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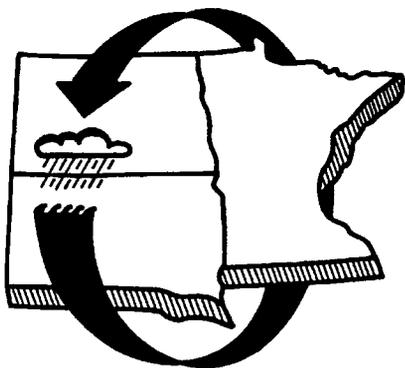
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Treatment Systems for Household Water Supplies: Iron and Manganese Removal

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Treatment Systems for Household Water Supplies: Iron and Manganese Removal

What problems are caused by iron and manganese in household water?

Neither iron nor manganese in water present a health hazard. However, their presence in water may cause taste, staining and accumulation problems.

Because iron and manganese are chemically similar, they cause similar problems. Iron will cause reddish-brown staining of laundry, porcelain, dishes, utensils and even glassware. Manganese acts in a similar way but causes a brownish-black stain. Soaps and detergents do not remove these stains, and the use of chlorine bleach and alkaline builders (such as sodium carbonate) can actually intensify the stains.

Iron and manganese deposits will build up in pipelines, pressure tanks, water heaters and water softeners. This reduces the available quantity and pressure of the water supply. Iron and manganese accumulations become an economic problem when water supply or softening equipment must be replaced. Also, pumping water through constricted pipes or heating water with heating rods coated with iron or manganese minerals increase energy costs.

What are the sources of iron and manganese in household water?

Iron and manganese are concentrated in water by contact with rocks and minerals, and occasionally fabricated materials like iron and steel pipes. Groundwater supplies may require treatment for high levels of iron and manganese; generally few surface water supplies have high enough levels of either to cause problems. Occasionally discharge of acid industrial wastes or mine drainage may increase iron or manganese to problem levels in surface water.

Iron and Manganese Solubility

Iron and manganese exist in many different chemical forms. The presence of a given form of iron or manganese in geologic materials or water depends on many different environmental factors. We can often anticipate iron and manganese problems in water by observing a few general principles that affect water chemistry.

An important principle to remember about chemical reactions is that, if allowed enough time, they will reach an equilibrium with the surrounding environment. When the conditions of that environment are changed, such as

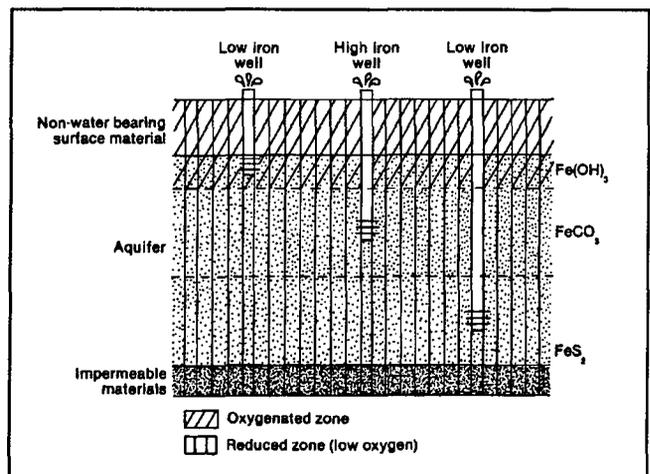
pumping water from an underground aquifer, the chemical equilibrium is upset. This will lead to either solution or precipitation of certain elements such as iron and manganese.

A general rule of thumb is that oxygenated water will have only low levels of iron and manganese. The reason is that both iron and manganese react with oxygen to form compounds that do not stay dissolved in water. Surface water and shallow groundwater (Figure 1) usually have enough dissolved oxygen to maintain iron and manganese in an undissolved state. In surface water, iron and manganese are most likely to be trapped within suspended organic matter particles.

Waters not in regular contact with the atmosphere tend to be low in oxygen (oxygen poor). Iron and manganese carbonates in an oxygen poor environment are relatively soluble and can cause high levels of dissolved iron and manganese. However, if iron is associated with sulfur as iron sulfide rather than iron carbonate, dissolved iron remains low. Dissolved oxygen generally decreases with depth, so these types of conditions are more likely to occur in deep wells.

