A Layman's Guide to Inorganic and Organic Contaminant Removal by Standard Filtration Methods

Plant operators, maintenance engineers and mechanics, specifying engineers, installation technicians, and others involved in inorganic and organic contaminant removal are oftentimes called upon to choose and apply filtration solutions. To best make these decisions, it is helpful to review information and updated insight on basic filtration technologies, along with their advantages and disadvantages.

What are Inorganic and Organic Contaminants?

The basic definition of organic compound is a compound that contains carbon atoms. Therefore, any compound that does not contain carbon is an inorganic compound. This is a good general rule to use. However, like most rules, there are exceptions. Some notable exceptions are carbon dioxide and carbon monoxide gases along with minerals like calcium carbonate (calcite) which are inorganic compounds.

Inorganic Contaminants

The vast majority of inorganic contaminant removal applications are sediment or particulate reduction. In this case, particles in the water or fluid will need to be removed before the fluid can be used for its intended purpose. The particles may be visible to the naked eye or they may require magnification. Most people cannot see particles smaller than 40 microns (1 micron is one one-thousandth of a millimeter or 1/1000 mm). For comparison purposes, the approximate size of common particles and substances are listed below:

- Dust is up to 1 micron
- Cement dust is 3 to 4 microns
- A human red blood cell is 5 microns
- Pollen is 7 to 10 microns
- Silt is 10 to 75 microns
- The diameter of a human hair is 100 microns
- Sand is 75 to 1000 microns

Standard sediment removal filters, both bags and cartridges, are very effective at removing most sediment and particles from fluids. There are many different filter options for removing sediment and particles and these applications will be covered later in this article.

Inorganic contaminants can also be present in water as a dissolved substance, usually a mineral. Since these contaminants are present in ionic form and are not particles, they will pass through most standard filters. A good analogy is salt water. If salt water is filtered with standard filters, the product is cleaner salt water (not purified water). Inorganic contaminants in ionic form can be removed using ion exchange systems and reverse osmosis systems.

Free chlorine in water is another type of inorganic contaminant. It is added to many municipal water supplies because of its disinfecting capabilities. However, it can be an undesirable substance due to its oxidative properties and the unpleasant taste and odor it can add to water. Free chlorine is comprised of dissolved chlorine gas (Cl_2), hypochlorous acid (HOCl) and/or hypochlorite ion (OCl^-). Carbon filtration is effective at removing free chlorine.

Organic Contaminants

There are two main categories of organic contaminants: Volatile Organic Compounds (VOCs) and Total Organic Carbon (TOCs). VOCs are contaminants like solvents, hydrocarbons, alcohols, and other industrial compounds. TOCs are all-organic carbon compounds including decaying plant and animal matter. High TOC levels may be found in some surface water supplies (streams, rivers, lakes, reservoirs, etc.) It is less of an issue in ground water supplies. Carbon filtration is effective at removing most organic contaminants.

Removal of Inorganic Particulate Contamination

There are seemingly endless choices of sediment removal filters, from bag filters to a variety of cartridge filters – each with advantages and drawbacks. The intended application should determine which filter to use and which to avoid.

Bag Filters

Bag filters yield high flow rates in a relatively small and cost effective system. They are offered in many different materials, for a higher range of chemical and temperature compatibilities. Bag filters are available in a wide variety of micron ratings from 0.5 micron up to 1500 micron. Bag filters usually exhibit long life between filter changes and offer high dirt holding capacity. Special multi-layer bag filters with increased removal efficiencies are also available.

The main drawback of bag filters is that they do not always form a tight seal with the housing, which can result in filter by-pass, and allow a high percentage of particles to remain in the fluid after filtration. This can be minimized by using Poly Flange adaptors in place of sealing rings on the bag filters, or by using hold down springs or hold down bars in the housings.

Bag filters and strainers are well suited for coarse filtration (filtration of larger particles) and high-flow applications that can tolerate some by-pass. They are excellent prefilters or first stage filters in multi-stage filtration systems. They are also effective in closed loop or re-circulation systems where there are multiple opportunities to remove the contaminant (or when the goal is to reduce the sediment load in the system to an acceptable level).

