

Iron and Iron Bacterial Problems in Montana Groundwater

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The Nature of the Problem

"We've got good, soft well water but terrible iron. It covers everything - the clothes, the sink, even the toilet. I'd sure like to have a better well!"

"That iron is ruining the house! I'm sick of driving 10 miles to town just to do wash. Either we get a better well, or else it's back to hauling water."

Sound familiar? For many Montanans, iron-rich well water has been part of the rural lifestyle for years. Symptoms of an iron-rich groundwater supply are easily visible in eastern Montana households and towns. In addition to fouling and discoloring clothes, plumbing fixtures, dishwashers, dishes and house siding, solid iron deposits like iron hydroxide can, over a period of years, plug house plumbing and even water wells. Iron bacterial accumulations occur in a large percentage of wells with high iron in eastern and central Montana.

These bacteria are not the cause of high iron concentrations but thrive in iron-rich groundwater,

aggravating problems. Montana landowners are frequently faced with iron bacterial infestations they cannot recognize or treat until it's too late.

Montana residents adapt to many aspects of groundwater chemistry, including high hardness levels, total dissolved solids, sodium and sulfate. High iron levels, however, are extremely difficult to adapt to. While of strictly aesthetic, rather than health concern, the annual economic damage by iron and iron bacteria in groundwater can be counted in the tens of thousands of dollars. Aesthetic losses, in terms of fouled laundry, stained porcelain fixtures, household siding and similar situations, cannot be readily assessed. In most cases, the problem can be successfully treated and controlled. This publication will attempt to answer such often-asked questions as:

- *How serious is this iron problem?
- *Will drilling a new well solve the problem?
- *Is water treatment to remove iron practical?
- *Do iron bacteria make the water unfit to drink?

Chemistry of Iron in Groundwater

Iron and manganese are common constituents of many different types of rocks and sediments, some of which are aquifers. Groundwater tends to develop chemical characteristics that reflect the chemical composition of the aquifer. This is especially true if the aquifer is rich in easily soluble salts or minerals. Many types of rocks in Montana contain iron - rich minerals, including sandstone, shales, some coal beds, igneous rocks like granite, and volcanic rocks, such as basalt.

A mineral source of iron and manganese is not the only prerequisite for having iron in groundwater reach high levels. The chemical environment within the aquifer, primarily the oxidation level and pH,

strongly influence iron concentrations. Common minerals that control iron concentrations include iron carbonate (siderite), iron sulfide (greigite, pyrite), and iron oxide or hydroxide (hematite, amorphous iron hydroxide). Most groundwater is low in dissolved oxygen and of near-neutral pH. Under these conditions and in the presence of soluble iron minerals, dissolved ferrous (reduced iron) concentrations can rise to high values of 5 milligrams per liter (mg/L, or parts per million, ppm). For comparison, water with values above about 0.3 mg/L (the recommended EPA secondary drinking water limit) contains just enough iron to begin to cause fouling

problems with normal use. Dissolved iron concentrations of more than 0.3 mg/L, therefore, could be termed high. Concentrations greater than 3.0 mg/L would cause noticeable fouling. Such water could be termed very high in iron.

Iron entering a water well at high concentrations is in the reduced state: dissolved, colorless and invisible. When water is pumped from a well into cistern, sinks, toilets, lawn sprinklers or laundries, it enters an oxygen-rich environment very different from that within the aquifer, and the ferrous (reduced) iron is rapidly oxidized to ferric iron. The solubility of ferric iron is extremely low (less than 0.2 mg/L) under neutral (7.0) pH

conditions. When oxidized, however, it rapidly precipitates from solution as a fine, yellow- or red-brown hydroxide deposit. In standing water, this precipitate will settle form suspension and accumulate at the bottom. Hydroxides attach and bond firmly to porcelain, pipes, faucets, water heater tanks, siding and many other surfaces. Precipitation is usually rapid, just a few hours. Oxidizing agents, such as chlorine, permanganate, oxygen gas and air, accelerate the precipitation process.

