precipitation.

In practice, filtration may combine various mechanisms.

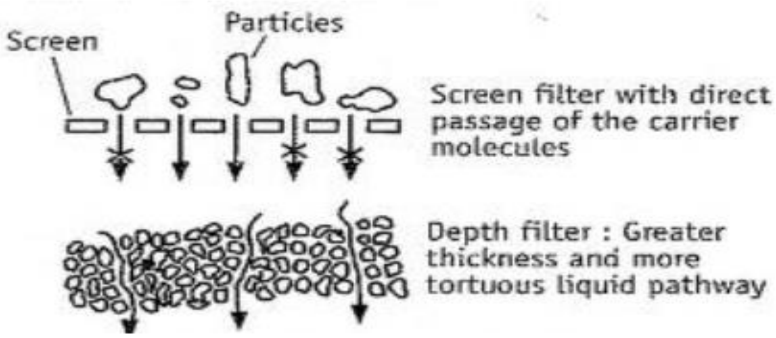
Types of Filtration

Based on the mechanism, two types of filtrations are broadly identified.

Surface filtration (Screen filtration): It is a screening action by Which pores or holes of the medium prevent the passage of solids. The mechanisms, straining and impingement are responsible for sur face filtration. For this purpose, plates with holes or woven sieves are used (Figure). Its efficiency is defined in terms of mean or maxi- mum pore size.

Depth filtration: In this process, slurry penetrates to a point where the diameter of solid particles is greater than that of the tortuous void or channel.

Depth filtration is aided by the mechanism entanglement. The solids are retained with a gradient density structure by physical restriction or by adsorption properties of the medium (Figure 8-2). It is extensively used for the removal of small amounts of contaminants from relatively large volumes of liquids (clarification). These are also used for roughing or prefiltering pharmaceutical solutions. Examples are ceramic filters, sintered (bed) filters.



Types of filtration.

Differences Between Surface and Depth Filtration

Surface filtration	*Depth filtration*
The size of the particles retained is slightly higher than the mean pore size of the medium.	The size of the particles retained is much smaller than the pores through which fluid passes.
Mechanical strength of the filter medium is less, unless it is made of stainless steel.	Mechanical strength is high.
It has low capacity.	It has high capacity.
The size of the particles retained is more predictable.	The size of the particles retained is less predictable.
Equipment is expensive because it should require ancillary equipment such as edge clamps, which should have much finer tolerances.	Cheaper because ancillary equipment is not required.
Example is cellulose membrane filter.	Examples are ceramic filters and sintered (bed) filters.

A special case of depth filtration is the sheet filtration, in which the slurry is passed through a series of pads mounted endwise to the flow of fluids. The pads commonly consist of a mixture of asbestos fibres embedded in cellulose.

Cake filtration: A filter consists of a coarse woven cloth through which a concentrated suspension of rigid particles is passed so that they bridge the holes and form a bed.

The cloth may be ineffective when the holes are likely to be much larger than the particles to be removed. Therefore, the cloth is presented with a concentrated suspension of rigid particles that bridge the holes and form a bed. The particles will be held back, while liquid passes through the small interstices. Example is filter cake made from diatomite (100 µm). This cake can remove submicrometric colloidal particles with high efficiency.

THEORIES OF FILTRATION

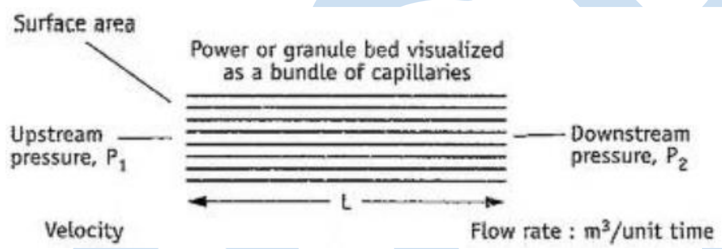
The flow of a liquid through a filter follows the basic rules that govern the flow of any liquid through the medium offering resistance. The rate of flow may be expressed as:

$$\text{Rate} = \frac{driving\ force}{resistance} \qquad (1)$$

The rate of filtration may be expressed as volume (litres) per unit time (dv/dt). The driving force is the pressure differential between the upstream and downstream of the filter. The resistance is not constant. It increases with an increase in the deposition of solids on the filter medium. Therefore, filtration is not a steady state.

The rate of flow will be greatest at the beginning of the filtration process, since the resistance is minimum. Once the filter cake is formed its surface acts as filter medium and solids continuously deposit adding to the thickness of the cake. The resistance to flow is related to several factors (Figure).

$$\text{Resistance to movement} = \frac{Pressure\ upstream - Pressure\ downstream}{length\ of\ capillaries} \qquad (2)$$



Filtration process parameters.