Shelco Filters HTF Series Filter Bags and BF Series Single or BFS Series Multi-Bag Housings are high quality, cost-effective bag filter options. They are offered in standard #1, #2, #3, and #4 sizes and special sized bags can be made to fit almost any bag housing. Bag filters made of special materials like Teflon and Nomex are available by special order. Food Grade bag filters can also be special ordered with certificates verifying that they were made with FDA compliant materials and manufacturing processes. Bag filter housings can also be used as strainers with special stainless steel mesh lined baskets or baskets with special sized perforations.

Resin-Bonded Filters

Resin-bonded filters have high collapse strength so they can be operated at higher differential pressures than most cartridge filters if necessary. They also offer a wide range of temperature and chemical compatibilities.

Most resin-bonded filters are only available in industrial grades, so they cannot be used in potable water or food and beverage applications. They are regarded by many as a “dirty” filter, which eliminates them from consideration for most high-purity applications. They typically do not work

well in water applications, especially hot water applications. Resin-bonded filters tend to cost significantly more than other filters that offer equivalent performance in most applications.

Instead, resin-bonded filters are much better suited for removal of viscous industrial fluids like coatings (inks, paints, etc.), lubricating oils, fuel oils, and machine coolants to name a few. They are also an excellent choice for batch filtration operations since they can operate at higher differential pressures, use only a single set of cartridges, and do not have to be changed in the middle of a batch.

Shelco Filters R Series Resin-Bonded Filters are high quality filters that offer superior performance in the applications listed above. They are available in standard diameters of 2.5" nominal outside diameters (OD) and 1" nominal inside diameters (ID) and various lengths from 9.75" to 40" and half-size filters of 4.78" to 5" length may be available by special order. Large Diameter Cartridge Filters, with 4.25" to 4.5" nominal OD are not readily available in this filter category.

Pleated Filters

Pleated filters are available in many different styles. These include nominally rated, pleated polyester or polypropylene cartridge filters, high efficiency, pleated polypropylene or micro-fiber glass cartridge filters, and absolute rated, pleated membrane cartridge filters in polyethersulfone (PES), Teflon and other membrane medias. Pleated filters can be used alone or as final stages in multi-stage filter systems for extended life.

Pleated filters offer higher flow rates with lower clean differential pressures and extended filter life than most cartridge filters. They are almost always made of FDA-grade materials for use in potable water and food and beverage applications.

The higher end, absolute rated filters are generally made in clean room environments for use in the most critical high purity applications. They typically offer high removal efficiencies with efficiencies of 99.9999% for the absolute rated membrane filters. Many pleated filters can be cleaned and reused in certain applications. Most high efficiency and absolute rated cartridge filters can be sanitized and even sterilized to allow reuse in potable water, food and beverage, and high-purity applications.

While pleated filters are typically more expensive, they offer longer filter life, especially with proper prefiltration and cleaning and reusing (when appropriate). Also, higher filtration costs are often built into the profitability of the types of products that require pleated filters.

Pleated Filters are applicable to a wide variety of filtration applications including:

- pre- and post-filtration on reverse osmosis (RO) systems
- potable water applications
- whole house and commercial building filtration
- De-ionized (DI) Water Systems
- chemical filtration (including solvents, alcohols, acids and bases, high purity chemicals and other specialty chemicals)
- food and beverage (including bottled water, beer, wine, soft drinks, juices, dairy)
- processing water.
- Electronics (including High Purity DI Water, ultra-pure chemicals, high purity acids and bases, etching compounds and rinse stations)

- Pharmaceutical Filtration (including cosmetics, tank vent filters, High Purity DI Water, protein broths, yeast removal, drug processing)

Shelco Filters ME, MP, MH, MD, WGA, & MA Series Pleated Filters are high-quality options for the above applications. They are available in standard diameters and various lengths from 9.75" to 40" and half-size filters may be available by special order. The high-efficiency and absolute rated filters can have larger outside diameters of 2.75" nominal and sometimes larger so be sure that the housing that they will be used in can tolerate this larger OD as some industrial housings can not accept these larger filters. Large Diameter Cartridge Filters, with 4.25" to 4.5" nominal OD, are available in some categories of pleated filters, usually the nominally rated versions.

