Water Treatment NOTES

Cornell Cooperative Extension, College of Human Ecology

Iron and Manganese in Household Drinking Water

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Fact Sheet 6, January 1999 (updated November 2005)

Sources and problems

Iron and manganese are common metallic elements found in nature. Water percolating through soil and rock dissolves iron and manganese, and these minerals subsequently enter groundwater supplies. Surface water does not usually contain high concentrations of iron or manganese because the oxygen-rich water enables both minerals to settle out as sediments.

In deep wells and springs, where both the oxygen content and pH tend to be low, water containing dissolved iron or manganese appears colorless. When exposed to air, the dissolved iron or manganese reacts with oxygen and is converted to a colored, solid material that settles out of the water. This process is called *oxidation.* Iron changes to white, then yellow, and finally to a reddish-brown. Manganese forms a black residue. High concentrations of these sediments cause reddish-brown or black stains on laundry and household fixtures.

Another result of iron and manganese in household water is the presence of harmless bacteria in soil, shallow groundwater supplies, and some surface waters that secrete large amounts of red-brown (iron) or black-brown (manganese) slimes that stain toilet tanks. A colony of these bacteria has a mat-like, fibrous appearance and may clog water treatment systems or distribution pipes.

Drinking water standards

Iron and manganese are primarily nuisance chemicals with characteristic staining properties, although high levels can impart a bittersweet or metallic taste to drinking water. For these reasons, iron and manganese are regulated by secondary drinking water standards established by the U.S. Environmental Protection Agency for public water supplies.

Understanding Drinking Water Standards

mg = milligram = one-thousandth of a gram

mg/L = milligram per liter = part per million (ppm)

µg = microgram = one-millionth of a gram

µg/L = microgram per liter = part per billion (ppb)

Secondary standards apply to drinking water contaminants that cause offensive taste, odor, color, corrosion, foaming, or staining problems. Secondary drinking water contaminants do not pose health risks to humans at levels usually found in water.

The drinking water standard for iron is 0.3 milligrams per liter (mg/l), and the standard for manganese is 0.05 mg/l. Private water supplies are not subject to these federal regulations, but consumers can use the standards as guidelines when evaluating the quality of a private well or spring. Typical values of dissolved iron and manganese in groundwater are less than 10.0 mg/l and 2.0 mg/l, respectively.

Water testing and treatment options

Iron and manganese exist in several different forms, which poses a challenge when selecting treatment options. Laboratory testing is important to determine the concentrations and specific forms of iron and manganese in the water supply. A laboratory certified by the New York State Department of Health should be used to perform the necessary analyses (contact your local health department or Cooperative Extension office for a list of certified labsor look online at: http://www.wadsworth.org/labcert/elap/comm.html)

If the water sample is clear at first but contains red or black particles after sitting in a glass, dissolved iron or manganese is present. Dissolved iron, also called soluble iron, is most frequently found in groundwater with a pH less than 7.0. This form of iron stains household fixtures and laundry. If the water has a red tint with particles that cannot be detected and do not settle after time, colloidal iron is present. Colloids are extremely small particles with high surface charges that repel each other and remain suspended in solution. Manganese usually exists in the dissolved state, although some shallow wells or surface waters may contain colloidal manganese; these waters have a black tint.

Iron and manganese may also combine with organic matter in water to form chemical complexes that are difficult to remove and do not react readily with other chemicals in solution. Combined iron and manganese are often present in both dissolved and oxidized forms and must be detected using a specific laboratory analysis. If household water contains high levels of iron and manganese in both forms, a multistage treatment operation may be necessary. For example, the water supply could be aerated to oxidize the bulk of iron and manganese, then chlorinated to oxidize residual iron and kill iron bacteria, followed by activated carbon filtration to remove excess chlorine and iron and manganese particles.

Finally, reddish-brown or black-brown slimy masses inside the toilet tank indicate the presence of iron and manganese bacteria. The most widely practiced method of removing these bacteria is chlorination followed by filtration. Start with a strong chlorine treatment of the household plumbing system and drinking water well to kill and help remove the bacteria. A periodic shock treatment with chlorine may control the problem (see *Water Treatment Notes 5: Chlorination of Drinking Water).* If bacteria problems persist, a continuous chlorination system with accompanying filtration unit may be required.

Water softener

A cation exchange water softener is effective for removing low concentrations of dissolved iron and manganese. Water softeners rely on the process of cation exchange to remove minerals that cause hard water such as calcium and magnesium and other nuisance constituents such as iron and manganese. During this process, iron and manganese are exchanged with sodium on a special resin. The iron and manganese are flushed from the resin during backwashing, while sodium-rich water is forced back through the resin into the treated water supply.

Water softeners produce treated water containing less than one hardness grain per gallon, which is equivalent to 17.1 mg/l of hardness.

