



IRON AND MANGANESE IN DRINKING WATER

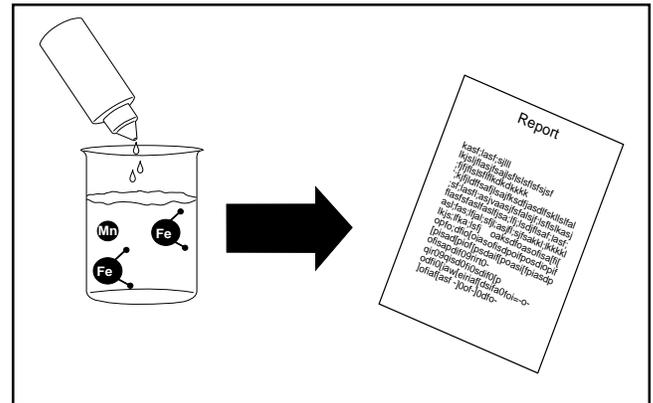
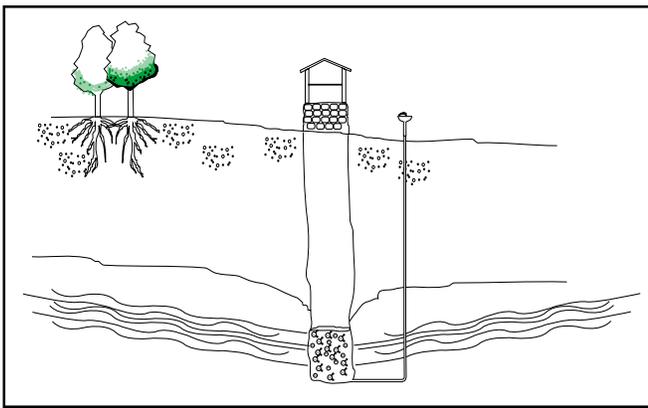
by

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INTRODUCTION

Iron and manganese (Fe/Mn) are common in groundwater supplies used by many Forest Service water systems. Iron is the more frequent of these two contaminants, but they often occur together. High levels of these contaminants can result in discolored water, stained plumbing fixtures, and an unpleasant metallic taste to the water. This can lead to employee and visitor complaints about the water. Iron deposits can build up in pressure tanks, storage tanks, water heaters, and pipelines causing decreased capacity, reduced pressure, and increased maintenance. These deposits can also cause self-closing valves to stick.

High levels of iron and manganese do not pose any known adverse health risks. The Environmental Protection Agency (EPA) has not set maximum contaminant levels (MCL) for iron and manganese in the National Primary Drinking Water Regulations. Secondary maximum contaminant levels (SMCL) recommended in the National Secondary Drinking Water Regulations are set for aesthetic reasons and are not enforceable by EPA, but are intended as guides to the States. The SMCL for iron is 0.3 milligrams per liter (mg/l) and the SMCL for manganese is 0.05 mg/l. States may adopt SMCLs as guidelines or enforce them as contaminants. FSM 7400 - Public Health and Pollution Control Facilities requires all Forest Service water systems to comply with the SMCLs.



TESTING

Have water quality tests performed by an accredited lab prior to planning, designing, or contracting treatment for iron and/or manganese. The ability of various treatment techniques to remove iron and manganese are affected by pH, hardness, presence of iron bacteria, silica, sulfur, tannin, organic material, and the concentration and form of iron and manganese. Water quality tests report the concentration of iron and/or manganese, but not the form.

Iron and manganese in water may be in three forms. When water comes from the tap clear, Fe/Mn is in the dissolved form of ferrous iron (Fe^{2+}) or manganous manganese (Mn^{2+}). When the water comes from the tap rust colored, Fe/Mn is in the precipitate form of ferric iron or manganic manganese. When the water comes from the tap with a clear yellow tint, the Fe/Mn has combined with organic matter and is called colloidal. Colloidal Fe/Mn is the most difficult to remove.

Iron bacteria may also be present in wells. A rust colored slime will form on fixtures and in pipes when iron bacteria are present. Iron bacteria should be controlled at the well to prevent fouling of well screens, by periodic shock chlorination.

