The Dangers of Toxic Blue-green Algae

Blooms and Implications for Effective Management

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Introduction:

Algae (also referred to as phytoplankton) serve as the base of the food chain for aquatic life of a higher trophic level. They provide zooplankton with nutrients for growth, filter the water, and are consumed by macro invertebrates. The lake fishery is dependent upon macro invertebrates as a primary food source. Thus, it is critical for a healthy and robust lake fishery to access a healthy population of algae in the lake. Not all algae has equal nutritive value, with small green algae and diatoms preferred by zooplankton and filter feeders and blue-green algae being the least desirable or palatable. Green and blue-green algae can also exist in a filamentous form which tends to form dense mats on the surface of water bodies, and this form is less desirable for lake health and aquatic life (Figure 1). Blue-green algae (also referred to as cyanobacteria) have become a serious threat to water quality in many water bodies and have led to significant public health concerns since many of them release toxins upon cell death.

Although limnologists (lake scientists) have studied blue-green algae for several decades and blooms were first noted by Francis in 1878, the discovery of toxins produced by them is relatively new. In particular, the genus *Microcystis* has been problematic to inland lakes in that it usually accompanies a hyper-eutrophic (highly nutrient-rich) state where DO depletion and fish kills are prevalent, water clarity is low, and nutrients such as phosphorus (P) and nitrogen (N) are elevated. Other toxins are produced by other blue-green algae genera such as *Anabaena, Oscillatoria, Aphanizomenon,* and *Lyngbya* (Carmichael, 1997). When a lake becomes dominated by toxic blue-green algae the effects go beyond the aquatic environment (Vasconcelos, 1995; Carbis et al., 1997) and impact human health (Kuiper-Goodman et al., 1999). The toxins (specifically, Microcystin-LR, RR, and YR) are proven nerve, liver, and kidney toxins. The World Health Organization has set a drinking water limit of no more than 1 microgram per liter (μgL^{-1}) of Microcystin-LR (Chorus and Bartram, 1999). Many of these toxins can be found not only in shallow eutrophic inland lakes but also major drinking water reservoirs. The production of technologies to detect these toxins in Microcytic and other toxin-producing blue-green algae took many centuries. Within the past few decades, the development of highly sensitive (detection limits as low as 50 pg ml-1) immunosorbent assays that are enzyme-linked along with sophisticated laboratory instruments (Metcalf et al., 2000; Ward et al., 1997) has allowed for toxin measurement and quantification. This area of toxin detection that is both economical and timely has become competitive among toxicology scholars.

Implications for Effective Management:

Hyper-eutrophic lakes are especially vulnerable to toxic algal blooms since the blue-green algae thrive in high nutrient waters that are warm. This is why blooms are much more prevalent in the summer months which occurs during peak lake management season. Figures 2 and 3 show widespread *Microcystis* blooms on Indian Lake (Cass County, Michigan) in August of 2011 prior to whole-lake aeration and in Spring Lake (Ottawa County, Michigan) in August of 2009, respectively. It used to be that lake managers knew only of the potential cause of these blooms (elevated nutrients such as phosphorus and nitrogen) but did not know of the consequences to the lake and human health and that there are toxins involved. The urgency to reduce these blooms has now become a critical and timely objective in the lake management field. Algaecides which are commonly used to treat nuisance filamentous algal blooms are minimally effective on toxic blue-green algae and may even exacerbate release of the Microcytic-LR toxin (Jones and Orr, 1994) since the toxin is released when the cell walls are shattered by the algaecide. Traditionally, algaecides have been used to treat nuisance algal blooms including blue-green algae blooms but the latter always re-appeared. This is because blue-green algae have evolved under substantial environmental stress and are very adaptable to high water temperatures and high turbidity, and are tolerant of algaecides. In the past, it was believed that the blue-green algae blooms were a natural outcome of the

Figure 1: Dense filamentous algae which compromise lake health (RLS, 2012)

nutrient-enriched environment and thus mitigation was not often pursued.

A new paradigm in lake management has since emerged that does not rely solely on algaecides but additionally seeks to reduce nonpoint source pollution (NPS) by using alternative in situ measures. For example; aeration, ozonation and external improvements such as NPS pollution reduction through implementation of Best Management Practices (BMP's) are used to reduce sediment and nutrient loads to lakes from the surrounding land. This new paradigm would not have come to fruition if not for the discovery of the toxins produced by blue-green algae, the urgency for their reduction, and the technologies produced for in situ and watershed improvements to reduce nutrients that create the environment needed for the toxic blue-green algae.

Figure 2: A dense Microcystis bloom on Indian Lake prior to whole-lake aeration in 2011.
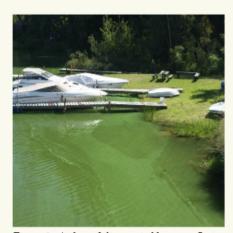

Figure 3: A dense Microcystis bloom on Spring Lake in 2009.

Future Concerns:

Lakes in the North Temperate Zone have already been classified as having saturated carbon dioxide (CO_2) levels (Cole et al., 1994) and actually act as sources of carbon to the atmosphere rather than sinks. In fact, Tranvik et al., (2009) demonstrates that the global annual emissions of carbon from lakes to the atmosphere are nearly equal to the carbon assimilation of the oceans. Much of this carbon was not necessarily a result of increased atmospheric carbon but likely from the partial pressure of CO_2 which is derived from both internal (respiratory) and external (import of carbon from the land into the water) processes (Kling et al., 1991). Furthermore, Sobek et al., (2005) reviewed data on 4,902 lakes and determined that increased temperatures do not necessarily lead to an increase in carbon but more likely from increased transport of dissolved organic carbon (DOC) from the land to the water. The control of carbon from the land to the lake will be critical for controlling carbon budgets given atmospheric increases. This further emphasizes the need for effective watershed management.

Inorganic carbon in the forms of CO_2 and bicarbonate (HCO_3-) are the primary sources of carbon that fuel submersed aquatic plant and algae growth (Wetzel, 2001). In general, lakes with a high pH will have more HCO_3- and those with low pH will have more CO_2 (Stumm and Morgan 1981). The ultimate ability of a given lake to buffer against increased inputs of carbon will determine the impacts on lake biota (Wetzel and Likens, 2000). Allen and Spence (1981) noted that the macroalgae (Chara spp.) were much more responsive to increased HCO_3- in the water column. Thus, lakes that have a high pH (and many in lower Michigan do) would expect to see even more Chara growth if the lake carbon concentration increased. If lakes with dense Chara experienced excessive biomass decay, then increased respiratory demands could result in internal carbon concentrations further increasing. Shapiro (1997) noted the ability of blue-green algae to exploit increased CO_2 levels for accelerated growth. Thus, lakes with increased CO_2 that have a strong population of blue-green algae may become further dominated by the alga as concentrations continue to increase. Feuchtmayr et al., 2009 found that an increase in nitrogen fixers is possible given increased nitrogen concentrations. Such impacts would potentially lead to a lowered

biodiversity that selects for algal species only able to tolerate unfavorable climatic conditions. ■ ■ ■

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