Inhibitory Potential of Nanoparticles on Some Harmful Microalgae Microcystis Species

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Abstract

Harmful algal blooms (HABs) consider a global environmental issue. It has gained massive attention in Saudi Arabia, in which two cases have been recorded in the same period. In 2017, Jeddah city witnessed obviously changing Fish Lake's color to pink with an unpleasant odor. The second case was in Alhasa city, where dead fish has spread on the coast of Alakeer Alhsa. In both sites, the water was contaminated with sewage. These phenomena were associated with the bloom of microalgal Microcystis sp. and laboratory examination of water samples from Fish Lake and alakeer coast have confirmed the presence of two different genera of Microcystis. In the last decade, the green fabrication of different types of engineered nanomaterials has gained attention owing to their unique physicochemical properties providing wide biomedical applications, among these types, metallic nanoparticles which are capable of developing a cost-effective and efficient candidate for treating many environmental problems. The aim of the article is to be understanding the effects of nanoparticles on growth of harmful algae blooms.

Keywords: *Blooms, Inhibitory, nanoparticles, cyanotoxins, Microcystis.*

INTRODUCTION

Water bloom refers to a disastrous ecological phenomenon consisting of algae or zooplankton in freshwater or explosive growthand high concentrations of bacteria, causing water bodies' discoloration (Bing et al., 2020). Blooms occur when a particular species of algae within a given area (such as a pond, lake, or regions of the open ocean or coastline) increases in abundance above background levels. The bloom can arise within a days or weeks, leading to disruption of microbial community and the water column becomes nearly monospecific with the blooming organism. The causes of blooms are varied, and the causes are likely distinct for each species.

They include factors that affect growth rate, predation, the ability to outcompete other species for nutrients, and/or the accumulation or aggregation of cells due to other biological or physical parameters under a given environmental regime. Blooms occur worldwide in all aquatic environments and often have seasonal periodicity and beneficial outcomes, for example, providing an extensive and steady food source for the higher trophic organisms. If the number of cells is high enough, the surface waters may become discolored to produce what is colloquially called a “red tide.” The term red tide has acquired a negative connotation because red tides have become synonymous with what is now distinguished as harmful algae blooms (McLean, 2013). Globally, the cyanobacterial bloom is considered one of the most harmful environmental issue that impact human and animal health. Food webs, drinking water safety, water, habitat quality, and freshwater ecosystems’ sustainability have been affected by cyanobacterial blooms and caused serious health problems (Paerl and Huisman, 2009a). Approximately 60,000 cases of human poisoning resulting from cyanobacterial blooms are reported each year, with an overall mortality rate of approximately 1.5%. Numerous cyanobacteria genera including Microcystis, Anabaena, Anabaenopsis, Aphanizomenon, Aphanocapsa, Hapalosiphon, Nostoc, Planktothrix (Oscillatoria), Pseudanabaena, Gloeotrichia, Synechococcus, and Synechocystis are known to produce various types of cyanotoxins (Svirčev, 2017). Generally, the toxicity of a cyanobacterial bloom is a complex phenomenon, defined by the mixture of species and strains with toxic and non-toxic genotypes present, the compounds produced, and the cyanotoxin concentrations achieved. The biosynthesis of Microcysties toxicity (MC) is regulated by both genetic and environmental factors, including irradiance, temperature, and nutrient concentrations (Svirčev, 2017). Globally, most cases of cyanobacteria have been recorded which are linked with animal and human poisoning for over 100 years. For instance, such associations with cyanotoxins have been reported in China, Japan, Bangladesh, Australia South Africa, Kenya, Ethiopia, Algeria, Argentina, the USA, and Canada. Most of the poisoning episodes and illnesses associated with exposure to cyanobacteria in Europe have involved MCs as the most likely causative cyanotoxins, and cases have been reported all across the continent: in Britain, Russia, Finland, Sweden, Norway, Denmark, Belgium, Switzerland, Spain, Italy and Serbia (Svirčev, 2017).

In recent years, the cyanobacterial bloom has gained massive attention in Saudi Arabia, in which two cases have been recorded in the same period. In 2017, Jeddah city witnessed obviously changing Fish Lake’s color to pink with an unpleasant odor (Figure 1). The second case was in Alhasa city, where dead fish has spread on the coast of Alakeer Alhsa (Figure 2). In both sites, the water was contaminated with sewage. These phenomena were associated with the bloom of microalgal Microcystis sp. and laboratory examination of water samples from Fish Lake and alakeer coast have confirmed the presence of two different genera of Microcystis.

Figure 1: The bloom of cyanobacteria in Jeddah in 2017

Figure 2: The bloom of cyanobacteria in Alakeer alhsa occurs in 2017.

In the last decade, the green fabrication of different types of engineered nanomaterials has gained attention owing to their unique physicochemical properties providing wide biomedical applications, among these types, metallic nanoparticles which are capable of developing a cost-effective and efficient candidate for treating many environmental problems) (Khalaj et al., 2018). In his context, many studies have thrown light of the effectiveness of utilizing metallic nanoparticles as an antimicrobial agent (Huang et al., 2016).

