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Escherichia coli in the Swash Zone at Four Ohio Bathing Beaches

WHAT IS THE SWASH ZONE?

The zone of the shoreline that is constantly washed by waves or tides, called the swash zone, is an attractive recreational area, especially for children who play in the sand. The swash zone, however, has been suggested as a possible habitat for waterborne disease-causing microorganisms (pathogens). The spaces between the sand grains, or interstices, offer habitats that may support the survival of certain bacterial, viral, and protozoan pathogens (U.S. Environmental Protection Agency, 1999). To investigate this possibility, the U.S. Geological Survey (USGS) determined the distribution of *Escherichia coli* (*E. coli*) in subsurface sediments and interstitial waters collected from near the swash zone at three Lake Erie urban beaches and one inland lake during the recreational seasons of 2000 and 2001. Water and lake-bottom sediment samples were also collected within the bathing areas and were analyzed for *E. coli*; these bathing-water data were compared to swash-zone data to determine whether swash-zone materials were enriched with *E. coli*.

HOW ARE BACTERIA LEVELS MONITORED AT BATHING BEACHES?

Pathogens come from human or animal waste and cause a risk to recreational users. No methods have yet been established to measure the risk for those who play in beach sands near or in the swash zone. There are methods, however, to determine the risk of pathogen exposure for those who swim, wade, or boat in recreational waters.

Because it is difficult and expensive to monitor for pathogens directly, states have developed water-quality standards for recreational waters that are based on concentrations of indicator organisms. Indicator organisms do not necessarily cause disease, but they are in feces and therefore indicate the possible presence of pathogenic organisms. The levels of indicator organisms provide a measure of the quality of the recreational water and the risk of illness for those involved in recreational activities. The State of Ohio uses the indicator bacterium *E. coli* to assess recreational water quality because it is the indicator recommended by the U.S. Environmental Protection Agency (U.S. Environmental Protection Agency, 1986). *Escherichia coli* is a natural inhabitant of the gastrointestinal tract of warmblooded animals and is direct evidence of fecal contamination from them. For Ohio, one way to measure bathing-water quality is to use the single-sample maximum level for *E. coli* of 235 colonies per 100 milliliters (col/100 mL); this level cannot be exceeded in more than 10 percent of samples collected during any 30-day period (Ohio Environmental Protection Agency, 2002).

WHY WAS THIS STUDY DONE?

Edgewater Park, Villa Angela, and Huntington Reservation are three Lake Erie urban beaches in the Cleveland, Ohio, metropolitan area that are used extensively during the May through August recreational season; Mosquito Lake is an inland lake in northern Ohio with a popular bathing beach (fig. 1). These beaches are posted with water-quality advisories if the levels of *E. coli* in bathing waters exceed water-quality standards. Possible sources of fecal contamination to the urban beaches in this study are stormwater runoff and combined-sewer overflows, boaters and swimmers, and animals. Possible sources of fecal contamina-

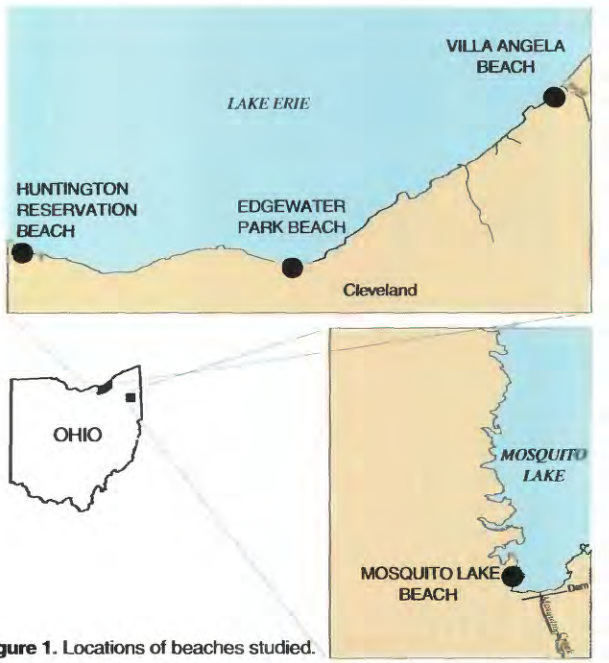

Figure 1. Locations of beaches studied.