Melt-Blown Filters (Poly Spun Filters)

Melt-blown or poly spun filters are almost always made of FDA-grade materials for use in potable water and food and beverage applications. They are usually a low cost, if not the lowest cost filter option. Absolute rated (99%+ efficiencies) melt-blown filters are becoming increasingly more popular as a way to get high-efficiency filtration at a dramatically reduced price compared to pleated high-efficiency filters.

The disadvantages of melt-blown filters are limited collapse strength and relatively low dirt-holding capacity as they are prone to surface blinding which causes premature clogging and low collapse strength, which can cause frequent cartridge changes.

Some manufacturers offer melt-blown filters with rigid polypropylene cores. These filters have increased collapse strength, but are more expensive. However, since there remains a significant cost advantage over many higher priced filters, it may still be cost effective to change these cartridges two or three times, compared to other filter options.

These filters are well suited to potable water, pre- and post-filters for RO Systems, and other applications where the sediment load of the fluid is low and an FDA-grade filter is preferred. For other applications, there are usually better options available.

Shelco Filters LM, MB & PDA Series Melt-Blown Filters are high-quality filters that offer superior performance in the applications listed above. They are available in standard diameters of 2.4" nominal outside diameters (OD) and 1" nominal inside diameters (ID) and various lengths from 9.75" to 40" and half-size filters in 4.78" to 5" lengths and 50" long filters may be available by special order. Large Diameter Cartridge Filters, with 4.25" to 4.5" nominal OD in 10" and 20" lengths are also available.

Stainless Steel Cleanable Filters

Stainless steel filters are durable, reusable filters with excellent chemical and temperature compatibilities. They typically have a heavy-duty design to operate at the highest differential pressures of any cartridge filter. Versions with threaded connections eliminate gaskets and o-rings, which allows the highest operating temperatures of any cartridge filter. High micron options in excess of 800 microns are available for screening applications. Mesh screen type stainless steel filters can be pleated for increased flow with lower clean pressure drops and increased dirt-holding capacity. Sintered metal type stainless steel filters offer depth filter characteristics.

Limitations of this type of filter are high cost per filter and low micron or sub-micron applications. Mesh screen type stainless steel filters are practical down to 3 to 4 micron and sintered metal type stainless steel filters are practical down to about 1 micron, however, the cost increases

dramatically at these lower micron ratings. The cleanable and reusable nature of these filters helps to keep the overall filtration costs down.

These filters are suited for steam, FDA-grade applications, high viscosity fluids, and almost any application above 1 micron.

Shelco Filters SS Series Mesh Screen Filters offer superior performance in the applications listed above. They are available in standard diameters of 2.5" nominal outside diameters (OD) and 1" nominal inside diameters (ID) and various lengths from 9.75" to 40" and half-size filters of 4.78" to 5" length may be available by special order. Large Diameter Cartridge Filters, with 4.25" to 4.5" nominal OD in 10" and 20" lengths also are available by special order.

Wound Filters (String Wound Filters)

Wound filters are versatile all-purpose filters that have high dirt-holding capacities, are relatively low cost (depending on the materials of construction), and work well in most applications. They can be made with a variety of materials (such as low-cost polypropylene materials if there are no chemical and temperature compatibility issues) or they can be made of more resistant materials (such as cotton, polyester, nylon, rayon or glass yarns with tin steel or 304 & 316 stainless steel). FDA-grade versions of the polypropylene and cotton yarn materials are available.

There are a few minor complaints regarding wound filters, however. One is that they can "unload" or release sediment that was previously filtered out of the solutions. This typically happens in low-quality, poorly wound filters under high differential pressures. Winding machines are greatly improved and as long as the machines are adjusted and maintained properly, high-quality wounds that resist unloading can be produced.

Another is that foaming can occur. This is due to the surfactants that are used in the manufacture of the yarns that are used to make wound filters. This minor issue typically occurs in applications such as rinse tanks where tanks are filled, the fluid is agitated, and the fluid is used many times before it is dumped.

