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Drinking Water: Iron and Manganese

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Common water contaminants iron and manganese are not health hazards but can cause offensive taste, appearance, and staining. Testing and treatment options are available for public and private water supplies.

Iron and manganese are nonhazardous elements that can be a nuisance in a water supply. They are similar metals and cause similar problems. Of the two, iron is found most frequently in water supplies. Manganese is often found in waters that contain iron.

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. In such water, the iron and manganese are in dissolved form. Water from the tap may be clear, but when exposed to air, iron and manganese are oxidized (combine with oxygen to become an oxide) and change from colorless, dissolved forms to colored, solid forms (often in the form of very small particles).

Oxidation of dissolved iron particles in water changes the iron to white, then yellow, and finally to red-brown solid particles (precipitates) 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, leaving the water with a black tint. These sediments are responsible for the staining properties of water containing high concentrations of iron and manganese. These sediments or precipitates 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 can be 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 also are associated increases in energy costs from pumping water through constricted pipes or heating water with electric 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, often detected in toilet tanks, and can clog water systems.

Potential Health Effects

Iron and manganese in drinking water are not considered health hazards. In addition, iron and manganese bacteria are not known to present a health risk.

Testing

Testing Public Water Supplies

The quality of water supplied by Public Water Systems is regulated by the U.S. Environmental Protection Agency (EPA) and Nebraska Department of Health and Human Services (DHHS) under the Federal Safe Drinking Water Act and the Nebraska Safe Drinking Water Act. This includes any well with 15 or more service connections or that regularly serves 25 or more people.

Public drinking water standards established by EPA fall into two categories: Secondary Standards and Primary Standards.

Secondary Standards are based on aesthetic factors such as taste, odor, color, corrosivity, foaming, and staining properties of water that may affect the suitability of a water supply for drinking and other domestic uses. Secondary Standards are recommended, but they are not enforceable.

Primary Standards are based on health considerations and are designed to protect human health. Primary Standards are enforceable.

Both iron and manganese are classified under the Secondary Maximum Contaminant Level (SMCL) standards, indicating that they are recommended but are not enforced by either the Federal or State Drinking Water Acts. If an individual's water comes from a public water supply, they can contact the water utility office to inquire about the iron and manganese levels in the water. The public water system may have this information on hand.

Testing Private Water Supplies

Water quality in private wells is not currently regulated at the federal or state level. Thus, the regular testing of a private water supply is not required under state or federal law. If individuals want to know the concentration of dissolved iron and/or manganese in a private water supply, they will need to have the water tested at their own expense. If foul odor (which is not a rotten egg smell) and a red or black slime layer is found in places like the toilet tank or bowl, individuals should also request to have the water tested for iron and manganese bacteria.

Tests to determine the presence of iron or manganese, and of iron and manganese bacteria in drinking water should be done by a laboratory utilizing approved EPA methods for the detection of iron and manganese. Because iron and manganese are "secondary" contaminants, there is no formal approval of laboratories by the Nebraska DHHS. Individuals approaching a commercial or local governmental laboratory to request either iron or manganese water analysis should ask if they use an approved EPA method for iron or manganese analysis in drinking water. See NebGuide G1614, *Drinking Water: Approved Water Testing Laboratories in Nebraska* for guidance and contact information for laboratories in Nebraska.

Interpreting Test Results

Public Water Supply Test Results

The SMCL for iron in drinking water is 0.3 milligrams per liter (mg/l), sometimes expressed as 0.3 parts per million (ppm). The SMCL for manganese in drinking water is 0.05 mg/l (ppm). Water with less than these concentrations should not have an unpleasant taste, odor, appearance, or side effect.

Private Water Supply Test Results

Since EPA and Nebraska regulations do not apply to private drinking water wells, users of private drinking water typically evaluate iron and manganese based on the degree of nuisance of these dissolved metals. They may also consider the EPA guidelines of 0.3 ppm iron and 0.05 ppm manganese and the presence or absence of iron and/or manganese bacteria in assessing the degree of nuisance associated with their water supply.

Options

Public Water Supplies

Secondary iron and manganese standards are established as guides to manage taste, odor, and color of water. Drinking water suppliers are not required by federal or state law to meet these secondary standards. If iron and/or manganese levels in drinking water approach or exceed the SMCL, some public water suppliers voluntarily remove or reduce iron and manganese from the water.

Nebraska public water suppliers most commonly use **aeration followed by filtration, chemical oxidation followed by filtration, or phosphate treatment** to remove excess iron and manganese from the source water. These treatment options are detailed below in the Private Water Supplies section.

