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## Iron and Manganese in Drinking Water

Iron and manganese are non-hazardous elements that can be a nuisance in a water supply. Iron and manganese are chemically similar and cause similar problems. Iron is the most frequent of the two contaminants in water supplies; manganese is typically found in iron-bearing water.

### Sources of iron and manganese in drinking water

Iron and manganese are common metallic elements found in the earth's crust. Water percolating through soil and rock can dissolve minerals containing iron and manganese and hold them in solution. Occasionally, iron pipes also may be a source of iron in water.

### Indications of iron and manganese

In deep wells, where oxygen content is low, the iron/manganese-bearing water is clear and colorless (the iron and manganese are dissolved). Water from the tap may be clear, but when exposed to air, iron and manganese are oxidized and change from colorless, dissolved forms to colored, solid forms. Oxidation of dissolved iron particles in water changes the iron to white, then yellow and finally to red-brown solid particles that settle out of the water. Iron that does not form particles large enough to settle out and that remains suspended (colloidal iron) leaves the water with a red tint. Manganese usually is dissolved in water, although some shallow wells contain colloidal manganese (black tint). These sediments are responsible for the staining properties of water containing high concentrations of iron and manganese. These precipitates or sediments may be severe enough to plug water pipes. Iron and manganese can affect the flavor and color of food and water. They may react with tannins in coffee, tea and some alcoholic beverages to produce a black sludge, which affects both taste and appearance. Manganese is objectionable in water even when present in smaller concentrations than iron. 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 use of chlorine bleach and alkaline builders (such as sodium and carbonate) may 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 water softening equipment must be replaced. There are also associated increases in energy costs from pumping water through constricted pipes or heating water with heating rods coated with iron or manganese mineral deposits.

A problem that frequently results from iron or manganese in water is *iron or manganese bacteria*. These nonpathogenic (not health threatening) bacteria occur in soil, shallow aquifers and some surface waters. The bacteria feed on iron and manganese in water. These bacteria form red-brown (iron) or black-brown (manganese) slime in toilet tanks and can clog water systems. If you are having problems with iron, manganese, and/or occasional sulfur odors we typically recommend testing for Iron and Iron / Sulfur bacteria.

### Potential health effects

The regulations regarding iron and manganese in drinking water were established as secondary standards, which means the limits were set because of nuisance problems and aesthetic concerns. It has recently been discovered that a portion of the public may be suitable to Iron Overload or Hemochromatosis. The symptoms of hemochromatosis vary and can include: chronic fatigue, arthritis, heart disease, cirrhosis, cancer, diabetes, thyroid disease, impotence, and sterility.

Hereditary hemochromatosis is only one of several iron overload diseases. It is the most common genetic disease, and tragically the most undiagnosed.

## **Water testing**

The method used to test water for iron and manganese depends on the form of the element. If water is clear when first drawn but red or black particles appear after the water sits in a glass, dissolved (ferrous) iron/manganese is present. If the water has a red tint with particles so small they cannot be detected nor do they settle out after a time, colloidal (ferric) iron is the problem. Typically, laboratory tests are needed only to quantify the extent of iron and manganese contamination, but testing of additional water parameters such as pH, silica content, oxygen content, hardness and sulfur may be necessary to determine the most appropriate water treatment system. All necessary tests are available through Montana Environmental Lab.

## **Interpreting test results**

The Environmental Protection Agency (EPA) standards for drinking water fall into two categories; Primary Standards and Secondary Standards. Primary Standards are based on health considerations and are designed to protect people from three classes of pollutants: pathogens, radioactive elements and toxic chemicals. Secondary Standards are based on taste, odor, color, corrosivity, foaming and staining properties of water. Iron and manganese are both classified under the Secondary Maximum Contaminant Level (SMCL) standards. The SMCL for iron in drinking water is 0.3 milligrams per liter (mg/l), sometimes expressed as 0.3 parts per million (ppm), and 0.05 mg/l (ppm) for manganese. Water with less than these concentrations should not have an unpleasant taste, odor, appearance or side effect caused by a secondary contaminant.

## **Options**

If excessive iron or manganese is present in your water supply, you have two basic options; obtain an alternate water supply or use some type of treatment to remove the impurity. The need for an alternate water supply or impurity removal should be established before making an investment in treatment equipment or an alternate supply. Base your decision on a water analysis by a reputable, qualified laboratory.

It may be possible to obtain a satisfactory alternate water supply by drilling a new well in a different location or a deeper well in a different aquifer. Several methods of removing iron and manganese from water are available. The most appropriate method depends on many factors, including the concentration and form of iron/manganese in the water, if iron or manganese bacteria are present, and how much water you need to treat.

Generally speaking, there are five basic methods for treating water containing iron and/or manganese. They are: (1) phosphate compounds ; (2) ion exchange water softeners; (3) oxidizing filters; (4) aeration (pressure type) followed by filtration ; and (5) chemical oxidation followed by filtration. The table below summarizes iron and manganese treatment options.