Water softening is most useful when dissolved iron and manganese exist in low concentrations, the pH of the water is higher than 6.8, and the total hardness is 3-20 grains per gallon. The exact removal capacity of the water softener depends on the design of the softener and a number of other variables. Most manufacturers set a tolerance level for iron for their equipment. It is also important that untreated water (before softening) not be exposed to air or chlorine, which will convert dissolved iron and manganese into solid particles that clog the cation exchange resin. This is a common problem that can be treated by lowering the pH of the water or regenerating the cation exchange resin with backwash. Otherwise, the degraded resin will have a shorter life span and a reduced capacity for removing contaminants.

Like other water treatment devices, water softeners should be designed and installed to meet specific conditions of the household water supply. The manufacturer of a water softener can usually recommend the appropriate resin for a particular concentration of iron and manganese. Not all water softeners can remove iron and manganese, especially if these minerals exist in various forms such as organic iron, that is, iron complexed with dissolved vegetative decay materials. Some softeners can remove partially oxidized iron and manganese, although this method is not as effective as filtration. A manufacturer will sometimes recommend adding a "bed cleaning" chemical to each backwashing to prevent clogging.

Finally, some water softeners may pose a health concern for people on sodium-restricted diets. In such cases, the softener may be connected only to the hot water line, leaving un-softened cold water for cooking and drinking. For removal of iron and manganese, however, the softener must treat both hot and cold water to prevent staining of fixtures. If necessary, a separate tap can be installed to provide un-softened water for cooking and drinking. Alternatively, some water softeners use potassium instead of sodium during the cation exchange process. These water softeners do not contribute sodium to the treated water supply. In general, it is recommended that consumers consult a physician about possible health concerns before installing a water softener in their home.

Polyphosphate treatment

To keep iron in its soluble form, polyphosphates are sometimes used as a control chemical.

Poly phosphates do not remove iron from water, but stabilize and disperse it, so it keeps the water clear and cannot stain the laundry. However, this treatment will be nullified when the water is boiled. The phosphates will revert to a different chemical state which cannot stabilize iron any longer. Addition of polyphosphates is effective for iron concentrations up to 1 mg/L. Polyphosphate treatment is not allowed in states that control phosphates discharges to water bodies, so be sure to check with either the local department of health or extension office for your specific rules.

Chemical oxidation and filtration

For household water containing high levels of iron and manganese, the best method of removal is oxidation followed by filtration. Oxidation is the process by which soluble contaminants are converted during a chemical reaction to soluble by-products or insoluble products that can be filtered.

Filtration is the process by which solid particles are physically strained from the water by various media such as activated carbon. If iron and manganese are not oxidized from a dissolved (soluble) to a solid (insoluble) state, they will pass through the filter.

Oxidation and filtration is recommended when dissolved iron levels exceed 5.0 mg/l or the use of a water softener is not practical. Following the introduction of a strong chemical oxidant such as chlorine or potassium permanganate, the iron and manganese particles are allowed to grow until they are large enough to be filtered. A coagulant is sometimes added to ensure that the smaller particles grow into larger ones. If the water contains high levels of both manganese and iron, more oxidant is required.

Chlorine is an extremely effective oxidant. When chlorine is used for treating iron and manganese, excess chlorine remains in the treated water as a residual, usually in a concentration less than 1.0 mg/l. If the downstream particle filter is made of calcite, sand, anthracite, or aluminum silicate, a minimal quantity of chlorine should be used to avoid the unpleasant aftertaste that can result from excess chlorination. An activated carbon filter can be used to remove both excess chlorine and solid iron and manganese particles. The ideal pH range for chlorination is 6.5-7.5. Chlorination is not recommended for high manganese levels because a pH greater than 9.5 is needed for complete oxidation.

Ozone is another extremely strong oxidant. It is a form of oxygen in which the molecule has three atoms, which makes ozone highly reactive, unstable, and short-lived. As a result, it must be generated on site shortly before use, and it is difficult to maintain a residual in the treated water. In addition, ozone tends to be a more expensive treatment than other systems. When properly administered, ozone will effectively treat bacterial iron. It is most effective when incorporated into a complete filtration package that is properly designed and maintained.

Some oxidation and filtration units, such as birm filters, treat both soluble and insoluble iron in one tank. The filtration medium is enriched with oxygen that is either replenished from the excess natural dissolved oxygen in the water or by a regeneration process. The dissolved iron in the water is oxidized and then filtered by the media along with the insoluble iron particles. Most oxidizing media are able to remove iron from water in which concentrations do not exceed 10-15 mg/l and the pH is 7.0-8.5. They require frequent backwashing and can also be used to treat water containing hydrogen sulfide.

Aeration

Aeration systems commonly use a pressure aerator to mix oxygen-rich air with untreated water, which converts dissolved iron and manganese to solid particles that are filtered. Aeration typically requires no chemical inputs to the water, although a coagulant may be added following use of the aerator to increase the size of the particles for effective settling and filtration.

In addition, the filter must be backwashed frequently, and the appropriate pumping capacity must be maintained for adequate air intake and retention time.

