G1714: Natural Resources, Water Management
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Drinking Water: Iron and Manganese

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Iron and manganese are two naturally occurring drinking water contaminants that can cause poor taste and odor issues, and be associated with discoloration that leads to staining of fixtures, dishes, and laundry. They are primarily found in Eastern Nebraska groundwater and most people mention these issues when iron levels exceed 300 micrograms per liter (µg/L) and manganese levels exceed 50 µg/L. Levels of iron can be much higher and are not associated with health concerns but manganese concentrations above 300 µg/L may pose a health issue for rice or soy formula-fed infants. Higher levels, over 1,000 µg/L, may pose a risk for all consumers. It is important to highlight that testing and treatment options are available to detect and remove these contaminants from drinking water.

Iron and manganese can be a nuisance in a water supply. They are similar metals and cause similar taste, appearance, and staining problems. Of the two, iron is found most frequently in water supplies, associated with both source water and piping material. Manganese is often found in source water that contain iron. Neither iron nor manganese are regulated under the Safe Drinking Water Act but the U.S. Environmental Protection Agency (EPA) does have a lifetime health advisory for manganese of 300 micrograms per liter (µg/l).

Sources of Iron and Manganese in Drinking Water

Iron and manganese are common minerals found in the earth's crust. Water percolating through soil and rock can dissolve minerals, such as iron and manganese, which then, as part of groundwater, make their way into your drinking water. Occasionally, iron pipes also may be a source of iron in drinking water.

Iron is an essential mineral that is naturally found in many foods such as lean meat, poultry, seafood, nuts, beans, vegetables, and iron fortified grain products such as: breads, cereals, and pastas. Iron's primary purpose is to carry oxygen throughout the body within the hemoglobin of the red blood cells. It is also necessary for cellular function, neurological development, and physical growth. Manganese is an essential nutrient found in many foods such as tea, leafy green vegetables, grains, fruit, nuts, legumes, fish, some meats, and some infant formulas, especially rice and soy. It is essential for bone development and many processes in the body but like all minerals, it can have adverse health effects when humans and/or animals ingest too little or too much. Food and drinking water are the primary source of manganese for adults and children. Breast milk, soy and rice-based formula and cereals are the primary sources of manganese for infants.

Indications of Iron and Manganese

In deep wells, where oxygen content is low, groundwater containing iron and manganese 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 that settle out of the water. Iron that does not form particles large enough to settle out suspended (colloidal iron) and gives the water a red tint. Manganese usually is dissolved in water, although some shallow wells contain colloidal manganese, giving the water a black tint.

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. 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 can build up in pipes, pressure tanks, water heaters and water softeners. This reduces the available quantity and pressure of the water supply. Iron and manganese accumulation becomes an economic problem when water supply or water softening equipment must be replaced. There also are increases in energy costs associated with pumping water through constricted pipes or heating water with electric heating rods coated with iron or manganese deposits.

A problem that frequently results when there is high iron or manganese levels in water, is the presence of iron or manganese bacteria. An indicator of iron and manganese bacteria is a foul odor, similar to a rotten egg smell. The odor is a byproduct of the bacteria feeding on the iron and/or manganese. These bacteria occur in soil, shallow aquifers, and some surface water. They may be introduced into a well or water system when it is constructed or repaired. The bacteria are not a health concern but may form red-brown (iron) or black-brown (manganese) slime layers, often detected in toilet tanks, and may clog water systems.

Potential Adverse Health Effects

Iron in drinking water is not considered a health hazard and iron and manganese bacteria that may be present in water pipes and fixtures are also not known to present a health risk. Manganese in drinking water at elevated levels, however, can pose a health risk. Infants fed soy or rice-based formula, which is naturally rich in manganese, are at greater risk for adverse neurological effects if the water used to make the formula also contains high levels of manganese, greater than 300 micrograms per liter (μg/l). Infants are at a greater risk than older children and adults due to higher manganese adsorption rates and their brains and bodies are rapidly developing. Older children and adults are at an increased risk when manganese levels exceed 1,000 (μg/l).

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. Primary Standards are based on health considerations and are designed to protect human health. Primary Standards are enforceable. 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 are not enforceable.

