Drinking Water Treatment

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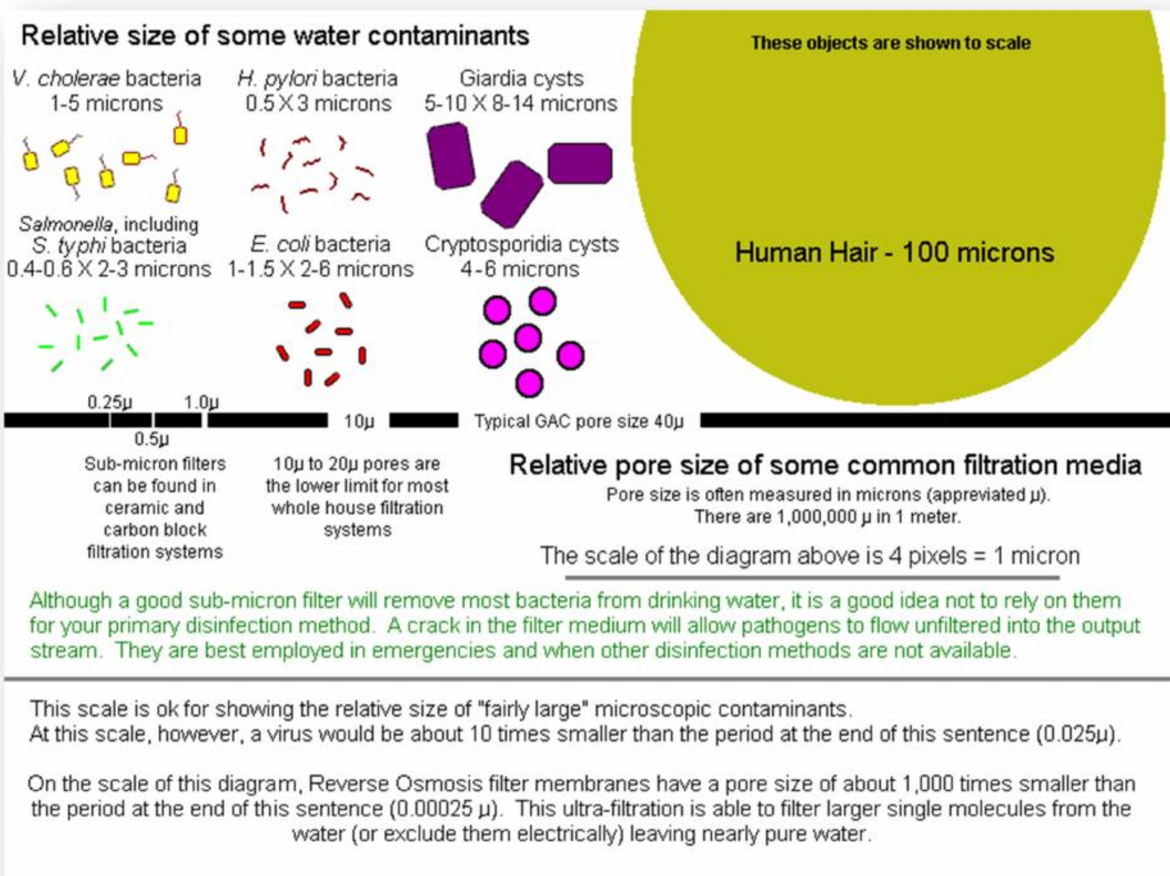
In order to determine which of the solutions is best for your needs you might want to consider the following:

1. How much purified water you would like to use per day for drinking and cooking (a family of four will probably use 15 to 30 lit per day).
2. Which contaminants are actually in your water (and which ones might occasionally show up)? The only way to know this for sure is to have your water tested.
3. Which contaminants you are interested in removing.
4. The cost of the solution you decide upon, both the **initial cost** and the **ongoing costs**

Point Of Use (POU) treatment is the treatment of water frequently at the kitchen sink. This means only the water that is actually used for drinking, cooking, etc. is treated. This has the advantage of economy - only about 40 – 50 lit need to be treated per year instead of many thousands if all of the water entering the home were to be treated.

