PALL

Food and Beverage

Technical Article

Understanding Particle Filtration in Liquids in Food and Beverage Industry Applications

Overview

In food and beverage production there is often a need for particle removal filtration of liquids and gases, with the goal of achieving high product quality while driving down manufacturing costs. The purpose of this filtration is to remove undesired particles from a fluid to achieve a desired cleanliness level, prevent contaminants from entering a process fluid stream, or adsorb unwanted contaminants.

The proper selection of filtration equipment for particle removal is critical to achieving desired outcomes, while minimizing cost of ownership. There is a large variety of equipment available, ranging from relatively small direct flow filters, sometimes called “dead-end” filters, to crossflow filter systems and other systems for handling higher suspended solids loads.

Filters are available with many types of filtration materials, designs, performance characteristics, and separation mechanisms, so much so that their proper selection can seem daunting.

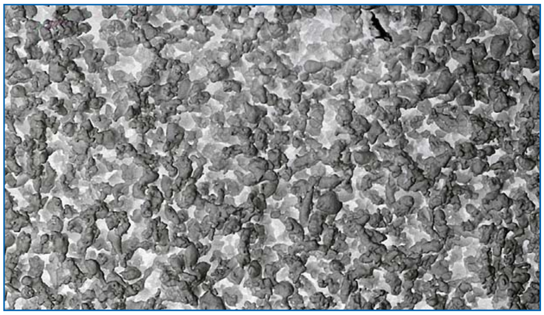
This article focuses on a narrower discussion about particle removal performance in liquids with cartridge and bag filters, *i.e.* in the microfiltration range of over 0.1 micron, and the filtration mechanisms involved.

Particle Removal with Surface and Depth Filtration

Based on their materials of construction and structure, cartridge and bag filters for particle removal offer a combination of surface and/or depth filtration. They most often comprise disposable filters with polymeric, woven or blown fibrous materials of construction such as polypropylene, polyester, nylon, cellulose and glass fibers, or cleanable metal cartridge filters of sintered metal powder or fibers (Figures 1a-1b).

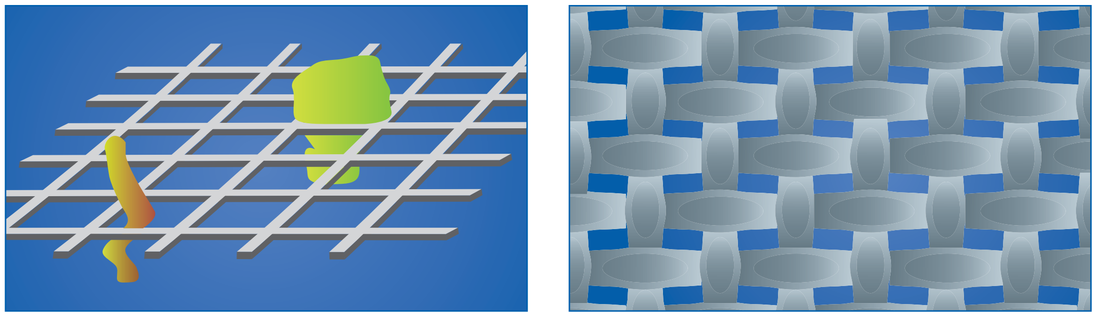
Figure 1a: SEM image of fibrous media

Figure 1b: SEM image of sintered metal media



The most extreme definition of surface filtration is that provided by a single layer screen or sieve, in which all filter pores rest on a single plane and particles larger than the surface openings are retained (Figure 2). Mesh filter bags provide a good industrial example of surface filtration. While they will retain coarse suspended solids, once the openings are blocked they no longer provide further filtering action. As such, mesh bags tend to block relatively quickly. Particles rarely are of perfect spherical dimensions, so they can bypass the filter openings, as can gels or fibers. Mesh openings can flex and unload retained particles especially under pressure fluctuation conditions (Figure 3). These filters provide very nominal filtration with unfixed pores but have their place in applications requiring coarse, extremely non-critical particle removal, or ones located upstream in the process requiring protection of finer, higher performance filters downstream.

Figure 2: In a single layer screen or mesh construction, particles are retained by size exclusion or easily pass through.



