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Groundwater Quality in Kentucky: pH

R. Stephen Fisher
Kentucky Geological Survey

Introduction

The parameter pH (the negative base-10 logarithm of hydrogen ion activity, measured in moles per liter) indicates whether a substance will behave as an acid or base. It is one of the most important parameters that describe groundwater quality, because pH largely controls the amount and chemical form of many organic and inorganic solutes in groundwater.

Both temperature and dissolved gases affect the pH of groundwater. For example, the pH of neutral water (neither acid or basic) is 7.0 at 77°F and 7.5 at 32°F (Hem, 1985). Rain that has dissolved atmospheric carbon dioxide has a pH of about 5.6 (Hem, 1985); lower pH values in acid rain occur when the atmosphere also contains sulfur and nitrogen gases from industrial or automobile emissions. Soil water in contact with organic material can have pH values as low as 4, and the pH of water that has reacted with iron sulfide minerals in coal or shale bedrock can be even lower. In the absence of iron sulfide minerals, the pH of groundwater typically ranges from about 6.0 to 8.5, depending on the type of soil and rock that has reacted with the groundwater. Reactions between groundwater and carbonate strata it flows through can result in values as high as 8.5. Streams and lakes in moist regions such as Kentucky typically have pH values between 7 and 8.

There are no health-based drinking-water standards for pH. However, pH values outside of the range 6.5 to 8.5 can lead to high dissolved concentrations of some metals for which there are drinking-water standards and potential health effects. The U.S. Environmental Protection Agency has established a secondary standard of 6.5 to 8.5 for pH. Water with pH higher than 8.5 is likely to deposit scale in pipes and water heaters, whereas water with pH lower than 6.5 can corrode water-handling equipment and stain clothes. Kentucky Revised Statutes (KRS) 350.028 and 350.420 require that the pH of water discharged from areas disturbed by strip mining and reclamation operations be between 6.0 and 9.0.

pH in Groundwater

Data Sources

Data for this report were extracted in March 2002 from the Kentucky Groundwater Data Repository, which is maintained by the Kentucky Geological Survey (KGS). The repository was established in 1990 to archive and distribute groundwater data collected throughout Kentucky. Sources of data for the repository include the Kentucky Division of Water, Kentucky Geological Survey,

U.S. Geological Survey, U.S. Department of Energy, and U.S. Environmental Protection Agency.

The KGS data repository contains pH records of groundwater that was sampled for a variety of reasons dating back to 1947. Reports from samples that were collected to monitor known or suspected contamination sites were excluded from this report. Nevertheless, pH measurements from some contaminated sites may have been inadvertently included here if the fact that the sites were contaminated was not documented in the data repository. The database query produced 7,147 pH measurements from 1,464 sites.

Variations in pH

Nearly 95 percent of the pH measurements fall between 5.5 and 9.0, and approximately 80 percent of the values fall between 6.5 and 8.5 (Fig. 1; note that this plot excludes the highest and lowest 0.01 percent of the values).

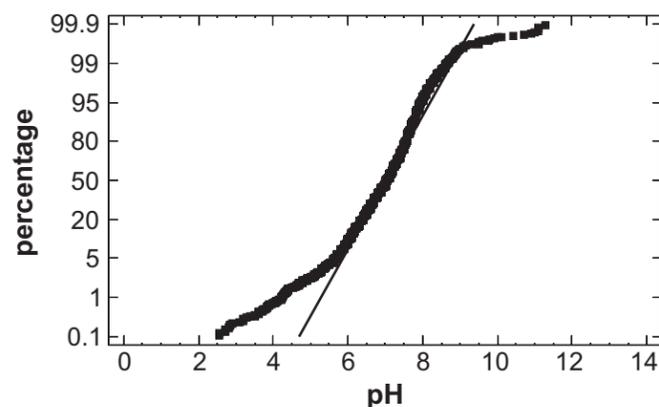


Figure 1. Cumulative percentage plot of pH values.

Table 1 summarizes pH data for each of the physiographic regions in Kentucky. The geographic distribution of the data is far from uniform. More than 70 percent of the measurements and 50 percent of the sites are in the Eastern Kentucky Coal Field, and 13 percent of the measurements and 22 percent of the sites are in the Western Pennyroyal Region. Median values range from 6.41 in the Jackson Purchase to 7.60 in the Inner Bluegrass. The spread of pH values, indicated by the difference between the 25th and 75th percentile values, varies from 0.39 pH units in the Outer Bluegrass to 1.05 pH units in the Western Kentucky Coal Field.

