USGS
science for a changing world

In cooperation with the Missouri Department of Natural Resources

Microbiological Quality of Public-Water Supplies in the Ozark Plateaus Aquifer System, Missouri

Introduction

In 1986, Congress amended the Safe Drinking Water Act (SDWA) requiring the U.S. Environmental Protection Agency (USEPA) to promulgate disinfection requirements for all public-water supplies. The USEPA promulgated the Surface Water Treatment Rule (SWTR) in June 1989 to establish disinfection requirements for surface-water supplies and for ground water under the direct influence of surface water. To complete the requirements of the SDWA, the USEPA plans to propose and promulgate disinfection requirements for ground water not under the direct influence of surface water to protect the public health of persons served by those systems (U.S. Environmental Protection Agency, written commun., 1992).

Preliminary investigations by the Department of Health and Human Services, Centers for Disease Control, and the USEPA indicate that illnesses related to drinking water may be more prevalent than previously reported. From 1971 to 1979, an estimated 57,970 persons in the United States were involved in waterborne disease outbreaks (Craun, 1986). The consumption of contaminated ground water was responsible for 45 percent of all reported cases of waterborne disease in the United States (Gerba, 1988). As many as 65 percent of the documented outbreaks of waterborne disease in the United States could be attributed to illness of probable viral etiology (Keswick and Gerba, 1980).

More than 120 different types of potentially harmful enteric viruses are excreted in human feces, and they are widely distributed in type and number in domestic sewage, agricultural wastes, and septic drainage systems (Gerba, 1988). The health significance of these viruses in humans ranges from poliomyelitis (polio), hepatitis, and gastroenteritis to innocuous infections. Contamination of ground water and resulting outbreaks of illness from viruses often are caused by extremely low viral densities.

Missouri is widely dependent on ground water as a source of drinking water for its public-water systems, businesses, farms, and rural homes. Ninety-five percent of the public-water systems in the State depend on ground water, and about 3,700 public-water-supply (PWS) wells are located within the State (fig. 1). Historically, water provided from the deep bedrock aquifers in the Ozark Plateaus (most of the southern one-half of Missouri) generally has been free of microbiological contamination. Years of bacteriological monitoring has confirmed that water drawn from properly constructed wells in this area are free of indicator bacteria (Kenneth Duzan, Missouri Department of Natural Resources, written commun., 1997).

The U.S. Geological Survey (USGS), in cooperation with the Missouri Department of Natural Resources, Public Drinking Water Program (MDNR-PDWP), sampled 109 PWS wells in water year 1997 (October 1996–September 1997) and will sample them again in water year 1998 (October 1997–September 1998) to characterize the microbial activity of ground water in the Ozark Plateaus region. Much is known about bacterial contamination, but little is known about viral contamination and its relation to the bacterial and chemical characteristics of the ground water. The data derived from this study will be related to hydrogeology and land use. Results of this study will provide State regulatory agencies with data needed to make informed decisions on treatment of potable ground-water supplies in the Ozark Plateaus and will provide useful and timely input to the USEPA for establishing ground-water disinfection rules for this type of carbonate aquifer system. This Fact Sheet describes the cooperative study and presents preliminary results of the first round of sampling.