Spreading of Cyanobacterial blooms

Photosynthetic prokaryotic organisms where adapt in most environments such as freshwater and marine environment and even extreme habitat are cyanobacteria. It plays a vital role in an aquatic system, considered the base of the food web. However, eutrophication can occur in lakes and reservoirs due to wastewater discharges from industrial and agricultural operations. These discharge of pollutants can cause proliferation of harmful cyanobacteria (Huang et al., 2016). Spreading this phenomenon has become a hazard issue in the most important areas around the world including Lake Victoria in Africa, Lakes Erie and Michigan in US-Canada, Lake Okeechobee and Lake Ponchartrain in the USA, Lake Taihu in China, Lake Biwa in Japan, the Baltic Sea in Northern Europe, the Caspian Sea in west Asia ,and many other ecologically and economically important lakes, rivers and estuaries (Table.1) (Paerl and Huisman, 2009a).Most of the countries have recorded a considerable number of bloom cases. For example, Australia, Asia, Europe., Africa, and the Americas. Particularly, all continent except Antarctica has been experienced cyanobacteria Microcystis bloom (Figure 3) (Svirčev, 2017). The most potential species of cyanobacteria causing harmful algae bloom are Oscillatoria and Microcystis on freshwater prawn culture ponds (Table. 2) (Tayaban et al., 2017)

Table 1: Recorded events of cyanobacteria blooms

Year	The bloom site.	Species	Effect	Reference
1878	Lake Alexandrina, Australia.	*Nodularia spumigena*	Several hundred livestock deaths	(Hilborn and Beasley, 2015b)
1930-1931	Elk River, Kanawha River, Ohio River, West Virginia; Ohio River Ohio; Ohio River, Kentucky, United States;	*Anabaena flos-aquae*	FISH DEATH. GASTROINTESTINAL ILLNESS AMONG THOUSANDS OF PEOPLE RECEIVING DRINKING WATER FROM RIVERS.	(Hilborn and Beasley, 2015b)
1948	Storm Lake, Iowa, United States.	*Anabaena flos-aquae*	Fish, dogs died.	(Hilborn and Beasley, 2015b)

1951	Lake Dauphin, Manitoba, Canada.	*Aphanizomenon flos-aquae*	Horse, dogs died.	(Hilborn and Beasley, 2015b)
1959	Echo Lake, Qu'Appelle Lake, other lakes in Saskatchewan, Canada	*Anabaena circinalis*	Multiple livestock, fish, geese,dogs died. Gastrointestinal illness among individuals with recreational exposure to lakes.	(Hilborn and Beasley, 2015b)
1977	Hegman Reservoir, Montana, United States.	*Anabaena spp. And Aphanizomenon flos-aquae.*	Cattle, dogs died.	(Hilborn and Beasley, 2015b)
1979	Lakes in Pennsylvania, United States.	*Anabaena spp.*	Dog illness.	(Hilborn and Beasley, 2015b)
1984	Lake in Montana, United States.	Unspecified bloom.	Cattle deaths.	(Hilborn and Beasley, 2015b)
1985	Lake in Alberta, Canada.	Unspecified bloom.	Bats, ducks died.	(Hilborn and Beasley, 2015b)
1987	Guandiana River in Portugal.	*Aphanizomenon flos-aquae bloom.*	Fish deaths. Gastroenteritis, dermatitis among those who consumed drinking water.	(Hilborn and Beasley, 2015b)
1989	Lake Rutland Water in Leicestershire, United Kingdom.	*Microcystis aeruginosa bloom.*	Dog and sheep deaths. Gastroenteritis, dermatitis among those who recreated in water	(Hilborn and Beasley, 2015b)
1994	Zeekoevlei Lake, and others, nearor in Western Cape Province, South Africa.	*Nodularia spumigena and Microcystis aeruginosa bloom.*	Dog and livestock deaths.	(Hilborn and Beasley, 2015b)
2002	Pond in Mymensingh, Bangladesh.	*Anabaena flos-aquae and Microcystis aeruginosa bloom*	Fish and goat deaths. Rash, eye and ear irritation.	(Hilborn and Beasley, 2015b)
2003	River Meuse, Venlo Municipality, Netherlands.	Unspecified cyanobacteria.	Fish and bird deaths. Rash.	(Hilborn and Beasley, 2015b)
2004	Buccaneer Bay Lake, multiple other lakes, Eastern Nebraska, United States.	*Anabaena, Microcystis, Oscillatoria, Aphanizo-menon*	Dog, livestock, wildlife deaths. More than 50 reports of rash, skin lesions, headache and/or gastroenteritis.	(Hilborn and Beasley, 2015b)
2007	Baltic sea.	Cyanobacteria bloom.	discolorations at the water causing economic loss for the tourist industry.	(Wasmund et al., 2012)

