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A Note on Algal Toxins in Wisconsin Waters Experiencing Blue-green Algal Blooms

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ABSTRACT

Certain blue-green algae commonly found in lakes can produce potent toxins during blooms. In Wisconsin there were several incidents over the years when wildlife and domestic deaths were attributed to algal toxins; however, little information existed on how widespread these toxins were in Wisconsin's many lakes and ponds. Thus, a study was undertaken to determine the incidence of measurable toxins in Wisconsin waters. Samples were collected from 86 lakes and ponds, the algae identified by genus, and the toxicity tested using a mouse bioassay. In 25 lakes toxins were present during bloom conditions. Lakes with toxins were found in both the southern and northern portions of the state. The results indicated toxic blooms were not uncommon in Wisconsin, and that algal toxins may be a more critical lake management issue than generally realized.

Introduction

Certain genera of blue-green algae, including *Microcystis*, *Anabaena*, *Aphanizomenon*, *Gloeotrichia*, *Oscillatoria*, and *Lyngbya*, can produce toxins during algal blooms (Carmichael, 1986 a,b; Spoerke and Rumack, 1985). Algae that produce toxins are found in lakes and ponds all over the world, and have been reported in the United States, Canada, Europe, New Zealand, Australia, the USSR, India, Bangladesh, Japan, South Africa, Argentina, and Israel (Carmichael et al. 1985). In Wisconsin, algal blooms containing toxins were found in several lakes during the late 1960s (Karl, 1970). There were also sporadic incidents of animal deaths in previous years where algal toxins were suspected. In general, however, algal toxins have been perceived as an uncommon occurrence and, thus, received little attention in Wisconsin and elsewhere.

During the summer of 1985 two incidents occurred that renewed interest in toxic algae in Wisconsin. The first was the death of two dogs following a swim in a lake located in Polk County, Wisconsin. The deaths received considerable publicity since the lake had just been treated with copper sulfate to control algae, and residents suspected that the poisoning was related to the treatment. The second incident involved the deaths of nine dairy cows that ingested water from a farm pond located in Green County in southwest Wisconsin. In both of these cases algal toxins were eventually identified as the cause of the deaths.

As a result of these animal deaths, and because of other unexplained domestic and wildlife deaths that occurred in the past, a study was conducted of algal toxins in Wisconsin waters. Lakes and ponds from around the state were sampled, mostly during bloom conditions, to determine if toxins were present.

Materials and Methods

Water samples were collected from 86 water bodies—lakes, impoundments, and ponds—from June to November of 1986. The waters sampled generally had a history of algal problems, and samples were taken during bloom conditions, often from areas of the lake where algae were concentrated. Seven highly eutrophic southern Wisconsin water bodies were sampled regularly throughout the summer. Eight public water supplies that use surface water as their source were sampled, at both raw water intakes and at finished water taps, three times during the summer. Where possible, surface accumulations of algal cells were targeted for collection. Samples were collected in sterile, 250 ml, high density polyethylene bottles and stored at 4°C until analysis. The analysis was begun within 48 to 72 hours following sampling.

In the first step of the analysis an aliquot of a thoroughly mixed sample was examined microscopically to determine the genera and relative proportion of algae present. Standard microscopic observations of both wet mount and India ink preparations were used to make these determinations (Bold and Wynn, 1978).

Following algal identification, a mouse bioassay was used to determine whether toxins were present in the sample. The procedure used was similar to that described by Carmichael (1986b) to break down cell walls and free toxins and other intracellular components. It is important to note that algal cells were not concentrated in the laboratory. A cell concentration procedure, such as centrifugation, might be considered for future testing.

Pairs of female Sprague-Dawley mice (25–30 g) were then injected in the abdominal cavity with 0.5 cc of the lysed sample. As a control, an additional mouse was injected with 0.5 cc of 0.9 percent normal saline. After injection, the mice were observed for symptoms of toxicity, including lethargy, muscle tremors and fasciculation, piloerection, paralysis, respiratory distress, and salivation. After a 24-hour observation period the mice were sacrificed. A necropsy (autopsy) was then conducted to determine if there was an engorged liver or necrotic organs.

The assay results were classified: (1) positive, (2) marginally positive, or (3) negative. An assay was positive if the mice died within 24 hours and signs of algal toxicity were noted. If effects of algal toxicity were observed but the mice survived for the 24-hour period, the assay was marginally positive. A negative result was reported when the mice survived with no signs of algal toxicity. As a quality control check results of several Wisconsin samples were independently verified at the laboratory of Dr. Wayne Carmichael at Wright State University. In a few cases—where marginally positive responses were found—verification indicated the presence of strong toxicity. This variance was possibly a result of using raw, rather than lab concentrated, samples.