These treatment techniques are effective in water that has an almost neutral pH (approximately 7.0). The phosphate compound treatment is an exception and is effective in the pH range of 5.0 to 8.0. Exceptions are noted for manganese removal.

## **Phosphate treatment**

Low levels of dissolved iron and manganese at combined concentrations up to 3 mg/l can be remedied using phosphate compound treatment. Phosphate compounds are a family of chemicals that can surround minerals and keep them in solution. Phosphate compounds injected into the water system can stabilize and disperse dissolved iron at this level. As a result, the iron and manganese

are not available to react with oxygen and separate from solution. The phosphate compounds must be introduced into the water at a point where the iron is still dissolved in order to maintain water clarity and prevent possible iron staining. This should be before the pressure tank and as close to the well discharge point as possible. Phosphate compound treatment is a relatively inexpensive way to treat water for low levels of iron and manganese. Since phosphate compounds do not actually remove iron, water treated with these chemicals will retain a metallic taste. In addition, too great a concentration of phosphate compounds will make water feel slippery. Phosphate compounds are not stable at high temperatures. If phosphate compound-treated water is heated (for example, in a water heater or boiled water), the phosphates will break down and release iron and manganese. The released iron and manganese will then react with oxygen and precipitate. Adding phosphate compounds is not recommended where the use of phosphate in most cleaning products is banned. Phosphate, from any source, contributes to excess nutrient content in surface water.

### **Ion exchange water softener**

Low to moderate levels of dissolved iron, at less than 5 mg/l concentrations, usually can be removed using an ion exchange water softener. Be sure to check the manufacturer's maximum iron removal level recommendations before you purchase a unit. Capacities for treating dissolved iron typically can range from 1 to 5 mg/l. Oxidized iron or levels of dissolved iron exceeding the manufacturer's recommendations will cause a softener to become plugged. The principle is the same as that used to remove the hardness minerals, calcium and magnesium; i.e., iron in the untreated water is exchanged with sodium on the ion exchange medium. Iron is flushed from the softener medium by backwashing (forcing sodium-rich water back through the device). This process adds sodium to the resin medium, and the iron is carried away in the waste water. Since iron removal reduces the softening capacity of the unit, the softener will have to be recharged more often. The manufacturer of the softener medium is able to make recommendations concerning the appropriate material to use for a particular concentration of iron. Some manufacturers recommend adding a "bed cleaning" chemical with each backwashing to prevent clogging. Not all water softeners are able to remove iron from water. The manufacturer's specifications should indicate whether or not the equipment is appropriate for iron removal. Water softeners add sodium to the water, a health concern for people on sodium-restricted diets. Consider installing a separate faucet to provide unsoftened water for cooking and drinking.

### **Oxidizing filter**

An oxidizing filter treatment system is an option for moderate levels of dissolved iron and manganese at combined concentrations up to 15 mg/l. The filter material is usually natural manganese green sand or manufactured zeolite coated with manganese oxide, which absorbs dissolved iron and manganese. Synthetic zeolite requires less backwash water and softens the water as it removes iron and manganese. The system must be selected and operated based on the amount of dissolved oxygen. Dissolved oxygen content can be determined by Montana Environmental Laboratory.

### **Aeration followed by filtration**

High levels of dissolved iron and manganese at combined concentrations up to 25 mg/l can be oxidized to a solid form by aeration (mixing with air). For domestic water processing, the "pressure-type aerator" often is used. In this system, air is sucked in and mixed with the passing stream of water. This air-saturated water then enters the precipitator/aerator vessel where air separates from the water. From this point, the water flows through a filter where various filter media are used to screen out oxidized particles of iron, manganese and some carbonate or sulfate.

The most important maintenance step involved in operation is periodic backwashing of the filter. Manganese oxidizes slower than iron and requires greater quantities of oxygen. Aeration is not recommended for water containing organic complexes of iron/manganese or iron/manganese bacteria that will clog the aspirator and filter.

### **Chemical oxidation followed by filtration**

High levels of dissolved or oxidized iron and manganese greater than 10 mg/l can be treated by chemical oxidation, using an oxidizing chemical such as chlorine, followed by a sand trap filter to remove the precipitated material. Iron or manganese also can be oxidized by adding potassium permanganate or hydrogen peroxide to untreated water. This treatment is particularly valuable when iron is combined with organic matter or when iron bacteria is present. The oxidizing chemical is put into the water by a small feed pump that operates when the well pump operates. This may be done in the well, but typically is done just before the water enters a storage tank. A retention time of at least 20 minutes is required to allow oxidation to take place. The resulting solid particles then must be filtered. When large concentrations of iron are present, a flushing sand filter may be needed for the filtering process.

