



Iron and Manganese

Iron and manganese control is the most common type of municipal water treatment in Minnesota. Iron and manganese occur naturally in groundwater. Neither element causes adverse health effects at concentrations typically found in Minnesota. These elements are, in fact, essential to the human diet.

Water containing excessive amounts of iron and manganese can stain clothes, discolor plumbing fixtures, and sometimes add a rusty taste and look to the water. Surface water generally does not contain large amounts of iron or manganese, but iron and manganese are found frequently in water systems that use groundwater.

The Safe Drinking Water Act secondary standards (aesthetic, not health related) for iron in drinking water is 0.3 parts per million (ppm) and 0.05 ppm for manganese. If water contains more than 0.05 ppm iron, or 0.01 ppm manganese, the operator should implement an effective hydrant-flushing program in order to avoid customer complaints.

BACTERIA AND IRON AND MANGANESE

Iron and manganese in water also promote the growth of bacteria (including iron bacteria). These organisms obtain energy for growth from the chemical reaction that occurs when iron and manganese mix with dissolved oxygen. These bacteria form thick slime growths on the walls of the piping system and on well screens. These slimes tend to be rust-colored from iron and black-colored from manganese. Variations in flow can cause these slime growths to separate from pipe walls, resulting in dirty water in the system.

The growth of iron bacteria can be controlled by chlorination. However, when water containing iron is chlorinated, the iron is converted from the ferrous state to the ferric state—in other words, rust—and manganese is converted into black manganese dioxide. These materials form a coating on the inside of the water main and, when they break loose, a customer will sometimes complain of dirty water.

Iron bacteria will use even small amounts of iron present in the ferrous state, oxidize it, and then use the energy. Manganese is also used by other bacteria to form organics, which contribute to the iron bacteria slime in the well and/or water system.

Iron bacteria are found anywhere a food source of iron is available. The presence of one bacterium is all that is needed to start an infestation in a well or a distribution system.



IRON AND MANGANESE CONTROL

Methods to control iron and manganese in distribution systems include arranging for alternate water sources, adding phosphate to the water to keep iron and manganese in solution, and oxidizing and removing both by filtration.

Alternate Sources

In some situations, abandoning a well and drilling a new one into an aquifer with a lower iron or manganese concentration may be cost effective. It may also be possible to blend the water from the well with the high concentrations with water from another source with lower concentrations.

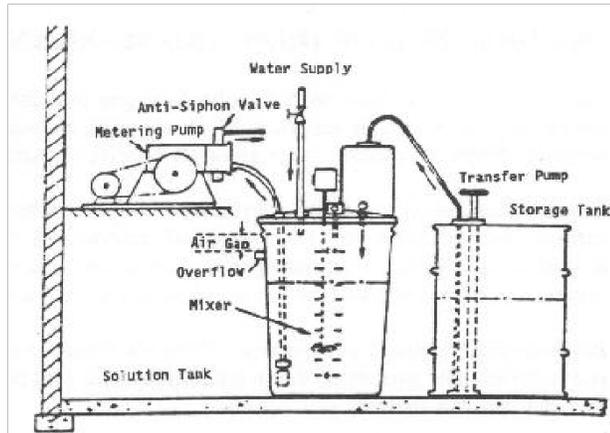
Phosphate Treatment

Phosphate can be added at the source to mask the effects of elevated iron concentrations in the distribution system. This is effective when the water contains less than 0.3 ppm of iron or 0.1 ppm of manganese. Phosphate delays the precipitation of oxidized manganese and iron, thereby greatly reducing the layer of scale that forms on the pipe. The effect is called sequestration. The iron or manganese ion is surrounded by a chain of phosphate molecules and is not allowed to precipitate in the water.

Pyrophosphate, tripolyphosphate, and metaphosphate may be effective as iron and manganese sequestering agents. However, the most effective seems to be sodium phosphate in low concentrations. The proper dose and type of phosphate should be selected only after bench-scale testing is performed by a qualified technician or consultant.

