Thinking Differently About *E. coli*

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Introduction

Roughly twenty percent of our planet's water lies within the Great Lakes watershed. These lakes supply over 33 million people from the United States and Canada with the water they need for life. The Lake Michigan watershed, the second largest of these vital water bodies, supplies over 10 million U.S. citizens, including the residents of Northwest Indiana, with their water.

Consider the many ways we rely on Lake Michigan's water. We drink it, we bathe in it, we use it for transportation, commerce, agriculture, and industry. We fish from it; we boat in it; we swim in it. The list goes on.

Unfortunately, this precious water is often polluted in a variety of ways. The primary focus of this article is on sewage contamination and the problems with current efforts to monitor recreational water quality.

History of Water Quality Monitoring

How exactly do people monitor the water quality at area beaches to protect human health? The tests that beach managers administer today have their roots in research done 150 years ago. In 1855, a gentleman named John Snow of London showed that contaminated water could transmit disease. He learned that the feces from people who were ill with cholera could somehow get into the water supply and when others drank the water, they too caught the disease. (Dufour, 2003) In 1885, a researcher named Escherish discovered a microorganism in infant feces. Other scientists showed that the microorganism was found in all feces. In 1892 a scientist named Schardinger suggested that if this microorganism was found in water, it would indicate the presence of fecal contamination. Many other researchers followed these, all working toward an effective way of testing water for fecal contamination. Eventually, the microorganism discovered by Escherish (now called *Escherichia coli* or *E. coli*), became used as an indicator of fecal contamination. (Dufour, 2003)

E. coli is a type of bacteria that is present in the gastrointestinal tracts of all warm-blooded animals. Although there are harmful strains of E. coli, it is most generally a relatively harmless intestinal bacterium. (Geldreich, 1978, cited by Nevers and Whitman, In Press) We use *E. coli* as an indicator because if it is present, there may be more harmful pathogens that are commonly associated with fecal contamination present as well. (Cabelli et al., 1979, cited by Nevers and Whitman, In Press) These could include Cryptosporidium, Giardia, and enterovirus amongst many others. Compared to the pathogens themselves, *E. coli* is cultured fairly easily. That fact, in combination with its common occurrence with fecal contamination, has lead *E. coli* to be the designated indicator for bacterial contamination of fresh recreational waters. (US EPA, 1986 cited by Nevers and Whitman, In Press)

Criteria for Monitoring Bacteria at Beaches Today

Snow learned that contaminated drinking water can cause illness. Today, we know that swimming in contaminated water can also cause a variety of diseases, ranging from skin rashes and eye and ear infections to hepatitis and respiratory infections. Epidemiological studies are currently being conducted by the United States Environmental Protection Agency (EPA) and the Centers for Disease Control, in cooperation with the United States Geological Survey (USGS) and the National Park Service, to validate indicator tests, set indicator limits based on disease incidence, and investigate swimming related disease. In the mean time, according to the Beaches Environmental Assessment and Coastal Health (BEACH) Act (2000), all states must adopt the US EPA's established water quality criteria for monitoring bacteria. That criteria is based on *E. coli* levels, and specifies that no single water sample can have an E. coli count that exceeds 235 CFUs (colony forming units) per 100 ml of water, or a geometric mean of 126 over the course of 30 days. (Nevers and Whitman, In Press) Public beach managers now test their water quality periodically and close beaches if *E. coli* levels are above the standards for safe swimming.

Is *E. coli* an Effective Indicator?

But, unfortunately, there is "trouble in paradise". Much research is being done on water quality and beach monitoring. As this research progresses, problems with the current system of monitoring are brought to light. (Nevers and Whitman, In Press) Researchers today have discovered that *E. coli* may not always be an effective indicator of water quality. While it is true that *E. coli* is found in the intestines of warm blooded animals, scientists have recently revealed that E. coli can also persist and perhaps thrive in many other natural environments! (Whitman and Nevers, 2003)

Take soil for example. Research conducted at the USGS Lake Michigan Ecological Research Station (USGS LMERS) has shown that temperate forest soils in the Indiana Dunes harbor *E. coli* throughout the entire year (winter included)! The sediments and soil in the watershed of Dunes Creek (a Lake Michigan tributary) contain *E. coli*, and the persistently high *E. coli* counts in Dunes Creek itself may be due to rainfall and streamflow eroding the sediment-borne bacteria into the water. In these cases there was no significant human fecal input, yet the *E. coli* was there. (Byappanahalli, et al., 2003)