TREATMENT

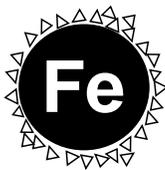
Treatment options include sequestering, ion exchange, oxidizing filters, and oxidation and filtration or settling. The most appropriate and cost effective option depends on the concentration and form of Fe/Mn, water chemistry, and how much water needs to be treated.

Sequestering

Sequestering does not remove Fe/Mn from the water. Sequestration binds the Fe/Mn in soluble form preventing them from oxidizing on contact with air or chlorine. This is only an option if the iron is in the form of ferrous iron (Fe^{2+}) and manganese as manganous (Mn^{2+}) and combined concentration is less than 1-3 mg/l. Sequestering prevents staining of plumbing fixtures and discoloration of the water, but still leaves a slight metallic taste. Sequestering agents break down at high temperatures found in water heaters.

Polyphosphates followed by chlorination can be an inexpensive method for sequestering Fe/Mn. Polyphosphates can be added to the water as a dry feed crystal or as a liquid solution with a metering pump. Polyphosphates can be effective in a pH range of 5.0 to 8.0. Because phosphate compounds are nutrients that contribute to the eutrophication of surface waters, appropriate methods of treating the waste water must be used.

Sodium silicate and chlorine is effective to sequester iron, but is less effective for manganese. Sodium silicate does not break down as readily as phosphate compounds in hot water heaters.

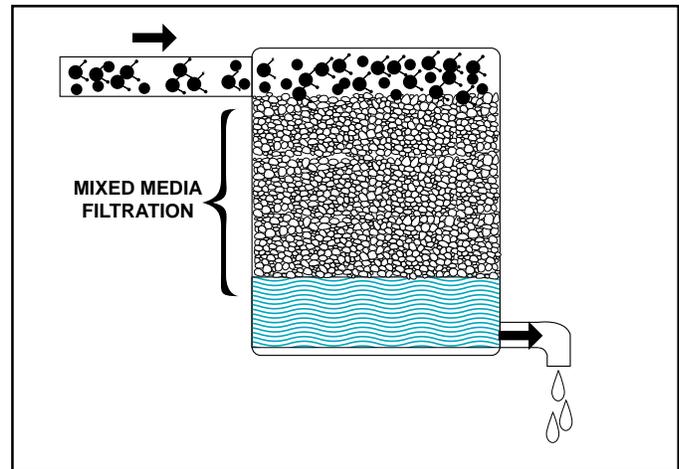


Ion Exchange

Ion exchange, such as salt-based water softeners, can remove small amounts of soluble iron and/or manganese from water. Potassium chloride may be used to regenerate the resin beads instead of sodium chloride if the added sodium is of concern. Water softeners are usually only considered if water hardness is also a problem. Softeners should be considered as an option when the combined iron and manganese is less than 2-5 mg/l. At higher concentrations, precipitated iron residue may build up on the softening

resin, decreasing the efficiency of the softener. Washing the resin with an acid or sodium bisulfate is necessary to remove the residue.

Ion exchange will not work if the iron has oxidized. It also will not work if the iron has combined with organic material or humic acid, or if iron bacteria is present.



Oxidizing Filters

Oxidizing filters can remove up to 15-25 mg/l of combined concentrations of Fe/Mn. Greensand, anthracite sand, natural or synthetic zeolites are used in a mixed media or a pressure filter. Potassium permanganate is used to coat greensand and anthrasand with manganese oxide, giving it a catalytic effect. This coating oxidizes and removes Fe/Mn, usually without requiring an additional oxidation/precipitation step. The coating can be maintained either by a continuous potassium permanganate feed, or by backwashing at set intervals with a potassium permanganate solution.

Natural and synthetic zeolite filter media have a catalytic effect that does not require chemical backwashing to remove the precipitate. The filter media may use venturi air injection as an oxidant, with an air relief valve that bleeds off excess air. The oxidation process is completed in the zeolite media filter, and the precipitate is filtered out. The filter is periodically backwashed to remove the precipitant.

