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Groundwater Quality in Kentucky: Barium

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Introduction

Barium is a silver-white alkaline earth metal that is not found free in nature because it is highly reactive with sulfate and carbonate. Barium compounds can be naturally occurring or man-made. The most common natural occurrence of barium is in the mineral barite (barium sulfate), which has many uses in industry, such as a filler in the making of rubber, plastic and resin, white pigment, drilling lubricants used in the oil and gas industry, paint, bricks and glass (Agency for Toxic Substances and Disease Registry, 2004). Barium sulfate is very slightly soluble in water and absorbs X-rays, making it an excellent material for producing X-ray images of the intestinal tract (patients drink a barium sulfate mixture prior to being X-rayed).

The health effects of barium compounds on humans depend primarily on their degree of solubility in water. Barium compounds that are not very soluble in water are generally not harmful (Agency for Toxic Substances and Disease Registry, 2004). The EPA has set the maximum contaminant level (MCL) for barium in drinking water at 2.0 mg/L (milligrams per liter, or parts per million). Short-term exposure to barium at levels above the MCL can result in breathing difficulty, hypertension (high blood pressure), heart arrhythmia, stomach irritation, brain swelling, muscular weakness, and damage to the liver, kidneys, heart, and spleen (Thomas Jefferson National Accelerator Facility, 2004). There have not been sufficient studies to determine whether barium is a carcinogen to humans. Long-term exposure (1 year or more) to barium above the MCL has been shown to cause hypertension (U.S. Environmental Protection Agency, 2002).

Concentrations in Groundwater

Data Sources

Data for 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. Some of the primary 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, the U.S. Environmental Protection Agency, and other research programs.

The database query produced 6,170 analyses of barium from 1,019 wells and 259 springs throughout Kentucky; most of the sites had been sampled two or more times. Analyses were excluded from the data set if they were from known or suspected contaminated sites, including Resource Conservation and Recovery Act, Solid Waste, and Underground Storage Tank regulatory programs. Both dissolved and total concentrations were included in the data set.

Regional Variations in Barium Concentrations

This map shows sites where barium has been measured; different symbols show concentration ranges. Sites that have been sampled on multiple occasions may have more than one symbol, and symbols may overlap if the sites are close to each other. Sample site distribution is relatively even throughout Kentucky, except for parts of the Jackson Purchase and the Outer Bluegrass Regions. No site in the Inner Bluegrass, Knobs, or Jackson Purchase Regions had water with a barium concentration above the MCL.

Approximately 99 percent of all barium measurements were less than the MCL of 2 mg/L (Fig. 1), and only 25 sites had barium concentrations greater than the MCL (Table 1). Sites where barium concentrations exceeded the MCL are found predominantly in the Eastern Kentucky Coal Field. The median value for barium in each of Kentucky's physiographic regions is less than 0.05 mg/L, well below the MCL.

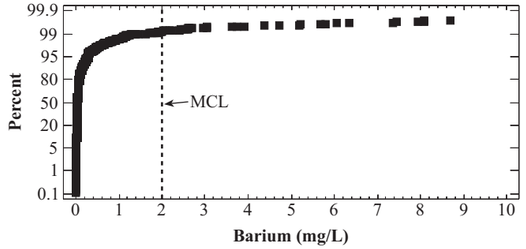

Figure 1. Cumulative percentage plot of barium values (MCL=2.0 mg/L). Higher values were excluded to better show the majority of the values.

Physiographic Region	Maximum Value (mg/L)	Median Value (mg/L)	No. of Sites	No. of Sites Above MCL
Inner Bluegrass	0.962	0.025	54	0
Outer Bluegrass	79.8	0.048	136	7
Knobs	1.1	0.027	77	0
Eastern Ky. Coal Field	639.9	0.035	329	14
Western Ky. Coal Field	3.04	0.031	114	1
Jackson Purchase	1.2	0.046	232	0
Eastern Pennyroyal	5.79	0.037	58	2
Western Pennyroyal	16.7	0.044	280	1

Table 1. Summary of barium concentrations.

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Figure 2 summarizes barium concentrations for each physiographic region. In this plot, boxes enclose the central 50 percent of the values. The median value is shown by vertical line through the box, and lines extend from each edge of the box for a distance of 1.5 times the barium concentration range represented by the central box. Values beyond this range are shown as individual squares.