Manganese is a common trace metal in iron-rich minerals because its chemical nature is similar to that of iron. Manganese can occur in the reduced state up to concentrations

Table 1. Categories of susceptibility to high iron concentrations in some common Montana aquifers

Categories	Susceptibility to iron problems	Aquifer (Geologic age, million
A	High	Glacial aquifers (Pleistocene, 0.01-2) Alluvial aquifers (Cenozoic, 0-63)
B	Moderate	Fort Union formation (Tertiary, 2-63) Judith River formation (Cretaceous, 63-138) Eagle formation (Cretaceous, 63-138) Kootneai formation (Cretaceous, 63-138)
C	Low	Hell Creek formation (Cretaceous, 63-138) Fox Hills formation (Cretaceous, 63-138) Swift formation (Jurassic, 138-205) Ellis group (Jurassic, 138-205) Amsden group (Mississippian, 330-360) Big Snowy group (Mississippian, 330-360) Madison group (Mississippian, 330-360)

Figure 1. Dissolved iron concentrations in Montana groundwater. Large circles indicate samples with very high iron (3.0 mg/L or more); small circles have high iron (0.3 mg/L or more), the EPA secondary limit. Source: *Ground Water Information Center*

DISSOLVED IRON IN MONTANA GROUNDWATER

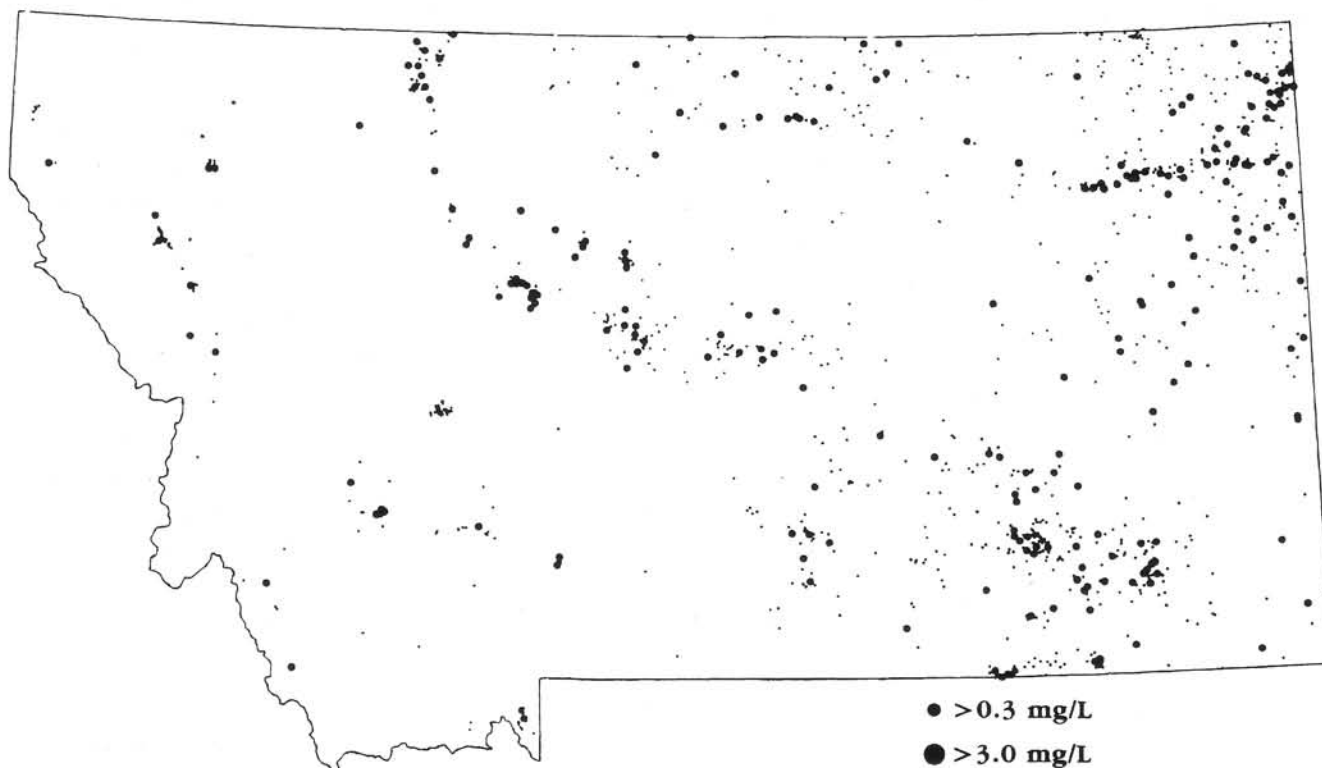
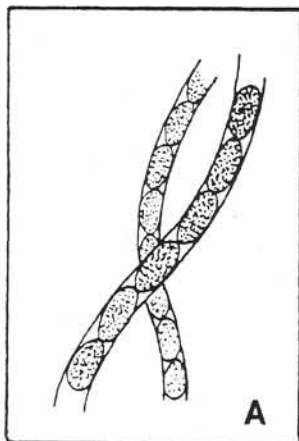
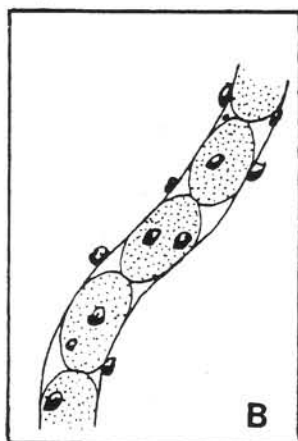