Sometimes oxygen-poor conditions can also occur in relatively shallow wells that have stagnant water with very slow turnover. Then iron and manganese problems are most likely to develop in water from wells with high

Figure 1. The amount of iron and manganese dissolved in water often follows a trend of low to high and back to low again as depth of the well increases. (Snoeyink, V.L. and D. Jenkins, 1980)



carbonate and low oxygen as shown in the middle well in Figure 1. Problems occur when this type of water is pumped to the surface. The chemical equilibrium is changed upon exposure to the atmosphere. The end result is precipitation of iron and manganese compounds in plumbing, on fixtures, and on clothing, dishes and utensils.

Iron and manganese bacteria

Some types of bacteria derive their energy by reacting with soluble forms of iron and manganese. These organisms are usually found in waters that have high levels of iron and manganese in solution. The reaction changes the iron and manganese from a soluble form into a less soluble form, thus causing precipitation and accumulation of black or reddish brown gelatinous material (slime). Masses of mucous, iron, and/or manganese can clog plumbing and water treatment equipment and can slough off in globs that become iron or manganese stains on laundry. Bacterial reactions with iron and manganese do not cause any additional precipitation compared to normal exposure to oxygen. However, precipitation caused by bacteria occurs faster and tends to concentrate staining, thus making it more apparent.

Water system pipelines

An additional source for dissolved iron may be the pipelines through which water flows. Water with high salinity or acidity from dissolved carbon dioxide or other acids will be corrosive to metal pipes. In order to establish equilibrium, iron and other metals will be dissolved from the pipelines. If household pipes are being attacked by corrosive water and cause problem levels of metals such as iron, copper and lead, the water can be treated to reduce corrosiveness as well as the level of dissolved metals.

Acidity can be reduced by either adding alkaline materials such as sodium carbonate or passing water through filters made of alkaline material. Salinity can be treated by either distillation or reverse osmosis.

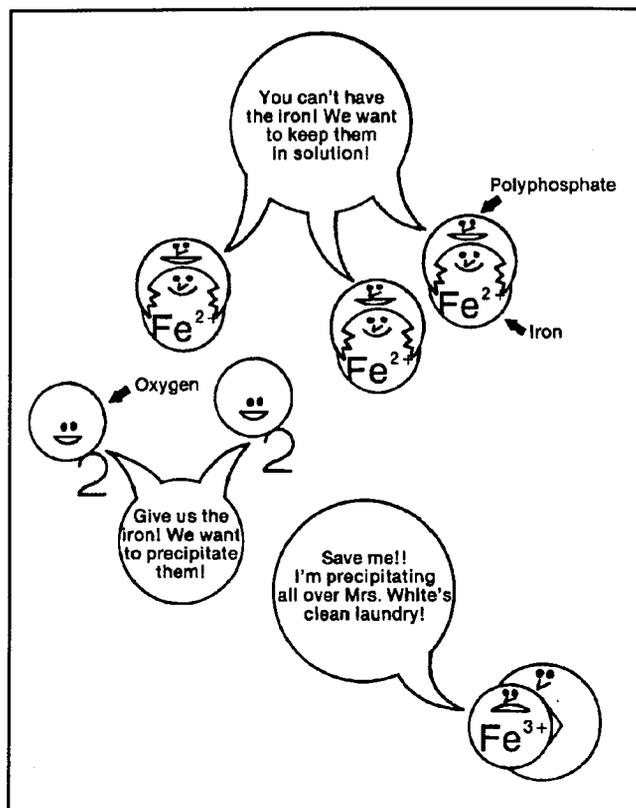
Because different metals are more or less corrodible, a solution to the problem may be to use a more resistant metal. A plumber should be consulted regarding materials that are best suited to local water conditions.

How much is too much?

How much iron or manganese in the water is needed to cause these sorts of problems? There is no pat answer to this question, because it varies with each household situation.

