The Occurrence of Cyanotoxins in the Nearshore and Coastal Embayments of Lake Ontario

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Lake Ontario, as many other lakes in the world, has suffered from a variety of environmental problems over the past fifty years. Massive blooms followed by die-backs of *Cladophora*, a filamentous algae, and by diebacks of the alewife, a fish, fouled beaches along the Lake Ontario shoreline in the 1960s. The phosphorus abatement program, agreed to by both Canada and the United States, successfully reduced the levels of phosphorus that stimulated the growth of algae. As a result of the reduction of phosphorus, once commonly found in detergents and sewage plant effluent, algae populations including the once ubiquitous shoreline *Cladophora* species were reduced by the late 1980s. Similarly with the introduction of the alewife-eating Pacific Salmon [11], lake alewife populations were reduced and the massive die-offs are no longer observed on the shores of Lake Ontario.

With the 1980s, came the realization that Lake Ontario fish were tainted by Persistent Bioaccumulative Toxic chemicals, including mirex and polychlorinated biphenyls, commonly known as PCBs [6]. In fact, a health advisory still exists on eating fish from Lake Ontario although there is some evidence of recent declines in mirex in salmon tissue [10]. Also, in the 1980s, came the invasion of several exotic or invasive species, such as the zebra and quagga mussel [4] and the fishhook water flea *Cercopagis* [9]. The effect of these, and other invasive species, on the food chain of Lake Ontario are still being assessed by researchers [7].

The approach of the management and research community to many environmental problems, such as those in Lake Ontario, has been reactive: that is, a problem emerges and the science and management communities react to it. Great Lakes' scientists are attempting to take a proactive approach by identifying new problems or emerging issues before they have an impact on either the lakes or the people who use them [8]. One of these emerging issues is cyanotoxins.

Cyanotoxins are produced by Cyanobacteria, among the oldest organisms on the planet. They are bacteria-like organisms that are capable of photosynthesis and at one time were commonly called blue-green algae or "pond scum". They can live in freshwater, saltwater or in mixed "brackish" water. Cyanobacteria are often considered to be nuisance organisms because they tend to occur on the surface of water in large numbers, called a bloom, affecting recreation, especially swimming.

It is known that light, temperature, and the water's nutrient content play roles in bloom formation. Under favorable conditions, slow-moving water or water rich in run-off from farms or sewage treatment plants are common places for the development of blue-green algae blooms. Some Cyanobacteria produce toxins that are harmful to humans and animals. These Cyanobacteria include *Microcystis, Cylindrospermopsis, Anabaena, Nodularia, Oscillatoria, Lyngbya* and *Aphanizomenon.* Some varieties of these algae, but not all, produce toxins within their cells which are released when the cells die or are ruptured.

There are many types of toxins, but those produced by Cyanobacteria mainly fall into three categories including hepatotoxins, neurotoxins and dermatoxins. Hepatotoxins affect the liver, neurotoxins affect the nervous system, and the dermatotoxins affect the

