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محتوى المحاضرة

THEORY OF FILTRATION

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

The rate may be expressed as volume per unit time and the driving force as a pressure differential. The apparent complexity of the filtration equations arises from the expansion of the resistance term. Resistance is not constant since it increases as solids are deposited on the filter medium. An expression of this changing resistance involves a material balance as well as factors expressing permeability or coefficient of resistance of the continuously expanding cake.

These factors have been taken into account in the formation of the *Darcy's equation:*

where, *A* = Filter area
P= total pressure drop through cake and filter medium
V = volume of filtrate
T = time
η = filtrate viscosity
L = bed thickness in direction of fluid flow
K = permeability coefficient

It is convenient to summarize the theoretic relationship as:
Interpretation of the basic equations, however, leads to a general set of rules:
1)Pressure increases usually cause a proportionate increase in flow unless the cake is highly compressible. Pressure increases on highly compressible, flocculent, or slimy precipitates may decrease or terminate flow.
2)An increase in area increases flow and life proportional to the square of the area since cake thickness and thus resistance, are also reduced.

3)Cake resistance is a function of cake thickness, therefore, the average flow rate is inversely proportional to the amount of cake deposited.

4) The filtrate flow rate at any instant is inversely proportional to viscosity so, filtration efficiency also may be affected by changes in temperature. The viscosities of most liquids decrease with increase in temperature. Increasing the temperature of heavy pharmaceutical syrups lowers the viscosity and increases filtration rates

5) The permeability coefficient may be examined in terms of its two variables: porosity and surface area
,the cake porosity depends on the way in which particles are deposited and packed. A fast deposition rate, given by concentrated slurries or high flow rates, may give a higher

porosity because of the greater possibility of bridging and arching in the cake Surface area

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unlike porosity, is markedly affected by particle size and is inversely proportional to particle diameter. Hence, a coarse precipitate is easier to filter than a fine precipitate even though both may pack with the same porosity.

Most clarification problems can be resolved empirically by varying one or more of these factors

FILTER MEDIA

The surface upon which solids are deposited in a filter is called the filter *medium*. For the pharmacist selecting this important element, the wide range of available materials may be bewildering. The selection is frequently based on past experience, and reliance on technical services of commercial suppliers is often advisable. The ideal filter material should have the following characteristics:

1)A medium for cake filtration must retain the solids without plugging and without excessive bleeding of particles at the start of the filtration. In clarification applications in which no appreciable cake is developed, the medium must remove all particles above a desired size.

2)It should offer minimum resistance and the resistance offered by the medium itself will not vary significantly during the filtration process. 3)It allows easy discharge of cake.

4)It should be chemically and physically inert.

5)It should not swell when it is in contact with filtrate and washing liquid. 6)It should have sufficient mechanical strength to withstand pressure drop and mechanical stress during filtration.

There are a variety of different depth filter and membrane filter materials used in pharmaceutical processes. Depth filters are mainly polymeric fibrous materials. The filter fabrics are commonly woven from natural fibers such as cotton and from synthetic fibers and glass

Filter cloth, a surface type medium, is woven from either natural or synthetic fiber or metal. Cotton fabric is the most common and is widely used as a primary medium, as backing for paper or felts in plate and frame filters, and as fabricated bags for coarse straining. Nylon is often superior for pharmaceutical use, since it is unaffected by molds, fungi, or bacteria, provides an extremely smooth surface for good cake discharge, and has negligible absorption properties. Both cotton and nylon are suitable for coarse straining in aseptic filtrations, since they can be sterilized by autoclaving. Monofilament nylon cloth is extremely strong and is available for openings as small as 10 µm. Teflon is superior for most liquid filtration, as it is almost chemically inert, provides sufficient strength, and can withstand elevated temperatures.

Woven wire cloth, particularly stainless steel, is durable, resistant to plugging, and easily cleaned. Metallic filter media provide good surfaces for cake filtration and are usually used with filter aids. As support elements for disposable media, wire screens are particularly suitable, since they may be cleaned rapidly and returned to service. Wire mesh filters also are installed in filling lines of packaging equipment

Non-woven filter media include felts, bonded fabrics, and kraft papers. A *felt* is a fibrous mass that is free from bonding agents and mechanically interlocked to yield specific pore diameters that have controlled particle
retention. High flow rate with low pressure drop is a primary characteristic. Felts of natural or synthetic material function as depth media and are recommended where gelatinous solutions or fine particulate matter are involved.