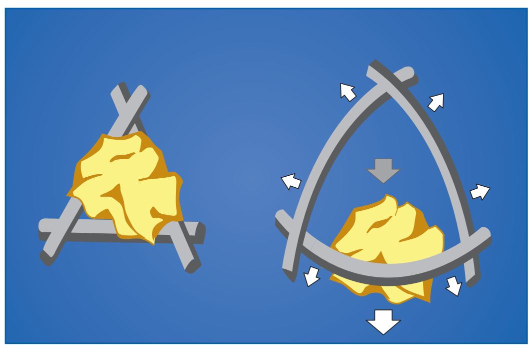


Figure 3: Contaminant unloading occurs when filter fibers do not have a fixed pore structure and flex under pressure.

Most manufactured media has depth. Adding depth to the filtration media in greater degrees helps with prolonging filter life and capturing an increasingly heterogeneous range of particle sizes, as well as deformable gels. While some surface filtration still takes place, the greater the depth of the filter medium, the more tortuous path contaminants must travel within the filter resulting in a greater contaminant holding capacity of the filter. Depth filters block less easily due to the alternative number of flow paths (Figures 4a-4b).

Figure 4: Adding depth to filter media increases dirt holding capacity and therefore filter life.

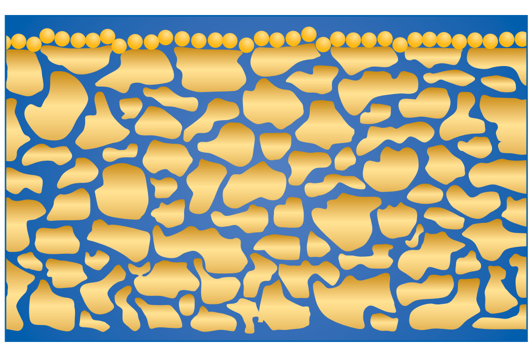


Figure 4a: Filtration begins at surface.

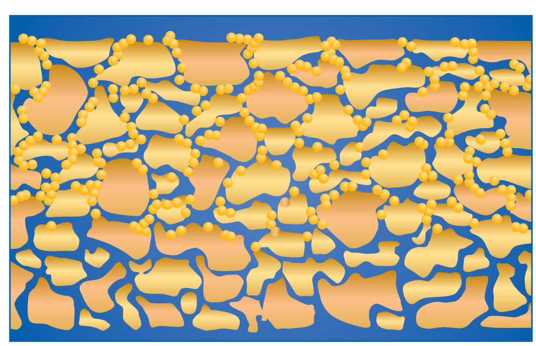


Figure 4b: Tortuous path in depth media increases contaminant holding capacity.

Pleated Filters

Along the continuum from surface to depth filtration, there are pleated filters with more but thinner pleats better suited to particle removal from fluids with narrow particle size distribution, and pleated filters with less but thicker pleats better suited to particle removal from fluids with wider particle size distribution, fluids with higher viscosity or deformable gels. The media employed within the pleats may consist of melt blown material, which enhances the depth filtration effect to some extent. Unique pleat designs (*e.g.* laid-over pleats) optimize the amount of surface area available for the filtration task (Figures 5a-5c).

Figure 5: Adding depth to filter media increases dirt holding capacity and therefore filter life.

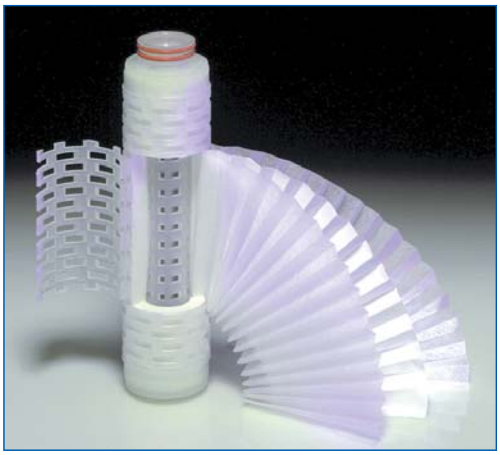


Figure 5a: Filters with thin fan pleats, such as PREcart PP II and Poly-Fine® II cartridges, feature highest surface area but minimal depth, ideally suited for filtering particles of homogenous size.

