Common Domestic Water Treatment Systems of the Appalachian Coalfields

Many individual water supply sources in the Appalachian region are of a quality that they require some level of treatment to make their use acceptable. The type of treatment system required is predicated on the type(s) and concentration of contaminants and to some degree the level of water utilization.

Common contaminants in Appalachian region wells and springs include elevated concentrations of metals (i.e. iron and manganese), hardness (calcium and magnesium), acidic water (acidity exceeds alkalinity), coliform bacteria (frequently fecal coliform), and elevated sulfate concentrations. There are site by site cases where other less common contaminants may be present at problematic levels.

Treatment Methods

Sediment Filters

Sediment filters without or coupled with pre-aeration are often used to reduce the concentrations of iron. The water oxidized physically or chemically prior to filtration increases the efficacy of the filters (Figure 1). The pore size of the filters generally ranges from 0.2 to 2.0 microns. Reportedly up to 25 mg/L can be effectively treated with filtration. Most sources indicate a concentration up to 10 mg/L is about the most that can be treated. At lower iron concentrations (e.g. 3 to 5 mg/L or less) it is possible to use an ion exchange system (discussed below). The addition of a chemical oxidant such as chlorine prior to the filter will improve the efficiency of the filter by causing the iron to precipitate more effectively and rapidly thus forming larger particles that will be trapped by the filter.

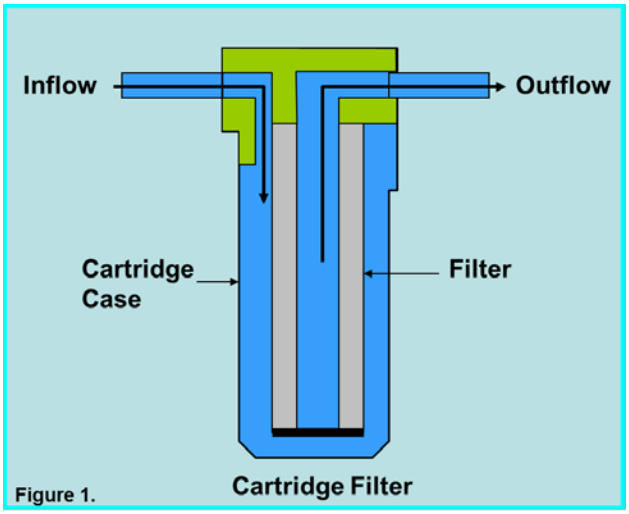


Figure 1.

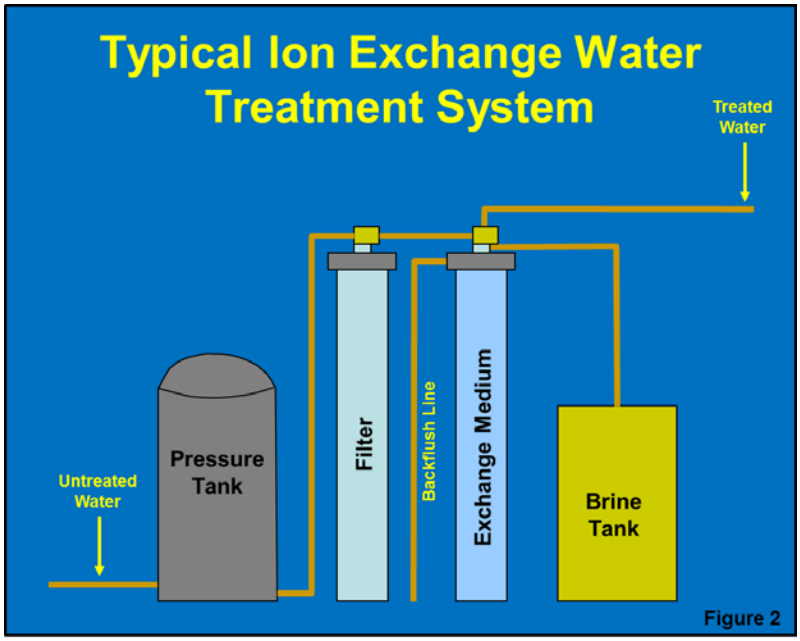
Carbon Filter

Activated carbon filters function by attracting and adsorbing specific contaminants. The activated carbon has a very high surface area per unit mass. One pound of the carbon is estimated to have a surface area of between 60 and 150 acres (MidWest Plan Service, 2009). Activated carbon filters are very efficient at removing organic compounds including but on limited to PCBs, solvents, pesticides, and various other chemicals. Chlorine can also be removed with carbon filters. Unwanted taste and odors are often treated with these filters. Microbes are not removed and in fact because the chlorine is removed, the filters can become an ideal place for microbes to thrive. So, it is recommended that the carbon be replaced on a regular basis. In a household situation, a carbon filter may continue to function effectively for 1 to 3 years depending on the amount of water used and the levels of contaminants that are targeted for removal.

