2007

Groundwater Quality in Kentucky: Manganese

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Introduction

Manganese is a common constituent of Kentucky rocks and soils and, along with iron, is one of the most widespread causes of problems in groundwater supplies. Rainwater seeping through soils and bedrock dissolves manganese and carries it in the groundwater system to wells and springs. In deep, slow-moving systems that lack oxygen, manganese remains in solution. Under oxidizing conditions, however, such as in shallow groundwater systems or where the water is exposed to air, manganese combines with oxygen to form black particles that can clog plumbing fixtures and stain containers and clothing.

In addition to occurring naturally, manganese is released by coal combustion. It also is a component of some pesticides and can enter the groundwater system as a result of over-application of those pesticides. Manganese in drinking water is not considered a health threat; in fact, small amounts of manganese are essential to human health. Excessive amounts of manganese can affect the flavor and color of food and water, however (National Drinking Water Clearinghouse, West Virginia University, 1998). Manganese is considered a secondary or aesthetic contaminant in water because of its clogging and staining properties. For these reasons, the U.S. Environmental Protection Agency (2003) has set a secondary maximum contaminant level for manganese of 0.05 mg/L (or the equivalent parts per million).

Manganese Concentrations in Groundwater

Data Sources

Results of manganese analyses used in this report were compiled from the Kentucky Groundwater Data Repository, maintained by the Kentucky Geological Survey. The repository was established in 1990 to archive and disseminate groundwater data collected by various agencies in Kentucky. Major data sources for the repository include the Kentucky Division of Water, the Kentucky Geological Survey, the U.S. Geological Survey, the National Uranium Resource Evaluation Program, and the U.S. Environmental Protection Agency.

The database contained 20,657 analyses of manganese from 6,190 wells and 1,391 springs throughout Kentucky as of November 2004. Of the analyses, 6,349 were identified as total manganese (unfiltered groundwater), 8,223 were identified as dissolved manganese (filtered groundwater), and the rest were unspecified. Analytical results for groundwater samples collected from known or suspected contaminated sites, identified by regulatory program names such as the Resource Conservation and Recovery Act, Solid Waste, and Underground Storage Tank programs, were not included in this report because they are not representative of regional groundwater quality. Samples from wells deeper than 1,000 ft were excluded because such deep wells are not likely to be used for domestic or industrial water supplies.

Variations in Manganese Concentrations

Manganese concentrations of several hundred mg/L have been reported. The maximum manganese concentration in each of Kentucky's geologic regions far exceeds the cosmetic and aesthetic level of 0.05 mg/L. Even the median manganese concentration exceeds 0.05 mg/L in all regions except the Inner Bluegrass and the Jackson Purchase (Table 1). In the Eastern Kentucky Coal Field, Eastern Pennyroyal, Outer Bluegrass, Knobs, and Western Kentucky Coal Field Regions, more than two-thirds of the sampled sites produced water with greater than 0.05 mg/L manganese. Approximately 50 percent of all recorded manganese concentrations were greater than 0.05 mg/L (Fig. 1).

Table 1. Summary of manganese concentrations.

Region	No. of Measurements	25th Percentile Value (mg/L)	Median Value (mg/L)	75th Percentile value (mg/L)	No. of Sites	Percent of Sites > 0.05 mg/L
Eastern Ky. Coal Field	8,690	0.03	0.113	0.44	2,808	71
Eastern Pennyroyal	948	0.011	0.06	0.131	621	72
Inner Bluegrass	830	0.003	0.015	0.06	219	47
Outer Bluegrass	1,570	0.006	0.07	0.69	564	75
Knobs	526	0.009	0.075	0.22	257	66
Western Pennyroyal	3,575	0.01	0.095	0.55	1,359	47
Western Ky. Coal Field	1,968	0.037	0.148	0.55	1,022	77
Jackson Purchase	2,550	0.004	0.013	0.05	731	40