Figure 2. Morphological sketches of four common genera of iron bacteria found in water wells. *Sphaerotilus* (A), *Leptothrix* (B), and *Crenothrix* (C) are filamentous, sheathed forms; *Gallionella* (D) is a stalked form, marked by its characteristic bean-shaped cell.

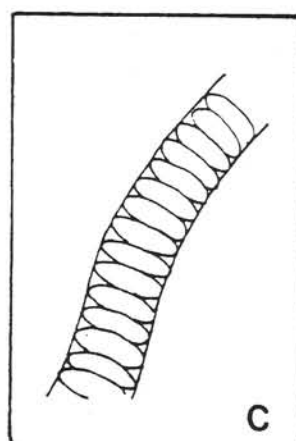
Sphaerotilus



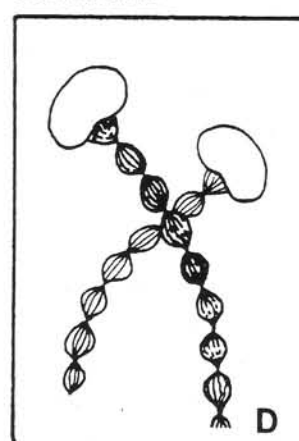
Leptothrix



Crenothrix



Gallionella



greater than 1 mg/L in unoxidized water of near-neutral pH. When oxidized, it forms a black precipitate. Manganese occurs at generally lower concentrations than iron and slowly precipitates as an oxide. The EPA secondary drinking water limit for manganese is 0.05 mg/L, for aesthetic reasons similar to iron. A very high value for manganese in groundwater would be >0.5 mg/L. Well water with high levels of iron will commonly, but not always, exhibit high levels of manganese. Manganese is more difficult to remove by water treatment because it is oxidized more slowly.

Some formations in Montana that are especially iron-rich include sandstone of Cretaceous (Eagle, Judith River and Kootenai formations) and Tertiary (Fort Union formation) age found extensively on the Montana Great Plains and volcanic deposits primarily in the mountainous portions of Montana. Physical erosion by glaciers and rivers breaks up bedrock materials, making them more susceptible to chemical dissolution. For this reason, alluvial and glacial sediments derived from iron-rich bedrock formations contain aquifers with some of the highest iron concentrations in Montana.