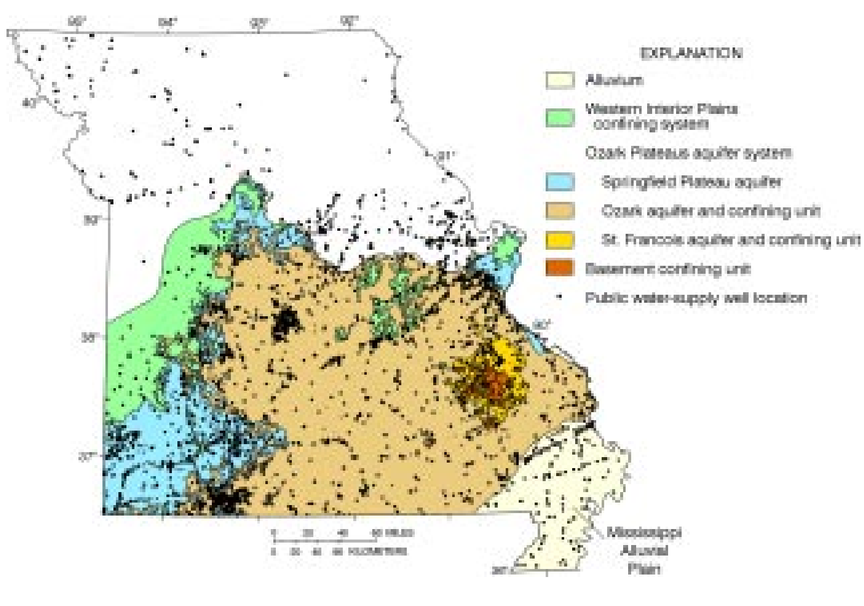

Figure 1. Location of hydrogeologic units (modified from Imes and Emmett, 1994) and public-water-supply wells (Missouri Department of Natural Resources, Public Drinking Water Program) in Missouri.

Ozark Plateaus Aquifer System

The Ozark Plateaus aquifer system generally is characterized as a carbonate aquifer with numerous karst features throughout (Imes and Emmett, 1994). Five geohydrologic units have been identified in the Ozark Plateaus aquifer system according to differences in permeability and well yields (fig. 1). The St. Francois aquifer, the St. Francois confining unit, the Ozark aquifer, the Ozark confining unit, and the Springfield Plateau aquifer collectively comprise the Ozark Plateaus aquifer system, the principal source of fresh ground water in central and southern Missouri.

The most important source of water for public supplies is the Ozark aquifer, both where it is unconfined and where it is confined by the Ozark confining unit and Springfield Plateau aquifer in southwest Missouri. To a much lesser extent, the St. Francois aquifer is used for public-water supplies where it is unconfined. These aquifers consist primarily of limestone and dolomite strata that have been weathered to form karst features such as caves, sinkholes, and springs.

Karst aquifers are characterized as having relatively free exchange of surface and ground water with limited geologic restrictions on water movement, which makes the aquifers susceptible to surface contamination. Microbiological activity in ground water can be affected by the presence of fractures, faults, and karst features such as losing streams, sinkholes, or solution channels in ground-water recharge areas that can affect the ability of viruses and bacteria to enter and move rapidly through the aquifers. The unconfined Ozark aquifer in south-central Missouri has the most mature karst features (fig. 2) and is considered most vulnerable to viral and bacterial contamination. These features were mapped by Harvey (1980) and have been categorized into primary and secondary karst areas. Primary karst areas are characterized as having sinkhole densities greater than 10 per 100 square miles, whereas secondary karst areas are characterized as having sinkhole densities of 1 to 10 per 100 square miles. The unconfined Ozark aquifer in central Missouri has less developed karst features and is considered somewhat less vulnerable, and the confined Ozark aquifer

Cave opening upstream of River Bluff Cave, St. Louis County, Missouri. Photo courtesy of J.E. Vandike, Missouri Department of Natural Resources.

in southwest Missouri is considered the least vulnerable. However, the proximity of the aquifers to the land surface and the land-use practices in the areas where the aquifers crop out may greatly affect the presence of microbiological activity in ground water.

Land Use in the Ozark Plateaus

Land use in southern Missouri (fig. 3; U.S. Geological Survey, 1990) is primarily forest and agriculture, including pasture, cropland, and confined animal operations. Second-growth, deciduous forest mixed with evergreen forest is predominant in the eastern two-thirds of the Ozark Plateaus, and agricultural land use is predominant in the southwestern part of the Ozark Plateaus. Agricultural land use in the study area consists primarily of the raising of livestock, including beef and dairy cattle, poultry, and swine. Numerous confined poultry operations are present in southwest Missouri. Waste generated by cattle, poultry, and swine operations is a major source of nutrients and fecal bacteria. Much of the manure is applied to local pastures as fertilizer (Davis and others, 1995).

