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Mini Review

What Do We Know About Toxigenic, Bloom-Forming Cyanobacteria at the Beginning of The 21st Century?

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Abstract

Cyanobacteria are microscopic, prokaryotic organisms capable of mass development in aquatic ecosystems. Cyanobacterial blooms, observed often in various fresh and brackish waters, are growing global problem due to the eutrophication process and climate changes. Different cyanobacterial species may produce wide range of various biologically active secondary metabolites, which may be harmful to aquatic organisms, animals and humans. Microcystins (MCs) are the most known and frequently studied cyanobacterial compounds classified to cyanotoxins. But cyanobacteria are producers of several hundred of other toxins (e.g. nodularins, cylindrospermopsins, anatoxins, saxitoxins), and potentially harmful substances (e.g. oligopeptides other than MCs). In this paper, the present knowledge about cyanobacterial blooms, toxins and other metabolites is shown concisely with references to the latest review reports broadly describing the issues discussed. Human health risks caused by cyanobacteria is also presented.

Keywords: Cyanobacteria; Cyanotoxins; Anatoxin; Nodularin; Oligopeptides; Eutrophication

Introduction

Cyanobacteria (Cyanoprokaryota, blue-green algae) are ubiquitous, phototrophic microorganisms, which inhabit fresh-, brackish-, and marine waters, as well as terrestrial environments. In recent decades, global warming and increasing water eutrophication have intensified harmful cyanobacterial blooms [1], which characterize significant production of biomass over a short period of time [2]. The formation of cyanobacterial blooms is controlled by environmental factors among which water temperature, concentrations of key nutrients-phosphorus and nitrogen-and light are the most important [1]. Cyanobacterial blooms present a real hazard to the health of humans, animals and functioning of aquatic biocenoses due to the ability of cyanobacteria to production of numerous biologically active (bioactive) secondary metabolites [3,4,5]. Thus, cyanobacteria and their compounds are of growing global concern. Gogle Schoolar database contains over 421,000 records for 'cyanobacteria' and over 17,000 for 'cyanotoxins' at the present time.

Cyanobacterial secondary metabolites

Part of cyanobacterial compounds was classified as cyanotoxins [2,3,5]. This group contains more than a hundred metabolites which may strongly differ in their chemical structure and toxicological properties. Cyanotoxins are usually arranged into three or four classes according to physiological systems, tissues, organs, or cells which are primarily affected. In general, hepatotoxins (microcystins, cylindrospermopsins and nodularins) induce liver injuries, neurotoxins (anatoxin-a, anatoxin-a(S), saxitoxins, β-N methylamino-L-alanine and lipopeptides) alter the neuromuscular transmission, whereas dermatotoxins (aplysiatoxins and lyngbyatoxins) induce skin irritation [2]. Codd et al. [3] classified cyanotoxins to hepatotoxins, neurotoxins, cytotoxins and irritants. Cylindrospermopsins were classified by the authors to cytotoxins. These toxins show also multiple organ toxicity, neurotoxicity and genotoxicity [5]. Microcystins, with almost one hundred of variants like MC-LR, MC-RR and others, are the most frequently studied and the most widespread toxins. However, cyanobacteria may produce many, other than cyanotoxins, less known compounds that may be potentially harmful to living organisms. For example, oligopeptides other than microcystins are a huge group (ca. 500 compounds) of mostly non-ribosomal peptides, which include aeruginosins, microginins, anabaenopeptins, cyanopeptolins, microviridins and cyclamides [4]. Oligopeptides commonly occur in eutrophic water bodies at high concentrations but their ecological and biological role still remains unclear.

The most common, toxigenic and bloom-forming freshwater cyanobacterial species belong to coccoid *Microcystis, Woronichinia* (Chroococcales), and *filamentous Dolichospermum, Aphanizomenon, Cuspidothrix, Cylindrospermopsis* (Nostocales), *Planktothrix*, and *Planktolyngbya* (Oscillatoriales) genera. *Nodularia spumigena* and *L. majuscula* are the most known marine cyanobacteria, capable to production of toxins and other secondary metabolites. Recently, the massive appearance of alien and invasive species, such as the toxic tropical species *Cylindrospermopsis raciborskii*, has been observed in many European lakes as a probable result of water eutrophication and climate warming [5].

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Human health risk

References dating from 1931 describe a range of human illnesses associated with exposure to cyanobacteria, which resulted in hay fever-like and gastro-intestinal symptoms, pruritic skin rashes, allergic reactions and more serious acute illnesses, with symptoms such as severe headache, fever, pneumonia, myalgia, vertigo, blistering in the mouth or even death [3,6]. In general, routes of exposure of humans to cyanobacteria and their metabolites are [3]:

a) oral-ingestion of drinking or recreational water, food (shellfish, fish in case of toxin accumulation), dietary supplements (pills, capsules) if containing dried cyanobacterial cells with toxins

b) pulmonary-inhalation of aerosols containing cyanobacterial cells during recreation, work, showering

c) dermal-skin, mucosal contact with water during recreation, work, showering

d) haemodialysis-water used for haemodialysis

Wood [6] lists many poisoning cases of livestock and domestic dogs after cyanobacteria exposure. Many cyanobacterial metabolites have been studied for potential pharmaceutical applications [7]. For example, some of them (like microviridin BE-4, apratoxins, caulerpenyne) show anti-cancer activity and provide a great opportunity for new drug discovery.

Conclusion

Degradation and nutrient pollution of aquatic ecosystems resulting in cyanobacterial water blooms are global problems representing serious health and ecosystem risks. In recent decades, significant research attention has been paid to cyanobacterial blooms, cyanotoxins (mostly microcystins) and some other newly discovered metabolites. Further studies in the field of biological activity and ecological role of cyanobacterial secondary metabolites are strongly required.

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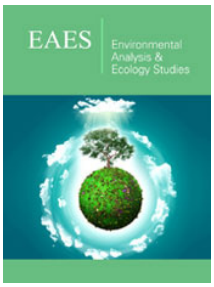

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