Porous stainless steel filters are widely used for the removal of small amounts of unwanted solids from liquids (clarification) such as milk, syrup, sulfuric acid, and hot caustic soda. Porous metallic filters can be easily cleaned and repeatedly sterilized

Membrane filter media
are the basic tools for microfiltration, ultrafiltration, nanofiltration and reverse osmosis, Membrane filters, classified as surface or screen filters, are made of various esters of cellulose or from nylon, Teflon, polyvinyl chloride, polyamide, polysulfone, or silver
The filter is a thin membrane, about 150 µm thick, with 400 to 500 million pores per square . centimeter of the filter surface. The pores are extremely uniform in size and occupy about 80% of filter volume

The high porosity permits flow rates at least 40 times higher than those obtained through other media of comparable particle retention capability

Because of surface screening characteristics, prefiltration is often required to avoid rapid clogging of a membrane. The selection of a membrane filter for a particular application is a function of the size of the particle or particles to be removed

Surface-type cartridges of corrugated, resin-treated paper are common in hydraulic lines of processing equipment, but are rarely applied to finished products. Ceramic cartridges have the advantage of being cleanable for reuse by back-flushing. Asbestos and porcelain filter candles are acceptable for some sterile filtrations along with membrane filters

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FILTER AIDS

Usually, the resistance to flow due the filter medium itself is very low, but increases as a layer of solids builds up, blocking the pores of the medium and forming a solid, impervious cake. Poorly flocculated solids offer higher resistance than do flocculated solids or solids providing high porosity to the cake.

In the case of cake filtration, the rate varies with the square of the volume of liquid. When the volume of the filter cake solids per unit volume of filtrate is low, the solids deposited on the filter medium may penetrate the void space, thus making the filter medium more resistant to flow. At a higher concentration of solids in a suspension, the bridging over of openings over the void space, rather than blinding of the openings, seems to predominate

The filter medium becomes plugged or slimy with the accumulation of solids, and the flow of filtrate stops. A filter aid acts by reducing this resistance.

Filter aids are a special type of filter medium. Ideally, the filter aid forms a fine surface deposit that screens out all solids,

preventing them from contacting and plugging the supporting filter medium.
Usually, the filter aid acts by forming a highly porous and noncompressible cake that retains solids, as does any depth filter. The duration of a filtration cycle and the clarity attained can be controlled as density, type, particle size, and quantity of the filter aid are varied.

The quantity of the filter aid greatly influences the filtration rate. If too little filter aid is used, the resistance offered by the filter cake is greater than if no filter aid is used, because of the added thickness to the cake. On the other hand, if high amounts of filter aid are added, the filter aid merely adds to the thickness of the cake without providing additional cake porosity

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typical plot of filter aid concentration versus permeability. In the figure, flow rate and permeability are directly proportional to each other. At low concentrations of filter aid, the flow rate is low because of low permeability. As the filter aid concentration increases, the flow rate increases and peaks off. Beyond this point, the flow rate decreases as the filter aid concentration is increased The ideal filter aid performs its functions physically or mechanically and no absorption or chemical action is involved in most cases.
The important characteristics for filter aids are the following:

1)It should have a structure that permits formation of pervious cake. 2)It should have a particle size distribution suitable for the retention of solids, as required.
3)It should be able to remain suspended in the liquid.
4)It should be free of impurities.
5)It should be inert to the liquid being filtered.
6)It should be free from moisture in cases where the addition of moisture would be undesirable
Filter aids are considered to be equivalent in performance when they produce the same flow rate and filtered solution clarity under the same operating conditions when filtering a standard sugar solution
Diatomite (diatomaceous earth) is the most important filter aid.

Processed from fossilized diatoms, it has irregularly shaped porous particles that form a rigid incompressible cake. Since diatomite is primarily silica, it is relatively inert and insoluble

Cellulose, asbestos, filter aids are also commercially available. Cellulose is highly compressible and costs two to four times more than diatomite or perlite. It is reserved for applications where the liquids may be incompatible with silica compounds. Cellulose is used as a coarse precoat

Asbestos has good retention on coarse screens, but has limited application because of its high cost, and leaching of fibers into the filterate that might be toxic. Asbestos filters may be used in pharmaceutical industry if their application is followed by membrane filtration

Water-soluble polymers such as flocculating agents are often used as filter aids. The polymers may be derived from vegetable or animal sources, or they may be produced synthetically. Water-soluble polymers may be classified as nonionic, anionic, or cationic, depending on their property to ionize in water

New, high performance filter aids with self flocking (SF) property
provide low tortuosity and fine particle filtration with high flow rates. These filter aids are compounded calcined rice hulls that coagulate extremely fine particles into large, rigid, permeable, flocculated particles
Filter aids may be applied by *precoating* or *body-mix* techniques. Precoating requires suspending the filter aid in a liquid and recirculating the slurry until the filter aid is uniformly deposited on the filter septum

Body mix (direct addition of filter aid to the filter feed) is more common in batch pharmaceutical operations

Often, a filter aid performs its function not physically or mechanically, but chemically, by reacting with the solids. These chemicals may cause the solids depositing in a filter bed to adhere more strongly to the filter medium.

Filter aids are chosen by trial and error in either laboratory or plant. Within the ranges previously indicated, the filter aid is usually selected to give acceptable filtrate at the highest flow rate; however, in pharmaceutical operations in which quality is a primary consideration, the selection usually favours the fine grades, which yield low flow rates.

The most important pharmaceutical factor is inertness. A filter aid may have such extensive absorption properties that desired coloured substances and active principles are frequently removed. The total quantity of any ingredient absorbed may be small, but it may be a considerable portion of the original concentration