Poiseuille's Equation

Poiseuille considered that filtration is similar to the streamline flow of a liquid under pressure through capillaries. Poiseuille's equation is:

$$V = \frac{\pi \Delta P r^4}{8L\eta} \qquad (3)$$

Where V = rate of flow, i.e., volume of liquid flowing in unit time m^3 s (l/s)

ΔP = pressure difference across the filter. Pa

R = radius of the capillary in the filter bed, m

L = thickness of the filter cake (capillary length), m

η = viscosity of the filtrate, Pa.s

If the cake is composed of a bulky mass of particles and the liquid flows through the interstices (correspond to a multiplicity of capillary tubes), then the flow of liquids through these may be expressed by Poiseuille's equation.

Darcy's Equation

Poiseuille's law assumes that the capillaries found in the filter are highly irregular and nonuniform. Therefore, if the length of a capillary is taken as the thickness of the bed, a correction factor for radius is applied so that the rate equation is closely approximated and simplified. The factors influencing the rate of filtration has been incorporated into an equation by Darcy, which is:

$$V = \frac{KA\Delta P}{\eta L} \qquad (4)$$

Where K = permeability coefficient of the cake, m^2

A = surface area of the porous bed (filter medium), m^2

Other terms are same as shown in equation. The term K depends on the characteristics of the cake, such as porosity, specific surface area and compressibility.

Permeability may be defined quantitatively as the flow rate of a liquid of unit viscosity across a unit area of cake having unit thickness under a pressure gradient of unity.

This model relates not only to filter beds or cakes but also applies to other types of depth filter. Equation is valid for liquids flowing through sand, glass beads and various porous media.

Darcy's equation is further modified by including characteristics of K by Kozeny-Carman.

Kozeny-Carman Equation

Poiseuille's equation is made applicable to porous bed, based on a capillary type structure by including additional parameters. Thus, the resultant equation, which is widely used for filtration is Kozeny-Carman equation.

$$V = \frac{A}{\eta S^2} \cdot \frac{\Delta P}{KL} \cdot \frac{\varepsilon^3}{(1-\varepsilon)^2}$$

Where ε = porosity of the cake (bed)

S = specific surface area of the particles comprising the m^2/m^3

K = Kozeny constant

Other terms are same as shown in equations (4) and (3) The Kozeny constant is usually taken as 5. The effect of compressibility of the cake on flow rate can be appreciated from equation (1), since the flow rate is proportional to $\varepsilon^3/(1-\varepsilon)$. A 10 per cent change in porosity can produce almost 3-fold change in V.

Limitations of Kozeny Carman equation: Kozeny Carman equation does not take into account of the fact that the depth of the granular bed is lesser than the actual path traversed by the fluid. The actual path is not straight throughout the bed, but it is sinuous or tortuous.

FACTORS INFLUENCING FILTRATION

A simple straining process does not provide a complete description of how particles are removed from a suspension. The particles are exposed to a number of forces including gravity or electrical fields. Some of the factors influencing the filtration are:

a) Properties of the liquids-density, viscosity and corrosiveness.
b) Properties of the solids-particle shape, particle size, particle charge, density, particle size distribution, rigidity or compressibility of the solid under pressure and tendency of particle to flocculate or adhere together.
c) Proportion of solids in the slurry-rate at which the filter cake is formed, especially in the early stages of the filtration.
d) Objectives-whether the solids or the liquid or both are to be collected.
e) Temperature of the suspension.

Surface Area of the Filter Medium

According to equation (5), rate of flow of filtrate flowing through the filter is inversely proportional to the specific surface of the filter bed. On the other hand, if the surface area of the filter medium is considered, the rate of filtration is directly proportional to the surface area of the filter medium (equation 4). Hence, the rate can be increased either using a larger filter or connecting a number of small units in parallel. For example, filter press works on the principle of connecting the units in parallel. Pleating the filter paper or using a pleated funnel increases the effective surface area for filtration.

Pressure Drop Across the Filter Medium

According to equation (5), rate of filtration is directly proportional to the overall pressure drop across filter medium and filter cake. The pressure drop can be achieved in a number of ways:

Gravity: A simple method of obtaining a pressure difference is maintaining a head of slurry above the filter medium. The pressure developed depends on the density of the slurry. As a rough guide, a head of 10 metres of water creates a pressure difference of 100 kilopascals.

Applying pressure: The most common method of obtaining a pressure difference is applying pressure on the surface of the slurry i.e., Pumping the slurry onto the filter.