Iron and manganese are currently both classified under the Secondary Maximum Contaminant Level (SMCL) standards, indicating that removing these contaminants to the SMCL is recommended, but not enforced by either federal or state drinking water regulations.

In 2020, DHHS completed a survey of all public water systems in Nebraska. If manganese levels were found to be greater than 300 μg/l, it was requested that the system provide notice to consumers. Generally, manganese levels were found to be highest in Eastern Nebraska. Please contact your water utility office to inquire about the iron and manganese levels in your community.

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. Test kits can be obtained from a Drinking Water Laboratory or this testing can be done by a water quality professional in your area.

Tests to determine the presence of iron or manganese 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. See NebGuide G1614, Drinking Water: Approved Water Testing Laboratories in Nebraska for more information on laboratories. If foul odor and a red or black slime layer is found in places like water using appliances such as like the toilet tank or bowl, individuals should also request to have the water tested for iron and manganese bacteria.

Interpreting Test Results

Public Water Supply Test Results

Secondary Maximum Contaminant Level (SMCL)—Aesthetic Issues

The SMCL for iron in drinking water is 300 µg/l, which is the same as 0.3 milligrams per liter (mg/L) and is sometimes expressed as 0.3 parts per million (ppm). The SMCL for manganese in drinking water is 50 µg/l (0.05 mg/l or ppm). Iron and manganese levels in drinking water below SMCLs are not associated with aesthetic issues.

Health-Based Levels—Potential Adverse Health Effects

Iron in water does not in itself present a health risk. Your body needs iron to transport oxygen in the blood. Most tap water in the United States supplies approximately 5 percent of the dietary requirement for iron. Manganese levels in drinking water above 300 µg/l should not be used to mix rice and soy formula for infants. Manganese levels in drinking water above 1,000 µg/l should not be used for drinking water consumption. Alternative water, filtered or bottled, should be utilized. Health concerns should be discussed with one's healthcare provider.

Private Water Supply Test Results

Users of private drinking water often evaluate iron and manganese based on the degree of nuisance of these dissolved metals. EPA and Nebraska public water supply regulations do not apply to private drinking water wells. Private drinking water well owners are encouraged to follow the EPA guidelines for public water supplies. The EPA SMCLs are 300 µg/l (0.3 ppm) iron and 50 µg/l (0.05 ppm) manganese.

Treatment 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 these levels, 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 provided in more detail below.

Private Water Supplies

If excessive iron or manganese is present in a private drinking water, 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.

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. Select a treatment unit certified by NSF, or Water Quality Association (WQA) to remove the contaminant(s) you are concerned about. These organizations do not, however, certify treatment units for manganese. For more information, see NebGuide G1488, Drinking Water Treatment: What You Need to Know When Selecting Water Treatment Equipment.

Dissolved iron and manganese

Point-of-use (POU) devices such as Reverse Osmosis, Distillation, and carbon filtration can remove dissolved manganese (and often iron), and are good options for providing safe drinking water. Note that some filters, including pour through pitchers and in-line facet units, include carbon and other adsorbents engineered to remove manganese. Read the manufacturer's instructions to confirm the filter removes manganese and for recommendations for when to change the filter. When manganese concentrations are higher than 200 μg/L, however, the effective life of the filter may be significantly shortened, and replacement, more frequent then that indicated by the manufacturer, may be necessary. For more information on Reverse Osmosis, Distillation, and Carbon Filtration, see NebGuide G1490, Drinking Water Treatment: Reverse Osmosis, NebGuide G1493, Drinking Water Treatment: Distillation and NebGuide G1489. Drinking Water Treatment: Activated Carbon Filtration, respectively.

Since excess iron and manganese are aesthetic problems that affect all potential uses of the water (e.g. stains on fixtures or laundry), in many cases these are removed from all water entering the home using Point-of-entry (POE) treatment devices.

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

Treatment techniques are most 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 most effective in the pH range of 5.0 to 8.0. An individual should work with a reputable water treatment professional to select the best treatment method

- Ion exchange water softeners

Conventional water softeners can be effective for removing dissolved iron concentrations below 5,000 μg/L and dissolved manganese concentrations below 500 μg/L. Iron and manganese removal is accomplished in the same way as calcium and magnesium (hardness) removal in water Iron and manganese are exchanged with sodium on the ion exchange resin. The resin can then be backwashed to remove the trapped iron and manganese and then can be regenerated for reuse. Softening with potassium chloride regeneration, however, may be more effective than sodium chloride in removing manganese. For more information on ion exchange see NebGuide G1491, Drinking Water Treatment: Water Softening (Ion Exchange.)