Private Water Supplies

If excessive iron or manganese is present in a private drinking water supply, users might consider an alternative source for drinking water, or water treatment. Decisions should be based on iron and/or manganese analysis by a reputable laboratory and consulting with a water quality expert.

It may be possible to obtain a satisfactory alternate water supply by drilling a new well in a different location or at a different depth in the same or different aquifer. The Conservation and Survey Division of the University of Nebraska–Lincoln can provide general information on the possible location of a water supply with satisfactory quality.

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 treated water is needed. Treatment options for water containing **dissolved iron and manganese,** and **iron and manganese bacteria** are discussed below.

Dissolved iron and manganese

Note that point-of-use (POU) devices such as Reverse Osmosis and Distillation can remove dissolved iron and manganese. However, these treatment systems are not generally recommended. Since excess iron and manganese are aesthetic problems that affect all potential uses of the water (e.g. stains on fixtures or laundry), they are most often removed from all water entering the home using point-of-entry (POE) treatment devices. For more information on Reverse Osmosis and Distillation, see NebGuide G1490, *Drinking Water Treatment: Reverse Osmosis* and NebGuide G1493, *Drinking Water Treatment: Distillation*, respectively.

The four most commonly applied methods for treating water containing dissolved iron and manganese, are: **ion exchange water softeners, oxidizing filters, aeration (pressure type) followed by filtration, chemical oxidation followed by filtration. An additional method that may apply to some situations is phosphate treatment.**

Treatment techniques are effective for iron and manganese removal 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. All five methods can be successful if performance criteria are met. An individual should work with a reliable, competent water treatment dealer to select the best treatment method for a given situation.

- *Ion exchange water softeners*

Conventional water softeners are sometimes effective for removing dissolved iron and manganese concentrations of approximately 5 mg/L or less from water. Iron and manganese removal is accomplished in the same way as calcium and magnesium (hardness) removal in water by an exchange process. Iron and manganese are exchanged with sodium on the ion exchange resin. For more information on ion exchange see NebGuide G1491, *Drinking Water Treatment: Water Softening (Ion Exchange)*. The iron and manganese are then removed from the softener resin bed through backwashing and regeneration. How efficiently softeners remove iron and manganese will vary depending on the iron concentration, water hardness, and pH. It is important to check the manufacturer's maximum iron removal level recommendations, which typically range from 1 to 5 mg/L, before purchasing a unit. The softeners will be clogged if levels of oxidized or dissolved iron exceed the manufacturer's recommended level. Some vendors recommend using special softener salt that contains additives (e.g., food-grade acids) that remove accumulated iron from the resin during regeneration. Also, not all water softeners are able to remove iron and manganese from water, so be sure to check the manufacturer's specifications.

One of the major difficulties with ion exchange for controlling iron and manganese is that if any oxidation occurs during the process, the resulting precipitate can coat and foul the ion exchange media. Thus, it is important that the raw water should not come in contact with any oxidizing agent like air and chlorine before entering the softener. If oxidized iron and manganese are present in raw water, filtration should be used for the removal.

- *Oxidizing filters*

Oxidizing filters, which oxidize and filter iron and manganese in one unit, are the most widely used option for managing moderate levels of dissolved iron and manganese at combined concentration up to approximately 15 mg/L. Because these units combine oxidation and filtration, they can be used to treat raw water with dissolved and/or oxidized iron and manganese.

An oxidizing filter typically contains a filter media of natural manganese greensand or manufactured zeolite coated with manganese oxide. The filter media is periodically treated with potassium permanganate to form a coating that oxidizes the dissolved iron and manganese so each form precipitates. This precipitated iron and manganese is filtered out by the manganese greensand because it also acts as a filtering media. Caution must be exercised with potassium permanganate, as it is both poisonous and a skin irritant.

Oxidizing filters, such as manganese greensand filters, require significant maintenance including frequent regeneration with a potassium permanganate solution as it is consumed during oxidation of the dissolved metals. In addition, these units require regular backwashing to remove the oxidized iron and manganese particles. The potassium permanganate solution used for regeneration is toxic and must be handled and stored with care. Compared to manganese greensand, synthetic zeolite requires less backwash water and softens the water as it removes iron and manganese.