Excluding the St. Louis metropolitan area, the 1990 population within the Ozark Plateaus was approximately 1.6 million. Springfield, Missouri, is the largest city with a 1990 population of about 140,000. Cape Girardeau, Jefferson City, and Joplin, Missouri, are the only other cities with populations exceeding 30,000. Recreational activities in the Lake of the Ozarks and the Table Rock Lake-Lake Taneycomo areas have attracted many tourists and year-round residents. The populations of these areas have increased by more than 90 percent since 1970 (Adamski and others, 1995). Waste from private septic systems and municipal wastewater-treatment plants can contaminate ground water.

Selection of Wells for Sampling

The USGS and MDNR-PDWP selected a total of 109 PWS wells of which 105 PWS wells are located within the Ozark Plateaus aquifer system to represent ground water in the confined and uncon-

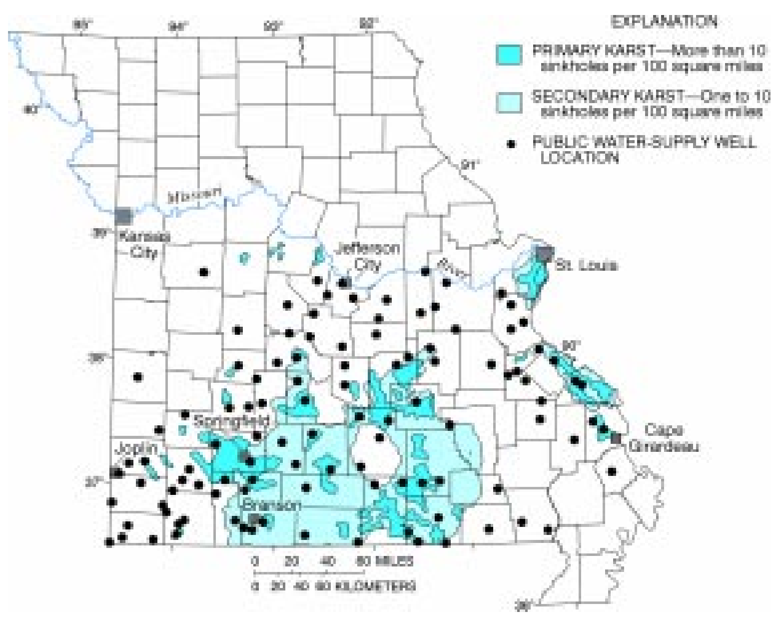

Figure 2. Karst areas in Missouri (Harvey, 1980) and location of public-water-supply wells sampled.

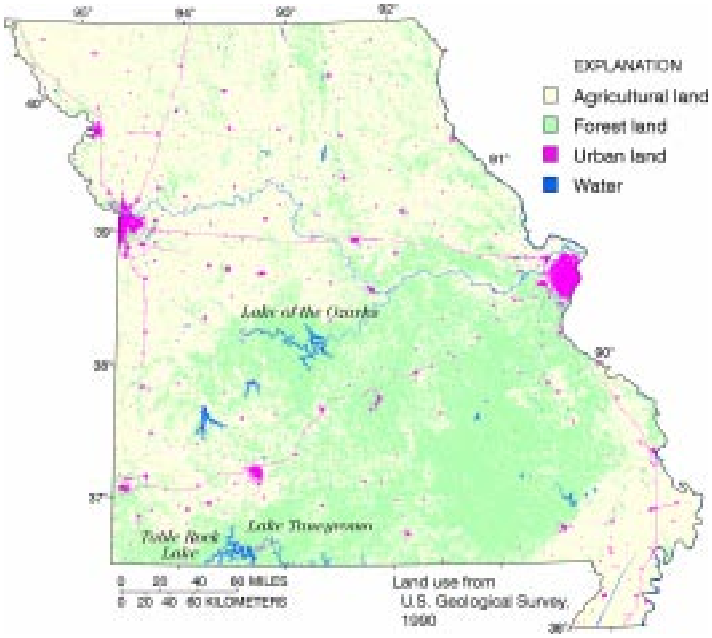

Figure 3. Land use in Missouri.

fined Ozark and St. Francois aquifers. In addition, four PWS wells were selected as control sites. Two of the control sites are located in western Missouri where the Ozark aquifer is confined by the Ozark confining unit, the Springfield Plateau aquifer, and the Western Interior Plains confining system, and two are located in the Mississippi Alluvial Plain of southeastern Missouri (fig. 2).