Shelco Filters MS Series Wound Filters are high-quality filters that offer superior performance in most industrial applications. They are available in standard diameters of 2.5" nominal outside diameters (OD) and 1" nominal inside diameters (ID) and various lengths from 9.75" to 40" and half-size filters of 4.78" to 5" length are also available. Other lengths and diameters may be available by special order. Large Diameter Cartridge Filters, with 4.25" to 4.5" nominal OD in 10" and 20" lengths also are available.

Case History for Inorganic Contaminant Removal

In an informal field test with machine coolant fluids containing high sediment loads, the MS Series Wound Filters were compared with Melt-Blown Filters and Nominal Rated Pleated Polyester Filters from various competitors.

The MS Series Wound Filters lasted on average 3 to 5 times longer than comparable melt-blown filters. In some isolated instances, the MS Series Wound Filters lasted up to 10 times longer than the comparable melt-blown filters. In these same tests, the MS Series Wound Filters had comparable-to-slightly longer life than nominal rated pleated polyester filters. In both cases, the melt-blown and pleated filters experienced surface blinding where the MS Series Wound Filters were able to resist the surface blinding and utilize the interior depth of the filter for dirt-holding which led to greatly increased filter life.

Since the MS Series Wound Filters cost about the same as the melt-blown filters (and cost 4 to 7 times less than the nominal rated pleated polyester filters), they proved to offer a lower total cost of filtration in this application.

Free Chlorine in Water

As stated earlier in this article, chlorine is added to many municipal water supplies to eliminate harmful bacteria in the water supply. The chlorine is added in the form of calcium hypochlorite, sodium hypochlorite or chlorine gas. Once dissolved in the water, the chlorine forms *free chlorine*, which is comprised of dissolved chlorine gas (Cl_2), hypochlorous acid (HOCl) and hypochlorite ion (OCl^-) – in various states of equilibrium depending on pH and other factors. In spite of the benefits, free chlorine has a taste and odor that can be undesirable in drinking water and water that is used to manufacture certain products. Activated carbon is an effective way to reduce the amount for free chlorine in water.

Free chlorine has a taste and odor threshold between 0.4 and 0.2 (mg/L as Cl_2). Concentrations above these levels produce a noticeable taste and/or odor. Instead of completely removing free chlorine, most treatment systems that are designed to address taste and odor issues simply aim to reduce free chlorine levels to below the threshold.

Free Chlorine Reduction by Activated Carbon Filtration

Activated carbon filtration is an effective way to reduce the amount of free chlorine in water. Activated carbon reduces the amount of free chlorine in three ways. Free chlorine is adsorbed onto the surface of the carbon granule, absorbed into the structure of the carbon granule, and the carbon can act as a catalyst for the dissociation of hypochlorous acid to the chloride ion, which is tasteless and odorless.

Activated carbon has a large amount of surface area per gram. This is due to the nature of the surface of activated carbon. Activated carbon has countless numbers of cracks or fissures, which extend deep into the granule. The surface area of these cracks adds to the total surface area of the carbon granule. There has been much estimation of the surface area of activated carbon and some of the more common estimations fall between 300 and 2,000 m^2 per gram.

The fissures in the activated carbon granule are called pores and there are different pore sizes. The pores are grouped into three main categories based on size (which can be more or less effective at removing certain substances). The larger pores are called macropores, the intermediate size pores are called mesopores and the smallest are called micropores.

Since the free chlorine must adhere or stick to the surface of these pores, the contact time of the free chlorine with the carbon is important. In general, the slower the flow rate of water containing the free chlorine per volume of activated carbon, the higher the percentage of free chlorine that the carbon is able to remove or catalyze.

Since a large portion of the surface area is buried deep within the activated carbon granule, it can be inaccessible to the water flow at the flow rates required for chlorine reduction systems. When the larger activated carbon granules are ground or crushed into smaller particles, a high percentage of the inaccessible surface area within the larger granules become accessible. So even though the total surface area has not changed, the usable surface area increases as the particle size decreases.

