Division of Drinking and Ground Waters
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Ohio Environmental Protection Agency

Explaining Common Well Water Conditions

Oxidation and Reduction Processes in Ohio's Ground Water

Do rust stains form on your sink and toilet bowl? Has your water ever smelled like rotten eggs? Have you ever tested your water and noticed high concentrations of nitrate, iron, or arsenic? If so, reduction and oxidation (redox) processes are playing an important role in the quality of your water.

What does "reduction" and "oxidation" (redox) mean?

In the simplest terms, water that interacts with the atmosphere is oxidized and water that is isolated from the atmosphere is reduced. The redox state of your drinking water can affect the quality of your water in terms of taste, smell or health concerns. Understanding redox and how it affects water quality can help a homeowner make more educated choices.

The depth of a well has a lot to do with the redox conditions of the water. Figure 1 shows that shallower ground water contains oxygen because of contact with the atmosphere. The area between the ground surface and the water table is porous, and changes in atmospheric pressure drive the air into and through the pore space and down to the water table. The oxygen in the atmosphere is exchanged into the ground water, just like oxygen is exchanged into rivers and streams. Oxidized ground water is indicated by the presence of dissolved oxygen and/or nitrate (NO3). The depth of wells with nitrate varies depending on site-specific factors like the depth to the water table, but typically, wells deeper than 70-75 feet do not have nitrate.

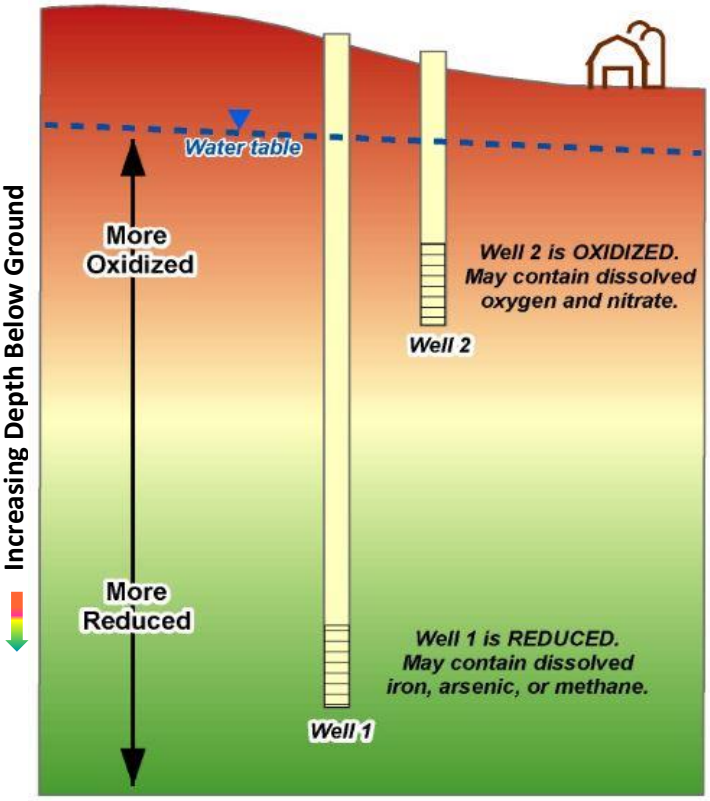

Figure 1. Redox conditions and the resulting ground water chemistry are controlled by the depth of the well and isolation from the atmosphere.

The deeper the well, the less contact the ground water has with the atmosphere. Oxygen-loving microbes and various chemical reactions consume the dissolved oxygen, making the water reduced. Once the dissolved oxygen is gone, the microbes break down other compounds containing oxygen, such as nitrate (NO3), iron oxides and sulfate (SO4) to gain energy for their growth. These processes result in higher dissolved iron and arsenic in deeper wells than in shallow wells, and virtually no nitrate in deeper ground water.

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Why are there iron stains on my sink?

Water that has high iron (above 300 parts per billion) can stain your laundry, sinks, bathtubs or toilets (Figures 2 and 3). To address this, as well as the bitter metallic taste, the U.S. Environmental Protection Agency (U.S. EPA) has established a secondary maximum contaminant level for iron at 300 parts per billion (ppb). When reduced water flows out of the faucet, it interacts with the atmosphere. The water becomes oxidized (oxygen is exchanged with the atmosphere), triggering iron oxides to form, which can cause rust stains. The iron that is dissolved in deep (reduced) ground water is generally naturally occurring.

Figure 2. Sink discolored from high iron content in the water.

Should I be concerned if my water has high iron?

