Source-Tracking Tools for Understanding Fecal Contamination and Predicting Water Quality at Lake Erie Beaches

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INTRODUCTION

Work was done in 2004 to help identify the sources of *E. coli* contamination at two Lake Erie beaches. At Edgewater in Cleveland, Ohio, *E. coli* concentrations were often elevated on days when changes in environmental conditions such as increased rainfall had not occurred. The origins of fecal contamination were hypothesized to be from local activities (swimmers, wildlife, or boats), from wastewater effluents or combined-sewer overflows at remote locations, and (or) from storage pockets in lake-bottom or foreshore sediments (Francy and others, 2003). Because Edgewater is in an urban setting without any substantial domestic animal inputs, it is generally believed that the sources of fecal contamination are human and (or) waterfowl. At Lakeview Beach in Lorain, Ohio, water-quality advisories were issued on 84 days during the recreational season of 2004. The sources of fecal contamination to Lakeview are largely unknown.

SPATIAL PATTERNS OF *E. COLI* IN THE NEAR-SHORE AND BATHING AREAS

Nearshore surveys were done at Edgewater to identify potential origins of fecal contamination (such as rivers or outfalls) and determine *E. coli* concentrations along transient paths to the beach. In addition, spatial patterns of *E. coli* concentrations in the bathing area were determined to identify local contamination patterns.

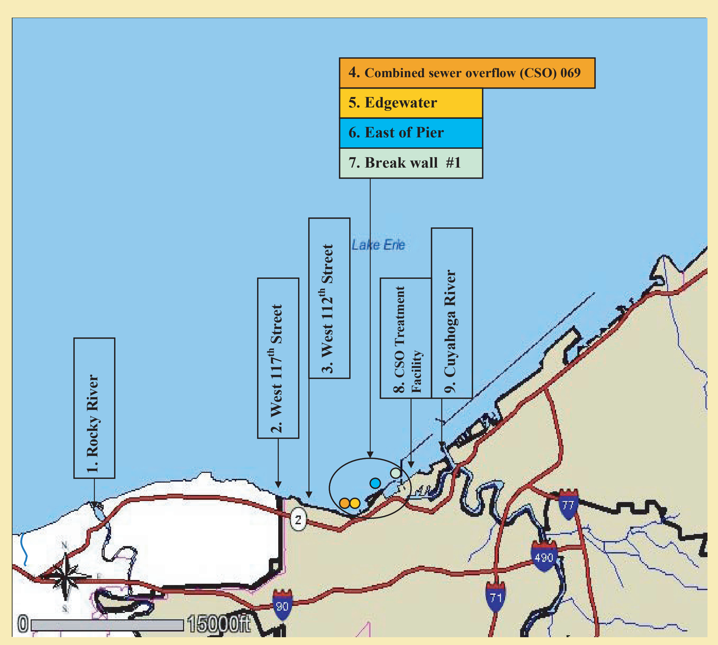

Figure 1. Nearshore sampling locations, Cleveland, Ohio, 2003 and 2004.

Methods. Nearshore surveys were done from May through September on 16 days in 2003 and 6 days in 2004; surveys were done during a range of weather conditions. Water samples were collected from a boat by means of a grab-sampling technique at nine sampling locations that were less than 150 ft offshore (figure 1). In other surveys, spatial patterns of *E. coli* were determined on 8 days during 2004 at 1-, 2-, and 3-ft water depths at two sampling locations in the Edgewater bathing area. Samples were analyzed for *E. coli* by use of the modified mTEC method (U.S. Environmental Protection Agency, 2002).