For activated carbon filtration, the removal efficiencies and capacities increase when smaller particle sizes are used. Therefore, it is important to have as many small carbon particles in a carbon filter as possible. The challenge faced by most carbon filter manufacturers is to make a filter with the highest amount of small carbon particles without forming such a tight filter structure that water flow is restricted to the point that the cartridge is impractical.

Organic Contaminant Reduction by Activated Carbon Filtration

Activated carbon filtration is also an effective way to reduce organic contaminants like VOCs and TOC. The activated carbon removes organic contaminants from water almost entirely through adsorption onto the surface of the activated carbon.

Coconut shell carbon is generally considered to be the best type of carbon for organic contaminant reduction. That said, most of the information listed above for free chlorine reduction is pertinent to VOC and TOC reduction. Accessible surface area is extremely important. Since smaller carbon particles have more accessible surface area, carbon filters that contain higher percentages of small carbon particles will perform better and last longer in VOC and TOC reduction applications.

Activated Carbon Filtration Systems

There are a number of different types of carbon filtration systems. The most popular types of carbon filtration are activated carbon beds, carbon impregnated paper or felt filters, granular activated carbon filters and carbon block filters.

Activated Carbon Beds

Activated carbon beds are large tanks filled with loose granular activated carbon and they can hold from 1 cubic foot to dozens of cubic feet for large municipal water suppliers. These systems work well for high-flow applications; however, they are very labor intensive when the carbon requires changing. They are usually not very practical except for very high flow applications in the million gallons per day range and higher.

They also are not able to hold small carbon particles that are present in bulk carbon. Since only large activated carbon granules can be contained in these filters, a large portion of the surface area is inaccessible and there are voids between the particles where there is no carbon at all. This decreases the contact time between the water and activated carbon and reduces the total volume of carbon contained in the filter.

The smaller particles tend to flow out of the filter at start-up so the water runs gray in color for 30 to 45 minutes or more, which requires flushing the system until it starts to flow clean water. This can waste thousands of gallons of water (along with time).

Carbon Impregnated Paper or Felt Filters

These filters were one of the first forms of carbon cartridge style filters. They are made by saturating or impregnating filter paper or felt with powdered activated carbon. The impregnated paper or felt can be pleated and formed into a pleated cartridge or it can be wound into a cylinder with multiple layers. An advantage to this type of filter is high flow rates with a low clean pressure drop.

The main drawbacks of this type of filter are that they usually do not contain much carbon and the higher flow rates reduce the contact time so the carbon that is in these cartridges is less effective at free chlorine removal. Since there is a relatively small amount of activated carbon in these cartridges, they do not last long which increases labor costs and down time during filter changes. It is also difficult to keep smaller carbon particles impregnated on the paper or felt media. These particles can be released as carbon fines when a new cartridge is put into service.

Granular Activated Carbon Filters

These filters are hollow canisters or cylinders that are filled with granular activated carbon. They hold a larger volume of activated carbon and they usually flow at much lower flow rates than the carbon impregnated paper or felt filters. The advantage to this type of filter is increased free chlorine removal efficiencies and increased free chlorine removal capacities, which can translate into increased filter life.

There are a few main drawbacks of this type of filter: they usually can only contain larger activated carbon granules within the cylinder; any small carbon particles mixed in with the larger granules flow out of the filters when they are put into service; they are usually only constructed in 10” lengths; and they can rupture easily.

Since only large activated carbon granules can be contained in these filters, a large portion of the surface area is inaccessible. Additionally, there are voids between the particles where there is no carbon at all, which decreases the contact time between the water and activated carbon and reduces the total volume of carbon contained in the filter.

When the small particles flow out of the filter at start-up, the water runs gray in color for 5 to 15 minutes or more. This requires flushing the system, which can waste up to 10 to 30 gallons of water or more on small systems and hundreds or thousands of gallons of water on larger systems (along with wasting time).

Typically, these filters only come in ten-inch long cartridges, so they are not very practical for larger systems or applications exceeding 40 to 50 gpm. In 20” and longer housings, these filters must be stacked to fit into the housings, thereby creating an increased opportunity for by-pass.

