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Review

Global solutions to regional problems: Collecting global expertise to address the problem of harmful cyanobacterial blooms. A Lake Erie case study

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ABSTRACT

In early August 2014, the municipality of Toledo, OH (USA) issued a 'do not drink' advisory on their water supply directly affecting over 400,000 residential customers and hundreds of businesses (Wilson, 2014). This order was attributable to levels of microcystin, a potent liver toxin, which rose to 2.5 $\mu g\,L^{-1}$ in finished drinking water. The Toledo crisis afforded an opportunity to bring together scientists from around the world to share ideas regarding factors that contribute to bloom formation and toxigenicity, bloom and toxin detection as well as prevention and remediation of bloom events. These discussions took place at an NSF- and NOAA-sponsored workshop at Bowling Green State University on April 13 and 14, 2015. In all, more than 100 attendees from six countries and 15 US states gathered together to share their perspectives. The purpose of this review is to present the consensus summary of these issues that emerged from discussions at the Workshop. As additional reports in this special issue provide detailed reviews on many major CHAB species, this paper focuses on the general themes common to all blooms, such as bloom detection, modeling, nutrient loading, and strategies to reduce nutrients.

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1. Introduction

In early August 2014, the municipality of Toledo, OH (USA) issued a 'do not drink' advisory on their water supply directly affecting over 400,000 residential customers and hundreds of businesses (Wilson, 2014). This order was attributable to levels of microcystin, a potent liver toxin, which rose to 2.5 μg L^{-1} in finished drinking water and exceeded the 1 μg L^{-1} WHO advisory guideline value. This toxic drinking water was caused by a large bloom of cyanobacteria (CHAB: cyanobacterial harmful algal bloom) in the western basin of Lake Erie that was constrained by prevailing winds to the region around the city of Toledo's water intake. CHABs are not new to Lake Erie; in fact they have recurred annually over the past two decades (Steffen et al., 2014a) and may be occurring with increasing intensity (Michalak et al., 2013; Ho and Michalak, 2015). Whereas this event gained great notoriety as national news in the US, CHABS occur annually on a global scale, promoting chronic and acute health hazards while concurrently producing serious economic effects (Roegner et al., 2014 and references therein). Wherever they are found, the suspected causes of CHABs are typically nutrients arising from various sources including fertilizer, wastewater, the atmosphere, and internal cycling from sediments (Paerl et al., 2011). Recent studies have developed models that predict CHAB intensity in Lake Erie from farm-derived nutrient loads linked to rainfall (Stumpf et al., 2012; Michalak et al., 2013; Obenour et al., 2014). The Toledo crisis afforded an opportunity to bring together scientists from around the world to share ideas regarding factors that contribute to bloom formation and toxigenicity, bloom and toxin detection, as well as prevention, and remediation of bloom events. These discussions took place at an NSF- and NOAA-sponsored workshop at Bowling Green State University on April 13 and 14, 2015.

The objective of the Workshop was to identify the major knowledge gaps regarding the understanding of bloom formation, detection, and mitigation along with discussion of current bloom remediation efforts around the world. The workshop featured NSF- and NOAA-funded researchers and NOAA staff scientists who examined the biology of CHAB species, organism and toxin detection, nutrient management, and bloom forecasting in Lake Erie. Providing the broader international perspectives on bloom mitigation were scientists who have studied CHABs in China, Europe, Australia, and Canada. In all, more than 100 attendees from six countries and 15 US states gathered together to share their perspectives. The purpose of this review is to present the consensus summary of the issues that emerged from discussions at the Workshop. Whereas the Workshop and this review focus largely on the 2014 Lake Erie CHAB as a case study, the general conclusions provided here can inform future research aims and mitigation strategies for diverse CHAB events globally. As additional reports in this special issue provide detailed reviews on many major CHAB species, this paper focuses sequentially on the general themes common to all blooms, such as nutrient loading, bloom detection methods, modeling, mitigation strategies, and economic incentives for bloom prevention.

2. Nutrient sources and watershed influences–Lake Erie case study

2.1. Phosphorus loads

Phosphorus (P) is a limiting nutrient widely responsible for controlling algal biomass in freshwater systems (Schindler, 1977). The Maumee River, which drains into the southwestern corner of Lake Erie, is the primary source of the P that is driving CHABs in the lake (Ohio Environmental Protection Agency, 2013; US EPA, 2015a). With an area of 17,115 km^2, its watershed is the largest draining into the Great Lakes. In 1975 the National Center for Water Quality Research at Heidelberg University initiated detailed nutrient-loading studies on the Maumee River at the USGS stream gaging station near Waterville, OH. Land use upstream from this station, which accounted for 95.8% of the watershed area, consisted primarily of row crop agriculture (73.3%), with smaller portions occupied by forests (6.5%), pasture/hay/grassland (6.3%), and urban areas (10.6%) (United States Department of Agriculture, 2006). Combined municipal and industrial point source inputs of total P (TP) upstream from Waterville accounted for only about 6.6% of the average annual TP export (Baker et al., 2014a). The TP load from the Maumee River was composed of 25% dissolved reactive P (DRP) and 75% total particulate P (TPP). Since DRP was considered to be 100% bioavailable while TPP in the Maumee River was potentially 25% bioavailable (Baker et al., 2014a), DRP is projected to account for ~56% of the total bioavailable P load based on the estimates at Waterville, OH.

The annual discharge and annual loads and flow-weighted mean concentrations (FWMCs) for the period-of-record (water years 1975–1978 and 1982–2014) at the Waterville station are