Oxidizing filters can be used with ferrous or ferric iron, and manganous or manganic manganese. The minimum pH is 7.0. A pH of 8.0 is needed when the manganese concentration is high. Filtering over marble chips can raise the pH if needed. The rate of backwash is higher than for ion exchange, but potassium permanganate is not an environmental issue like phosphate and sodium chloride are.

Tannins and hydrogen sulfides will foul the filter media, reducing efficiency. Oxidizing filters work best with water low in phosphate and organic material. Chlorine will adversely affect the catalytic property of the filter media, and should be added after filtration.

Oxidation and Filtration/Settling

Oxidation

Oxidation is required before precipitation, settling and/or filtration. Soluble ferrous iron (Fe^{2+}) is oxidized to a ferric iron (Fe^{3+}), which readily forms the insoluble iron hydroxide complex $\text{Fe}(\text{OH})_3$. Manganous (Mn^{2+}) is oxidized to manganic (Mn^{4+}), which forms insoluble manganese dioxide (MnO_2). The insoluble metals can be precipitated out in a settling tank, or removed by filtration.

Aeration can be an effective, low-cost method of oxidation of iron. Water is passed down a series of porous trays by gravity to provide contact between air and water. Air stripping towers can also provide aeration. The water trickles down through a tower packed with an open plastic media while air is forced up through the media. Aeration towers also remove sulfides, radon, and volatile organic chemicals (VOCs). Venturi nozzles can be used to introduce air into the water. Aeration will not be as effective if iron bacteria or humic materials are present. The rate of reaction for manganese is very slow at pH values less than 9.5.

Chlorine is commonly used as an oxidant. Chlorine feed rate and contact time can be determined by simple jar tests. Trihalomethanes (THMs) may be a problem if organic material (VOCs, humic materials, etc.) is present in the water. The water will need to be monitored for chlorine residual content in the distribution system. Certified water treatment operators are required when chlorine is added to drinking water.

Potassium permanganate (KMnO_4) is a very efficient oxidant of both iron and manganese. It is more expensive than chlorine, but capital equipment costs are usually less. The dose of potassium permanganate must be carefully controlled. Too little will not oxidize all the iron and manganese, too much will leave a pink tinge in the water.

Settling/Filtration

A detention tank allows contact time for the oxidation process to occur. The size of the detention tank depends on flow rate, oxidation method, tank configuration, and other oxidizable contaminants in the water. A jar test or bench test can be useful to select an oxidation method and detention time. Fill a sample jar with water. Mix air or chemical oxidant with the water and let it stand. Record the time it takes for the water to turn a rusty color and the dose and type of oxidant added. Leave the sample undisturbed and record the time it takes for the rusty color to settle to the bottom of the jar; or pour the rust colored water through a lab filter of known pore size.

Aeration oxidation followed by a settling tank is an inexpensive treatment option for small water systems that does not require chemical addition or frequent monitoring. It will not be effective in all cases and bench or jar tests must be done to determine the feasibility and cost of this method. Inclined plate settlers, tube settlers, or baffles can be used in the settling tank to provide the maximum detention time. Settling tanks must be designed to allow the precipitate to be removed periodically.

Filtration

Filtration is the most common method of removing iron and manganese after oxidation. Slow sand filters, bag or cartridge filters, pressure filters, or conventional filters can remove the oxidized contaminants. Slow sand filters and conventional filters are the most expensive alternatives and not normally used for removing Fe/Mn unless colloidal particles, bacteria, or other filterable contaminants are present. Bag or cartridge filters have a very low capital cost, but higher maintenance cost in filter replacement. Automatically backwashing pressure filters have a higher capital cost and lower maintenance cost.

Packaged, pre-engineered iron and manganese filters are available in any size. Most companies that pre-engineer Fe/Mn filters will test a sample of your water and recommend chemical dose, pretreatment requirements, size, and filter media type. Ensure that these systems or all components have been tested to NSF Standard 61 or equivalent for potable water or food grade use.

REFERENCES

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Wisconsin Department of Natural Resources "Iron in Drinking Water" WS-35.

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