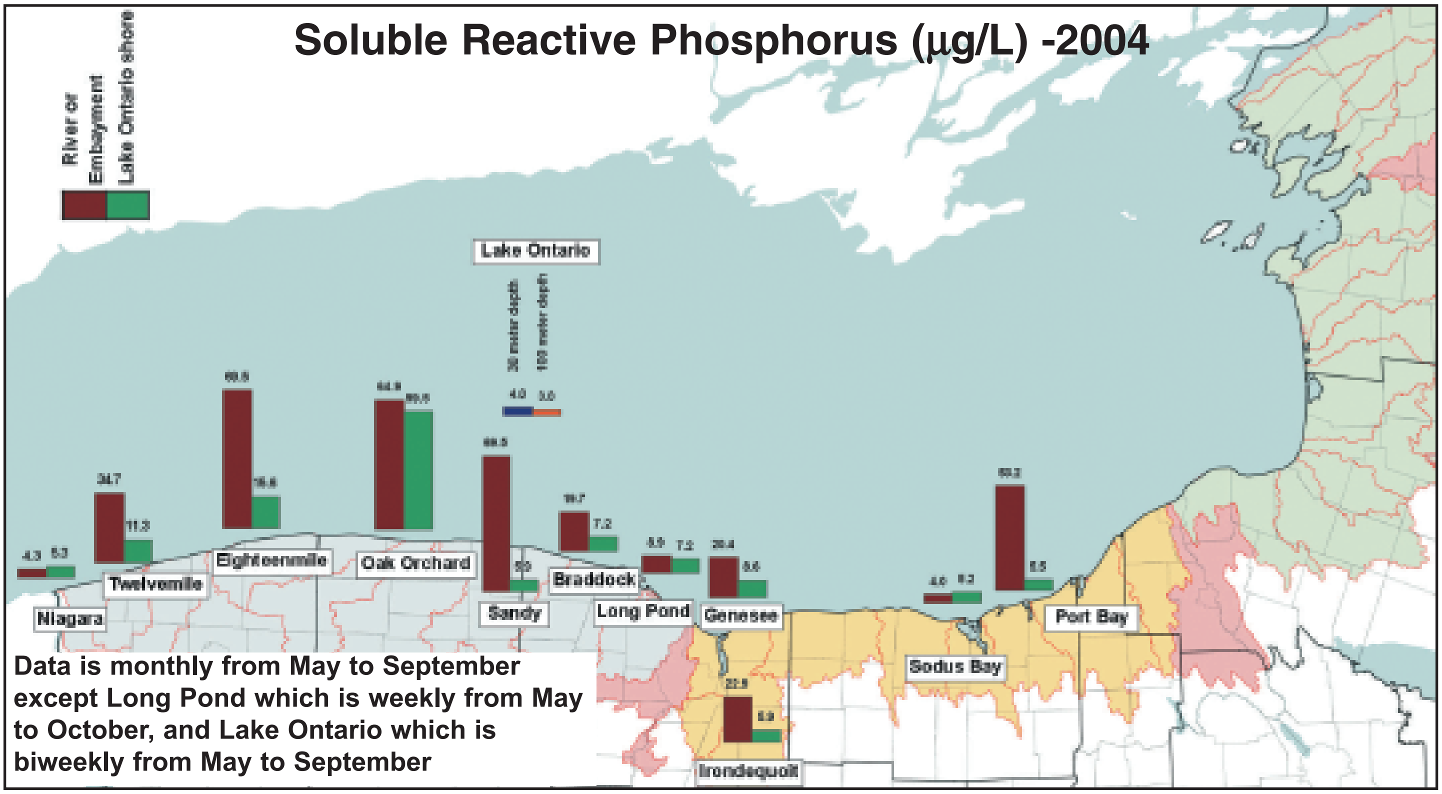

Figure 1. Levels of soluble reactive phosphorus in streams, embayments and the nearshore of Lake Ontario, 2004. Methodology follows APHA (1999).

skin and mucous membranes. Laboratory studies of these toxins indicate that at high concentrations the neurotoxins and hepatotoxins can be deadly to mice and to humans. Besides fatalities, swimming in and drinking water tainted with cyanotoxins can lead to allergic reactions on the skin, nausea, gastroenteritis, fever and headache. There have been numerous cases of people, dogs and livestock becoming ill after drinking or wading into water with cyanotoxins present. The most notorious case being in Brazil when 60 kidney patients died after drinking water contaminated with microcystin, a hepatotoxin, most likely produced by the Cyanobacteria *Microcystis* [12].

Unfortunately, it is not possible by visual inspection of an algae bloom to determine if it is a toxic bloom. At present, fairly sophisticated laboratory instrumentation is required for identification of toxins. Over time, these toxins are diluted and eventually break down and disappear. However, some of these toxins can remain in fish, which have consumed Cyanobacteria. As a result of these outbreaks, the World Health Organization [3] has placed limits, the Tolerable Daily Intake of cyanotoxins, on drinking water and recreational exposure to help prevent these outbreaks.

Why Be Concerned About Lake Ontario?