Ion Exchange

Cation exchange systems are frequently used to treat for hard water (elevated calcium and magnesium concentrations) (Figure 2). However, low to moderate levels of iron and manganese can also be removed using these systems. In general, they function by exchanging sodium for calcium, magnesium, iron, and/or manganese facilitated by an exchange medium. The exchange medium can be greensand (glauconite), gel zeolites, and various synthetic organic compounds with a negative ionic charge. These systems work by passing water with elevated concentrations of calcium, magnesium and/or iron through the exchange medium which is charged with sodium ions. The sodium exchanges with the other

cations softening the water. At some point the exchange medium becomes sodium depleted and begins to lose effectiveness. At this point, a brine (NaCl) solution is passed through the medium in a process called backflushing. This action recharges the exchange medium with sodium ions and the treatment process can resume.



Iron exchange systems have a few downsides. They can have a significant footprint and in dwellings where space is limited, this can be a problem. A considerable amount of water has to be used to backflush the system and the backflush water is highly mineralized waste water that must be disposed of properly. These systems also tend to add appreciable concentrations of sodium to the water. For individuals who have to restrict sodium in their diet for health reasons, this can be problematic.

Reverse Osmosis

Some contaminants such as sulfate cannot be removed via conventional filtering or ion exchange. The more common method to reduce the concentration of sulfate, nitrate, sodium, arsenic, and/or total dissolved solids is reverse osmosis (RO). Essentially, RO uses a membrane filter that allows water to pass through, but larger molecules are halted (Figure 3). The pore aperture size range for RO membranes is between 0.1 and 1000 nanometers. RO is fairly energy intensive in that substantial pressures are required to force the water through the membrane. Additionally, a considerable amount of water is wasted with these systems. Something between 5 and 15 percent of the water is used (recovered) for consumption; the remaining 85 to 95 percent is drained as waste water. The waste water will have even greater concentrations of the contaminants that the RO system is designed to remove and will need to be disposed of properly. Most professionals recommend the waste water be drained to the septic system.

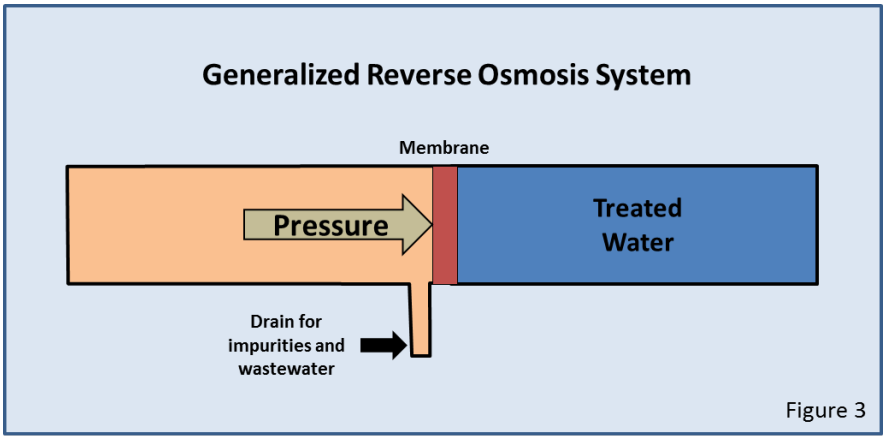


Figure 3

Chlorine Disinfection

Continuous chlorine injection systems are frequently employed on water supplies that are derived from surface water sources. Properly managed, these chlorinators work efficiently to kill bacteria and viruses.

However, they are ineffective for such large parasites as *Giardia* and *Cryptosporidium*. The chlorine is introduced (injected) as it enters the dwelling from the source and before the holding tank.

The concentration or amount of chlorine ("chlorine demand") required to disinfect is predicated on it being completely mixed into the water stream and sufficient contact time is established. Chlorine demand is the amount of chlorine needed to kill the bacteria present in the amount of time between introduction and ultimate use. The water quality factors into the chlorine demand. If there is dissolved iron it will utilize some of the chlorine initially and additional solution will likely be needed. The concentration of chlorine, as well as water temperature and pH affect the contact time. In general, the higher the temperature and the lower the pH, the shorter the required contact time. Additional contact time can be built into the plumbing system with the addition of baffling in the holding tank or lengthening the flow length by use of additional piping. Often a length of coiled pipe is added to increase the chlorine contact time.

It is important to regulate the chlorine rate to prevent a substantial amount of residual chlorine being present in the water at the point of use. If too little chlorine is used no residual chlorine may be present at the end. However, if too much is used the water may have the objectionable smell and taste of chlorine. A residual of 3 to 4 mg/L is a practical amount of chlorine to have left in the water for a domestic supply source. However, many users consider the taste and smell from that concentration range unpleasant. As mentioned above, a carbon filter at the access point works well to remove residual chlorine.

A potential problem with chlorine use is that if there are appreciable amounts of dissolved organic carbon (DOC) trihalomethanes can be formed. Trihalomethanes are potentially carcinogenic. If the DOC is below 5.0 mg/L, the potential for harmful concentrations of trihalomethanes being formed is greatly minimized.

