

Iron and Manganese Removal

Iron and manganese removal is the most common type of municipal water treatment in Minnesota. Iron and manganese occur naturally in water, especially groundwater. Neither of the elements causes adverse health effects; they are, in fact, essential to the human diet. However, 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.

Iron and manganese in water also promote the growth of iron bacteria, a group of organisms that obtains its 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. Such slimes are rust-colored from the iron and black-colored from the manganese. Variations in flow can cause these slime growths to come loose, 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.

The Safe Drinking Water Act (SDWA) secondary standards (aesthetic, not health related) for iron in drinking water is 0.3 parts per million (ppm); for manganese it is 0.05 ppm. If the water contains more than 0.02 ppm of manganese, the operator should implement an effective hydrant-flushing program in order to avoid customer complaints.

OCCURRENCE OF IRON AND MANGANESE

Iron and manganese react with dissolved oxygen to form insoluble compounds. Therefore, they are usually not found in waters that contain high amounts of dissolved oxygen. Surface water generally does not contain large amounts of iron or manganese.

Iron and manganese are found frequently in water systems that obtain their water from wells and springs. Iron bacteria will use even small amounts of iron present in the ferrous state, oxidize it, and then use the energy. The manganous ion is used in a similar fashion by other bacteria to form organics, which contribute to the iron bacteria slime in the well and/or water system.

Iron bacteria are found everywhere. They are found in any area where their 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.

CONTROL OF IRON AND MANGANESE

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

ALTERNATE SOURCES

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

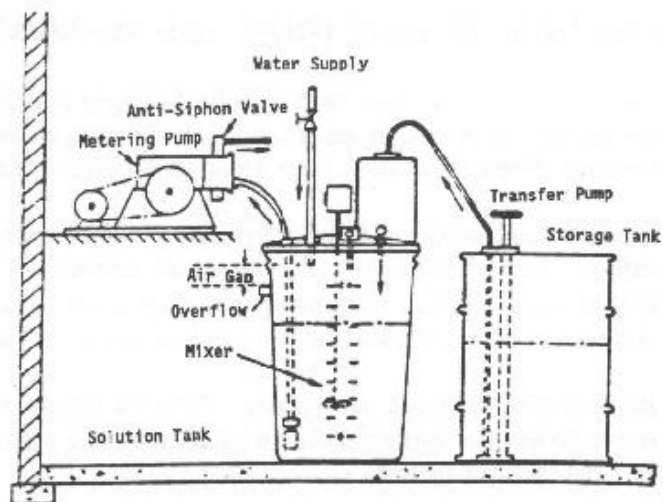
PHOSPHATE TREATMENT

Sometimes a polyphosphate is added at the source to mask the effects of high iron concentrations in the distribution system. This is effective in cases in which the water contains up to 0.3 ppm of iron and less than 0.1 ppm of manganese. The 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 all be effective as iron and manganese sequestering agents. The most effective one, however, 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.

FEEDING PHOSPHATE SOLUTIONS

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



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

Solutions of polyphosphates can also be made up from powder in a saturator similar to the one that is used in making up solutions of dry-fluoride compounds. See the chapter on Fluoridation for a description of the feed pump and saturator systems.

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 varies, but in Minnesota the amount generally has to be approximately two parts actual phosphate (as product) for one part of iron and manganese to accomplish the desired result. It is important to remember that a chlorine residual must be maintained throughout the distribution system to control bacterial growth. This 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. It is important for the operators to know if the detention time will be exceeded and that the iron or manganese problem may not be resolved with polyphosphate treatment.

REMOVAL BY ION EXCHANGE

Ion exchange by a home softener may also remove iron and manganese. 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 treated 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.

IRON REMOVAL FOR MUNICIPAL WATER SYSTEMS

Removing iron and manganese from drinking water instead of trying to sequester it is recommended if the water contains over 0.3 ppm of iron and over 0.05 ppm of manganese. There are many methods for removing iron and manganese. They can be removed during softening with lime, but most commonly, iron and manganese removal is done by filtration after oxidation with different agents. A discussion follows on the processes of oxidation with air, potassium permanganate, and chlorine, followed by filtration.

OXIDATION USING AERATION

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

Operation of the aeration process requires careful control of the flow through the process. If the flow becomes too great, not enough air is applied to oxidize the iron and manganese. If the flow is too small and the aeration is not cut back, 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.

There are many ways to provide the aeration. Either the water being treated is dispersed into the air or else air is bubbled into the water. Other aeration methods include cascade trays, cone aerators, and porous air stones. These are discussed and pictures are provided in the chapter on Aeration.

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

A reaction basin can be provided after the aeration to allow the oxidation to proceed to completion. The detention time is commonly provided by a head on the filters rather than by providing a separate tank. The 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.

If the reaction basin is separate from the filters, the basin must, on a regular schedule, be cleaned and monitored for sludge accumulation.