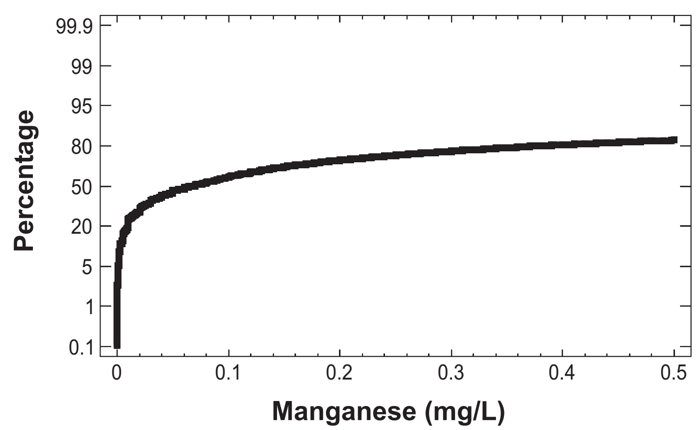

Figure 1. Cumulative plot of reported manganese concentrations. Values range as high as 540 mg/L. Values greater than 0.5 mg/L were excluded from this graph to better show the region of interest.

The map shows the locations of wells and springs where manganese in groundwater has been measured, with different symbols to indicate concentration ranges. Sites that have been sampled more than once may have more than one symbol, and sites that are near each other may have superimposed or overlapping symbols. The density of sampled sites is greater below approximately 38°N latitude because the extensive sampling for the National Uranium Resources Evaluation Program did not extend north of this line.

The Eastern Kentucky Coal Field, Eastern Pennyroyal, Outer Bluegrass, and Western Kentucky Coal Field Regions have the highest percentage of sites where the SMCL is exceeded, whereas the Inner Bluegrass, Western Pennyroyal, and Jackson Purchase Regions have the lowest percentage of such sites.

Figure 2 summarizes total manganese (measured from unfiltered water) and dissolved manganese (measured from filtered water) concentrations. In this plot, boxes enclose the central 50 percent of the values, from the 25th percentile value to the 75th percentile value. The median value is shown by a vertical line through the box. Lines extend from each edge of the box for a distance of 1.5 times the concentration range represented by the central box. Extreme values are shown as individual squares. Total manganese concentrations have a higher median value, higher 75th percentile value, and larger range of values in the central 50 percent of the reported concentrations than dissolved manganese. This comparison shows that unfiltered groundwater typically has a higher manganese concentration than filtered water; therefore, suspended particulate manganese is commonly present.

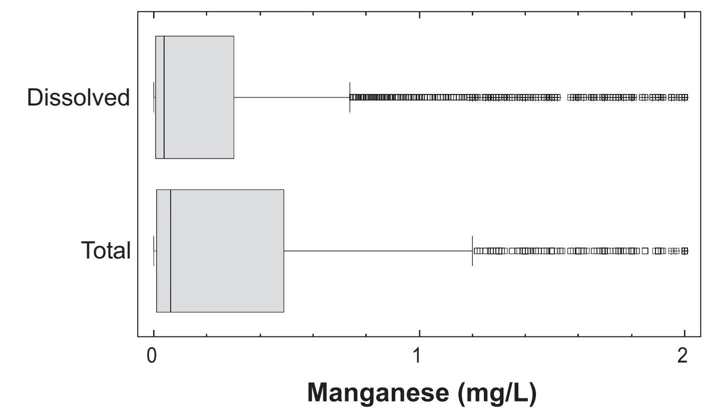

Figure 2. Comparison of dissolved (filtered sample) and total (unfiltered sample) manganese concentrations. Values greater than 2.0 mg/L were excluded to better show the region of interest.

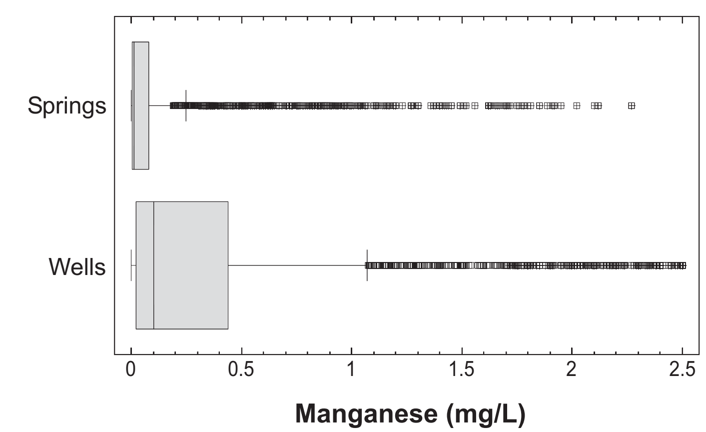

Figure 3. Comparison of manganese concentrations in water from springs versus wells. Values greater than 2.5 mg/L were excluded from this graph to better show the region of interest.