- *Aeration followed by filtration*

High levels of dissolved iron and manganese at combined concentrations up to approximately 5 to 10 mg/L can be treated with an aeration (mixing with air) followed by filtration system. In this system, air is sucked in and mixed with the passing stream of water to oxidize the iron and manganese into particles. The air-saturated water then enters the precipitator/aerator vessel, usually a pressure-type aerator for domestic use, where air is separated from the water. The water then flows through a filter, which uses various filter media to filter out oxidized particles of iron and manganese. More time and oxygen are required for treating manganese compared to iron with this type of system.

Periodically backwashing the filter is the most important maintenance step involved in operation to ensure proper performance. Aeration is not recommended for water containing organic complexes of iron/manganese or iron/manganese bacteria that will clog the aspirator and filter.

The next two options described below are commonly applied to public water supplies and are less frequently applied to private water supplies due to their complexity and cost.

- *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 followed by a sand trap filter to remove the precipitated particles. This treatment is particularly useful when iron is combined with organic matter or when iron bacteria are present.

In this method, the water is treated with an oxidizing agent such as ozone, chlorine, or potassium permanganate to convert any dissolved iron and manganese into solid, oxidized forms that can then be filtered through a sand trap filter. Significant retention or contact time is required to allow oxidation to take place. For this reason, a storage tank may be used. If chlorine is used as the oxidizing agent, it may be necessary to install an activated carbon filter to remove taste and odor from residual chlorine left in water after oxidation. For more information on activated carbon filters see NebGuide G1489, *Drinking Water Treatment: Activated Carbon Filtration*.

The pH of the water supply plays an important role when choosing an oxidizing agent. Chlorine bleach is most effective for oxidizing iron at pH level 6.5 to 7.5. If the pH of water is less than 6.5, a neutralization of water is needed before chemical oxidation. Furthermore, chlorine is not recommended as an oxidant for very high manganese levels, as a very high pH (pH of 9.5 or greater) is necessary to completely oxidize manganese. Potassium permanganate is more effective in oxidizing manganese at pH values above 7.5 and is more effective than chlorine in oxidation of organic iron if that is a problem.

Regular maintenance of this system is required. Solution tanks must be routinely refilled and mechanical filters need to be backwashed to remove accumulated iron and manganese particles. If a carbon filter was also installed, the carbon needs to be replaced occasionally as it becomes exhausted. The frequency of maintenance is primarily determined by the concentration of the metals in the raw water and the amount of water treated. If potassium permanganate is used, careful calibration, maintenance, and monitoring of the water treatment equipment is necessary. Caution must be exercised with potassium permanganate, as it is both poisonous and a skin irritant.

- *Phosphate treatment*

Water containing a dissolved iron concentration less than 1 mg/L may be treated using a food-grade polyphosphate compound. Phosphate addition generally does not work as well for treating manganese. Once the phosphate is fed into the water using a chemical feed pump, the phosphate chemical sequesters ("coats" and "ties up") the dissolved iron ions, preventing oxidation and formation of iron colloids or particles. Since sequestering prevents the staining effect but does not actually remove iron and manganese, water treated with these chemicals may retain a metallic taste. In addition, a high phosphate concentration will give the water a slippery feeling and may cause diarrhea. In some cases, polyphosphates can also increase the corrosion rate of copper plumbing. Phosphate compounds are not stable at high temperatures, and if the water is heated or boiled, the phosphates will break down and release iron. The released iron will then react with oxygen and precipitate. Also, 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.

Iron and manganese bacteria

The most common approach to control iron and manganese bacteria is shock chlorination. This involves introducing a concentrated chlorine solution into the entire water distribution system, letting the system remain idle for at least two to three hours, and then flushing the system to remove the chlorine. Shock chlorination procedures are described in NebGuide G1761, *Drinking Water Treatment: Shock Chlorination*. It is almost impossible to kill all the iron and manganese bacteria in a system. In most cases, they will grow back eventually. The shock chlorination procedure will most likely need to be repeated from time to time.

If bacteria regrowth is rapid, repeated shock chlorination becomes time consuming. Continuous application of low levels of chlorine may be more effective. An automatic liquid chlorine injector pump or a dispenser that drops chlorine pellets into the well are common choices.

Chlorine will change dissolved iron into oxidized 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 water has high levels of iron and manganese in both dissolved and solid forms, a multistage treatment operation is necessary. For example, the water 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. A water softener may be used for hardness control as well as removal of any residual, dissolved iron or manganese.

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 taste and appearance. Treatment of these elements depends on the form in which they occur in the untreated water. Therefore, accurate testing is important before considering options and/or selecting treatment equipment.

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