The type of algal toxin present was determined based on observations of the mice. Hepatotoxins were differentiated from neurotoxins at necropsy. Hepatotoxins produce enlarged, darkened or mottled livers, while neurotoxins do not (Carmichael, 1986a,b). Neurotoxins produce signs of respiratory distress, convulsions, muscle tremors and fasciculations, and salivation, with no gross pathology at necropsy. Contact irritant toxins produce severe dermatitis following direct contact. In the mouse assay, petechial lesions on peritoneal organs indicated the presence of a contact irritant.

Results

Eighty-six of the sites sampled contained blue-green algae capable of producing toxins. Samples from 25 of these sites were toxic (positive or marginally positive) in the mouse bioassay. Table 1 lists the water bodies where toxins were found. Two of the sites were relatively small fish-rearing ponds. The most common symptoms were those of hepatotoxicity. Only one lake produced a neurotoxic response in the mice.

The blue-green algal genera most commonly observed in the samples were *Microcystis*, *Anabaena*, *Aphanizomenon*, *Oscillatoria*, *Lyngbya*, and *Gloeotrichia*. *Microcystis* was the most common genus in the lakes sampled, followed by *Anabaena* and *Aphanizomenon*. All tests of potable water supply systems, both raw and finished, were negative for algal toxins. However, low concentrations of *Microcystis*, *Anabaena*, and *Oscillatoria* were observed in some of the raw water samples, and algal toxins were present at a different location in one of the lakes used for a drinking water supply.

Discussion

The results of this study were surprising because algal toxins were found in samples from many more lakes than anticipated. Thus, it appears that the production of toxins is not uncommon in Wisconsin

Table 1.—Wisconsin water bodies containing algal toxins.[a]

TOWNSHIP	RANGE	LAKE NAME	TYPE[b] OF TOXIN
T13N	R06E	Delton	N
T11N	R08E	Wisconsin	H
T15N	R13E	Little Green	C
T33N	R10W	Ten Mile	H
T33N	R11W	Prairie	H
T28N	R12W	Menomin	H
T29N	R12W	Tainter	H
T14N	R14E	Beaver Dam	H
T31N	R18W	Squaw	H
T13N	R03E	Redstone (marginally positive)	H
T32N	R16W	Martin Pond (marginally positive)	H
T34N	R18W	Frokner Pond (marginally positive)	H
T33N	R15W	Magnor (marginally positive)	H
T19N	R21E	Big Long	H
T41N	R14W	Staples	H
T24N	R21E	Green Bay (grid 1001)	H
T36N	R17W	Big Butternut	C
T33N	R17W	Wapogasset	H
T35N	R16W	Bone	H
T20N	R18E	Winnebago	U
T18N	R04E	Petenwell	H
T26N	R06E	Big Eau Pleine	H
T38N	R09W	Sissabagama (marginally positive)	H
T31N	R18W	Riverdale Flowage	U
T14N	R12E	Maria Lake (marginally positive)	C

[a] Bioassay results that were only marginally positive (mice exhibited toxic effects but survived) are noted. The type of toxin, as determined from observation of toxic symptoms and necropsy, are also given.

N = neurotoxin; H = hepatotoxin; C = contact poison; u = unknown the Department of Natural Resources who provided many of the samples.

ters. This occurred despite a cool d windy summer, where—according observers in the field—there were er concentrated (i.e., "pea soup") al blooms than usual. Further, if al toxins are relatively common in consin, they probably are relatively mon in other states where lakes blue-green algal problems exist.

akes with toxic algae were found a broad geographical area, as cted in Figure 1. Not surprisingly, greatest concentrations of lakes toxic algae were found in the more and intensely developed ern and northwestern portions of tate. These areas are also where ost severe nonpoint source pollu- problems have been identified Dep. Nat. Resour. 1986).

he north central part of the state, Wisconsin's largest concentra- lakes exists, no toxic algae were (Fig. 1). These lakes are located ested area and generally receive urface runoff. Most are oligo- , and nuisance growths of algae equent. Toxic algae probably do in some lakes in this area, but quency is probably much less