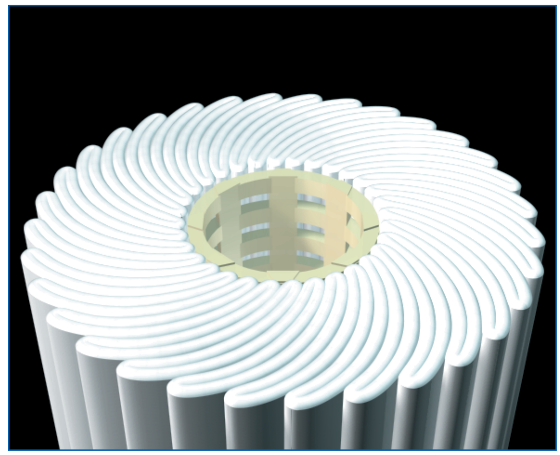


Figure 5b: Filters with laid-over pleat geometry, such as in Profile® UP cartridge with Ultipleat® design, feature high surface area and increased depth, ideally suited for filtering particles with heterogenous size distribution.

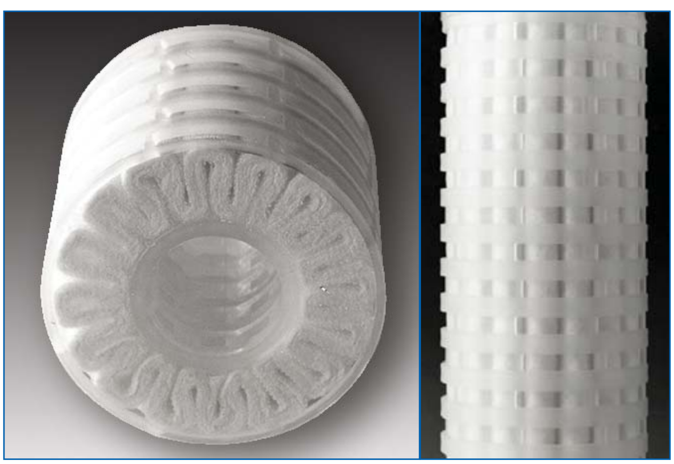
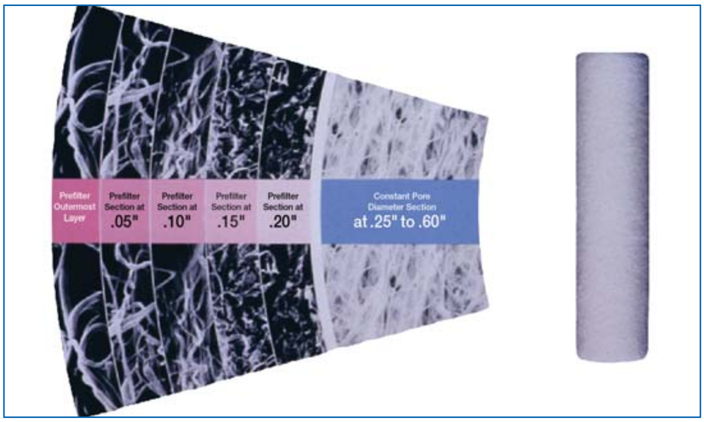


Figure 5c: Filters with thick pleats, such as Profile Star cartridge, feature highest degree of depth, ideally suited for filtering particles with heterogenous size distribution or viscous fluids and gels.

Melt Blown Depth Filters

Melt blown depth cartridges have no pleats and are primarily suited for depth filtration, capturing the widest range of particles. Unique melt-blowing technology enables the creation of different zones with coarse to finer media pore sizes, or gradient pore structure, such that larger particles are captured within the outer layers of the filter media and smaller particles within the inner layers. Graded pore density increases filter service life many fold (Figure 6).

Figure 6: Profile II and Nexis® T cartridges are ideally suited for clarification due to their graded pore structure.



Filter Bags and Metal Cartridges

Filter bags also vary in design from coarse mesh bags for surface filtration to bags made of felt material for slightly greater depth, and finally bags made of melt blown depth media with fixed pores for highest depth filtration performance (Figures 7a-7c).