- We only need to consider POU treatment, if water is supplied by a municipal corporation, since it is municipality's responsibility to provide biologically and chemically safe water that has most objectionable taste and odor causing substances removed.
- The contaminants most people using public water would be liable to experience at harmful or unacceptable levels are:
- Residual disinfectants (chlorine and/or chloramine, for example) added to keep water safe during distribution.
- Disinfection byproducts, like the trihalomethanes.



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- Brief, accidental contamination by microorganisms (*E.coli*, *giardia*, *cryptosporidia*, etc.) or other contaminants.
- If you live in an agricultural region, unacceptable levels of nitrates or organic compounds.
- POE treatment is the treatment of water entering the entire household or housing complex. It is indicated when the water has problems that affect all areas of the home. The most common example is a water softener that removes calcium, magnesium and some other ions. Hard water, while quite healthy to drink, can cause scale buildup in pipes and on fixtures, interfere with the effectiveness of soap, and shorten the life of appliances, like dish washers and hot water heaters. Other POE water treatment systems are designed to remove iron and manganese, adjust pH levels, add chlorine or other disinfectant, etc.
- People using water from a private well, spring, or surface sources are most likely to require POE treatment.

Treatment Methods

Boiling

In an emergency, boiling is the best way to purify water that is unsafe because of the presence of parasites or bacteria.

If the water is cloudy, it should be filtered before boiling. Use of paper filters, towels (paper or cotton) or a cotton plug in a funnel are effective ways to filter cloudy water.

Place the water in a clean container and bring it to a full boil and continue boiling for at least 3 minutes (covering the container will help reduce evaporation). You must increase the boiling time to at least 5 minutes if you are more than 5,000 feet above sea level, (plus about a minute for every additional 1000 feet). Boiled water should be kept covered while cooling.

The advantages of Boiling Water include:

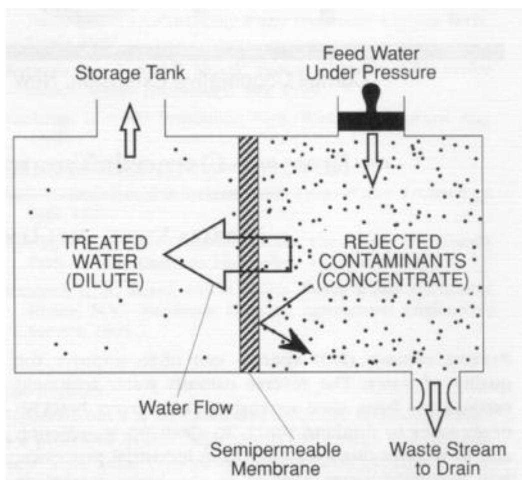
- Pathogens (disease causing microorganisms) that might be present in water will be killed if the water is boiled long enough.
- Boiling will also drive out some of the Volatile Organic Compounds (VOCs) that might also be in the water. This method works well to make water that is contaminated with living organisms safe to drink, but because of the inconvenience, **boiling is not routinely used to purify water except in emergencies.**

The disadvantages of Boiling Water include:

- Boiling should not be used when toxic metals, chemicals (lead, mercury, pesticides, solvents, etc.), or nitrates have contaminated the water.
- Boiling may concentrate any harmful contaminants that do not vaporize as the relatively pure water vapor boils off.
- Energy is needed to boil the water

Reverse Osmosis (RO)

A reverse-osmosis system is a good treatment option for people who have unacceptably high levels of dissolved inorganic contaminants in their drinking water which cannot be removed effectively or economically by other methods. Water from shallow wells in agricultural areas



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that contains high nitrate levels is a good example of a situation where RO would make sense.

Water pressure is used to force water molecules through a membrane that has extremely tiny pores, leaving the larger contaminants behind. Purified water is collected from the "clean" side of the membrane, and water containing the concentrated contaminants is flushed down the drain from the "contaminated" side. The average RO system is a unit consisting of a sediment/chlorine pre filter, the reverse-osmosis membrane, a water storage tank, and an activated-carbon post filter.

The advantages of Reverse Osmosis include:
Reverse osmosis significantly reduces salt, most other inorganic material present in the water, and some organic compounds. With a quality carbon filter to remove any organic materials that get through the filter, the purity of the treated water approaches that produced by distillation.

