Chapter 54
Cyanobacterial Toxins in Water Sources and Their Impacts on Human Health

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ABSTRACT

Cyanobacteria are a group of phytoplankton of marine and freshwaters. The accelerated eutrophication of water sources by agricultural and industrial run-off has increased the occurrence and intensity of cyanobacterial blooms. They are of particular concern because of their production for potent hepato-, neuro-, and dermatoxins, being hazardous to human health. Dissemination of knowledge about cyanobacteria and their cyanotoxins assists water supply authorities in developing monitoring and management plans, and provides the public with appropriate information to avoid exposure to these toxins. This chapter provides a broad overview and up-to-date information on cyanobacteria and their toxins in terms of their occurrence, chemical and toxicological characteristics, fate in the environment, guideline limits, and effective treatment techniques to remove these toxins from drinking water. Future research directions were also suggested to fill knowledge and research gaps, and advance the abilities of utilities and water treatment plant designers to deal with these toxins.

INTRODUCTION

Cyanobacteria are ancient prokaryotic microorganisms that have been in existence for at least 2.7 billion years and the first organisms to have released oxygen into the primitive atmosphere (Zanchett & Oliveira-Filho, 2013). Cyanobacteria were formerly regarded as blue-green algae because of the presence of chlorophyll a and performing oxygen-evolving photosynthesis in a manner very similar to algae. They occupy a broad range of habitats including freshwater, marine, terrestrial and even extreme niches such as hot springs. In aquatic ecosystems, cyanobacteria constitute the most important compartment in the food web, as they are one of the main primary producers of organic matter and serve as a food source for aquatic organisms. However, cyanobacteria become a problem only when they increase to excessive numbers forming water blooms under eutrophication conditions (high nutrient concentrations) along

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with suitable light and temperature. These blooms can also consume all of the oxygen in the water when they die and decompose, leaving a dead zone (hypoxia) where fish and other animals cannot survive (Diaz & Rosenberg, 2008). The hypoxic dead zone is typically found in the central basin of Lake Erie for decades (Zhu, Michalak, Beletsk, Rao, & Richards, 2015). Additionally, because many species of cyanobacteria are capable of producing potent toxins called cyanotoxins, these blooms are harmful and may lead to many negative environmental impacts such as mortality of domestic and wild animals, and unsustainability of the overall ecosystem. Cyanotoxins vary in their chemical structure and mode of toxicity in human including hepatotoxins, neurotoxins, and irritants and gastrointestinal toxins (Codd, Morrison, & Metcalf, 2005). These cyanotoxins may lead to a wide array of biological impacts on aquatic organisms, including: allelopathic effects on other phytoplankton (Suikkanen, Fistarol, & Granéli, 2004); suppression of zooplankton grazing, leading to reduced growth and reproductive rates and changes in dominance, toxic effects on fish and accumulation of toxins in tissues of invertebrates (Lehtiniemi et al., 2002) and fish (Mohamed, Carmichael, & Hussein, 2003). Furthermore, cyanotoxins are known to affect a number of processes in plants, and their presence in water used for irrigation may have considerable impact on the growth and development of crop plants (Wiegand & Pflugmacher, 2005). The exposure of edible crop and vegetable plants to cyanotoxins is also a concern for human health, as the toxins can accumulate in plant tissues and might be transferred into the food chain (Mohamed & Al-Shehri, 2010). Cyanotoxins are not easily removed by conventional treatment techniques as they are resistant to heat and most physico-chemical factors. Consequently, the presence of such potent toxins in water sources poses a risk to human health upon exposure to them. Additionally, *In vitro* and *in vivo* studies conducted by Zhou, Yu, & Chen (2002) and Svircev, Krstic, Miladinov-Mikov, Baltic, & Vidovic (2009) provided evidences that chronic exposures to low concentrations of the cyanotoxins contribute to the increased the risk for primary liver in China and Serbia and colon cancer development (Zegura, Volcic, Lah, & Filipic, 2008), as microcystin is mutagenic tumor promoter and inhibit DNA repair (Zegura, Straser, & Filipic, 2011). This chapter provides information on cyanotoxins and their human health risks in water sources because many water suppliers may have little understanding of how to manage them, particularly in rural communities and developing countries. This chapter covers six parts: section 1 introduces the occurrence of toxin-producing cyanobacteria in different water sources; section 2 presents the environmental factors promoting cyanobacterial blooms; section3 describes the human health impacts of cyanotoxins; section 4 presents the exposure routes to cyanotoxins; section 5 highlights management strategies and guideline levels of cyanobacteria and their cyanotoxins in the water sources; and finally section 6 sheds some light on the sustainability of cyanotoxins in the aquatic environment.

BACKGROUND ON OCCURRENCE OF TOXIN-PRODUCING CYANOBACTERIA

Cyanobacteria can be found in diverse environments including freshwater bodies, oceans and estuaries, extreme environments such as cold and hot springs, and Antarctic lakes (Taton et al., 2006; Mohamed, 2008). The ability of cyanobacteria to tolerate huge changes in salinity and temperature and survive low light intensity gives them an extremely large competitive advantage in these environments (Funari & Testai, 2008). Cyanobacteria can multiply rapidly in surface waters and form blooms when favorable conditions prevail, such as high temperature, intense light, high pH, and increased availability of nutrients, especially phosphorous and nitrogen, artificially released by anthropogenic activities (Funari & Testai, 2008). Blooms will persist in waters with temperatures between 15 and 30°C and pH levels

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