Figure 7: Different filter bag types provide solutions for multiple filtration uses.

Figure 7a: Mesh filter bag

Figure 7b: Felt filter bag

Figure 7c: Melt blown filter bag

Metal cartridge filters, manufactured of sintered metal powder or metal fibers can be cylindrical or pleated, and they too have varying degrees of depth in their design (Figure 8).

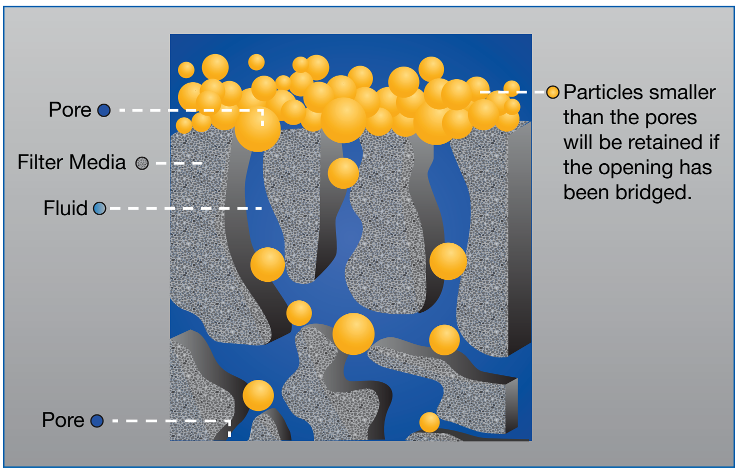
Figure 8: Rigimesh® and PSS® Porous Metal Cartridges

Filtration Mechanisms in Liquid Filtration

In liquid filtration, aspects which influence filtration efficiency include contaminant characteristics (*e.g.* particle size and density), fluid characteristics (*e.g.* density, viscosity), filter media characteristics, and the filtration mechanisms involved. The filtration mechanisms in liquid filtration include direct interception, inertial impaction, and retention by adsorption. These all combine in varying degrees to achieve particle removal.

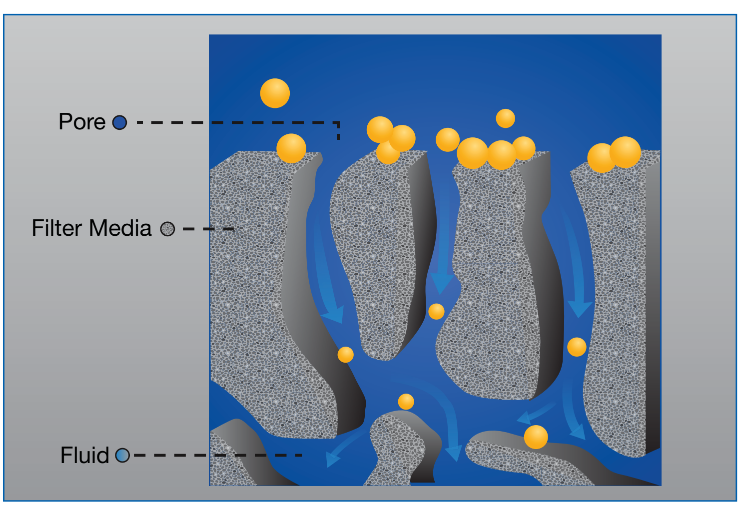
Direct interception is based on size exclusion, and is the filtration mechanism which works equally well in both liquids and gases. Particles are removed within the filter media when they are larger than the filter media pore size or flow path. Filter pores may also be blocked by irregularly shaped particles or by two or more particles as they “bridge” a filter pore, thus effectively reducing the pore size and excluding smaller particles (Figure 9).

Figure 9: Mechanism of Direct Interception –
Based on size exclusion, this mechanism is the most common one in liquid filtration.



Inertial impaction occurs to some extent in liquid filtration, although its effect is much more pronounced in gases. It takes place when fluids change direction as they pass through the filter media, and particles leave the stream lines of fluid flow due to their momentum, caused by their mass and velocity. As they impact the filter media, they are embedded into the media due to forces of molecular attraction. Particle sizes smaller than the filter pore sizes can be retained. This mechanism is very effective for particles greater than 0.5-1 micron in size (Figure 10).

