Minnesota Pollution Control Agency

Environmental Outcomes Division

Ground Water Monitoring & Assessment Program

Sulfate in Minnesota's Ground Water

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What is sulfate?

Sulfate is a chemical commonly found in air, soil and water. Since it is soluble (easily dissolved) in water, sulfate is found at high concentrations in many aquifers and in surface water. Combustion of fossil fuels releases large quantities of sulfur to the atmosphere. Sulfur in the atmosphere is oxidized to sulfate and eventually deposited with precipitation or through dry deposition. Because sulfate occurs as a dissolved ion, it is mobile in ground water.

What are sources of sulfate in ground water?

Sulfur occurs in a variety of oxidation states that affect its behavior in the environment. Sulfate is an oxidized form of sulfur. There are many potential sources of sulfate. Gypsum is an important source in many aquifers having high concentrations of sulfate. Reduced forms of sulfur are oxidized to sulfate in the presence of oxygen. This process often occurs when sulfide minerals are mined. In the past century, atmospheric fallout has become an important source of sulfate to soils and, eventually, to ground water. Other sources of sulfur include decomposition of organic matter (which is about 0.1 percent sulfur), fertilizers and natural sources, such as volcanoes. Since sulfate is mobile in soil, inputs to soil will impact shallow ground water.

What is considered a safe level of sulfate in ground water?

Sulfate does not have a health-based drinking water standard. There is a maximum contaminant level (MCL) of 500 mg/L (parts per million). Sulfate has laxative effects and imparts an unpleasant taste to water. Aquifers with high concentrations of hydrogen sulfide have a bad odor. The Minnesota Department of Health (MDH) recommends a limit of 400 mg/L for water used in infant formula (see the MDH fact sheet *Sulfate in Well Water*).

How is sulfate distributed in Minnesota ground water?

The MCL for sulfate was exceeded in 73 of the wells sampled from the Ground Water Monitoring and Assessment Program (GWMAP) statewide baseline network of 954 wells. The median concentration, however, was only 19 mg/L.

The distribution of sulfate in aquifers varies throughout the state. There were 41 and 17 exceedances of the MCL in buried Quaternary and Cretaceous

Minnesota Pollution Control Agency, 520 Lafayette Rd. N., Saint Paul, MN 55155-4194
(651) 296-6300, toll-free (800) 657-3864, TTY (651) 282-5332 or (800) 657-3864
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aquifers, respectively. This compares to one exceedance in surficial water table aquifers and no exceedances in Paleozoic bedrock aquifers (Prairie du Chien, Jordan, Galena, St. Peter, Mt. Simon and Franconia aquifers). Median concentrations in most aquifers were less than 25 mg/L, except for the Cretaceous aquifers, which had a median concentration of 420 mg/L.

Which aquifers are most sensitive to contamination with sulfate?

Aquifers in a variety of hydrologic settings can be sensitive to contamination with sulfate. High concentrations occur in shallow, unconfined aquifers that receive large inputs of sulfate from atmospheric deposition, fertilizer use and land application of animal wastes. These sources, however, should not result in concentrations exceeding the MCL. Aquifers underlying soils rich in gypsum have high concentrations of sulfate, often in excess of the MCL. Most soils containing sufficient gypsum to exceed the MCL in ground water are located in western Minnesota. Cretaceous aquifers contain large quantities of sulfate because of high concentrations in geologic materials comprising the aquifers. These aquifers have concentrations close to or exceeding the MCL. Locally, high concentrations occur from the decomposition of organic matter (as in wetlands, for example), oxidation of sulfur-bearing minerals (mining pits, for example) and industrial deposition (coal-burning power plants, for example).

Why is it important to measure sulfate concentrations in ground water?

Sulfate, an important ion in ground water, is used to ensure adequate quality control for ground water samples and laboratory analysis. It is useful for identifying different sources of water. Aquifers with a naturally occurring sulfate source, such as gypsum, will have very high concentrations of sulfate compared to other aquifers. Sulfate concentrations in ground water are therefore useful for programs such as Wellhead Protection, where it important to understand the source of ground water. Sulfate is also useful for understanding oxidation-reduction conditions in ground water and, therefore, for predicting the fate of contaminants, such as industrial solvents.

What are some management strategies for reducing risks from sulfate?

Proper waste management and fertilizer application, maintenance of wetlands and mining of low-sulfur minerals are management strategies for reducing anthropogenic (human) inputs of sulfate to ground water. Ground water impacts from anthropogenic sources of sulfate, however, are typically much smaller than from natural sources.

Reverse osmosis, distillation, and ion exchange are three treatment methods for removing sulfate from drinking water. These are discussed in the MDH fact sheet *Sulfate in Well Water*.

Additional information, including reports and distribution maps, can be found on the Minnesota Pollution Control Agency's Web site at ***http://www.pca.state.mn.us/water/groundwater/gwmap/index.html***.