The physiographic regions with the lowest range of values were the Inner Bluegrass, Western Pennyroyal, and Knobs Regions. The Eastern Kentucky Coal Field exhibited the widest range of values and the highest barium concentrations in the state.

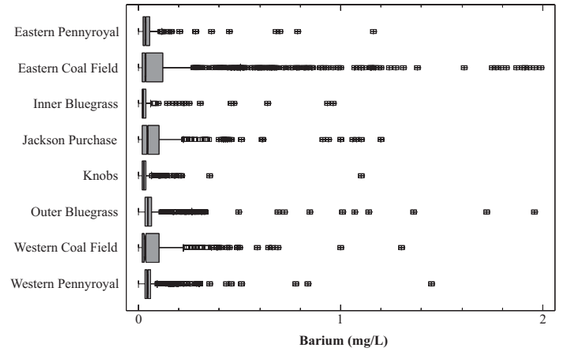

Figure 2. Box plots of barium concentrations grouped by physiographic region (MCL=2.0 mg/L). Higher values were excluded to better show the majority of the data.

Spring water was found to contain much lower barium concentrations than well water (Fig. 3). One possible explanation for this result is that most springs occur in carbonate terrain of the Inner and Outer Bluegrass and the Eastern and Western Pennyroyal Regions, where barium mobility is limited by low solubility of barium-sulfate and barium-carbonate minerals.

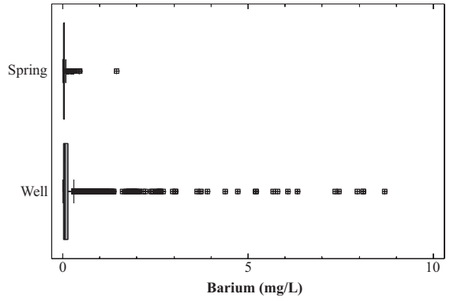

Figure 3. Comparison of barium concentrations in groundwater from wells and springs. Higher values were excluded to better show the majority of the data.

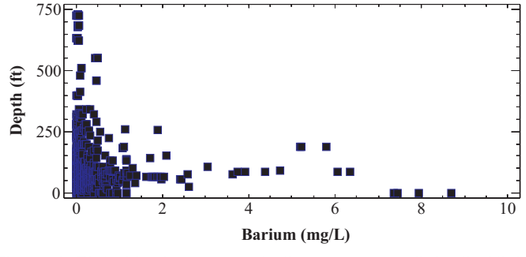

Figure 4. Plot of barium concentrations versus well depth. Higher values were excluded to better show the majority of the data.

The highest barium concentrations are found in wells less than 150 feet deep, rather than in the deeper wells (Fig. 4). Shallow wells are more likely to produce young groundwater that has not had sufficient time for barium to precipitate out as a sulfate or carbonate mineral.

Wunsch (1991) proposed three possible sources of high barium concentrations in groundwater from the Eastern Kentucky Coal Field: sulfur-reducing bacteria in groundwater that deplete dissolved sulfur, allowing more barium to occur in solution; mixing of barium-enriched brines with shallow fresh groundwater; and reaction between groundwater and barium-enriched rocks (primarily shales and underclays beneath coal beds). Barite (barium sulfate) also occurs in numerous limestone quarries and mines throughout central Kentucky, but barium concentrations in groundwater are not elevated in these areas because of the low solubility of this mineral.

Water-Quality Concerns

Barium in Kentucky groundwater generally does not exceed the MCL. Concentrations of barium that do exceed the MCL are spread across the state. With the exception of elevated barium values in the Eastern Kentucky Coal Field that may be related to groundwater associated with shales and underclays (Wunsch, 1991), barium concentrations are low throughout Kentucky. Further work is needed to study barium content in specific geologic units to determine possible relationships between rock type and barium content. These findings should be viewed as general patterns. Individual wells or springs should be tested for the occurrence of barium and other potential contaminants before being used as drinking-water supplies.

Barium in water can be removed by most water-softener systems, and well chlorination and disinfection can minimize barium concentrations by controlling bacteria that reduce sulfur (Wunsch, 1991). 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 provides information on maintenance of private wells and springs at www.water.ky.gov/gw/gwtech/gwwellproblems/.