Based on statewide water chemistry data, a simple classification (Table 1) describes aquifer susceptibility to iron problems. Glacial and alluvial aquifers (Category A) are highly

susceptible to iron problems over many areas of the state. Much older and often deeper bedrock aquifers, such as the Madison group, Fox Hills formation and Hell Creek formations (Category C), are generally low in iron and offer potential for development as a low-iron water source. A number of sandstone aquifers extensively used in the Hi-Line area (Category B) can exhibit high iron but in a lower percentage of wells than for glacial and alluvial aquifers. In which category is your aquifer?

Locations of domestic and stock wells known to have very high iron (>3 mg/L; large circles) and high iron (>0.3 mg/L; small circles) are illustrated for the state (Figure 1). The problem is statewide, with major areas of concentration in the northern and northeastern parts of Montana.

Iron Bacteria: The Hidden Hazard

"Iron bacteria" is the term loosely applied to several waterborne bacteria that thrive in iron-rich groundwater. Water of at least 0.2 mg/L iron is required for their survival. Figure 2 shows the bacterial groups. Naturally occurring infestations normally include several species. All are dormant at temperatures below about 40°F; grow slowly at normal groundwater temperatures (45° to 60 ° F); and grow more rapidly at higher temperatures, up to about 150°F; above which they die.

How wells become infested

with iron bacteria is not clear. These are common surface and soil bacterial forms, which some researchers believe are introduced by drilling equipment. Bacteria thrive in the well environment, where there is a high level of oxidation, suitable substrate for growth (well casing and pump), a heat source (the pump motor), and a steady influx of fresh nutrients in the groundwater gradually entering the well. Infestations normally begin at the well intake and spread upward to the distribution system and outward to the aquifer outside the well. They are killed by ultraviolet (UV) light and, hence, are always "hidden" down deep wells and in pipes, so that they are difficult to see or detect.

The easiest way to see an iron bacterial infestation is to pull the pump of an affected well. Bacteria are red-brown (ochre) to pink and grow in layers, with a slimy sheath around the active outer surface. The color is due to incorporation of hydroxide precipitates into this sheath. They attach firmly on substrate material, and their coating of slime and hydroxide resists attack from many chemicals and disinfectants used to clean water wells. The bacteria themselves are soft and slimy, in contrast to the hard, natural iron precipitates.

Iron bacteria do not pose a health hazard but can eventually make both well water and the well itself unusable. They commonly plug the pump or

Table 2. Representative list of currently available(1987) iron-treatment equipment for residential well use. No products in this list have been tested or verified to be effective by authors; their inclusion here is only to list some typical products, for which technical information is available. No endorsement is stated or implied.

Product name	Treatment principle	Flow capacity (gpm)	Maximum iron removal capacity (mg/L)	Oxidant
MacClean	oxidation/ filtration	4-1250	-	air
Kinetico	oxidation/ filtration	3-6	10-15	Potassium Permanganate
Watersoft Provectr 1	oxidation/ filtration	3-9	20	air
Kinetico Rust-Plus	ion exchange	3-6	50	none
Aqua-Mag	sequestration	N/A	4	none
Auto-Trol Land-O-Matic	down-well chlorination	N/A	-	Calcium Hypochlorite pellets

well intake with their own mass and with incorporated iron oxide products. If natural iron concentrations are high, the plugging can be accompanied by iron cementation and encrustation. In general, the higher the iron concentration, the faster the plugging. At advanced stages of infestation, corrosive sulfate-reducing bacteria cohabit the well with iron bacteria, causing further damage to well casing and water quality from the hydrogen sulfide gas produced. This gas is easily recognized by its rotten egg odor.