Ultraviolet Disinfection

Use of ultraviolet (UV) radiation to kill various organisms is commonly employed for both domestic and municipal water supplies. Specially-made low-pressure mercury lamps create fairly strong UV radiation which is effective in disinfecting relatively clear water from bacteria and viruses (Figure 4). Protozoans that are common to surface water sources are unaffected by UV treatment. If the water is turbid, the effectiveness of the UV lamps is diminished. It is common practice to install a filter prior to the UV treatment system. These filters will eliminate some of the protozoans that are unaffected by the UV and will reduce any turbidity. One downside to using UV radiation to disinfect water is that there is no continuing or residual effect as there is with chlorine introduction. So, any bacteria introduced after the water passed under the light are not killed. Additionally, there needs to be a fairly consistent source of electricity or water will pass through the system untreated. Most systems have mechanism by which the quartz sleeve that surrounds the mercury lamp can be periodically wiped clean to maintain its effectiveness.

Neutralization of Acidic Water

Acidic waters can occur from the impacts of mining or just from natural conditions. Regardless, acidic water can seriously corrode and degrade plumbing systems and fixtures. The water can be neutralized by injecting an alkaline solution in a manner similar to adding chlorine. Sodium carbonate (soda ash) or sodium hydroxide (caustic soda) solutions are the most common chemical used to effectively neutralize the water.

Some systems use a tank neutralizing filters where the water passes through a neutralizing filter comprised of limestone (calcium carbonate). When the raw water pH is between 6.0 and 6.9 standard units (S.U.), systems with just the limestone function well. However, when the pH is below 6.0 S.U. a more active alkaline material such as magnesia (magnesium oxide – (MgO) may be needed in addition to the calcium carbonate with the tank neutralizing filters. Because these filters also can trap other sediment, they need to be backflushed periodically to maintain their effectiveness. The calcium carbonate and magnesia are expended as the water is neutralized. So these materials have to be periodically replenished. Care should be taken not to over treat the water to the point it becomes hard and may require softening. Hardness up to 120 mg/L is generally considered acceptable. Ideally, the water should be net alkaline with a pH between 6.0 and 9.0 (S.U.) after neutralization.

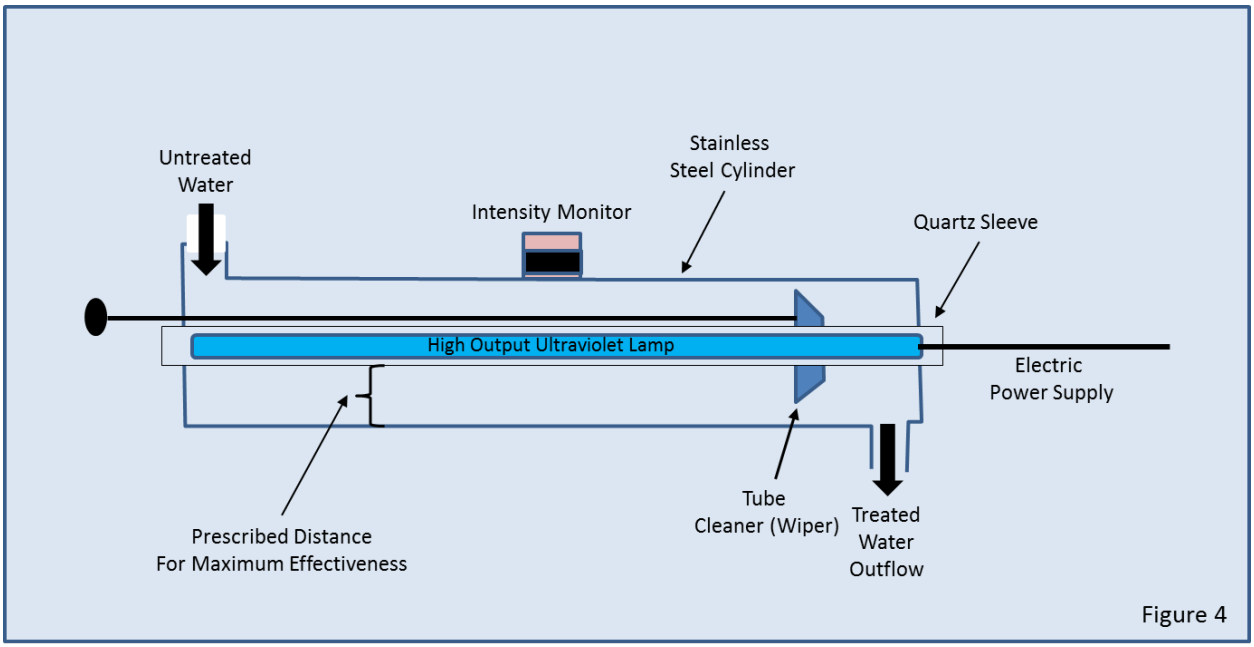


Figure 4

References:
MidWest Park Service, 2009, Private Water Systems Handbook, Fifth Edition, MWPS-14, Iowa State University, Ames, IA, 137 p.