tion to Mosquito Lake include discharges from septic systems, runoff from parking lots and wooded areas, birds, boaters, and swimmers. Subsurface sediments and interstitial waters in or near the swash zone may become contaminated with pathogens and indicators from wave actions that transport lake-water contamination to the swash zone. The swash zone may also be directly contaminated from bird droppings or other sources. There is a paucity of information, however, on concentrations of *E. coli* in interstitial waters and subsurface sediments in swash-zone areas.

HOW WAS THIS STUDY DONE?

Samples were collected on five days in 2000 at all beaches and on four days in 2001 at Edgewater Park and Mosquito Lake. Water and sediment samples from within the bathing area and near the swash zone were collected from one to three areas at each beach from 7 to 11 a.m. on each sampling day. Sampling areas for each beach were based on locations of convenient markers near or on the beach. For example, at Edgewater Park, sampling areas and locations were based on locations of lifeguard stations, as shown in figure 2.

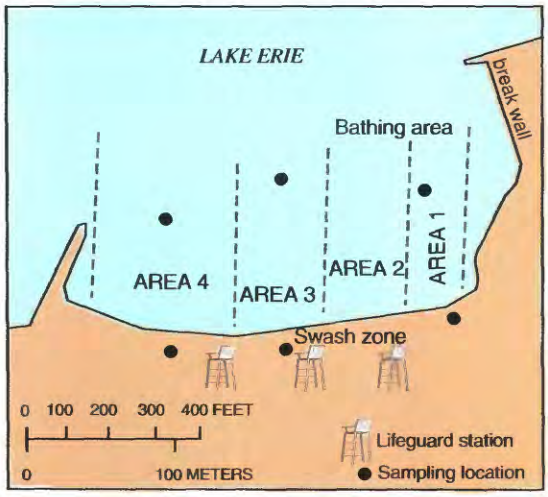

Figure 2. Sampling areas and locations at Edgewater Park, Cleveland, Ohio, 2000 and 2001.

Lake-water and lake-bottom sediment samples were collected in 3 to 9 feet of water within the designated bathing areas at each beach. Lake-water samples were collected 18 inches below the water surface using a grab-sampling technique that minimized contamination of sterile sampling containers (Myers and Sylvester, 1997). To collect lake-bottom sediments, a diver secured the lid on a 250-mL sterile sampling jar, opened the lid upon reaching the lake bottom, and scooped the bottom sediments to obtain a sample. The diver closed the lid of the jar before surfacing to minimize contamination by the overlying water. Because of spatial heterogeneity of bacteria concentrations in sediment, three sediment jars were collected from each sampling point and composited before analysis (Francy and Darner, 1998).

In each swash-zone sampling area, two sets of three holes were dug—one set 3 feet and a second set 6 feet inland from the outer edge of the swash zone (fig. 3). Swash-zone sampling locations were not consistent from day to day because they were dependent on lake levels and wave heights. Similarly, the depths of the holes below the surface to the water table ranged from 1.5 to 22.8 inches, depending on the slope of the beach and on weather conditions. Sterile well casings were inserted to prevent the holes from collapsing. To collect a sample, interstitial water was removed from a set of three holes and composited into one bottle. After that, sediment was removed and composited in the same manner. Water and sediment samples were brought to the laboratory and analyzed for concentrations of *E. coli*. For water, concentrations of *E. coli* are measured in colonies per 100 milliliters. For sediment, concentrations are measured in colonies per gram dry weight of sediment (col/g_{DW}).

Figure 3. Interstitial water and subsurface sediment samples were collected from two rows of holes 3 feet and 6 feet inland from the swash zone.