Figure 10: Mechanism of Inertial Impaction –
This mechanism is less pronounced in liquids. Due to their momentum, particles leave the streamlines of fluid flow and are captured in the filter media due to molecular attraction.

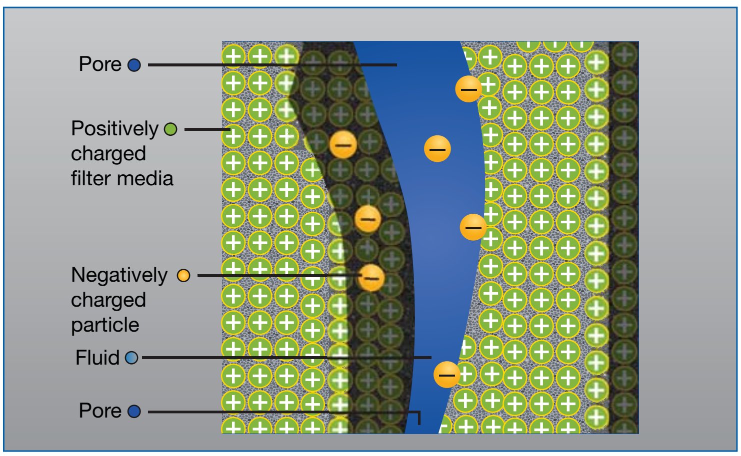


Adsorption in liquids also allows for the removal of contaminants smaller than the pore sizes of the filter. It occurs when particles are removed by nature of surface interactions with the filter media, rather than by mechanical separation as found in direct interception and inertial impaction. It results in the retention of suspended particles or colloids and some solutes. Common examples in the food and beverage industry include activated carbon filtration and electrokinetic attraction with positively charged filters.

Activated carbon filters provide binding sites which remove contaminants given enough exposure time. These filters are used to adsorb unwanted colors, odors, or chemicals such as in chlorine removal from water.

Electrokinetic attraction occurs when the filter media itself is positively or negatively charged such that particles in aqueous liquids carrying an opposite charge are attracted and captured. An example of this filter mechanism occurs with positive zeta potential glass fiber filter cartridges (*e.g.* Ultipor® GF Plus) attracting negatively charged particles. Most particles in nature are negatively charged, such as colloidal silica, yeasts, bacteria, and negatively charged protein molecules (Figure 11).

Figure 11: Mechanism of Electrokinetic Attraction –
This mechanism is one example of adsorptive filtration.



The retention efficiency of adsorption is affected by factors such as temperature, pH, and concentration. For example, as pH changes, the zeta potential or amount of electrical charge of the filter media can change significantly, thus influencing the degree of contaminant retention. As the concentration of charged particles in a fluid increases, the filter capacity may be exhausted due to the limited number of charged sites available on the filter, leading to their saturation. This can lead to deterioration of the filtrate quality as particles not retained pass through.

Aids to Liquid Filtration

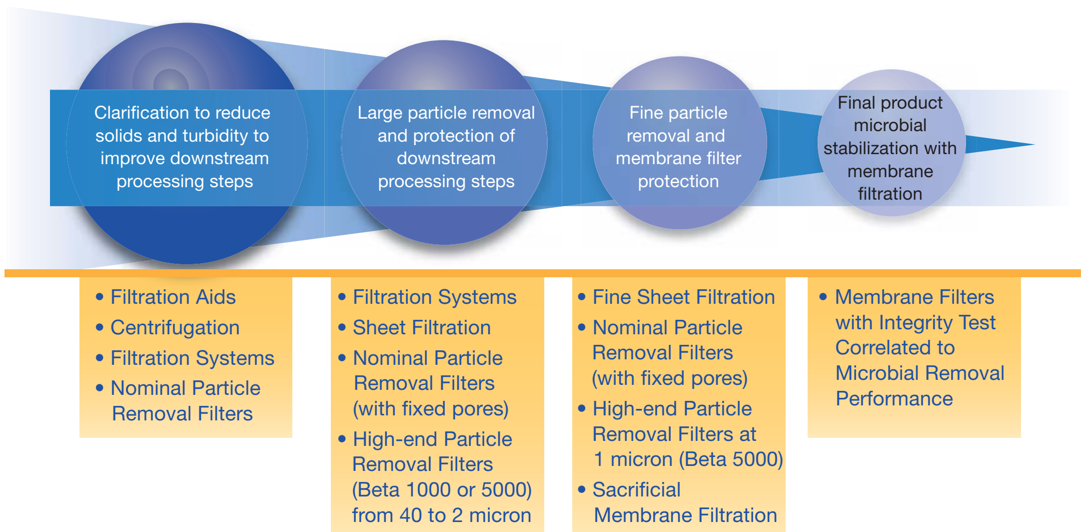
Flocculation materials added to process fluids, to make fine particles clump together so that they form larger particles, aids in liquid filtration. Adding bentonite to wine or polyelectrolytes such as starch to fluids are examples.

