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Synthesis of ecotoxicological studies on cyanotoxins in freshwater habitats – Evaluating the basis for developing thresholds protective of aquatic life in the United States

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Abstract
In recent decades, cyanobacteria harmful algal blooms (cyanoHABs) have increased inmagnitude, frequency, and duration in freshwater ecosystems. CyanoHABs can impact water quality by the production of potent toxins known as cyanotoxins. Environmental exposure to cyanotoxins has been associated with severe illnesses in humans, domestic animals, and wildlife. However, the effects of sustained exposure to cyanotoxins on aquatic life are poorly understood. In this study, over 150 peer-reviewed articles were critically evaluated to better understand the ecotoxicity of 5 cyanotoxin classes (microcystins, cylindrospermopsin, anatoxin-a, saxitoxins, nodularin) on fish, amphibians, aquatic invertebrates, and birds exclusively feeding in freshwater habitats. The systemic review demonstrated that microcystins, and more specifically microcystin-LR, were the most studied cyanotoxins. Ecotoxicological investigations were typically conducted using a fish or aquatic invertebrate model,with mortality, bioaccumulation, and biochemical responses as the most frequently measured endpoints. After excluding the studies that did not meet our acceptability criteria, remaining studieswere examined to identify the no-observed and lowest observed effect concentrations (NOEC and LOEC) for microcystins; the limited amount of data for other cyanotoxins did not allow for analysis. The published ecotoxicity data suggests that the U.S. EPA recreational water quality criteria for microcystin (8 µg/L) may be protective of acute toxicity in aquatic organisms but does not appear to protect against chronic toxicity. Individual U.S. states have developed more stringent recreational health-based thresholds, such as 0.8 µg/L in California. Comparisons of this threshold to the chronic NOEC and LOEC data indicate that more restrictive microcystins thresholds may be required to be protective of aquatic life. Additional research is needed to evaluate the sublethal effects of a wider array of microcystin congeners and other cyanotoxins on organisms relevant to U.S.watersheds to better support nationwide thresholds protective of aquatic life.