WHAT WERE THE STUDY RESULTS?

Wide ranges of *E. coli* concentrations were found in interstitial waters and subsurface sediments collected from near the swash zone. Concentrations of *E. coli* in interstitial waters ranged from less than 3 to 400,000 col/100 mL; in subsurface sediments they ranged from less than 1 to 30,000 col/g_{DW}. For interstitial water and subsurface sediment alike, the lowest median concentrations were found at Huntington Reservation (240 col/100 mL and 7 col/g_{DW})

and the highest were found at Mosquito Lake (1,200 col/100 mL and 100 col/g_{DW}).

Median concentrations of *E. coli* were higher in subsurface sediments collected from near the swash zone than in lake-bottom sediments collected within the bathing area at Mosquito Lake and Edgewater Park, but not at Huntington Reservation and Villa Angela (fig. 4). At the three Lake Erie beaches, 75 percent of the bathing-area and swash-zone sediment samples had *E. coli* concentrations less than 100 col/g_{DW}. In contrast, at Mosquito Lake, 75 percent of swash-zone samples were less than a much larger value—4,500 col/g_{DW}—even though 75 percent of bathing-area samples were less than or equal to 100 col/g_{DW}. This indicates that at Mosquito Lake, *E. coli* was concentrated in swash-zone sediments to a greater extent than at the other beaches.

Results from individual interstital water samples collected at Edgewater Park provide a picture of the distribution of *E. coli* in space and over time (fig. 5). Concentrations of *E. coli* in interstitial waters collected on the same date often differed among areas by one to more than two orders of magnitude. Concentrations in interstitial samples collected 3 feet inland were somewhat lower than those collected concurrently at 6 feet inland except on February 27 and August 4, 2002. Interstitial-water samples collected 6 feet inland showed a spatial pattern on August 4, 5, and 6; concentrations were highest in area 3 and lower in areas 1 and 4 on all three dates. Concentrations of *E. coli* during February 2001 were in the same range as many samples collected during the summer months. This finding indicates that there was a continuous source of *E. coli* during the winter and (or) an overwintering of *E. coli* in interstitial waters.

Although there are no standards for *E. coli* in interstitial waters and subsurface sediments collected from near the swash zone, the high concentrations found in this study could be of some concern for public health. Future research could include determination of whether interstitial materials harbor disease-causing microorganisms. The distributions in space and time of *E. coli* and pathogen concentrations in beach sands and the factors that affect these concentrations could be determined. Additional research could determine whether standards for interstitial materials are needed for the protection of public health.