An iron bacterial infestation follows a series of phases,

which can take from a few months up to several years, depending on conditions for growth. First, as the population grows, there is not visible indication of their presence except for a gradual loss in well efficiency, which lowers the pumping water level of the well. Later, the water level in the well falls to the level of the pump intake, causing it to suck air. This allows free access of oxygen to the production zone. By then, water may be strongly discolored with reddish iron hydroxide and yellow or brown organic matter, and carry foul odors. Finally, well production is reduced to much below its

original amount, and the well must either be reclaimed or abandoned. There is often little visible sign of a growing infestation until it is quite advanced, by which time remedial measures are only partly effective or are effective for only short periods. Often, when the well owner first senses that something is wrong with the well, it is too late to reclaim it.

How Common are such infestations?

Probably very common. Data from the Ground Water Information Center in Butte (GWIC) suggests that 10 percent to 30 percent of all wells in the central and eastern portions of the state have iron concentrations greater than 0.3 mg/L. Studies done in one area of Saskatchewan indicate that more than 90 percent of wells producing iron-rich water are affected by iron bacteria. These bacteria are the rule, not the exception. If your well water has high iron, your well probably supports iron bacteria.

Solving the Iron Problem: Removal and Treatment

Two distinct problems are commonly associated with iron-rich groundwater: how to remove the high iron load and how to control the iron bacteria.

Iron Removal

One approach to eliminating high iron load is to drill a new well into an iron-free aquifer. This is possible in some cases, but should only be attempted with careful planning and a good possibility of locating such a source within a reasonable drilling depth. Obtain information on other aquifers and their depth and water quality in your location from the Montana Bureau of Mines and Geology Ground Water Information Center (Montana Tech College, Butte, MT 59701). In many cases, iron-free

aquifers will be either too deep or of higher mineral content than shallower, high iron aquifers. On the other hand, some sand and gravel aquifers shallower than 100 feet have very low soluble iron.

A more realistic approach is to use water conditioning equipment to remove the iron load. This technology is both practical and affordable for residential-scale (<15 gpm) applications. Three approaches to treating iron-rich water are:

- to oxidize ferrous iron to ferric using either chemical or air oxidation, followed by removal using pressure filtration,

- to absorb ferrous iron onto an ion exchange resin in a conventional water softener, or
- to maintain ferrous iron in a soluble form using chemical additives (sequestering agents).

Most effective removal systems are of the first type, although some water softeners may handle small iron loads (<1 mg/L). For higher iron loads, use a filter system designed specifically for iron.

Iron filters for domestic water supplies oxidize iron with either chemicals or air. Chemical filters use a strong oxidant, such as potassium permanganate or chlorine, and a sand or greensand filter material. Greensand/permanganate filters can also remove manganese. Aeration filters use either a compressor or, in some recently developed systems, a passive Venturi valve to stream air into the water. Both require regular

backflushing of the filter material to remove iron oxides, much like a water softener requires regeneration with salt. Filter capacity for household units is normally insufficient for lawn irrigation, which would require a separate non-filtered line or a water storage tank. Typical system costs range from \$500-\$1,500. Some chemical and aeration units have been effective at iron concentrations in excess of 5 mg/L. Aeration-type filters are simpler to maintain and are generally adequate in removing high iron (but not manganese) loads.

Sequestering solutions are concentrated polyphosphate solutions, injected into a water line using a chemical feed pump to keep the iron in a soluble (ferrous) state, and prevent precipitation. Polyphosphate molecules bind tightly to ferrous iron and prevent oxidation. No iron is removed from the water, but the water remains clear and the iron stays suspended in solution. Different products have different solution chemistry and various intervals of effectiveness. There is some potential for nutrient loading in drain water, which could be of concern in areas adjacent to lakes and streams. There is also the risk of under- or over-application of chemicals. Antisiphon devices and check valves must normally be used to prevent concentrated feed solution from entering the well inadvertently. The major attraction of polyphosphates is low

cost: only a feed pump and a regular supply of chemicals are required. However, most vendors of polyphosphate products do not claim long-term effectiveness at iron concentrations greater than 3 mg/L. Water users with severe iron loading may, in many cases, be better off with a properly designed filter system.