Only community wells—municipal, PWS district, subdivision, and mobile home park—constructed in the last 15 years were considered. This study was designed to eliminate type of well construction as a variable for microbiological contamination so that interpretation could be limited to hydrogeology and land use. Well-selection criteria were based on availability of well construction and completion records (well and casing depth, size, and type), well operation and maintenance history, current usage, and geology. Finally, an attempt was made to obtain fairly even areal and vertical coverage in the aquifer and to represent the different land uses in the Ozark Plateaus.

Forested land use in the Ozark Plateaus. Photo courtesy of S.R. Femmer, U.S. Geological Survey.

Agricultural land use in the Ozark Plateaus. Photo courtesy of B.J. Smith, U.S. Geological Survey.

Sample Collection and Analysis

The first round of sampling was completed in July 1997. Samples from each PWS well were analyzed for the following microbiological species—total human enteric viruses, male-specific and somatic coliphage, and fecal indicator bacteria [fecal coliform, Escherichia coli (E. coli), and fecal streptococci]. Coliphage are viruses that attack E. coli and are being studied as possible indicators of the presence of human enteric viruses. The enteric virus and coliphage samples were collected by the USGS at the selected wells. Samples represent untreated water from the aquifer. Enteric virus and coliphage samples were analyzed by the University of New England in Biddeford, Maine, according to procedures described in the USEPA Information Collection Requirements rule for the collection and analysis of samples for protozoa and enteric viruses (U.S. Environmental Protection Agency, 1995a, 1995b). Indicator bacteria samples were collected and analyzed by the USGS according to procedures described in Myers and Wilde (1997).

In addition to the above microbiological species, samples were collected and analyzed for chemical constituents, such as nutrients, total organic carbon, and tritium, that may serve as indicators of possible surface contamination of the aquifer. All chemical analyses were done by USGS laboratories in Arvada, Colorado, or Ocala, Florida. Onsite analysis of specific conductance, pH, temperature, dissolved oxygen, and alkalinity were done at each PWS well according to procedures described by Wilde and Radtke (1997).

Preliminary Results

Results from the first round of enteric virus, coliphage, and fecal indicator bacteria sample collection are shown in figure 4. Of the 109 PWS wells sampled, 86 showed no presence of microbiological contamination. However, human enteric viruses were present in 9 of the 109 PWS wells at densities near the lower level of analytical detection. Contrary to what might be expected, most of the enteric virus contamination was observed outside the areas characterized as primary and secondary karst. Coliphage were observed in samples collected from 9 of the 109 wells—1 of which was a control site located in the Mississippi Alluvial Plain. Coliphage and enteric viruses were present in two wells located near the northern boundary of the Ozark Plateau aquifer system along the Missouri River. Fecal indicator bacteria

Virus sampling equipment and public-water-supply well.

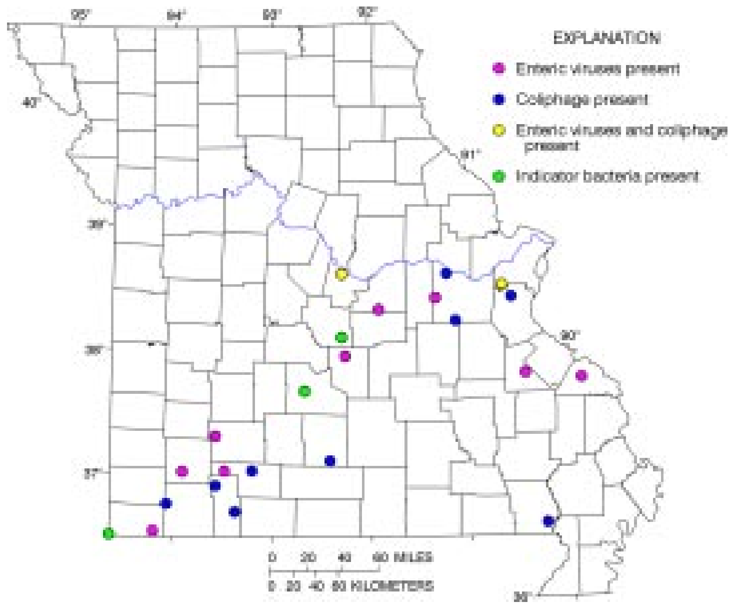

Figure 4. Results of enteric viruses, coliphage, and indicator bacteria analyses for samples collected at selected Ozark Plateaus aquifer system and Mississippi Alluvial Plain public-water-supply wells.