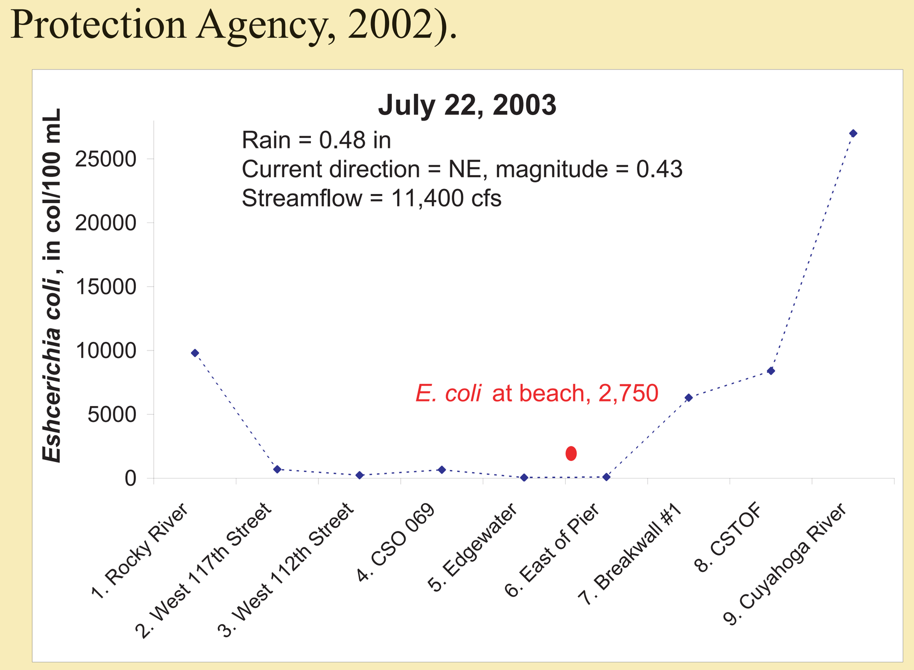

Figure 2. Concentrations of *E. coli* at nearshore sampling sites, Cleveland, Ohio.

Results. A common pattern of *E. coli* concentrations observed during nearshore samplings is shown in figure 2. On July 22, 2003 (0.48 in. of rainfall), *E. coli* concentrations were very high at the mouths of the Rocky and Cuyahoga Rivers, decreased along transient paths to Edgewater, and were elevated in the Edgewater bathing area. Average concentrations of *E. coli* in the bathing area on 8 selected days during 2004 are shown in figure 3.

Concentrations were highest at the east sampling locations at 1- and 2-ft depths.

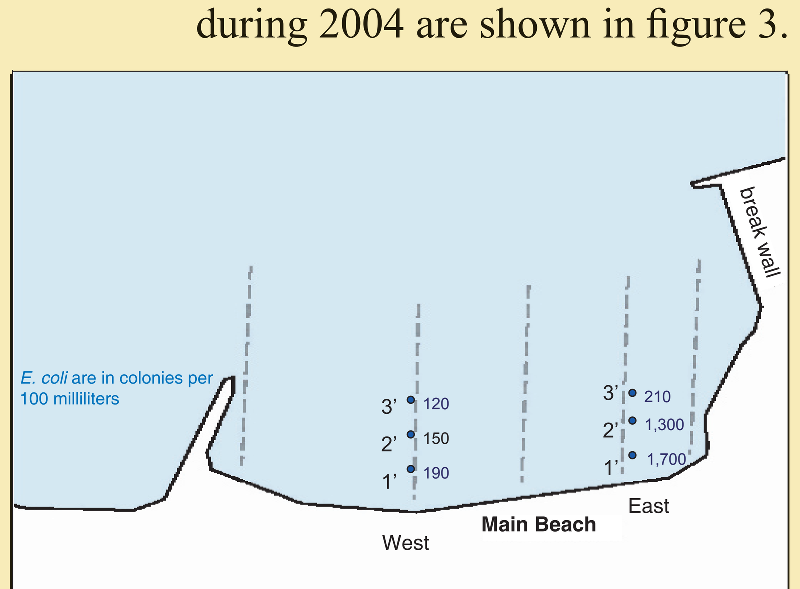

Figure 3. Average concentrations of *E. coli* on eight sampling days, Edgewater Beach, Cleveland, Ohio, 2004.

Conclusions. The nearshore surveys and spatial sampling in the beach area indicate that fecal contaminants from remote locations do not affect the recreational water quality at Edgewater. The contamination is most likely of local origin—water fowl or from storage pockets in lake-bottom or foreshore sediments.

ABSTRACT

Multiple lines of evidence were used to help identify sources of fecal contamination at two Lake Erie beaches—Edgewater, in Cleveland, Ohio; and Lakeview, in Lorain, Ohio. In several field studies at Edgewater, investigators determined the spatial distribution of *Escherichia coli* (*E. coli*) in nearshore surveys and in lake-water samples collected within the bathing area. Temporary shallow observation wells (piezometers) were installed at Edgewater to determine the direction of ground-water flow and *E. coli* concentrations in foreshore sands. At Lakeview, investigators tested the use of multiple antibiotic resistance (MAR) patterns of *E. coli* isolates as a source-tracking tool.