What about sand? *E. coli* is found in beach sand as well! Bacteria harbored in sand may even persist longer than in water because the bacteria adhere to sediment particles, unlike bacteria that are free in the water. (Whitman and Nevers, 2003) When various advisories keep swimmers out of the water, many people will remain on the beach. According to researchers at the USGS LMERS, “People spend far more time on the sand or within the wading zone, and whatever the conditions, small children spend the majority of their beach time in sand along the water’s edge – the site of high bacteria levels.” Although higher *E. coli* levels have been detected in the sand, an increased risk of disease has not yet been identified.

Research has shown that *E. coli* counts were higher in the nearshore sand and submerged sand than in the beach water. Additionally, the *E. coli* counts were typically several orders of magnitude higher in the sand than in the water. The geometric mean of *E. coli* counted in the foreshore sand in a study on 63rd street beach in Chicago was 4,000 CFU’s/ 100 ml of water, as compared to only 43 CFU’s /100 ml water in the water. (Whitman and Nevers, 2003) How ironic that by closing the swimming waters that may have 240 colonies/100 ml of water, we may actually be increasing the contact people have with even higher concentrations of *E. coli* (sometimes as high as 11,000 CFU/100 ml of water) in shallow water and sand. (Whitman and Nevers, 2003) The beach sand, itself, is a non-point source of *E. coli* contamination. When we have north winds bringing waves to the beach, those waves churn up the sand and carry the *E. coli* back out into the water.

E. coli is even in the algae! *E. coli* comes from many natural sources, and can reproduce in *Cladophora*, a kind of green algae found in the open waters of Lake Michigan. *Cladophora* often amasses along the Lake Michigan beaches, and harbors high densities of *E. coli* relative to beach sand. (Whitman, et al., 2003) In their recent study, Whitman et al. found the mean concentration of *E. coli* per gram (dry weight) of *Cladophora* to be 10,000 CFUs, with concentrations sometimes reaching as high as 100,000 CFUs. Compare that with the 235 CFUs/100 ml of water it takes to close a beach! Masses of this floating Cladophera, as a result of wave action, can release indicator bacteria that could potentially influence water quality. (Whitman, et al., 2003) In other words, the naturally occurring *E. coli* living in the algae can wind up closing a beach.

“Algal mats washed onto the beach sand may get buried in the sand by wave action or human activity, where they are protected from sunlight and desiccation. Here indicator bacteria may multiply due to available nutrients from the decomposing mats. The beach sand, in turn, can serve as a source for indicator bacteria for near shore water,” according to Richard Whitman, Chief Scientist of USGS LMERS in Porter, IN. Incredibly, *E. coli* can survive for extended periods (over 6 months) in a dried, refrigerated algal matt and quickly multiply once rewetted. (Whitman, et al., 2003)

E. coli seems to be virtually everywhere! It’s in the water bodies that are uncontaminated by humans. It’s in the soil. It’s in the algae. One recent study even found *E. coli* in the fluid of bog dwelling pitcher plants! (Shively, et al., 2004) Not only can *E. coli* exist in these parts of the environment, but recent studies indicate that in some of these areas they can actually reproduce as well! In one research project in the Indiana Dunes, hot water was used to treat the forest soil, killing off all but extremely small numbers of *E. coli.* After the heat treatment, not only did the bacteria multiply, but they persisted in the test plot for more than one year afterward! (Byappanahalli, et al., 2002)

These naturally occurring reservoirs of *E. coli* exist in the seeming absence of fecal material and cause one to question *E. coli*'s suitability as an indicator of fecal contamination.   In many cases, today's beach managers must close their beaches because of the presence of naturally occurring *E. coli* despite the fact that the water is actually uncontaminated.   Because of it's universal nature, in the overall scheme of water quality and beach closures, unless there has been a combined sewer overflow or another known source of human sewage input….*E. coli* levels alone may mean very little! The actual source of the *E. coli* and the co-presence of pathogens still need to be determined.