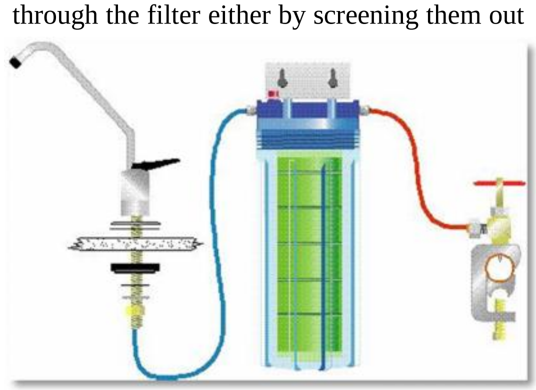
- Microscopic parasites (including viruses) are usually removed by properly functioning RO units, but any defect in the membrane would allow these organisms to flow undetected into the "filtered" water - they are not recommended for use on biologically unsafe water.
- RO systems can typically purify more water per day than distillers and are less expensive to operate and maintain.
- A variant of RO, Ultra-filtration (UF) systems, do not use electricity, although because they require relatively high water pressure to operate, they may not work well in low water pressure situations.

The disadvantages of Reverse Osmosis include:

- Point of Use RO units make only a few liters of treated water a day for drinking or cooking.
- RO systems waste water, typically twice or thrice the quantity of water produced which goes straight down the drain.
- Some pesticides, solvents and other volatile organic chemicals (VOCs) are not completely removed by RO. A good activated carbon post filter is recommended to reduce these contaminants.
- Many conditions affect the RO membrane's efficiency in reducing the amount of contaminant in the water. These include the contaminant concentration, chemical properties of the contaminants, the membrane type and condition, and operating conditions (like pH, water temperature, and water pressure).
- Although UF filters do not use electricity, they depend on a relatively high water pressure to force the water molecules through the membrane. In an emergency situation where water pressure has been lost, these systems will not function.
- RO systems require maintenance. The pre and post filters and the reverse osmosis membranes must be changed according to the manufacturer's recommendation, and the storage tank must be cleaned periodically.
- Damaged membranes are not easily detected, so it is hard to tell if the system is functioning normally and safely.

Water Filters

The topic of water filters is complicated because there are so many types of filtration strategies and combinations of strategies used. The basic concept behind nearly all filters, however, is fairly simple. The contaminants are physically prevented from moving through the filter either by screening them out



with very small pores and/or, in the case of carbon filters, by trapping them within the filter matrix by attracting them to the surface of carbon particles (the process of adsorption).

There are two main types of filters (sediment and activated carbon), and sometimes they are combined into a single unit. A third type, which uses high end filtration technology, is of course reverse osmosis.

Micron or sub-micron filtration is a measure of how good the filter is at removing particles from the water - smaller is better. A micron is about 1/100 the diameter of a human hair. A filter that removes particles down to 5 microns will produce fairly clean-looking water, but most of the water parasites, bacteria, cryptosporidia, giardia, etc. will pass through the pores. A filter must trap particles one micron or smaller to be effective at removing cryptosporidia or giardia cysts. Viruses cannot be effectively removed by any filtration method. In theory, reverse osmosis will remove viruses, but a small flaw in the membranes would allow viruses to pass undetected into the 'filtered' water.

The figure compares the relative size of several biological contaminants with the pore size of some common filters.

Sediment Filters

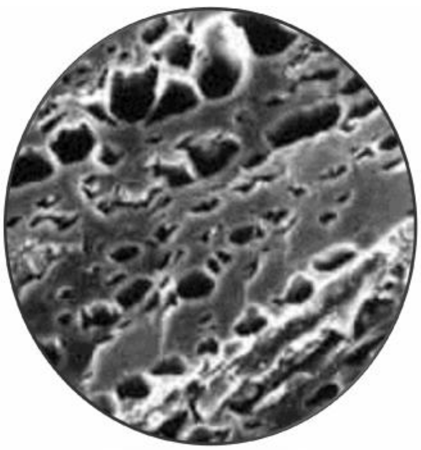
Solid particles are strained out of the water. Suspended sediment (or turbidity) is removed as water pressure forces water through tightly wrapped fibers. Some small organic particles that cause disagreeable odors and taste may also be removed. These filters come in a variety of sizes and meshes from fine to coarse, with the lower micron rating being the finer. The finer the filter, the more particles are trapped and the more often the filter must be changed.