We need iron in our daily diet to transport oxygen through our blood. High iron in drinking water usually does not present a health concern, but it can create mechanical or production problems. The presence of dissolved iron in a well may promote iron bacteria growth under certain conditions, causing clogging of well screens and pipes. Iron bacteria are not a health concern, but they are slime formers, producing red or grey cloudy water with unpleasant tastes and odors.

Reduced waters with elevated iron are more likely to contain arsenic than shallow, oxidized ground water. Approximately 30 percent of wells with elevated iron also contain arsenic. U.S. EPA has set a standard of 10 ppb for arsenic in public drinking water wells. The Ohio Department of Health has adopted this threshold as a health-based standard for private water systems that serve homes and smaller facilities not served by public water. Health-based standards for private water systems provide guidance to a well owner on the possible health effects of consuming the water. Arsenic is toxic at very high levels.

Figure 3. Water pipe that has rusted due to oxidation processes.

What can be done about high iron (and arsenic) in my water?

Iron can be removed with a water softener, but if your water is already discolored indicating high dissolved iron, it will plug up quickly. Special iron filters or chemical oxidants are recommended. Iron filters may also remove arsenic. In some cases, the water will need to be oxidized to effectively remove arsenic. Contact your local health department for more information.

If your well has a lot of iron bacteria, it needs to be cleaned using chemical and/or mechanical methods. The most common treatment is shock chlorination, but slime producing iron bacteria are difficult to remove and you may need to contact a licensed well driller or pump installer.

What causes the "rotten egg" smell?

If you smell something like a rotten egg when you turn on your water, this means that your water has high levels of dissolved sulfur, in the form of hydrogen sulfide. Hydrogen sulfide (H2S) is formed when sulfate is reduced deep in the ground water.

Once the dissolved hydrogen sulfide leaves your tap, the oxygen in the atmosphere starts oxidizing the H2S to form sulfates, a more oxidized form than sulfides. Sulfates do not have the same odor. Hydrogen sulfide is a toxic and flammable gas, but the unpleasant odor is obvious long before it reaches harmful concentrations. Odor is not always a reliable indicator because olfactory fatigue occurs at high concentrations and long exposure to low concentrations. Consult a hydrogen sulfide material safety data sheet (MSDS) for safety information. The standard treatment method to remove H2S from water involves oxidation to change the hydrogen disulfide to sulfate and then filtering to remove the sulfate precipitate.

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My well is shallow (oxidized) and I have no problems with iron staining or smelly water. Why should I be concerned with redox?

Oxidized waters in shallow wells (less than 50-70 feet) are a concern mainly because they are in direct contact with the surface. Local sources (septic systems, manure, agricultural, chemical and residential fertilizers) can increase nitrate in an oxidized environment. U.S. EPA has set a standard of 10 ppm (parts per million) for nitrate in public drinking water wells, and the Ohio Department of Health has adopted this threshold as a health-based standard for private water systems. Other land uses, such as manufacturing, waste disposal and deicers (salt), have the potential to impact local ground water.

As a homeowner, we encourage you to learn about things that can be done around your home to help protect your drinking water resources. These include:

- limit the use of pesticides, fertilizers and other lawn chemicals;
- do not pour chemicals down the drain;
- dispose of unwanted chemicals at local hazardous waste recycling events;
- recycle used motor oil and antifreeze;
- clean up animal waste; and have septic systems inspected regularly.

I've tested my well, but I don't understand the results. What do all these numbers mean, and should I be concerned about anything? Is my water oxidized or reduced?

The Ohio State University (OSU) Extension Office has created a website to help drinking water well owners understand their lab test results. Visit "Know Your Well Water" at ***ohiowatersheds.osu.edu/know-your-well-water*** and click on the "Well Water Interpretation Tool" link to enter your results. This site will not indicate the redox conditions, but if you have elevated iron, manganese or arsenic (based on Secondary Maximum Contaminant Levels, 300 ppb for iron and 50 ppb for manganese), your water is most likely reduced. The presence of nitrate indicates an oxidized environment.

For more information

For more information about ground water quality, contact the Ohio Environmental Protection Agency, Division of Drinking and Ground Waters at (614) 644-2752, or visit ***epa.ohio.gov/ddagw***. A technical report that discusses the microbial mediated reactions that control redox conditions is available at ***epa.ohio.gov/ddagw/gwqcp***. More information about private water wells, including testing and treatment, is available through the Ohio Department of Health's Private Water Systems Program webpage - ***odh.ohio.gov/wps/portal/gov/odh/know-our-programs/private-water-systems-program/private-water-systems-program***.

This fact sheet is part of a series discussing the water quality of Ohio's aquifers. A companion report, available online at ***epa.ohio.gov/ddagw/gwqcp***, describes the redox conditions in Ohio's ground water in more detail.