were observed at small densities in three PWS wells. Two wells had one colony per 100 milliliters of sample each of fecal coliform bacteria and one well had one colony per 100 milliliters of sample of fecal streptococci.

Until the second round of sample collection is complete and the microbiological and chemical data are analyzed, it is impossible to relate these results to the hydrogeology and land use of the study area. While definite conclusions cannot be made at this time, the data indicate that microbiological contamination of PWS wells in the Ozark Plateaus is not widespread. Also, these preliminary results indicate that coliphage and fecal indicator bacteria may not be useful indicators for the presence of human enteric viruses in public-water supplies.

—Jerri V. Davis and Emitt C. Witt, III

References

Adamski, J.C., Petersen, J.C., Freiwald, D.A., and Davis, J.V., 1995, Environmental and hydrologic setting of the Ozark Plateaus study unit, Arkansas, Kansas, Missouri, and Oklahoma: U.S. Geological Survey Water-Resources Investigations Report 94–4022, 69 p.

Craun, G.F., 1986, Waterborne diseases in the United States: Boca Raton, Fla., CRC Press.

Davis, J.V., Petersen, J.C., Adamski, J.C., and Freiwald, D.A., 1995, Water-quality assessment of the Ozark Plateaus study unit, Arkansas, Kansas, Missouri, and Oklahoma—Analysis of information on nutrients, suspended sediment, and suspended solids, 1970–92: U.S. Geological Survey Water-Resources Investigations Report 95–4042, 112 p.

Gerba, C.P., 1988, Methods for virus sampling and analysis of ground water, in Collins, A.G., and Johnson, A.I., eds., Ground-Water Contamination—Field Methods: Philadelphia, American Society for Testing and Material, ASTM STP 963, p. 343–348.

Harvey, E.J., 1980, Ground water in the Springfield-Salem Plateaus of southern Missouri and northern Arkansas: U.S. Geological Survey Water-Resources Investigations Report 80–101, 66 p.

Imes, J.L., and Emmett, L.F., 1994, Geohydrology of the Ozark Plateaus Aquifer System in parts of Missouri, Arkansas, Oklahoma, and Kansas: U.S. Geological Survey Professional Paper 1414–D, 127 p.

Keswick, B.H., and Gerba, C.P., 1980, Viruses in groundwater: Environmental Science and Technology, v. 14, p. 1,290–1,297.

Myers, D.N., and Wilde, F.D., eds., 1997, National field manual for the collection of water-quality data—Biological indicators: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A7.

U.S. Environmental Protection Agency, 1995a, Information Collection Requirements rule—Protozoa and enteric virus sample collection procedures: Washington, D.C., Office of Ground Water and Drinking Water, EPA/814–B–95–001, 63 p.

———1995b, Virus monitoring protocol for the Information Collection Requirements rule: Washington, D.C., Office of Ground Water and Drinking Water, EPA/814–B–95–002, 25 p. and appendices.

U.S. Geological Survey, 1990, Land use and land cover digital data from 1:250,000- and 1:100,000-scale maps: U.S. Geodata Users Guide 4, 33 p.

Wilde, F.D., and Radtke, D.B., eds., 1997, National field manual for the collection of water-quality data—Field measurements: U.S. Geological Survey Techniques of Water-Resources Investigations, book 1, chap. A6.

For More Information

For more information, please contact:

District Chief
U.S. Geological Survey
1400 Independence Road
Mail Stop 100
Rolla, Missouri 65401
(573) 308-3664

Additional information on other U.S. Geological Survey programs in Missouri can be obtained by accessing “http://wwwdmorll.er.usgs.gov” on the World Wide Web.