The pressure difference obtained by this method is greater than that is achieved by reduced pressure. Industrial plant may be operated at pressure up to 1500 kilopascals. However, in the early stages of filtration, pressure difference should be less. This is to prevent the pores of the filter medium from clogging or plugging, which subsequently increases resistance to the flow.

Reducing pressure: The pressure underneath the filter medium may be reduced below atmospheric pressure by connecting the filtrate receiver to a vacuum pump. This creates a pressure differential across the filter. This factor has limited applications, because the pressure difference of about 100 kilopascals may be achieved. Reduction of pressure lowers the boiling point of liquids so that it is possible for the filtrate to boil in the receiver. Apart from the loss of liquid, the vapour may damage the vacuum pump.

Advantage of this method is that it is safe. If a part of the equipment fails, it will collapse and not explode. Therefore, this method is commonly applied in a laboratory, where the apparatus is usually made of glass. However, in the industrial scale, the plant is usually constructed with a metal that is able to withstand high pressure.

Centrifugal force: Centrifugal force could replace the gravitational force and is used to increase the rate of filtration.

Viscosity of Filtrate

According to equation (5), rate of filtration is inversely proportional to the viscosity of the fluid. The viscosity of the liquid, not the slurry is important, since the resistance to flow occurs as the filtrate flows through the filter cake.

Raising the temperature of the liquid, which lowers the viscosity, may increase the rate of filtration. This is not practicable, if thermolabile materials are involved or if filtrate is volatile. Another alternative to decrease the viscosity is to dilute the filtrate. In this case, it is important to ensure that by doubling the volumes, the rate must be more than double, which should indicate the advantage.

In brief, surface area and pressure differences are the two factors, which are applied, in industrial practice. According to equation (5) other factors such as porosity also influences the rate of filtration. These are discussed below with filter aids.

MCQ Each carry 1 mark

1. Filtration is a unit operation that is commonly used for collecting
    a) Filtrate
    b) Particulate matter
    c) Precipitate
    d) Slurry
2. In the clarification process, which factor is more important
    a) Depth of the media
    b) Pore size of the filter media
    c) Surface area of the filter
    d) Volume of slurry
3. Who has proposed that the filtration process is like the streamlined flow of liquid under pressure through capillaries?
    a) Carman
    b) Darcy
    c) Kozeny
    d) **Poiseuille**
4. Which one of the following is not a mechanism of filtration?
    a) Entanglement
    b) Impact
    c) Impingement
    d) Straining
5. The process of separation of insoluble particles from suspension or slurry is called
    a. Filtration
    b. Sieving
    c. Distillation
    d. Drying
6. The separation process in which the amount of solid in a liquid is not more than 1% w/v is called

   - **a. Clarification**
   - b. Filtration
   - c. Centrifugation
   - d. Evaporation
7. Which of the following does not influence filtration?
   - a. Temperature
   - b. Density
   - c. Viscosity
   - **d. pH**
8. The rate of flow of the filtrate through the filter cake is………to the thickness of the cake
   - **a. Inversely proportional**
   - b. Directly proportional
   - c. Remain constant
   - d. None of above
9. Which of the following theory not describe the rate of filtration?
   - a. Darcy Law
   - b. Poiseuille's equation.
   - c. Kozeny Carman equation
   - **d. Noyes Whitney equation**
10. The slurry is
    - a. **A suspension to be filtered**
    - b. A porous membrane used to retain the solids
    - c. The solids which are present on the filter
    - d. A clear liquid passing through the filter.
11. The correct definition of filtration is:
    - **a. When solids are present in a very low concentration, i.e., not exceeding 1.0% w/v, the process of its separation from liquids**
    - b. When solids are present in a very low concentration, i.e., not exceeding 5.0% w/v, the process of its separation from liquids
    - c. When solids are present in a very low concentration, i.e., not exceeding 2.0% w/v, the process of its separation from liquids
    - d. When solids are present in a very low concentration, i.e., not exceeding 7.0% w/v, the process of its separation from liquid
12. In the equation of Poiseulle's & Konzeny's Theory, "V" stands for
    - a. Velocity
    - b. Viscosity
    - **c. Rate of filtration/flow**
    - d. None

Each carry 2 marks

1. List the factors influencing the rate of filtration.
2. Write Kozeny-Carman equation and give its significance.
3. Give the principle of filtration process.
4. Differentiate surface filtration and depth filtration.
5. Why depth filtration is necessary for the separation, while other methods are available?

Each carry 5 marks

1. Explain the mechanisms of filtration.

2. Explain factors affecting filtration.

Each carry 10 marks

1. Explain the theories of filtration giving the principle, mechanism and factors affecting the process.