Phosphate feed points should be separated from the chlorine injection point by as much distance as possible. The phosphate feed point should also be ahead of the chlorine injection point. If phosphate is fed after chlorine, there is a possibility the iron and manganese will be oxidized by the chlorine before sequestering can take place causing iron and manganese precipitates to be pumped out into the distribution system.

Feed equipment used for phosphate addition is similar to equipment used to feed fluoride. It consists of a storage tank, solution tank, feed pump, and controller to pace the feed rate. The storage tank and solution tank must contain at least 10 ppm of free chlorine residual to prevent bacterial growth in the phosphate solution (phosphate is an excellent food source for bacteria).



Phosphate solutions can be made up from powder in a saturator similar to the one used to make dry-fluoride solutions (see Fluoridation). Phosphate solutions containing more than one-half pound of phosphate per gallon (60 ppm) may be very viscous. It is important that any solution be fed within 48 hours of its production. Polyphosphates tend to break down into orthophosphate, which is much less effective in preventing manganese deposits.

The amount of phosphates required to sequester iron and manganese generally has to be approximately two parts actual phosphate (as product) for one part of iron and manganese. It is also important to remember that a chlorine residual must be maintained throughout the distribution system to control bacterial growth. The chlorine residual should be greater than 0.2 ppm at the most distant part of the system.

If the total detention time in the distribution system exceeds 72 hours, the phosphates may break down and release the iron and manganese in the outer portions of the system. If the detention is exceeded, the iron or manganese problem may not be resolved with phosphate.

Removal by Ion Exchange

Ion exchange may also remove iron and manganese (typically used in home softening). If the water has not been exposed to oxygen, the resins in the softener will remove the iron and manganese ions from the water. If the water contains any dissolved oxygen, the resin can be fouled with iron and manganese deposits. The resin can be cleaned, but the process is expensive and the capacity of this resin is reduced with each cleaning. This method is not recommended for municipal treatment.



Removal by Iron and Manganese Filtration

Removing iron and manganese from drinking water instead of sequestration is recommended if the water contains over 0.3 ppm of iron or 0.05 ppm of manganese. These elements can be removed during softening with lime, but most commonly iron and manganese is removed by filtration after oxidation (with air, potassium permanganate, or chlorine).

Gravity and pressure filters are both used, with pressure filters being the more popular.

The operator should frequently check to see that all the iron in the water entering the filter has been converted to the ferric (or insoluble particulate) state. The operator collects a water sample, passes it through a filter paper, and runs an iron test on the clean, filtered water (filtrate). If no iron is present, it has all been oxidized and is being removed in the filtration process. If iron is found in the filtrate, oxidation has not been complete and some of the iron will pass through the filter and end up in the treated water. In this case, the operator should consider adjustments to the oxidation process.

Most iron removal filters are designed so that the filters are backwashed based on head-loss on the filter. If iron breakthrough is a problem, the filters will have to be backwashed more frequently. Accurate records will reveal when breakthrough is expected so that the operator can backwash before it is likely to occur.

Oxidation with aeration

Iron is easily oxidized by atmospheric oxygen. Aeration provides the dissolved oxygen needed to convert the iron and manganese from ferrous and manganous (soluble) forms to insoluble oxidized ferric and manganic forms. It takes 0.14 ppm of dissolved oxygen to oxidize 1 ppm of iron, and 0.27 ppm of dissolved oxygen to oxidize 1 ppm of manganese.

Aeration requires careful control of the water flow through the process (see Aeration chapter). If water flow is too great, not enough air is applied to oxidize the iron and manganese. If water flow is too small, the water can become saturated with dissolved oxygen and, consequently, become corrosive to the distribution system. Corrosive water may lead to increased lead and copper levels at customers' taps.