A similar plot compares manganese concentrations in water from wells with that of water from springs (Fig. 3). The median value and the range of concentrations in spring water are less than the median value and concentration range in well water. This is probably because water from springs generally has a higher oxygen content than well water, so manganese is likely to precipitate out of spring water before it reaches the sampling site. Many of the springs may also be located in limestone terrain where bedrock and soils contain less manganese than in regions where sandstones and shales are more common and springs are less abundant.

With two exceptions, the highest manganese concentrations were observed in wells that were less than 100 ft deep (Fig. 4). The high concentrations observed in some of the shallow wells probably represent nonequilibrium conditions because of the short residence time of groundwater in shallow flow systems. Given sufficient time, dissolved manganese should precipitate out and reduce concentrations to the range of values seen in the deeper wells.

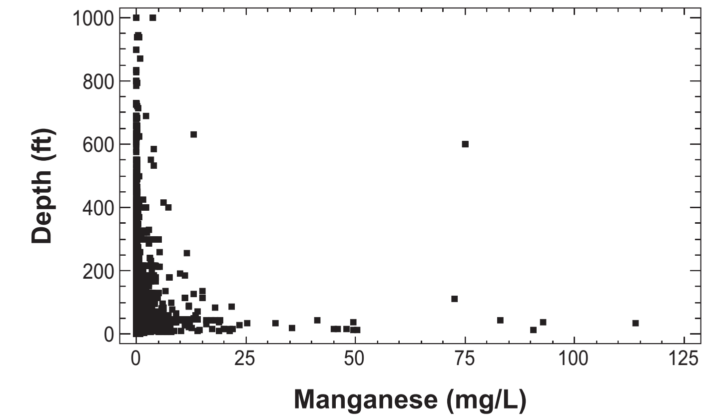

Figure 4. Plot of manganese concentrations versus well depth.

Water-Quality Concerns

Manganese in Kentucky groundwater commonly exceeds the SMCL of 0.05 mg/L. Manganese is present to some degree in all of Kentucky's bedrock types, and so in all the physiographic regions. Therefore, sites where manganese exceeds the SMCL are spread across the state, and pipe-clogging as well as clothing-staining is a common problem unless manganese is removed from water by some treatment process.

Various treatment options, including aeration, filtration, water softening, use of ion exchangers, ozonation, and chlorination are available to reduce manganese in groundwater supplies (Department of Public Health, Washington County, Minnesota, 2005). Citizens who have high manganese concentrations in their water supplies can consult with water-treatment companies to determine which method might work best in their particular situation.

These findings should be viewed as general patterns. Individual wells or springs should be tested for the occurrence of manganese and other potential contaminants before being used as drinking-water supplies. Citizens with concerns about the quality of water in private wells or springs should contact their local health department or the Groundwater Branch of the Kentucky Division of Water, a division of the Kentucky Natural Resources and Environmental Protection Cabinet. The Groundwater Branch can provide literature on maintaining private wells and springs and information on sampling for water-quality analysis. The Kentucky Groundwater Data Repository receives new results of analyses periodically. To view the latest data, visit kgsweb.uky.edu/DataSearching/watersearch.asp.

The Kentucky Interagency Groundwater Monitoring Network

This publication is a product of the Kentucky Interagency Groundwater Monitoring Network, which was established in 1998 by legislation (KRS 161.625) to collect groundwater quality data, characterize groundwater resources, and distribute the resulting information. The network is assisted by an Interagency Technical Advisory Committee on Groundwater, which was also created by statute (KRS 151.629). Additional information and a list of member agencies can be found at www.uky.edu/KGS/water/gnet/gnet.htm.