After the oxidation of the iron and manganese is completed, the water must be filtered to remove the precipitated material. The filters used are generally of pressure type and will be discussed in the Filtration chapter.

The 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. If there are high levels of manganese, the oxidation process can be slowed and the reaction tank has to be quite large. In addition, small changes in the 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

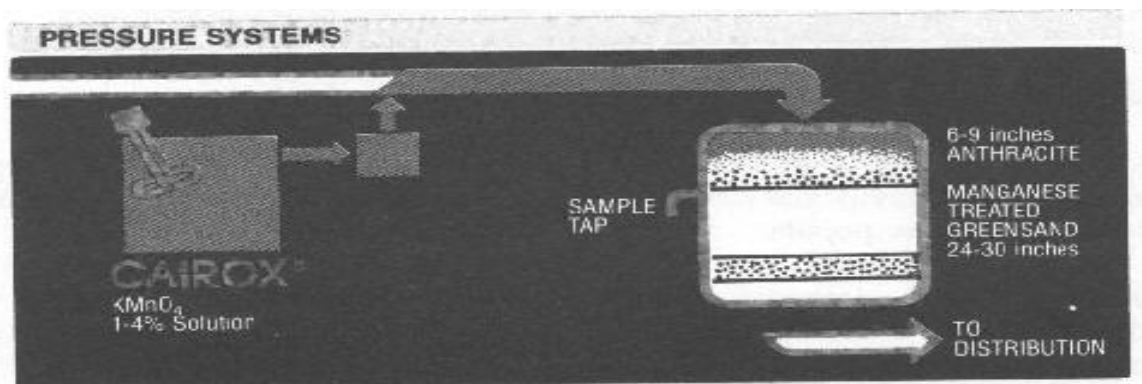
Iron and manganese in water can be oxidized by chlorine, converting them to ferric hydroxide and manganese dioxide. The flocculated material can then be removed by filtration. The higher the amount of chlorine fed, the more rapid the reaction. Some plants have been designed for an initial chlorine residual of 5 to 10 ppm. After filtration the chlorine is removed by the addition of sodium bisulfide, sulfur dioxide, or sodium bisulfide.

When using this process on water containing high organic color, the likelihood of generating disinfection by-products is greatly increased.

When dechlorinating, the operator must be careful that the chemical used for dechlorination is not overdosed. This could result in inadequate disinfection in the system since any chemical left in the water could also remove the necessary chlorine in the distribution lines.

OXIDATION WITH PERMANGANATE

The use of potassium permanganate for the oxidization of iron or manganese is 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 any adjustments of the feeders are needed. Use of permanganate is 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 KMnO₄ prior to the pressure filter. The

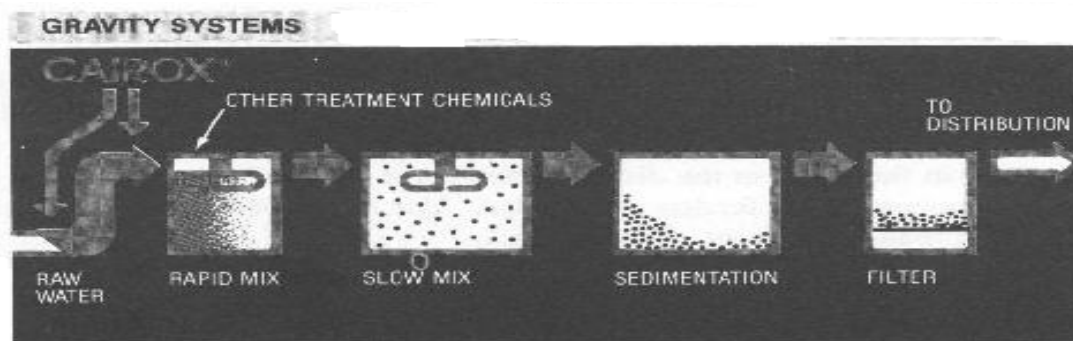
specially treated medium has the ability to act as a buffer in the treatment scheme. It has oxidation potential and also has the ability to take up excess permanganate.

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

When oxidizing with 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 will remove iron and manganese if the combined concentration is below 1 ppm. Higher concentrations require different type of filter materials and different methods of operation.

Potassium permanganate treatment is often done by the use of 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. After the filter is backwashed, it will be allowed to regenerate for a period of time with a high level of permanganate before it is put back into operation.

A common modification of the manganese greensand process is the adding of permanganate on a continuous basis. The permanganate is fed at the head of the filter so that the greensand is continuously recharged. The permanganate addition has to be carefully controlled; if the chemical is overfed, the effluent from the filter turns pink.



OPERATION OF IRON AND MANGANESE FILTERS

Filtration to remove the insoluble iron and manganese material is used as the final step in iron and manganese treatment. Gravity and pressure filters (see Filtration chapter) are both used, with pressure filters being the more popular.

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

Most iron removal filters are designed so that the filters are backwashed based on headloss through 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.