If organic-complexed or colloidal iron/manganese is present in untreated water, a longer contact time and higher concentrations of chemicals are necessary for oxidation to take place. Adding aluminum sulfate (alum) improves filtration by causing larger iron/manganese particles to form.

When chlorine is used as the oxidizing agent, excess chlorine remains in treated water. If the particle filter is made of calcite, sand, anthracite or aluminum silicate, a minimum quantity of chlorine should be used to avoid the unpleasant taste that results from excess chlorine. An activated carbon filter can be used to remove excess chlorine and small quantities of solid iron/manganese particles. Any filtration material requires frequent and regular backwashing or replacement to eliminate the solid iron/manganese particles. Some units have an automatic backwash cycle to handle this task. The ideal pH range for chlorine bleach to oxidize iron is 6.5 to 7.5. Chlorination is not the method of choice for high manganese levels since a pH greater than 9.5 is required for complete oxidation. Potassium permanganate will effectively oxidize manganese at pH values above 7.5 and is more effective than chlorine oxidation of organic iron if that is a problem. Potassium permanganate is poisonous and a skin irritant. There must be no excess potassium permanganate in treated water and the concentrated chemical must be stored in its original container away from children and animals. Careful calibration, maintenance and monitoring are required when potassium permanganate is used as an oxidizing agent.

## Treatment of iron and manganese in drinking water

| <i>Indication</i>  | <i>Cause</i>   | <i>Treatment</i>  |
|--|--|---|
| Water clear when drawn but red-brown or black particles appear as water stands; red-brown or black stains on fixtures or laundry | Dissolved iron or manganese  | -Phosphate compounds ( <i>less than 3 mg/l iron</i> )<br>-Water softener (<5 mg/l combined concentrations of iron and manganese)<br>-Oxidizing filter (manganese greensand or zeolite) (<15 mg/l combined concentrations of iron and manganese)<br>-Aeration (pressure) (<25mg/l combined concentrations of iron and manganese)<br>-Chemical oxidation with potassium permanganate or chlorine; followed with filtration (>10 mg/l combined concentrations of iron and manganese) |
| Water contains red-brown particles when drawn; particles settle out as water stands  | Iron particles from corrosion of pipes and equipment                 | Raise pH with neutralizing filter   |
| Water contains red-brown or black particles when drawn; particles settle out as water stands                                     | Oxidized iron/manganese due to exposure of water to air prior to tap | Particle filter (if quantity of oxidized material is high, use larger filter than in line; e.g., sand filter)   |
| Red-brown or black slime appears in toilet tanks or from clogs in faucets  | Iron or manganese bacteria   | Kill bacteria masses by shock treatment with chlorine or potassium permanganate, then filter; bacteria may originate in well, so it may require continuous feed of chlorine or potassium permanganate, then filter  |
| Reddish or black color that remains longer than 24 hours   | Colloidal iron/manganese; organically complexed iron/manganese       | Chemical oxidation with chlorine or potassium permanganate; followed with filtration  |

## Plumbing corrosion

Corroded pipes and equipment may cause reddish-brown particles in the water that, when drawn from the tap, will settle out as the water stands. This can indicate oxidized iron or, in some cases, it may only be iron corrosion particles. Raising the water's pH and using a sediment filter is the simplest solution to this problem.

## Iron and manganese bacteria

The most common approach to control of iron and manganese bacteria is shock chlorination. It is almost impossible to kill all the iron and manganese bacteria in your system. They will grow back eventually so be prepared to repeat the treatment from time to time. If bacteria regrowth is rapid, repeated shock chlorination becomes time consuming. Continuous application of low levels of chlorine may be less work and more effective. An automatic liquid chlorine injector pump or a dispenser that drops chlorine pellets into the well are common choices. Chlorine rapidly changes dissolved iron into oxidized (colored) iron that will precipitate. A filter may be needed to remove oxidized iron if continuous chlorination is used to control iron bacteria.

## Multistage treatment

If the water has high levels of iron and manganese and they are both the dissolved and solid forms, a multistage treatment operation is necessary. For example, a troublesome supply could be chlorinated to oxidize dissolved iron and kill iron bacteria, and filtered through a mechanical device to remove particles. This can be followed by activated carbon filtration to remove excess chlorine and a water softener for hardness control as well as removal of any residual, dissolved iron or manganese. If a chemical oxidizer is used, it might be possible to treat hydrogen sulfide, iron and manganese contaminants at the same time.

## Summary

Iron and manganese are common water contaminants that are not considered health hazards. Their presence in water results in staining as well as offensive tastes and appearances. Treatment of these elements depends on the form in which they occur in the untreated water. It is strongly recommended that your water be tested prior to the purchase or installation of any treatment devices. In some cases, it is necessary to test for Iron bacteria. Therefore, accurate testing is important before considering options and/or selecting treatment equipment. A summary of treatment options is shown in the above table. Often the treatment for iron and manganese is the same as for hydrogen sulfide, allowing removal of all three contaminants in one process.