New York has the second longest shoreline of any of the Great Lakes' states. The shoreline is where the vast majority of the general public comes in contact with the lake and is also the mostly likely location of toxin-producing Cyanobacteria blooms in Lake Ontario. Over six million people per year annually visit parks along New York's Great Lakes corridor [5]. Anglers spend $134 million per year fishing on New York's Great Lakes' and despite health advisories on fish consumption, often eat fish from Lake Ontario. Most importantly, over three million New Yorkers depend on Lakes Ontario and Erie for drinking water. Clearly, New York is an important Great Lake state relying on the lakes for drinking water, recreation and economic development .

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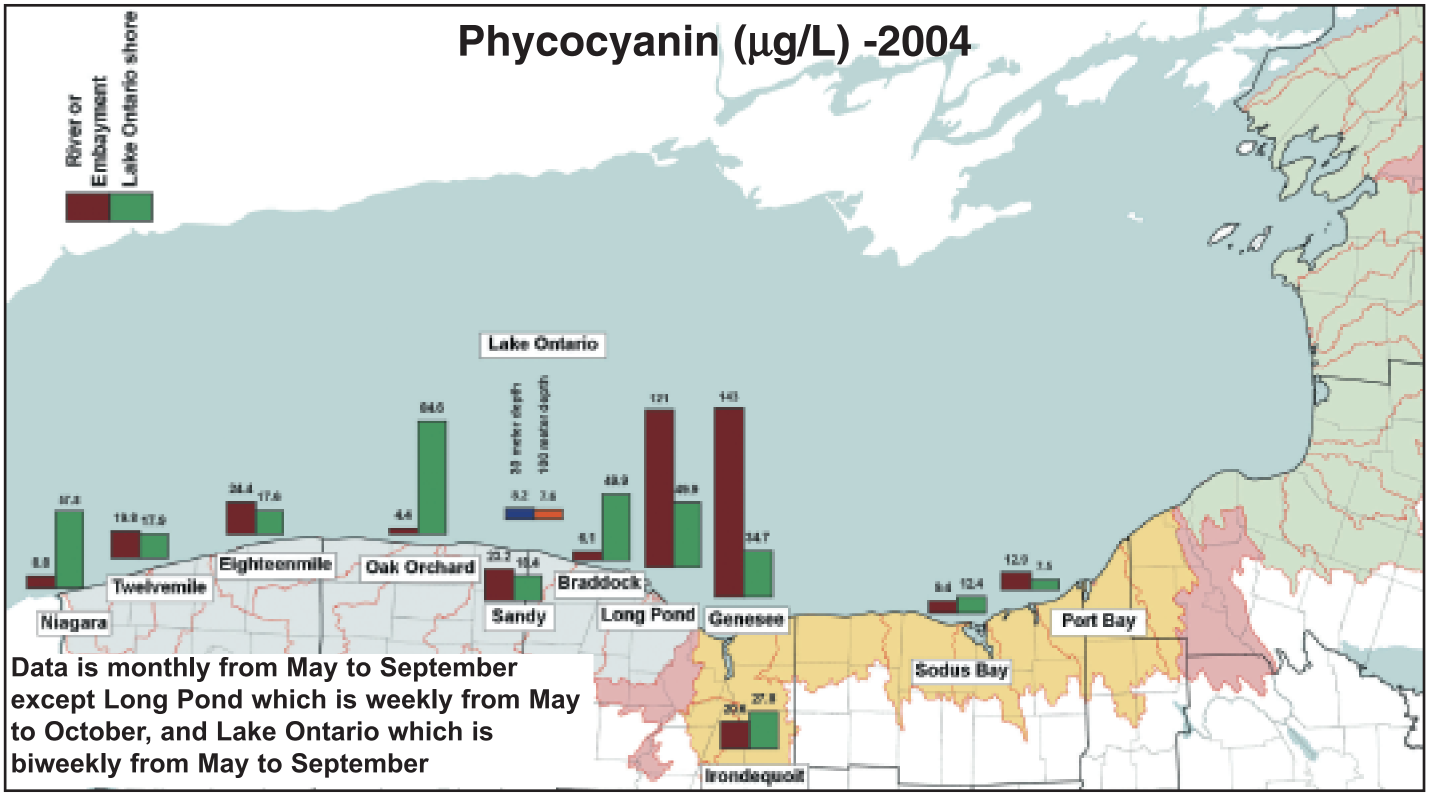

Figure 2. Levels of Cyanobacteria as indicated by phycocyanin in streams, embayments and the nearshore of Lake Ontario, 2004.