If the canister ruptures, the activated carbon is released into the water and flows past the filter contaminating the filtered water and any products made from it. This can also clog valves, flow control devices and pressure gauges.

Carbon Block Filters

These filters are made of a mixture of smaller activated carbon granules to form a rigid structure and provide strength, combined with powdered activated carbon. This carbon mixture is further mixed with a binder, and then is extruded through a die in a cylindrical shape and cut to length (or is placed into a mold and heated to form a cartridge).

Carbon block filters have many advantages over the carbon filtration options listed above. Since a thermoplastic binder is an integral part of the formulation of most carbon blocks and they are manufactured using heat and pressure, the majority (if not all) of carbon particles are immobilized within the carbon block structure. This reduces the required flush time of this type of filter since most (if not all) of the carbon fines are retained within the carbon block structure. Typical flush

times for carbon block filters are 1 to 5 minutes and this is usually due to carbon dust and other debris from the manufacturing process.

Since both large and small particles make up the carbon block structure, the smaller particles fill the voids between the larger particles. This allows carbon block filters to hold the highest volume of carbon in the same relative cartridge size. Carbon block filters have a high percentage of smaller carbon particles compared to any of the carbon filtration systems above so they offer the highest usable activated carbon surface area of any type of carbon filter.

The rigid structure of the carbon block resists cartridge collapse or any form of rupturing during operation. Even if there is a failure during operation, very little carbon can be released from the filter. This is because the binder immobilizes the carbon particles. A small amount of carbon at the failure site is all that might be released from the filter.

The main disadvantages of carbon block filters are that they usually have a tight structure with limited dirt-holding capacity. This can result in high clean pressure drops at moderate to high flow rates and premature clogging in fluids with a moderate to high sediment load. As previously stated, the lower the flow rate the higher the removal efficiency. So the high clean pressure drops serve as a way to ensure high quality filtration.

The issues regarding premature filter clogging are usually addressed with prefiltation. Adequate prefiltration is always recommended in carbon filtration applications. Carbon block filters can also develop cracks due to rough handling during shipment. The 30”, 40”, and large diameter filters are most susceptible to this and it is best to ship these filters strapped to a pallet. If it is not possible to ship the filters on a pallet, it is important to check for concealed damage and file a claim with the shipping company.

Shelco Filters SCB Series Carbon Block Filters are high-quality extruded carbon block filters that offer superior performance in most carbon filtration applications. They are manufactured in standard diameters of 2.5” nominal outside diameters (OD) and 1” nominal inside diameters (ID) and various lengths from 9.75” to 40” and half-size filters of 4.78” to 5” length are also available. Other lengths and diameters may be available by special order. Large Diameter Cartridge Filters, with 4.25” to 4.5” nominal OD in 10” and 20” lengths are also available.

Case History for Free Chlorine Removal Using Carbon Block Filters

A medium sized electric utility needed to replace an old carbon bed filtration system that provided de-chlorinated water to their production facility. After considering many different carbon filtration systems, they decided to order large 52FOS Series Multi-Cartridge Housings and use 40” long SCB Series Carbon Block Filters for free chlorine reduction.

The plant operators reported an increase in life of two times the old system. This reduced the filter change frequency to once annually (from once every six months with the prior system). The operators also gave favorable comments regarding the ease and decreased time and labor required to change the cartridges compared to changing the bulk carbon media on the old system.

Case History for VOC Reduction in a Bottled Water Process

A bottled water plant encountered high VOC levels in a new well. They decided to order 22FOS Series Multi-Cartridge Housings and use 40” long SCB Series Carbon Block Filters to reduce the VOCs to acceptable levels. The water is stringently monitored and has passed every water test since the carbon block filters have been in use. The plant manager is extremely happy with the

results of the carbon filtration system because it has allowed him to use a well that would otherwise have been abandoned.

Conclusion

As you can see by the length of this article, there are many different options for removing or reducing inorganic and organic contaminants – and there are many treatment technologies that were not covered within the scope of this article. There also can be more than one option that will work well for a particular application. With the information provided, system operators, engineers and maintenance technicians should be able to make good choices for their filtration needs.

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