The results from nearshore surveys and lake-water sampling at Edgewater indicate that fecal contamination is most likely of local origin. Shallow ground-water flow directions were toward the lake during two piezometer studies. The absence of *E. coli* in shallow ground water >50 ft inland and *E. coli* spikes at seemingly random locations further indicates a local source; this local source may be a surface source, such as bird excrement. The use of MAR patterns to distinguish between contamination from humans and waterfowl at Lake Erie beaches proved to be a promising method. In a small sampling at Lakeview, MAR indexes were able to distinguish gull fecal samples from sewage samples, and the MAR index for a bathing-water sample was similar to that of the gull fecal samples.

MULTIPLE ANTIBIOTIC RESISTANCE

Multiple antibiotic resistance is a source-tracking method based on *E. coli* resistance to a panel of antibiotics. The MAR patterns reflect the selective pressures imposed on the gastrointestinal flora during antibiotic use (Guan and others, 2002). Because humans are exposed to antibiotics, the *E. coli* they harbor will be more resistant to antibiotics than those *E. coli* found in the gastrointestinal tracts of wild birds.

Methods. Gull fecal samples and a bathing water sample were collected at Lakeview. A sewage sample from a local wastewater treatment plant also was collected. In the laboratory, samples were diluted and plated for *E. coli* on modified mTEC agar. Eighty colonies were picked from each source, isolated, and subjected to MAR testing. If growth on the antibiotic plate was at least 50 percent of the growth on the control plate containing no antibiotics, the isolate was recorded as resistant.

Results. The numbers of isolates resistant to the five different antibiotics tested and MAR indexes for the three sources are shown in table 1. (All five isolates from one gull fecal sample failed to grow on control plates making a total of 75 isolates instead of 80).

Conclusions. In this small sampling, the MAR indexes for gull fecal samples and water samples were similar and were lower than the MAR index for the sewage sample. Although more work is needed to determine the source of fecal contamination to the bathing waters at Lakeview, this method shows promise in distinguishing between human and water fowl contamination at beaches and will be used at Lakeview and Edgewater in 2005.

Table 1. Antibiotic resistance patterns of *E. coli* isolates from gull droppings, sewage, and lake water, September 2004.

Antibiotic	Concentration (µg/ mL)	Total resistant: Gull	Sewage	Water
Streptomycin	25	5	8	4
Nalidixic acid	25, 50	1	2	1
Sulfathiozole	2000	5	6	3
Ampicillin	10, 20	5	10	5
Tetracycline	25, 50	5	11	5
Total resistant		21	37	18
Total isolates		75	80	80
MAR index*		0.056	0.093	0.045

* total number of resistant isolates / number of antibiotics tested x total isolates tested

SPATIAL PATTERNS OF *E. COLI* AND FLOW DIRECTIONS IN SHALLOW GROUND WATER

Previous studies at Edgewater showed that *E. coli* concentrations in waters collected from foreshore sediments were as high as 100,000 col/100 mL (Francy and others, 2003). The source of *E. coli* was hypothesized to be (1) upgradient of the beach, (2) from bird excrement infiltrating through the foreshore sediments, or (3) from the bathing waters where it is concentrated in the sediments. To test these hypotheses, temporary piezometers were installed to determine ground-water flow directions and *E. coli* concentrations in the foreshore sediments.

Methods. Temporary piezometers were installed at various intervals at Edgewater on June 30 and July 28, 2004 (figure 4). After measuring water levels, water samples from piezometers were collected by use of a peristaltic pump with sterile tubing. Grab samples were also collected from the bathing area. Samples were analyzed for *E. coli* by use of Colilert (Idexx Corporation, Westbrook, Maine) (piezometer samples) or modified mTEC (lake-water samples).

Figure 4. Locations of temporary piezometers installed in the lake and at 0, 3, 6, 9, 20, 40, 60, 80, and 100 ft inland from the water's edge in July 2004.