Do Cyanotoxins Exist in Lake Ontario?

Little is known about the spatial and seasonal occurrence of cyanotoxins in Lake Ontario. Recent work by the State University of New York (SUNY) at Brockport and SUNY Environmental Science and Forestry has demonstrated that the coastal waters of Lake Ontario have the necessary conditions for cyanotoxin production. In 2004, 24 sites along the south shore of Lake Ontario, as well as bays and rivers, from the Niagara River to Port Bay were sampled for phosphorus and the occurrence of the Cyanobacteria. Surprisingly, ambient levels of phosphorus in the nearshore waters often exceeded New York State's Department of Environmental Conservation guidelines of 20 μg P/L. A total of nine sites of 24 sites sampled had average concentrations greater than 20 μg P/L (Figure 1). Four sites, Eighteenmile Creek, Oak Orchard Creek, Sandy Creek and Port Bay had average concentrations exceeding 50 μg P/L. In contrast, the offshore waters of Lake Ontario averaged less than 5 μg P/L for the same time period. Since phosphorus is generally considered to be the limiting factor of plankton growth, the high phosphorus levels in the nearshore zone of Lake Ontario suggest that algal blooms in the nearshore are likely. In fact, this is the case. Phycocyanin is a measure of the amount of blue-green algae present in the water. During May, June, July, August and September of 2004, phycocyanin or blue green algae levels were exceedingly high in the nearshore region (Figure 2). For example, phycocyanin levels at Oak Orchard averaged 84.6 μg/L, while the Genesee River and Long Pond averaged 143 and 121 μg/L, respectively, compared to less than 10 μg/L at the offshore deep water sites of Lake Ontario (Figure 2). The high phosphorus and phycocyanin levels observed during the summer of 2004 suggested that cyanotoxins, such as microcystins, may be present in the nearshore of Lake Ontario. This concern became more evident when satellite imagery clearly demonstrated that a bloom of algae was "hugging" the entire southern coastline of Lake Ontario during August 2004 (Figure 3); an area of state and municipally operated beaches, private beaches, as well as the location of many municipal intake pipes of drinking water supplies of cities, towns and villages.

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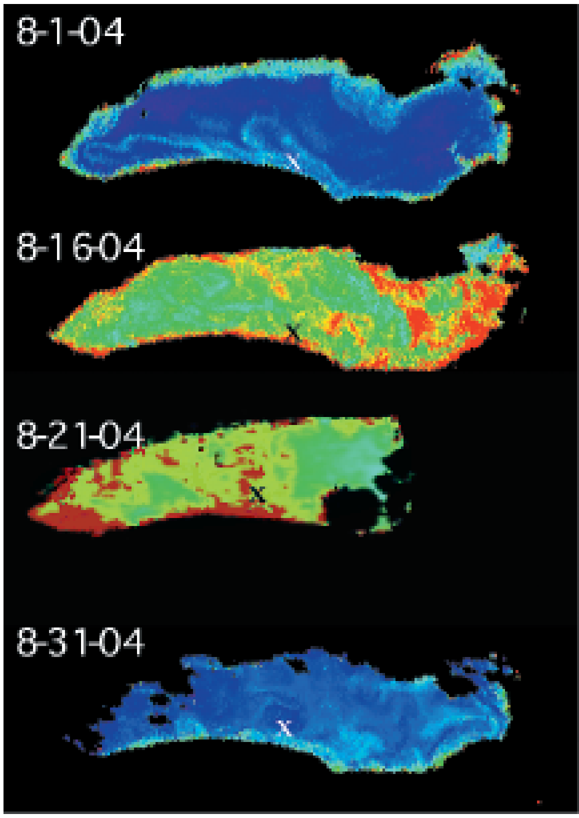

Site (Depth)	Date	MCY (µg/L)	CHLa (µg/L)	Phy (µg/L)
100m	8-3	.004	1.1	1.91
30m	8-3	.004	1.5	15.50
2m	8-3	.004	5.2	1.28
100m	8-18	.005	4.5	15.84
30m	8-18	.005	5.5	13.12
2m	8-18	.008	13.1	26.00
100m	9-2	.003	1.6	13.59
30m	9-2	.003	2.5	23.36
2m	9-2	.003	14.3	61.13

Imagery data complements of Paul Hopkins, SUNY ESF. Microcystin analysis was by protein phosphatase inhibition assay (Carmichael 1999).