Fiber Filters:

- These filters contain cellulose, rayon or some other material spun into a mesh with small. If you take a piece of cloth and pour water containing sand through it you will get the picture.
- Fiber filters are often used as pre-filters to reduce the suspended contaminants that could clog carbon or RO filters.
- Fiber filters will not remove contaminants that are dissolved in the water, like chlorine, lead, mercury, trihalomethanes or other organic compounds.

Ceramic Filters:

- Ceramic filters are much like fiber filters and use a process where water is forced through the pores of a ceramic filtration media. This provides mechanical filtration only. This type of filter can reduce asbestos fibers, cysts (if the pores are one micron or smaller), some bacteria (with pore sizes in the 0.2 - 0.8 micron range) and other particulate matter.
- Ceramic filters will not remove contaminants that are dissolved in the water, like chlorine, lead, mercury, trihalomethanes or other organic compounds, nor will they remove viruses. These filters may be used as a back-end to an activated carbon filter to provide a more thorough removal of contaminants.



Activated Carbon Filters

Activated carbon (AC) is particles of carbon that have been treated to increase their surface area and increase their ability to adsorb a wide range of contaminants - activated carbon is particularly good at adsorbing organic compounds

Contaminant reduction in AC filters takes place by two processes, **physical removal** of contaminant particles, blocking any that are too large to pass through the pores (obviously, filters with smaller pores are more effective), and a process called **adsorption** by which a variety of dissolved contaminants are attracted to and held (adsorbed) on the surface of the carbon particles. The characteristics of the carbon material (particle and pore size, surface area, surface chemistry, density, and hardness) influence the efficiency of adsorption.

AC is a highly porous material; therefore, it has an extremely high surface area for contaminant adsorption. *Under a scanning electron microscope the activated carbon looks like a porous bath sponge. This high concentration of pores within a relatively small volume produces a material with a phenomenal surface area. The equivalent surface area of 1 kg of AC ranges from 130 to 330 acres.*

AC is made of tiny clusters of carbon atoms stacked upon one another. The carbon source is a variety of materials, such as peanut shells, coconut husks, or coal.

The adsorption process depends on the following factors:

- physical properties of the AC, such as pore size distribution and surface area;
- the chemical nature of the carbon source, or the amount of oxygen and hydrogen associated with it;
- chemical composition and concentration of the contaminant;
- the temperature and pH of the water; and
- the flow rate or time exposure of water to AC.

Granular Activated Carbon (GAC)

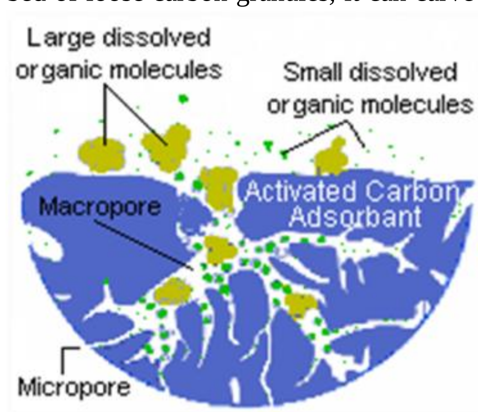
In this type of filter, water flows through a bed of loose activated carbon granules which trap some particulate matter and remove some chlorine, organic contaminants, and undesirable tastes and odors. The three main problems associated with GAC filters channeling, dumping, and an inherently **large pore size**. Most of the disadvantages discussed below are not the fault of the activated carbon filtration media, rather, the problem is the design of the filters and the use of loose granules of activated carbon.

The advantages of GAC filters include:

- Simple GAC filters are primarily used for aesthetic water treatment, since they can reduce chlorine and particulate matter as well as improve the taste and odor of the water.
- Loose granules of carbon do not restrict the water flow thereby maintaining a good water flow rate and pressure.
- Simple, economical maintenance. Typically an inexpensive filter cartridge needs to be changed every few months to a year, depending on water use and the manufacturer's recommendation.
- GAC filters do not require electricity, nor do they waste water.
- Many dissolved minerals are not removed by activated carbon. In the case of calcium, magnesium, potassium, and other beneficial minerals, the taste of the water can be improved.