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 151.625) 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 member agencies can be found at www.uky.edu/KGS/water/gnet/gnet.htm.

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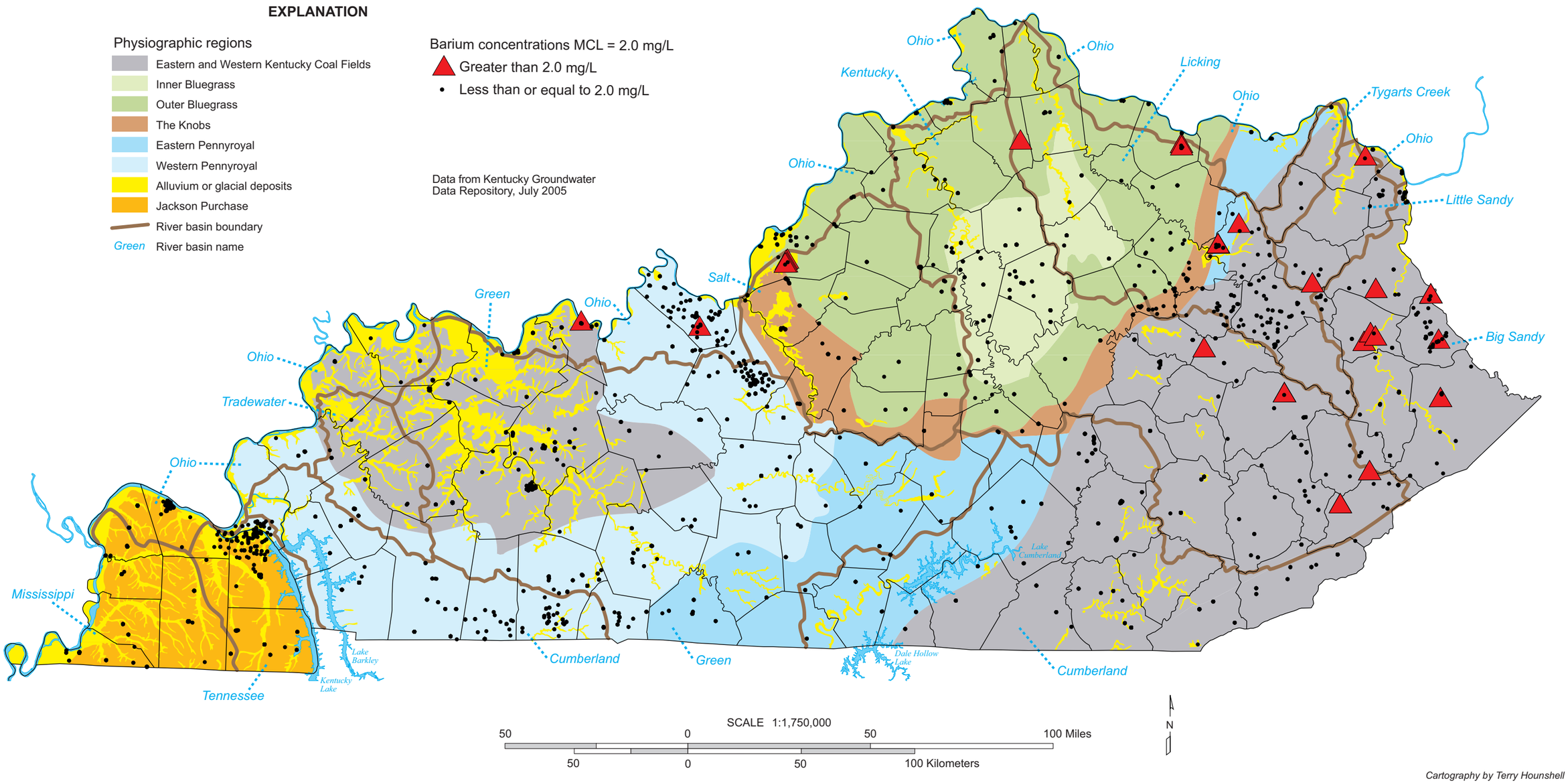
BARIUM CONCENTRATIONS IN WELLS AND SPRINGS IN KENTUCKY



Cartography by Terry Hounshell