Adding filter aids such as diatomaceous earth or perlite to process fluids initially creates a bridging effect on a filter surface, thus trapping smaller contaminants. As the amount of retained contaminants builds, the filter aid enables a porous structure within this “cake”, such that the cake itself takes on the characteristic of a filter. This approach is found in older technology (*e.g.* precoat filters) used for clarification of beer, enzyme solutions, wine and others. Diatomaceous earth and perlite are very effective and have found their place in modern use with their incorporation into filtration sheets and sheet-based modules.

General Application and Capabilities of Particle Removal Filters

Cartridge filters which remove solid particles, gels, colloids, and even reduce some large microbe contamination (*e.g.* yeast) are very well suited to pre-filtration applications. They are best used for fluid clarification and haze removal, to protect downstream equipment or enhance its performance, and to protect and prolong the life of downstream membrane cartridge filters where used. Bag filters which remove particles or gels provide mostly nominal performance and are well suited for placement in non-critical filtration applications, such as upstream of cartridge filters, on load-out applications or on relatively coarse filtration applications. Figure 12 illustrates a general schematic for a food and beverage liquid filtration application which includes coarse to fine to final microbial filtration.

Figure 12: Filter placement in food and beverage process fluid stream



Cartridge and bag filters feature very fine to very coarse particle removal performance based on their particle removal ratings (*e.g.* disposable cartridges from ~0.5 to 150 microns, metal cartridges from ~1 to 800 microns, filter bags from ~1 to 1500 microns) and removal efficiencies[1]. It is important to note that performance claims are limited only to particle and not bacteria removal, as validation methods for testing particle versus microbial removal filters differ substantially. Particle removal filters are also not suited for bacteria removal as they are not tight enough, nor can their performance be monitored as they are not integrity-testable.

Based on their materials of construction, they exhibit varying degrees of chemical compatibility and temperature resistance. Higher quality products feature fixed pore structure, such that unloading and media migration, with resulting fluid contamination is avoided.

Properly selected filtration solutions enable users to minimize production costs without compromising product quality. The least expensive solution is often not the least costly. A careful analysis of all aspects of filtration cost of ownership is indispensable in driving down costs per unit volume of fluid filtered.

Footnotes

[1] Pall Technical Article: “Understanding Particle Removal Performance in Liquids with Cartridge and Bag Filtration”

Examples of Food and Beverage Industry Applications

Particle filtration is necessary in many food and beverage processing applications, as illustrated by a few examples:

- Pre-filtration prior to final microorganism-reducing filters in wine, beer, cider, or other beverage bottling
- Filtration for barrel char removal in distilled spirits
- Sugar crystal removal in flavored spirits
- Guard filtration on bottling lines in spirits, and for yeast and particle removal in beer
- Trap filtration downstream of DE filters in beer, fermenter broths (*e.g.* enzymes), gelatin, others
- Trap filtration downstream of carbon treatment or resin columns in sweeteners, spirits, other fluids
- Particle removal in flavors, soy sauce, coffee, tea, juices, soft drinks, other fluids
- Load-out filtration in sweeteners and edible oils
- Incoming plant water treatment (*e.g.* carbon, resin or multi-media bed trap filtration, precipitated iron particle removal, pre-RO water filtration)
- Particle filtration on blending or ingredient water
- Cleaning water for crossflow membranes
- Rinsing water and chemical sterilant filtration on packaging machines

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