Flaws in *E. coli* Monitoring Methods

As if that were not enough, there are some very serious flaws in *E. coli* monitoring methods. According to Whitman and his fellow researchers, "One of the major shortcomings in using *E. coli* as an indicator is the time required before test results are available. Water samples for bacteria testing are collected and cultured, and then must incubate for 18 hours before the colony growth is visible. Therefore, after a water sample is collected , results are not available until the next day." By that time, the bacteria levels in our beach waters may have changed significantly. In fact, most studies show little or no correlation between indicator levels from the sampling day to the next day when the results are actually used by the beach managers to make decisions about beach closings. (Rabinovici, et al., 2004)

At Indiana Dunes National Lakeshore beaches, 33 water samples exceeded the water quality standard during the summer of 2004. However, only three of those exceedences occurred on consecutive days. "It is only when consecutive exceeding samples occur that 'closing' a swimming area based on the previous day's sample correctly warns the public of high bacteria levels," says Scott Hicks, Assistant Chief of Resource Management at the national lakeshore. This means only 9 % of the closures during 2004 accurately reflected E. coli levels that truly exceeded the EPA standards. Ninety-one percent of the times the national lakeshore beaches were closed, thousands of people may have been unnecessarily kept out of the water.

On the other hand, every report of a beach closure indicates that on the prior day, if the beaches were open, people were swimming in water that exceeded the standards for safe swimming. This happened 30 out of the 33 times samples exceeded the water quality standard during 2004 at Indiana Dunes National Lakeshore.

According to Dale Engquist, Superintendent of Indiana Dunes National Lakeshore, if signs on the beach were to accurately reflect the true situation, they might sound awfully confusing. Imagine arriving at the beach one day and reading, "The beach is closed today. We don't know if it needs to be. We'll be able to tell you that tomorrow. If you swam here yesterday, we're sorry but you swam in water with *E. coli* levels above the EPA standards for safe swimming."

Not only do test results vary from one day to the next, but studies in Lake Michigan and a marine beach in California show that fecal indicator bacteria levels can vary substantially over very short distances (from centimeters to meters) and over small time periods (from minutes to hours). (Rabinovici, et al., 2004) According to Nevers and Whitman, "When *E. coli* samples were collected hourly, a pattern of decrease could be seen as a gradual decline between 7 a.m. and 2 p.m. In beach monitoring, samples collected in the morning may have high counts, but the water may be safe for swimming within a few hours when counts fall below the limit set by the USEPA." One study at a Chicago Area Lake Michigan beach showed that morning *E. coli* levels were 3.1 times higher than afternoon densities and counts in the shallow water were 2.7 times higher than the deep water densities. According to information released at a recent beach conference, studies at West Beach in Indiana Dunes National Lakeshore showed a similar but more subtle pattern. (Wymer et al., 2001) This pattern has commonly been attributed to disinfection by increased sunlight which kills *E. coli* cells or makes them nonculturable. (Whitman and Nevers, 2004) At present, the vast majority of beach managers do their water sampling in the morning. If they did their sampling in the afternoon, perhaps the *E. coli* levels would fall below the 235 CFUs/100 ml closure level!

E. coli densities varied significantly from day to day, from one time of day to another, and from one water depth to another. (Whitman and Nevers, 2004) *E. coli* concentrations are higher in shallow water than in deep water. In one study on 63rd Street Beach in Chicago, researchers learned that at least 6 water samples would have to be taken in order to achieve 70% precision around the 235 CFUs/100 ml critical closure level. (Whitman and Nevers, 2004) Unfortunately, at some beaches, only a single sample is collected. In these cases, the samples "will not represent the high variation inherent in the beach water, and will likely grossly over- or underestimate the actual *E. coli* count in the water."

Each day a beach is closed may prevent swimmers from becoming ill but it also causes loss of valuable recreational access. On any given day, the net effect of this trade-off depends on the levels of contamination and health risk that actually existed, how many people were or would have been exposed to the water, and what the management decision was for that day. Rabinovici et al (2004) describe a method for evaluating the effectiveness of swim closure policies in terms of their overall costs and benefits to swimmers. Results from a case study using four summers (1998-2001) of water quality and visitor data from Indiana Dunes State Park beach showed that nearly two thirds of swim closures were unnecessary. Also, a typical closure day causes loss of recreational access worth thousands of dollars while providing only modest health benefits. (Rabinovici, et al., 2004)

So, there are problems. But beach managers continue to monitor for *E. coli*, following the letter of the law and trying to protect the public as best they can. They are frustrated, and so are the beachgoers. According to Bob Daum, Chief of Resource Management at Indiana Dunes National Lakeshore, "The public needs more information. They need a method to help them to make an informed decision rather than having to rely on a beach being designated as open or closed based on a system shown to be inaccurate."