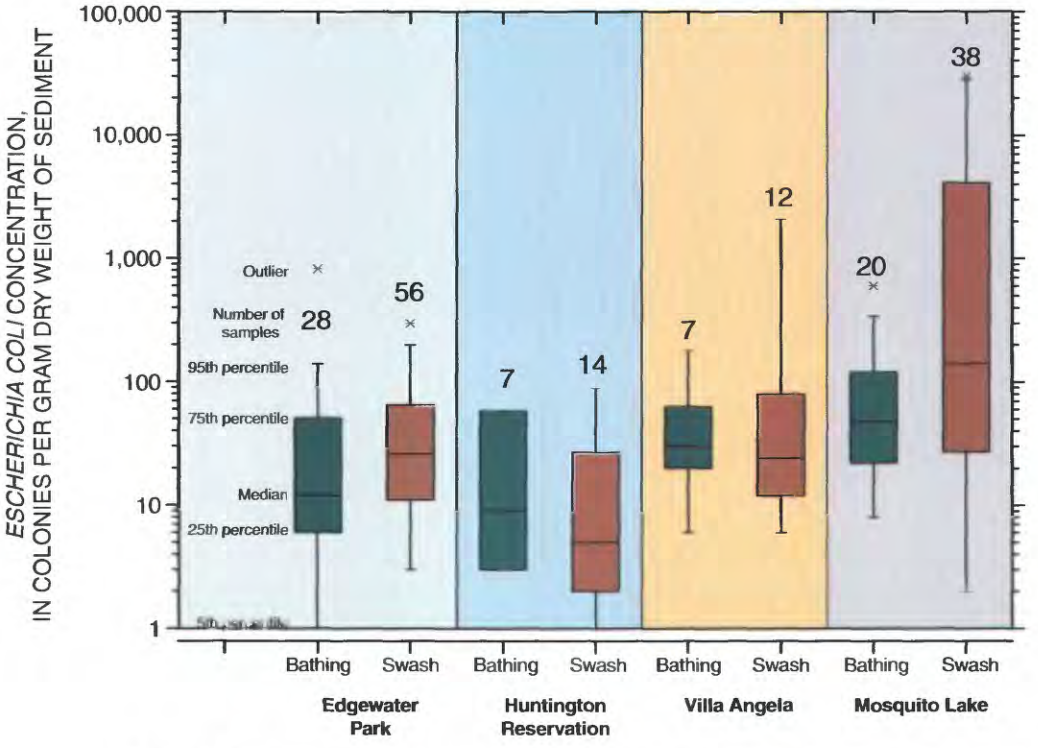

Figure 4. Concentrations of *Escherichia coli* in lake-bottom sediment samples collected within the bathing area (bathing) and in subsurface sediment samples collected from near the swash zone (swash), 2000 and 2001.

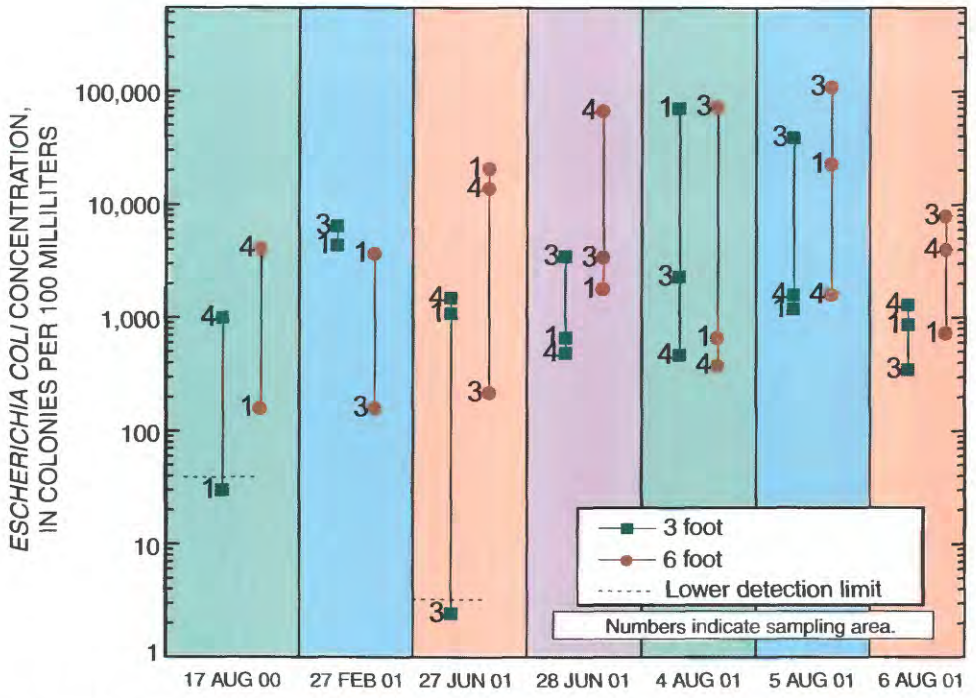

Figure 5. Concentrations of *Escherichia coli* in interstitial waters collected 3 feet and 6 feet inland from near the swash zone during 2000 and 2001 at Edgewater Park. (Bars are included to aid visual interpretation and do not indicate continuous data.)

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Information on technical reports and hydrologic data related to the above study can be obtained from:

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