Standards for iron and manganese are based on levels that cause taste and staining problems and are set under EPA Secondary Drinking Water Standards. For most individuals, 0.3 parts per million (ppm) of iron and

Figure 2. Polyphosphates protect dissolved iron and manganese from reacting with oxygen and precipitating on household appliances, bath/plumbing fixtures, and laundry.



0.05 ppm of manganese is objectionable. Usually iron and manganese do not exceed 10 ppm and 2 ppm, respectively, in natural waters. Iron and manganese are found at higher concentrations; however, that condition is rare.

How to test water for iron and manganese

The need to test for iron and manganese in water is not as critical as it is for other types of contaminants that can cause health problems. Iron and manganese are not a problem in household water until they become detectable by the senses. Consequently, elaborate laboratory analyses are not required to determine if iron or manganese are a problem. Laboratory analyses for iron and manganese are needed to quantify the problem.

Exposure of the sample to air will cause precipitation of iron and manganese. To get an estimate of the amount of iron and manganese originally

dissolved in the well water, precipitation must be prevented or the precipitated material must be redissolved. Before sampling for iron and manganese, a certified laboratory should be consulted. They will recommend a sampling procedure that will provide an accurate estimate of dissolved iron and manganese in the source water.

How to treat water to remove iron and manganese

Polyphosphate treatment

Polyphosphates react with dissolved iron and manganese by trapping them in a complex molecule that is soluble in water (Figure 2). As a result the iron and manganese are not available to react with oxygen and precipitate. Polyphosphates can be fed into the water system with controlled injection equipment.

Polyphosphates are not stable at high temperatures. If water is treated prior to heating in a water heater, the polyphosphates will release iron and manganese in the heater as they break down. The released iron and manganese will then react with oxygen and precipitate.

Polyphosphate treatment is a relatively cheap way to treat water for low levels of iron and manganese. Depending on the type of polyphosphate used, water with 1 to 3 ppm of iron can be adequately treated.

Figure 3. Household water softening units will remove some iron and manganese from water. Most units, however, are not designed to handle very large amounts of iron and manganese and may become plugged when concentrations are high.

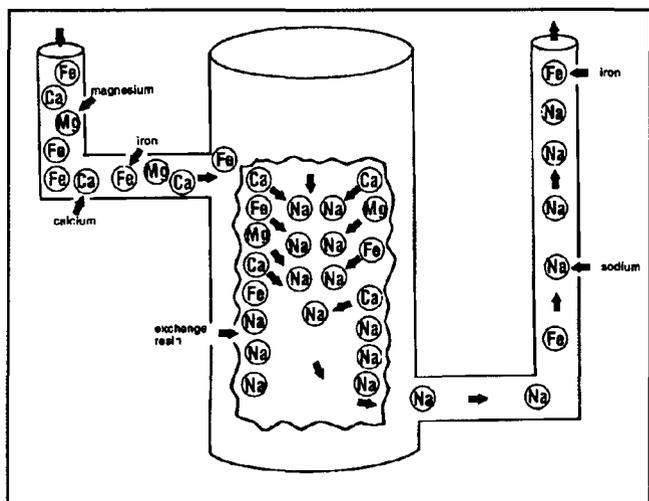


Table 1. Summary of Iron Treatment Methods

| Treatment Method | Range of Soluble Iron Removed (parts per million) |
|---------------------------|---|
| Polyphosphate | 0-3 |
| Ion (softener) | 0-10* |
| Greensand Filter | 0-10 [®] |
| Chlorination & Filtration | 0->10 ^Δ |

* Most softeners are rated for use at the lower end of the range. Check with the manufacturer.

[®] Most greensand filters are rated for use at the upper end of the range. Check with the manufacturer. If water pH is less than 6.8, greensand filters will not perform as rated.

^Δ Chlorination and filtration will work at all levels of soluble iron; however, it is recommended only for levels above 10 ppm of soluble iron.