Results. The horizontal and vertical hydraulic gradients were assessed using water levels from the piezometers (figures 5 and 6). Water levels for a single piezometer ranged from about 0.2 ft (100 ft from the swash zone) to about 0.6 ft (at the swash zone). The horizontal hydraulic gradients were consistently toward the lake during both studies. The measured vertical hydraulic gradients, between the shallow ground water (under the lake) and the lake, were very small and variable. In June and July, concentrations of *E. coli* in shallow ground water collected from locations greater than 50 ft inland were below detection or at low levels (figures 5 and 6). Spikes of *E. coli* were found at 50 ft inland in June and at 9 ft inland in July. In July, concentrations of *E. coli* at locations 3, 6, and 9 ft inland from the edge of water were in the same range as concentrations of *E. coli* in lake water.

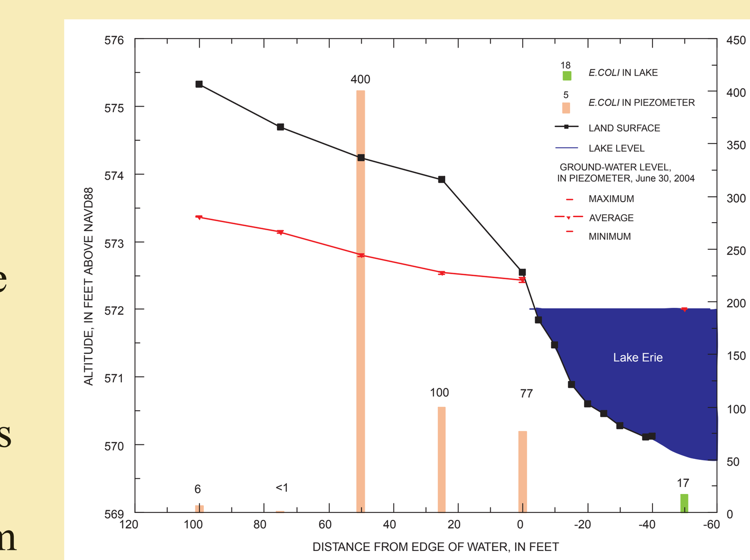

Figure 5. Average water levels and *Escherichia coli* concentrations in tempoary piezometers at Edgewater Beach, Cleveland, Ohio on June 30, 2004.

Conclusions. Shallow ground-water flow directions are toward the lake, and the absence of *E. coli* in shallow ground water >50 ft inland indicates that the source of *E. coli* is likely not upgradient of the beach. *E. coli* spikes at seemingly random locations show the heterogeneity of *E. coli* levels in foreshore sands and support a local surface source; large numbers of gulls have been observed to congregate on the foreshore sands. The range of shallow ground-water levels near the edge of water indicate that wave action may contribute to increased *E. coli* concentrations in foreshore sands.

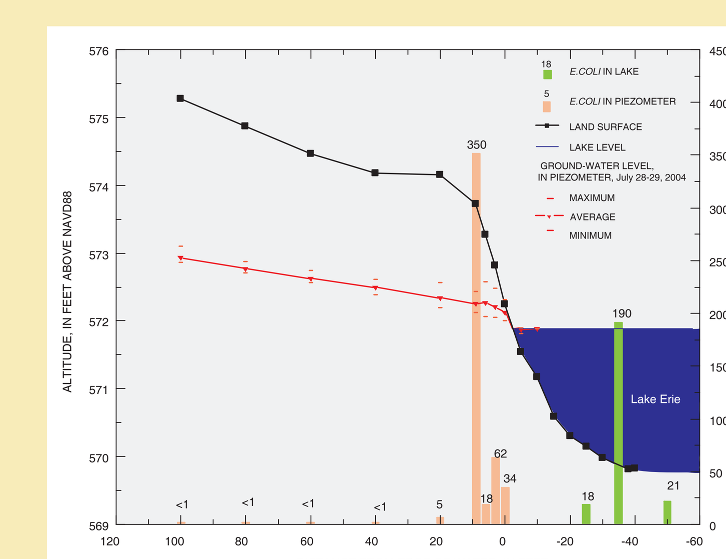

Figure 6. Average water levels and *Escherichia coli* concentrations in tempoary piezometers at Edgewater Beach, Cleveland, Ohio on July 28-29, 2004.

Cooperators and Acknowledgement

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