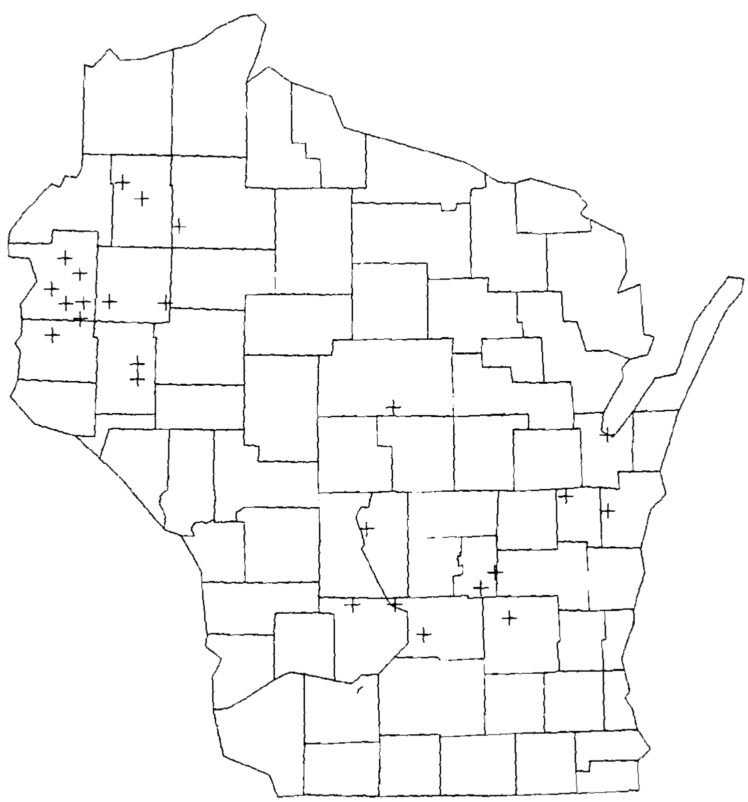

Figure 1.—Approximate locations of lakes/ponds where algal toxins were found in Wisconsin.

than in those parts of the state where lakes tend to be eutrophic.

Of the blue-green genera, hepatotoxins are produced primarily by *Microcystis* (Carmichael, 1986a). Indeed, *Microcystis* was the most predominant genera found in samples, and hepatotoxin symptoms were the most common in the mouse bioassay. *Anabaena* and *Aphanizomenon* are most often associated with neurotoxins (Carmichael, 1986a), and the sample exhibiting neurotoxin toxicity (Table 1) had both of these genera present. Contact irritants are not well understood. Although they once were thought to be produced only by *Gloeotrichia*, it is now believed that several species, including *Oscillatoria*, *Anabaena*, and *Aphanizomenon* can produce these toxins (Carmichael, 1986a). Contact irritants produced by algae are currently under investigation by the Wisconsin Department of Natural Resources. Contact irritants may produce the hundreds of unexplained complaints received by the Department from swimmers and other lake users.

Lake managers and other aquatic scientists must deal with many toxic compounds; however, it is surprising that more attention has not been directed to algal toxins, given their high potency. Carmichael (1986a) reports that the hepatotoxin produced by *Microcystis* is one of the most potent acute toxins known. Fortunately, this toxin is not stable over long periods, so that the effect is not long lasting. Our work, however, suggests that toxins may remain viable in a lake for over a week.

To date, the main threat of algal toxins is apparently to nonhumans. Most individuals are not going to drink from or swim in a lake during bloom conditions—times when toxin production is most likely. Nevertheless, there are some documented cases of humans being harmed by toxins (Bourke et al. 1983). Regardless of the impact on humans, poisoning of domestic animals and wildlife is probably much more common than generally realized. Until recently few veterinarians, for example, were aware of toxic algae and their symptoms. Undoubtedly, many algal poisonings go undiagnosed.

Current knowledge of algal toxicity is limited to acute effects. Virtually nothing is known about long-term or chronic effects. Ingesting small amounts of toxins (perhaps undetectable in the mouse assay) over long periods might lead to chronic diseases such as cancer. Work is currently underway by the authors to assess the potential chronic impact of algal toxins.

Lake managers need to be aware that the production of algal toxins is not necessarily a rare event. As a result of this study, information has been disseminated throughout Wisconsin concerning toxic algae. Included among those who have received information are veterinarians practicing in the state. Avoiding animal contact with lakes and ponds during bloom conditions is a simple management strategy easily implemented through information dissemination.

Finally, more research needs to be conducted on what triggers algae to produce toxins. Toxins are not found in all blooms. Conditions such as temperature, sunlight, water chemistry, etcetera. that lead to toxin production need to be identified so predictive models can be developed. Work by Smith et al. (1987), on predicting blue-green algal blooms on a genera-specific basis in lakes, is one type of approach that may prove very useful to lake managers.

Conclusion

Algal toxins are more common in Wisconsin lakes and pose a more serious problem than commonly perceived. Evidence of three types of algal toxins—hepatotoxins, neurotoxins, and contact irritants—were found, with hepatotoxins the most prevalent. Lake managers need to become aware that the occurrence of algal toxins is widespread since their acute toxicity is so high. More basic information is needed to identify the conditions that trigger algae to produce toxins and to examine the possibility that toxins may have chronic as well as acute effects.

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