An effective aeration system will remove up to 25 mg/l of dissolved iron. Removal of manganese is slower because greater quantities of oxygen are required to convert manganese from the dissolved state to a solid particle. Aeration is not recommended for water containing iron and manganese complexes or iron and manganese bacteria, both of which may clog the filter. To protect the water from bacterial contamination, the aeration system should be totally enclosed and only biologically safe water should be used.

Manganese greensand (Iron removal filter)

Manganese greensand is a purple-black filter medium coated with manganese oxide. This coating provides the greensand with special oxidation properties for removing iron, manganese, and small quantities of hydrogen sulfide. When used properly, manganese greensand can remove up to 99 percent of the iron, manganese, and hydrogen sulfide in water, although its actual removal capacities will vary depending on the characteristics of each compound.

Many equipment designs are available for manganese greensand systems, yet almost all rely on a bed of greensand (a minimum bed depth of 24-30 inches is recommended) in a pressure filter. Placing greensand in a pressure filter preserves the well pump pressure and allows one filter to be backwashed using pressurized water from the remaining filters. Backwashing is necessary to remove solid particles from the filter and regenerate the greensand. For water having low levels of dissolved oxygen, greensand is regenerated using potassium permanganate, which also adds a fresh coating of manganese oxide to the medium surface and improves its capacity to remove iron and manganese.

Potassium permanganate is a strong oxidizing chemical. Concentrated potassium permanganate is purple, poisonous, and a skin irritant that should be stored in its original container away from children and animals. Unlike chlorine, there should be no excess potassium permanganate in the treated water (a faint pink tinge is evident if potassium permanganate is present in the water). Hence careful calibration, maintenance, and monitoring of equipment are required. Potassium permanganate is sensitive to temperature extremes and performs best between 50 and 72 degrees Fahrenheit (the temperature of well water is approximately 55 degrees Fahrenheit). It is best used when the water pH is above 6.0 and below 8.0 and ideally when the pH is between 6.2 and 6.8. Raw water with a naturally lower pH should be adjusted to a minimum pH of 6.2 before treatment with manganese greensand.

There are two standard processes in which manganese greensand is used to remove iron and manganese from drinking water: intermittent regeneration (IR) and continuous regeneration (CR). The majority of home installations use the IR method, which is recommended for water supplies that require manganese removal, with or without the presence of iron. The IR process works equally well for both dissolved and insoluble iron, although it is limited to water with a maximum combined iron-manganese concentration of 10-15 mg/l and a maximum sulfide concentration of 2-5 mg/l. If the water contains appreciable amounts of iron, chlorine injection or aeration should be included as a preoxidation step in the treatment process. The advantages of IR include longer runs, lower operating pressure drops, and less backwash waste products because the manganese is deposited directly on the grains.

The CR method involves the oxidation of iron and manganese to solid particles, followed by filtration using manganese greensand or a manganese greensand and anthracite bed. The CR method is generally used when iron predominates in concentrations up to 15 mg/l or more and only small amounts of manganese are present. Thus it is not applicable for treating water in which removal of manganese is the main objective. The CR process involves feeding a predetermined amount of oxidant (chlorine is recommended) or combination of oxidants (such as potassium permanganate and chlorine) to the raw water before contact with the manganese greensand bed. This prechlorination step will oxidize the bulk of iron as well as any sulfides, which will be filtered by the manganese greensand bed and must be removed at regular intervals through backwashing. The potassium permanganate will complete the oxidation of trace amounts of iron and soluble manganese, but the medium must remain in a continually regenerated form at all times. This is accomplished by a visual check for the faint pink tinge in the filter influent or the presence of chlorine in the effluent.

Catalytic carbon

Catalytic carbon is a relatively new treatment technology that converts soluble iron to insoluble iron in the presence of dissolved oxygen. Essentially, catalytic carbon is activated carbon with a modified carbon surface that promotes oxidation on contact. This makes pretreating water for filtration less complicated. Iron removal becomes a one-step process, compared to the three steps of adding oxidants, adjusting pH, and filtering. Oxidation occurs at the point of contact with the filter medium rather than by adding a chemical such as chlorine or potassium permanganate. After oxidation, iron particles will settle out of the water and be mechanically filtered by activated carbon. Catalytic carbon is generally not recommended for water with soluble (ferrous) iron levels greater than 1.0 mg/l.

Summary

Iron and manganese are common household water contaminants with no known direct health effects at levels found in household water supplies. Their presence in water results in staining of plumbing fixtures as well as offensive tastes and odors. Treatment of these minerals depends on the form in which they occur in the raw water. Therefore, accurate testing of the water supply is important before selecting treatment options.

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FACT SHEET 6
JANUARY 1999 (UPDATED NOVEMBER 2005)

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This publication is issued to further Cooperative Extension work mandated by acts of Congress of May 8 and June 30, 1914. It was produced with the cooperation of the U.S. Department of Agriculture; Cornell Cooperative Extension; and the College of Agriculture and Life Sciences, the College of Human Ecology, and the College of Veterinary Medicine at Cornell University. Cornell Cooperative Extension provides equal program and employment opportunities. Helene R. Dillard, Director

329FS6 86/200 Rev. 1/99 1M MTS80064

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