During aeration, slime growths may develop on the aeration equipment, and if these growths are not controlled, they can produce taste and odor problems in the water. The growth of slime can be controlled by adding chlorine at the head of the treatment plant. The process should be inspected regularly to catch problems early.

A detention basin can be provided after aeration to allow complete oxidation. These basins should be cleaned regularly to avoid sludge accumulation. Detention time can also be provided with head on the filters rather than requiring a separate tank. Detention time before filtration should be at

least 20 minutes, more if possible. The pH of the water influences how much time is needed for the reaction to be completed. After oxidation of the iron and manganese, the water must be filtered to remove the precipitated iron and manganese.

Oxidation of iron and manganese with air is by far the most cost-effective method since there is no chemical cost; however, there are disadvantages. The oxidation process can be slowed and the reaction tank has to be quite large (if there are high levels of manganese). In addition, small changes in water quality may affect the pH of the water and the oxidation rate may slow to a point where the plant capacity for iron and manganese removal is reduced.

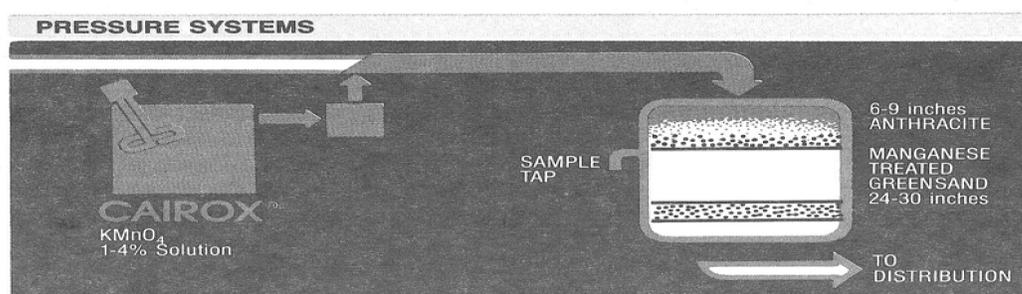
Oxidation with chlorine

Iron and manganese in water can also be oxidized by chlorine, converting to ferric hydroxide and manganese dioxide. The precipitated material can then be removed by filtration. The higher the amount of chlorine fed, the more rapid the reaction. Most treatment plants use 1-2 parts of chlorine to 1 part of iron to achieve oxidation.

When using this process on water containing organics such as total organic carbon or natural organic material, the likelihood of creating disinfection by-products increases.

Oxidation with permanganate

Using potassium permanganate to oxidize iron or manganese is fairly common in Minnesota. Potassium permanganate oxidizes iron and manganese into their insoluble states. The dose must be great enough to oxidize all of the manganese, but not too great as this will produce a pink color in the water in the distribution system. Observing water being treated will indicate if adjustments to the chemical feeders are needed. Potassium permanganate is typically more effective at oxidizing manganese than aeration or chlorination.



In **Pressure Systems**, potassium permanganate application is normally followed by greensand filtration. These processes are commonly used to treat well waters containing iron, manganese and hydrogen sulfide. The manganese-treated greensand system employs a continuous feed of KMnO_4 prior to the pressure filter. The

specially treated medium has the ability to act as a buffer in the treatment scheme. It has oxidation potential and also has the ability to take up excess permanganate.

The result is a system that is easy to control and extremely effective in removing iron, manganese and hydrogen sulfide.



When oxidizing with potassium permanganate, the operation of the filters becomes important since the reaction also continues to take place in the filter media. The normally-used filter media (sand) will remove iron and manganese if the combined concentration is below 1 ppm. Higher concentrations require different types of filter materials (greens and others) and different methods of operation.

Potassium permanganate is often used with manganese greensand, a granular material that is charged with potassium permanganate after the backwashing process. This method allows the oxidation process to be completed in the filter itself and is a buffer to help avoid pink water in distribution. After the filter is backwashed, it regenerates for a period of time with a high level of permanganate before it is put back into operation.