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ISSN 0075-5583

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INFORMATION CIRCULAR 14
SERIES XII, 2007

https://doi.org/10.13023/kgs.ic14.12

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Information Circular 14
Series XII, 2007
https://doi.org/10.13023/kgs.ic14.12

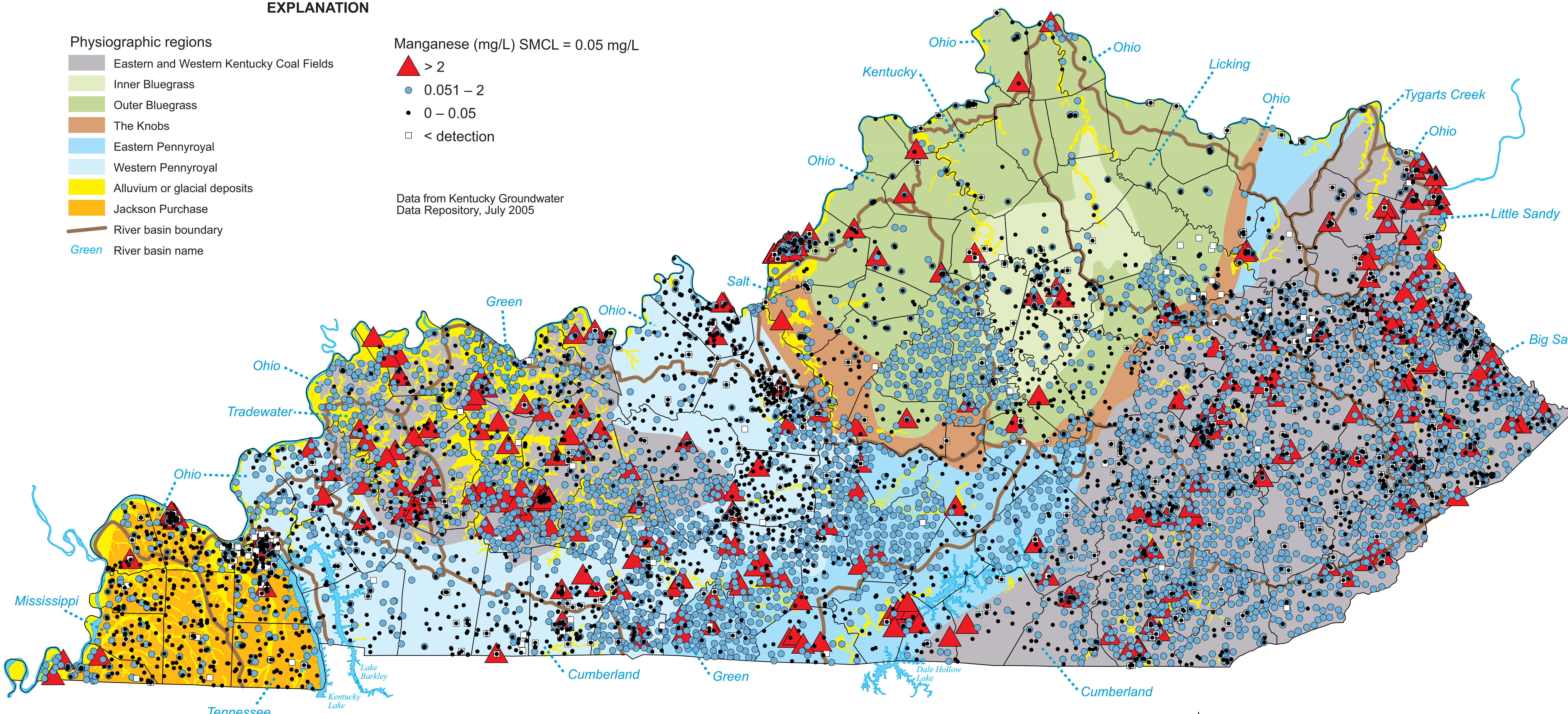
MANGANESE CONCENTRATIONS IN WELLS AND SPRINGS IN KENTUCKY

EXPLANATION

Physiographic regions
- Eastern and Western Kentucky Coal Fields
- Inner Bluegrass
- Outer Bluegrass
- The Knobs
- Eastern Pennyroyal
- Western Pennyroyal
- Alluvium or glacial deposits
- Jackson Purchase
- River basin boundary
- *Green* River basin name

Manganese (mg/L) SMCL = 0.05 mg/L
- > 2
- 0.051 – 2
- 0 – 0.05
- < detection

Data from Kentucky Groundwater Data Repository, July 2005



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Cartography by Terry Hounshell