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

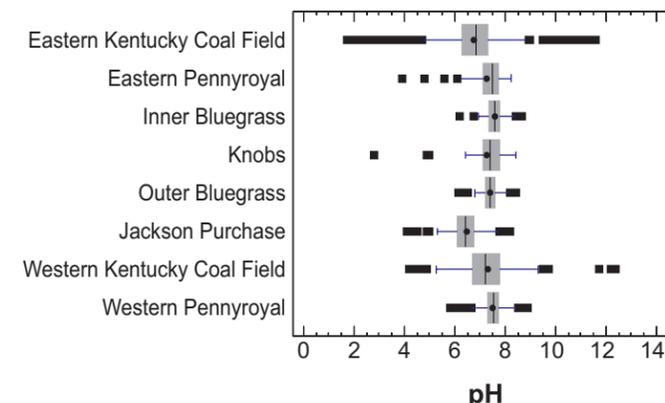


Figure 2. Box plots of pH values for each of the major physiographic regions of Kentucky.

The greatest range of pH values is found in the lithologically heterogeneous Eastern and Western Kentucky Coal Fields, as are the highest and lowest pH values reported. Samples from the dominantly carbonate Inner and Outer Bluegrass and the Western Pennyroyal have the smallest range of pH values.

The map shows sites where pH has been reported; symbols show three ranges of values. Repeatedly sampled sites may have more than one concentration-range symbol, and symbols may overlap for sites that are close to each other.

The map view shows the nonuniform distribution of measurement sites and the variability of pH values at particular wells or springs. The Eastern Kentucky Coal Field is densely sampled compared to the other regions, whereas relatively few measurements have been reported from the Inner and Outer Bluegrass, the Eastern Pennyroyal, and the Western Kentucky Coal Field. Despite a relatively large number of sample sites in the Jackson Purchase, the map view shows that much of the area has not been sampled. As a result of the variable lithology, pH values are highly variable at individual sites in the Eastern Kentucky Coal Field. In contrast, pH values in the regions underlain by limestone (Inner and Outer Bluegrass, Eastern and Western Pennyroyal) are generally buffered by reaction of the groundwater with the limestone to values between 6.5 and 8.5.

Water-Quality Concerns

Most pH measurements throughout Kentucky fall between 6.5 and 8.5. Both the occurrence of values outside this range and the variability of pH are strongly controlled by bedrock lithology. Values of pH are typically between 6.5 and 8.5 in carbonate terrain, lower than 6.5 in the sandy Jackson Purchase Region, and highly variable in the coal fields.

These findings should be viewed as regional patterns. Individual wells or springs should still be tested for pH and other water-quality parameters before being used for drinking-water supplies or other purposes. 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 maintenance of private wells and information about sampling for water analysis.

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 (ITAC), which was also created by statute (KRS 151.629). The following agencies are represented on ITAC:

- Kentucky Department for Environmental Protection
- Kentucky Department for Natural Resources
- Kentucky Department for Surface Mining Reclamation and Enforcement
- Kentucky Department of Mines and Minerals
- Kentucky Division of Conservation
- Kentucky Division of Environmental Health and Community Safety
- Kentucky Division of Forestry
- Kentucky Division of Pesticide Regulation
- Kentucky Division of Waste Management
- Kentucky Division of Water
- Kentucky Geological Survey
- Kentucky Water Resources Research Institute
- U.S. Geological Survey
- University of Kentucky College of Agriculture

Reference Cited

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey, Water-Supply Paper 2254, 263 p.