Ion exchange

Soluble iron and manganese (iron and manganese dissolved in water) can be exchanged for sodium on an exchange resin or zeolite (Figure 3). This process of iron and manganese removal is the very same ion exchange process that removes hardness or calcium and magnesium (refer to the "Softening" publication in the *Treatment Systems for Household Water Supplies* series). Iron and manganese are removed during normal operation of the water softener. They are later removed from the exchange medium along with calcium and magnesium during regeneration and backwashing. Some water softeners are capable of adequately treating water having iron up to 10 ppm (Table 1). However, others are limited to treating water with iron no greater than 1 ppm. If iron and manganese removal is desired in addition to hardness, the manufacturer's recommendations should be checked.

One of the disadvantages of depending on ion exchange for iron and manganese removal is precipitation by oxygen. Some of the precipitate becomes tightly bound to the exchange resin and over time reduces the exchange capacity by plugging pores and blocking exchange sites. If iron bacteria are present, the problem is even worse. Also, if suspended particles of insoluble forms of iron or manganese are present in the water prior to softening, they will be filtered out on the resin and cause plugging. Suspended iron and manganese should be filtered out before water enters the softener.

A clogged water softener can be cleaned by acid regeneration if the unit is made to withstand acid

corrosion. The manufacturer should be consulted before this is attempted. Problem iron bacteria can be eliminated by chlorinating (refer to the "Chlorination" publication in the Treatment Systems for Household Water Supplies series) and filtering the water at some point before it reaches the softener. As long as levels of iron and manganese in the water do not exceed the manufacturer's recommendations, iron and manganese clogging should not be a significant problem. When iron and manganese levels are higher than recommended by the manufacturer, iron and manganese removal will be necessary prior to softening.

Greensand (Adsorptive/Oxidative) Filtration

One of the first types of filters to be used to treat water was the "greensand" filter. The active material in "greensand" is glauconite. Glauconite is a green clay mineral that contains iron and has ion exchange properties. Glauconite often occurs mixed with other material as small pellets, thus the name "greensand." The glauconite is mined, washed, screened and treated with various chemicals to produce a durable greenish-black product that has properties that allow it to adsorb (collect in a condensed form on a surface) soluble iron and manganese.

As water is passed through the filter, soluble iron and manganese are pulled from solution and later react to form insoluble iron and manganese. Insoluble iron and manganese will build up in the greensand filter and must be removed by backwashing. Backwashing should be done regularly, twice a week, or as recommended by the manufacturer.

Eventually the greensand must also be regenerated by washing with a permanganate solution. Regeneration will leave the greensand grains coated once again with a manganese material that adsorbs soluble iron and manganese. Frequency of regeneration will depend on the level of iron, manganese and oxygen in the water and the size of the filter. The manufacturer's recommendations should be followed.

Most greensand filters are rated as effective for treating water with iron concentrations up to 10 ppm. Because some greensand filters are not rated this high, the manufacturer's recommendations should always be checked. The acidity or pH of the water will influence the ability of the filter to remove both iron and manganese. If the pH of the water is lower than 6.8, the greensand will probably not adequately filter out the iron and manganese. The pH can be raised above 7.0 by running the water through a calcite filter.

Regular backwashing is essential for effective filter performance and requires flow rates that are often three to four times the normal household usage rate. A backwash rate of about eight ppm/square foot of filter

bed is recommended. If the household system cannot support the needed flow rate for adequate backwashing, poor filter performance and failure are likely.

Chlorination (Oxidation) Plus Filtration

Chemical oxidation followed by filtration is the accepted method of iron and manganese removal when concentrations are greater than 10 ppm. A number of strong oxidants have been used in this procedure; however, chlorine is generally used in household systems (refer to the "Chlorination" publication in the *Treatment Systems for Household Water Supplies* series).

A chlorine solution is injected with a chemical feed pump ahead of a sand filter. Soluble iron and manganese begin to precipitate almost immediately after contact with the chlorine solution. However, approximately 20 minutes of contact time is needed for the precipitate to form particles that can be filtered. Often the standard 42 gallon pressure tank used on many household systems will provide the needed contact time if water is forced through the tank. A simple T-connection from the pipeline to the pressure tank will not work, since much of the water bypasses the tank. Additional contact time can be provided by connecting another tank in series or using a plastic pipe coil.