Figure 3. Satellite imagery of Lake Ontario showing chlorophyll levels. Red indicates high levels of chlorophyll. Note red area, which is an algal bloom, along the south shore of Lake Ontario on 16 and 21 August 2004. Data in the table represent microcystin (MYC), phycocyanin (Phy) and chlorophyll levels (CHLa) collected from a vessel on Lake Ontario during the bloom. Imagery is SeaWiFS (Sea-viewing Wide Field-of-view Sensor). "X" indicates the general location of the sampling site.

Fortunately, analysis for the cyanotoxin microcystin during the month of August indicated that although Cyanobacteria were present in large quantities, the levels of the hepatotoxin microcystin never exceed the World Health Organization guideline of 1 µg/L for drinking water (Figure 3). In fact, microcystin levels in the nearshore of the lake never exceeded 0.008 µg/L while levels in the bays and rivers were often higher, by an order of magnitude (e.g., 0.076 µg/L in Braddock Bay) (Table 1), but still significantly lower than the World Health Organization guidelines. Thus levels of the hepatotoxin microcystin were very low, near detection limits, along the south shore of Lake Ontario. However, elevated levels of microcystin exceeding WHO guidelines were observed during the summer in smaller lakes in the watershed of Lake Ontario. For example, microcystin levels were 5.07 µg/L in Conesus Lake, and 10.7 µg/L in Silver Lake in September 2004 and 1.59 µg/L in Lake Neatahwanta during July of 2004 – all lakes in central and western New York that drain into Lake Ontario.

Summary

Cyanotoxins are an emerging issue that Great Lakes' scientists are conducting research on to determine occurrence, spatial and seasonal distribution, monitoring strategies and potential causes in Lake Ontario. Conditions necessary for blooms of Cyanobacteria exist along the shoreline of Lake Ontario. This is especially true in some embayments and rivers as levels of the nutrient phosphorus that stimulates the growth of Cyanobacteria is above New York State Department's of Environmental Conservation guidelines. Monitoring in 2004 demonstrated that abundance of Cyanobacteria are indeed high in streams, embayments and the nearshore compared to offshore waters of southern Lake Ontario. Initial research suggests that microcystin production along the southern shoreline of Lake Ontario is minimal and well below WHO guidelines. However, production of the microcystin toxin often exceeds World Health Organization guidelines in inland lakes and may serve as a source to Lake Ontario. More information is required on the yearly variability of microcystin as wet and dry weather conditions appear to have affected the blooms of Cyanobacteria and the production of microcystin from year 2004 to year 2005 in both Lake Ontario and inland lakes. Vigilance by the general public utilizing the waters of Lake Ontario is still required. When visible blooms of algae are present at the surface, the general public and their animals should avoid contact with these waters.

Table 1. Microcystin (MCY), phycocyanin (Phy) and chlorophyll levels (CHLa) during the bloom of August 2004 sites along the lake proper but within the discharge plumes of creeks and bays along the south shore of Lake Ontario.

Lakeside Site in the discharge plume	Date (2004)	MCY (µg/L)	CHLa (µg/L)	Phy (µg/L)
Niagara River	8-24	.019	184.8	159.3
Twelvemile Creek	8-24	.006	2.87	19.1
Eighteenmile Creek	8-24	.037	9.69	34.9
Oak Orchard Creek	8-24	.008	3.63	14.0
Irondequoit Bay	8-25	.037	4.66	62.2
Genesee River	8-25	.063	5.65	123.4
Braddock Bay	8-25	.076	7.88	137.4
Port Bay	8-26	.006	2.36	20.5
Sodus Bay	8-26	.003	0.70	21.8

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