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EXPLANATION

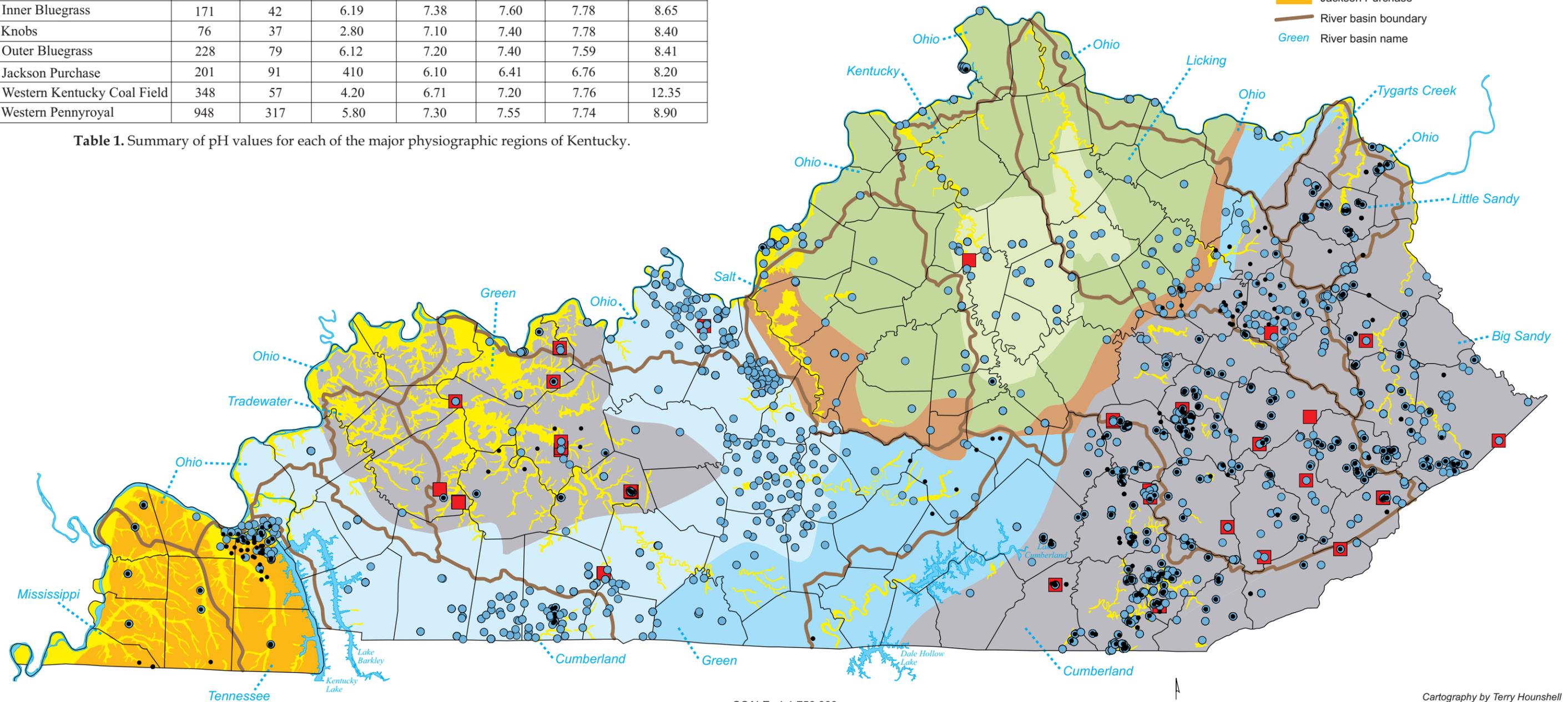
- pH values**
- Greater than 8.5
 - 6.5 to 8.5
 - Less than 6.5

- Physiographic areas**
- 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

Data from Kentucky Groundwater Data Repository, March 2002

Physiographic Region	Number of Values	Number of Sites	Minimum Value	25th Percentile	Median Value	75th Percentile	Maximum Value
Eastern Kentucky Coal Field	5,087	797	1.70	6.30	6.84	7.30	11.60
Eastern Pennyroyal	88	44	3.90	7.10	7.51	7.74	8.21
Inner Bluegrass	171	42	6.19	7.38	7.60	7.78	8.65
Knobs	76	37	2.80	7.10	7.40	7.78	8.40
Outer Bluegrass	228	79	6.12	7.20	7.40	7.59	8.41
Jackson Purchase	201	91	4.10	6.10	6.41	6.76	8.20
Western Kentucky Coal Field	348	57	4.20	6.71	7.20	7.76	12.35
Western Pennyroyal	948	317	5.80	7.30	7.55	7.74	8.90

Table 1. Summary of pH values for each of the major physiographic regions of Kentucky.



Cartography by Terry Hounshell

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