The disadvantages of GAC filters include:

- Water flowing through the filter is able to "channel" around the carbon granules and avoid filtration. Water seeks the path of least resistance. When it flows through a bed of loose carbon granules, it can carve



a channel where it can flow freely with little resistance. Water flowing through the channel does not come in contact with the filtration medium. The water continues to flow, however, so you do not realize that your filter has failed - you get water, but it is not completely filtered.

- Pockets of contaminated water can form in a loose bed of carbon granules. With changes in water pressure and flow rates, these pockets can collapse, "dumping" the contaminated water through the filter into the "filtered" flow.
- Since the carbon granules are fairly large (0.1mm to 1mm) the effective pore size of the filter is relatively large (20 – 30 microns or larger). GAC filters, by themselves, cannot filter bacteria.
- Hot water should NEVER be run through a carbon filter
- These filters might become breeding grounds for the bacteria they trap.
- Unless the filter plugs up or you notice an odor in the "filtered water, it may be difficult to know when the filter has become saturated with contaminants and ineffective.

Bottled Water

Bottled water is simply water from some source that a company has placed in a bottle for resale. Bottled water can have minimal (or no) processing - as in natural spring or mineral water, or it can be completely filtered and demineralized to nearly pure water and then have minerals added back in to make it taste better.

The advantages of Bottled Water include:

- An emergency source of water in the event your primary water source fails or becomes contaminated.
- A convenient source of usually safe water for drinking outside the home or travelling.
- Bottled water, since it does not contain chlorine, and may contain a mix of minerals to enhance flavor, may taste better than untreated tap water..

The disadvantages of Bottled Water include:

- **Cost** – high cost (10 times more than that of a typical POU treatment system)
- **Convenience -** Using bottled water requires moving and storing heavy jars and bottles. Water weighs about one kg per bottle or 20 kg per jar.
- **Environmental Impact -** unless containers are reused or recycled, they cause a waste disposal problem. Transporting bottles of water from the bottler to stores or homes also uses resources, transportation and vehicular pollution.
- **Hygiene** – unless the threaded caps of the opened, unrefrigerated bottles and jars are kept clean and untouched from inside the bacteria will begin to grow as soon as you break the seal. If ingested, these bacteria can cause gastrointestinal problems and other health risks.

The key is to maintain the cleanliness of your bottles and store them properly. Follow these hints:

- Store the bottle in a refrigerator just above freezing temperature.
- Wipe the seal with a clean cloth after each use.
- Avoid any type of buildup in the bottle cap.
- If your bottle / jar is refillable, make sure it is well-cleaned and rinsed before refilling.
- If possible, recycle the old jar and obtain a fresh, sterile, sealed one.

Ultra Violet Light

Water passes through a clear chamber where it is exposed to Ultra Violet (UV) Light. UV light destroys bacteria and viruses. However, how well the UV system works depends on the energy dose that the organism absorbs. If the energy dose is not high enough, the organism's genetic material may only be damaged rather than disrupted.

The advantages of using UV include:

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- No known toxic or significant nontoxic byproducts introduced
- Removes some organic contaminants
- Leaves no smell or taste in the treated water
- Requires very little contact time (seconds versus minutes for chemical disinfection)
- Improves the taste of water because some organic contaminants and nuisance microorganisms are destroyed
- Many pathogenic microorganisms are killed or rendered inactive.
- Does not affect minerals in water

The disadvantages of using UV include:

- UV radiation is not suitable for water with high levels of suspended solids, turbidity, color, or soluble organic matter. These materials can react with UV radiation, and reduce disinfection performance. Turbidity makes it difficult for radiation to penetrate water and pathogens can be 'shadowed', protecting them from the light.
- UV light is not effective against any non-living contaminant, lead, asbestos, many organic chemicals, chlorine, etc.
- Tough cryptosporidia cysts are fairly resistant to UV light.
- Needs careful cleaning of UV tube otherwise penetration power of UV rays get reduced thereby reducing the sterilization efficacy.
- Requires electricity to operate. In an emergency situation when the power is out, the purification will not work.
- UV is typically used as a final purification stage on some filtration systems. If you are concerned about removing contaminants in addition to bacteria and viruses, you would still need to use a quality carbon filter or reverse osmosis system in addition to the UV system.