Domestic-scale iron treatment may be a very good alternative if the existing well is in good working order and the quality of the water it produces is acceptable—low in total dissolved solids, hardness and nitrates. In such cases, it probably costs less to treat than to re-drill. A water quality analysis should be performed before selecting a unit. If possible, manufacturer's claims also should be verified by seeing an existing, successful installation treating water of similar quality. Table 2 gives a partial list of currently available iron treatment products, including a representative list of available market products.

Treatment and Control of Bacterial Infestations

Treating to remove iron will make water supplies more usable but will not affect bacterial populations in the well.

Detecting bacteria early is difficult. To be safe, assume that if your iron concentration is greater than 0.5 mg/L, your well is inhabited by iron bacteria. Signs of bacterial trouble include a change in color of well water from time to time, a

decrease in the pumping water level depth, or visual observation of slimes on pump or riser pipe or in household fixtures.

Regular well disinfections is the best preventative measure. Seriously plugged wells will generally need to be serviced by a water well contractor experienced in well rehabilitation. However, preventative disinfection is simple and can be done by many homeowners. For wells that are not badly plugged, disinfection can prevent further well deterioration. Regularly, one of two times a year, depending on iron level, bacteria-prone wells should be disinfected with a concentrated chlorine solution. First, the volume of water and chemicals required must be calculated by subtracting the non-pumping (static) water level in the well from the well depth. For a 6-inch diameter well, a quart of common laundry bleach and 30 gallons of water per 20 feet of water height should be added to the well, introduced through a rubber hose to the bottom of the well, if possible. For a 4-inch well, divide these amounts by 2.

The well should then be surged vigorously for 15-30 minutes by starting and stopping the pump intermittently. If there is no check valve on the pump, do not start and stop the pump too frequently or the pump could be damaged. Pumped water should be recirculated down the casing. Following surging, more clean

water (the same volume as before) should be added and the well allowed to stand without pumping for 12-24 hours. Then the disinfected well should be pumped to waste, by surging again, until the water is clear and the chlorine smell is gone. At least three times the volume of water added to the well should be pumped out, to make sure all chlorine is removed. This waste water should not be pumped onto a lawn or garden, or back into a cistern or pressure tank; it will be undrinkable and can kill grass. This entire procedure can be completed by individuals who feel knowledgeable working around well equipment, or by a pump or well service contractor.

This chlorination procedure should control, if not eliminate, the bacteria in a well. However, they will return; experience shows that a few bacteria outside the well bore survive even the most intensive disinfection. The key to control of iron bacteria is regular well disinfection and removal of iron and organic products. The cost of domestic well replacement is often comparable to and, in some cases, less than rehabilitation of a severely plugged well. Preventive disinfection is often the well-owner's only weapon against iron bacteria.

Another preventative technique is to frequently drop HTH (calcium hypochlorine) pellets to the bottom of the well. One commercially available device, the "Land-O-Matic" is a well-

head-mounted HTH pellet deliverer, designed for automatically timed regular well chlorination. Such low-level chlorination does not restrict growth of bacteria outside the well bore but may help restrict the growth somewhat in the well. It is not a substitute for periodic shock-chlorination as previously described.

Summary

Iron and iron bacterial problems are extensive in much of Montana groundwater but, if recognized early and treated, can be effectively controlled. For general information on your well installation or on any of the techniques described here, contact the Montana Bureau of Mines and Geology in Butte or Billings. For special problems

in iron removal or well rehabilitation, it is, in most cases, best to work with an experienced professional in the water conditioning or well water industry. Names of licensed professionals in these fields are available from the Department of Natural Resources and Conservation in Helena (Board of Water Well Contractors).

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