This type of system will remove both soluble and suspended particles of insoluble iron and manganese from the source water. Backwashing the sand filter to remove precipitated iron and manganese is an important part of continued filtration. As with the greensand filter, the system flow rate should be checked to make sure it can provide the needed rates for backwashing.

An additional advantage of using the chlorination system is its bactericidal effect. Iron and manganese bacteria along with other bacteria, are destroyed. Potential clogging problems in the sand filter are eliminated. Chlorination does produce trihalomethanes (THM) when organic matter is present in the water. THMs are considered to be carcinogenic (maximum contaminant level permissible in public water systems is 0.1 parts per million) and if necessary can be filtered out with an activated charcoal filter (refer to the "Activated Charcoal Filtration" publication in the *Treatment Systems for Household Water Supplies* series).

The optimum rate of oxidation of iron and manganese by chlorination is at a pH of about 8.0 and 8.5, respectively. Soda ash injected with the chlorine will increase the pH to optimum levels. Adjusting the pH to alkaline levels also reduces the corrosiveness of the water in pipes and plumbing.

What are the standards for iron and manganese removal equipment?

The Water Quality Association (WQA) has set voluntary performance standards for oxidative filtration methods. They specify that an oxidizing filter shall reduce:

- 10.0 ppm plus or minus 1.0 ppm soluble iron to not more than 0.2 ppm
- 2.0 ppm plus or minus 0.2 ppm soluble manganese to not more than 0.05 ppm.

A directory of validated equipment that meet these standards is available from WQA, National Headquarters and Laboratory, 4151 Naperville Road, Lisle, IL 60532 (708/505-0160).

WQA also recognizes that the following water treatment methods can be used to meet the EPA's Secondary Drinking Water Standards for both soluble iron and manganese: 1) oxidizing filters; 2) cation exchange; and 3) chlorination - precipitation/filtration. Polyphosphate treatment does not meet the drinking water standards, because it ties up iron and manganese but does not remove it. Reverse osmosis, distillation, (refer to the "Reverse Osmosis" and "Distillation" publications in the *Treatment Systems for Household Water Supplies* series) and pressure aeration/filtration are also recognized by WQA as water treatment methods that can be used to meet the iron and manganese drinking water standards.

The consumer should be cautioned to note that different water treatment systems vary considerably in their ability to treat a specific contaminant. Water treatment equipment should be selected only after careful consideration of the water problem and type of equipment to be used for its removal. As a part of the installation procedure, the performance of the equipment should be tested by water analysis. Periodic water analysis is recommended to check for continued equipment performance.

Further information

For further information contact your local county Extension Office or state Health Department. Additional information can be found in other publications in this series: *Treatment Systems for Household Water Supplies*.

- Activated Carbon
- Chlorination
- Filtration
- Distillation
- Reverse Osmosis
- Softening

References

Hem, J. D. **Equilibrium chemistry of iron in groundwater**. 1967. In S. D. Faust and J. V. Hunter (ed.) pp. 625-643, **Principles and applications of water chemistry**. John Wiley and Sons, Inc., New York.

Machmeier, R. E. **Iron in drinking water**, AG-FO-1318. Reviewed 1990. Minnesota Extension Service, University of Minnesota, Agriculture.

O'Connor, J. T. **Iron and Manganese**. 1971. In M. E. Flentje and R. J. Faust (ed.) pp. 380-396, **Water quality and treatment - a handbook of public water supplies**, 3rd Edition. Prepared by The American Water Works Association, Inc. McGraw-Hill Book Co., New York.

Snoeyink, V. L. and D. Jenkins. **Water Chemistry**. 1980. John Wiley and Sons, Inc., New York.

Water Quality Association. **Recommended industry standards for household and commercial water filters—a voluntary industry standard**, S-200. 1988. National Headquarters and Laboratory, Lisle, Illinois.

Water Quality Association. **Treatment Techniques For Meeting the National Secondary Drinking Water Regulations With the Application of Point-of-use Systems**. 1989. Recognized R28 National Headquarters and Laboratory, Lisle, Illinois, 1989.



Printed on recycled paper with agribase ink.



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Funding for this publication was by the U.S. Department of Agriculture, Extension Service, under project number 90-EWQI-19252.

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