How efficiently softeners remove iron and manganese will vary depending on the concentration of these contaminants, water hardness, and pH. It is important to check the manufacturer's maximum iron removal level recommendations, which typically range from 500 to 5,000 μg/L, before purchasing a unit. The softeners will be clogged if iron levels 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. Not all water softeners are able to remove iron and manganese from water. Be sure to check the manufacturer's specifications.

One of the major difficulties with ion exchange for removing iron and manganese is oxidation, caused by exposure to oxygen or the presence of chlorine in the water. Thus, it is important that the raw water should not come in contact with any oxidizing agent like air or 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, are the most widely used option for managing moderate levels of dissolved iron and manganese at combined concentration up to approximately 1,000 μg/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 that it is pulled out of solution in the form of a red/brown (iron) or black (manganese) flakes or particles. These larger particles of iron and manganese can then be filtered out by the greensand. Caution must be exercised when using potassium permanganate it is a strong skin, eye, and lung irritant.

Oxidizing filters, such as manganese greensand filters, require significant maintenance including frequent regeneration with a potassium permanganate solution. In addition, these units require regular backwashing to remove the oxidized iron and manganese particles. The potassium permanganate solution used for regeneration 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 5,000 to 10,000 µg/L (5 to 10 mg/L) can be removed with aeration (mixing with air) followed by filtration. In this process, air is mixed with water to oxidize the iron and manganese into particles. The air-saturated water then enters the vessel, usually a pressure-type aerator for domestic use, where air is separated from the water. The water then flows through a filter to remove the iron and manganese particles. More time and oxygen are required for removing manganese compared to iron with this type of system. Periodically backwashing of 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 10,000 µg/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 a 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.

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.

Regular maintenance of any treatment system is required for it to work effectively. Solution tanks must be routinely refilled and mechanical filters need to be backwashed to remove accumulated iron and manganese particles. The frequency of maintenance is primarily determined by the concentration of iron and manganese in the source water and the amount of water treated. If potassium permanganate is used, careful calibration, maintenance, and monitoring of the water treatment equipment is necessary.

- Phosphate treatment

Water containing dissolved iron less than 1,000 µg/L may be simply treated using a food-grade polyphosphate compound. The addition of phosphate, however, generally does not work well for manganese removal. This process involves the addition of phosphate to the water using a chemical feed pump, the phosphate chemical sequesters ("coats" and "ties up") dissolved iron but does not actually remove iron. Water treated with phosphate may retain a metallic taste but helps to prevent staining of fixtures, dishes, and laundry. Since manganese is not removed, this process is not recommended for high levels of manganese. In addition, a high phosphate concentration may cause diarrhea. In some cases, it 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, which can react with oxygen and precipitate out. The addition of phosphate should not be used where the use of phosphate in cleaning products is banned. Phosphate, from any source, that gets into surface water, can, like nitrates, contribute to nutrient pollution of the waterbody.

Iron and manganese bacteria

Iron and manganese bacteria are not a health issue but a nuisance issue. The most common approach to control iron and manganese bacteria is with 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 not possible to kill all iron and manganese bacteria in a system but shock chlorination is a method for minimizing their occurrence. Therefore, shock chlorination 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 to remove particles. This can be followed by activated carbon filtration to remove excess chlorine and then water softening for hardness control and to remove any residual, dissolved iron or manganese.

Summary

Iron and manganese are naturally occurring common water contaminants that can cause poor taste, appearance, and staining issues. High levels of iron in drinking water do not pose a health concern but can cause significant aesthetic issues. High manganese concentrations can be associated with both aesthetic and health issues. Manganese levels above 300 µg/l may be a health concern, for rice and soy formula-fed infants. Manganese levels above 1,000 µg/l should not be used for drinking water. Treatment of these elements depends on the form and concentration in which they occur in raw water. Therefore, testing is important before selecting treatment options.

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