Water Softeners and deionizers

Water softeners operate on the ion exchange process (specifically a cation exchange process where + ions are exchanged). In this process, water passes through a media bed, usually sulfonated polystyrene beads. The beads are supersaturated with sodium (a positive ion). The ion exchange process takes place as hard water passes through the softening material. The hardness minerals (positively charged Calcium and Magnesium ions) attach themselves to the resin beads while sodium on the resin beads is released simultaneously into the water. When the resin becomes saturated with calcium and magnesium, it must be recharged. The recharging is done by passing a concentrated salt (brine) solution through the resin. The concentrated sodium replaces the trapped calcium and magnesium ions which are discharged in the waste water. Softened water is not recommended for watering plants, lawns, and gardens due to its elevated sodium content.

Several factors govern the efficiency of a cationic softener:

- Type & quality of resin used;
- Amount of salt per cubic foot of resin for regeneration;
- Brine concentration in the resin bed during regeneration;
- Brine flow rate through the resin bed (contact time) during regeneration;
- Raw water hardness;
- Raw water temperature – softeners perform better at higher temperatures; and
- Optimal flow rate of hard water through the resin bed.

The advantages of water softeners include:

- The nuisance factor of hard water is reduced.
- Some other cations like barium and iron may be reduced depending on the manufacturer's specifications.

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The disadvantages of water softeners include

- The process of regenerating the ion exchange bed dumps salt water into the environment.
- The elevated sodium concentration of most softened water can affect the taste
- Cation exchange neither reduce the anions level (like nitrates), or biological contaminants (bacteria, viruses, cysts) ; nor the levels of most organic compounds.
- Typically, approx. 7 lit of rinse water per lit of resin is required to totally remove hardness and excess salt from the resin after each regeneration.

Water Deionizers

These use both Cation and Anion Exchange to exchange both positive and negative ions with H+ or OH- ions respectively, leading to completely demineralized water. Deionizers do not remove uncharged compounds from water, and are often used in the final purification stages of producing completely pure water for medical, research, and industrial needs.

A potential problem with deionizers is that colonies of microorganisms can become established and proliferate on the nutrient-rich surfaces of the resin. When not regularly sanitized or regenerated, ion-exchange resins can contaminate drinking water with bacteria.

Ozonation

The formation of oxygen into ozone occurs with the use of energy. This process is typically carried out by an electric discharge field (corona discharge simulation of the lightning).

The ozone molecule contains three oxygen atoms whereas the normal oxygen molecule contains only two. Ozone is a very reactive and unstable gas with a short half-life before it reverts back to oxygen. Ozone is the most powerful and rapid acting oxidizer man can produce, and will oxidize all bacteria, mold and yeast spores, organic material and viruses given sufficient exposure.

The advantages of using Ozone include:

- Ozone is primarily a disinfectant that effectively kills biological contaminants.
- Ozone also oxidizes and precipitates iron, sulfur, and manganese so they can be filtered out of solution.
- Ozone will oxidize and break down many organic chemicals including many that cause odor and taste problems.
- Ozonation produces no taste or odor in the water.
- Since ozone is made of oxygen and reverts to pure oxygen, it vanishes without trace once it has been used. In the home, this does not matter much, but when WTP operators use ozone to disinfect the water there is no residual disinfectant, so chlorine or another disinfectant must be added to minimize microbial growth during storage and distribution.

The disadvantages of using Ozone include:

Ozone treatment can create undesirable byproducts that can be harmful to health if they are not controlled (e.g., formaldehyde and bromate).

- The process of creating ozone in the home requires electricity. In an emergency with loss of power, this treatment will not work.
- Ozone is not effective at removing dissolved minerals and salts.
- The effectiveness of the process is dependent, on good mixing of ozone with the water, and ozone does not dissolve particularly well, so a well designed system that exposes all the water to the ozone is important.

Activated Alumina

Activated Alumina is a granulated form of aluminum oxide. In this process, water containing the contaminant is passed through a cartridge or canister of activated alumina which adsorbs the contaminant. The cartridge of activated alumina must be replaced periodically. Activated alumina devices can accumulate bacteria, so treated water may have higher bacteria counts than raw water.

The advantages of Activated Alumina filters include:

An effective way to reduce levels of fluoride, arsenic, and selenium

The disadvantages of Activated Alumina filters include:

The use of other treatment methods would be necessary to reduce levels of other contaminants of health concern.