Research Continues

A great deal has been learned about *E. coli* as an indicator of recreational water quality in recent years. Yet there is still much to learn. Even today scientists seek out and study alternative indicators of fecal contamination, strive to identify rapid testing techniques, and develop models that can be used to predict real-time water quality.

One near real-time model has recently been developed to predict the water quality at West Beach in Indiana Dunes National Lakeshore. Richard Whitman, Chief Scientist at the USGS LMERS, is researching a system which principally uses the volume and water quality of Burns Ditch (a Lake Michigan tributary flowing into the lake just east of West Beach) and lake conditions to predict the water quality at West Beach and vicinity. This system may prove quite useful to resource managers in their decisions to open or close these swimming beaches.

The Bottom Line

We need to understand that the real world is not sterile… there are actually bacteria everywhere. As stated by a University of Arizona microbiologist, Dr. Charles P. Gerba, (a man who gave his son the middle name Escherichia, the *E* in *E. coli*), "Bacteria are unavoidably, inevitably - and, usually, utterly benignly – a part of our world." (New York Times, 11/9/2004) All bathing waters, even treated swimming pools and spas, carry a certain degree of risk. According to a report in the Nov 2, 2001 issue of Science-Week, "Because of frequent fecal contamination, the inability of chlorine disinfection to rapidly inactivate several pathogens, and the common occurrence of accidental ingestion of pool water, transmission of pathogens can occur even in well-maintained pools." In fact, this transmission of pathogens is much more likely to happen in a pool than in the waters of Lake Michigan.

All told, the water in Lake Michigan is generally healthy and safe to swim in. The average number of CFUs per 100 ml of water for all samples from Indiana Dunes National Lakeshore's beaches in 2004 was a mere 71. According to Richard Whitman, "Indiana Dunes National Lakeshore has some of the cleanest beaches in southern Lake Michigan." Generally speaking, if there hasn't been a heavy rain, you can feel quite confident that Lake Michigan's waters are clean enough for you to swim. The *E. coli* that has been causing us to close our beaches may often come from natural sources, and not sewage at all.

The Real Issues

Instead of focusing on *E. coli* levels, perhaps we should direct our attention to the sources of the actual sewage itself. Lake Michigan and the tributaries that flow into it, can become contaminated with sewage in a number of ways. Domestic animal waste, sewage discharges from boats, faulty septic systems, and combined sewer overflows (CSOs) are all culprits. CSOs are a huge problem. During heavy rains, many sewage treatment facilities cannot accommodate the high volume coming into their facility for treatment. When this happens, untreated sewage combined with stormwater often bypasses the system and empties directly into our area waterways (particularly Salt Creek and the Little Calumet River). It is actually when combined sewer overflows occur that our waterways and beaches become contaminated and unsafe for swimming. Over 686 million gallons of untreated sewage were reported to have flowed into Indiana's Lake Michigan tributaries through CSOs in the summer of 2004. (Hicks, 2004) The key to staying out of contaminated water is to avoid swimming after heavy rain events when CSOs are likely to occur, and to watch for CSO announcements. Indiana Dunes National Lakeshore advocates better CSO reporting and an instant system of public notification. Citizens can help by reducing their water use, especially during heavy rain events, and by supporting efforts to increase capacities for sewage treatment facilities.

Waste from birds, pets, and other warm-blooded animals can also cause contamination. Pet feces should be cleaned up quickly and removed by the pet owner. The high concentration of *E. coli* associated with gull feces suggests that gulls may be a significant source of indicator bacteria on our beaches. (L. R. Fogarty et al., 2003) Efforts should be made to avoid feeding or otherwise attracting gulls to the beach.

In addition to contaminating our swimming beaches, sewage creates other problems as well. When human or animal waste enters a river, lake, or stream, it decays, using up oxygen in the water and releasing ammonia. Particularly in the summer (when the warmer water holds less oxygen to begin with), as large amounts of waste decay in our waters, the lowered oxygen levels and ammonia can impact our fish and macro-invertebrate populations, causing massive die offs. In the Indiana Dunes area, sewage can also flow downstream, emptying into Lake Michigan sometimes near our drinking water intakes and our public beaches.

Not only is our water a source of recreation, it is our source of life. Doing what we can to keep that water clean and free of sewage only makes sense.

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