			Toxic and sometimes cause death of animals and illness of people.	
2010	Lakes, Ohio, United States.	*Anabaena spp., Cylindro-spermopsis raciborskii, Aphanizomenon spp., Planktolyngbya limnetica*	Dog, fish deaths, bird illness. Multiple effects including dermatologic, respiratory, neurologic illness and/or gastroenteritis	(Hilborn and Beasley, 2015b)
2011-2016	Jordan lake, North Carolina.	Cyanobacteria bloom.	Causing deterioration of water quality.	(Wiltsie et al., 2018)
2014	Korea.	*Limnothrix redekei, Pseudanabaena galeata, Pseu-danabaena amphigranulata, Sphaerospermopsis aphanizomenoides, and Calothrix parietina.*	Toxic Cause serious environmental and socioeconomic problems.	(Song and Lee, 2015)
Dec. 2014-Jan. 2015	freshwater prawn farms in Central Luzon, Philippines.	*Oscillatoria* (Oscillatoriales) and *Microcystis* (Chroococcales) *Anabaena* (Nos-tocales)	Bring damaging consequences to the aquaculture industry, food safety, and the environment.	(Tayaban et al., 2017)

Table 2: Recorded events of Microcystis Spp. Blooms

Year	**The bloom site**	**Species**	**Effects**	**Reference**
May 1998	Lake Tres Pascualas, Chile	*Microcystis Sp.* Bloom	danger for human and livestock health.	(Neumann et al., 2000)
2001	Windhoek(namib a)	*Microcystis Sp.* Bloom	Hepatoenteritis, liver enzyme ,diarrhea.	(Svircev et al., 2017)
2002	Brazil.	*Microcystis Sp.* bloom.	Liver failure (visual disturbances, nausea, vomiting, muscle weakness).	(Svircev et al., 2017)
2009	China, lake Taihu	*Microcystis Sp.* bloom.	LIVER enzyme (ALT, AST, ALP, LDH.	(Liu et al., 2016)
2010	Siri lanka	*Microcystis Sp.* bloom.	Chronic kidney disease.	(Svircev et al., 2017)
2010	Portugal	*Microcystis Sp.* bloom.	MC(mouse intraperitoneal bioassay)(Vascon- celos 1994).	(Svircev et al., 2017)
2011	USA	*Microcystis Sp.* bloom.	HCC,CRC	(Svircev et al., 2017)
2011	Saudi arabia – Egypt.	*Microcystis Sp.* bloom.	-----	(Mohamed, 2011b)

2013	Serbia	*Microcystis aerginosa M.flos-aquae*	Hepatitis B,C ,liver cirrhosis.	(Svircev et al., 2017)
2013	Algerian lake	*Microcystis Sp.* bloom.	Toxic and poisoning of animals.	(Bouhaddada et al., 2016)
2014	Serbia	*Microcystis aerginosa M.flos-aquae*	13 cancer.	(Svircev et al., 2017)
2014	Portogal	*Microcystis Sp.* bloom.	Liverenzyme (GGT,AST,ALT) liver, colon and rectum cancer,hepatitis A,C,B.	(Svircev et al., 2017)
2014-2015	San Francisco Esturay California.	*Microcystis Sp.* bloom.	Water quality.	(Kurobe, 2018).
2014	Canada	*Microcystis Sp.* bloom.	Liver cancer.	(Svircev et al., 2017)
2016	Lake Gaohai, China.	*Microcystis Sp.* bloom.		(Feng et al., 2019)

The impact of cyanotoxins

Generally, cyanobacteria are considered as a primary producer of the phytoplankton. However, during eutrophication, cyanobacteria may overproduce cells leading to cyanobacterial bloom formation. That bloom can be toxic and harmful for all organisms and their environment. Mass occurrence of toxic cyanobacteria can be observed as greenish scum or reddish-brown flouting in surface water. These phenomena lead to avoiding water use because of releasing strong odors and spoiled taste of water. The scientists prove that plenty of animal poisoning reports are associated with cyanotoxins around the world (Wood, 2016). Human exposure to cyanobacterial toxins may occur through a direct route such as drinking and recreational waters or an indirect route such as consumption of contaminated food, for example, accumulation of these toxins in edible tissues of fish and vegetable plants exposed to contaminated waters (Svirčev, 2017). The primary source of microcystin exposure for humans is through drinking water. However, other routes such as food, recreational waters, and nutritional supplements can be significant for some cultures and individuals. There are fewer data available that quantify the intestinal route of absorption, but the most plausible mechanism suggests small intestine absorption. Few data are available quantifying the respiratory or dermal route of absorption (Chen, 2005). The distribution of microcystin in organs and tissue occurs by facilitated transport through the membrane receptors in the Organic Acid Transporter polypeptide (OATp) family. This uptake mechanism limits the ability of microcystin to cross cell membranes. OATps are located in the liver, brain, testes, lungs, kidneys, placenta, and other humans' tissues. Once inside the cell, microcystin bind to the enzymes protein phosphatase (PP1 and PP2A). others cover more details of the main enzymes and their role in microcystin toxicity and biotransformation (Campos and Vasconcelos, 2010) (He et al., 2016).

On human

Clearly, the human and animal health impacts of harmful cyanobacteria are increasing and documenting frequently. There is a relation between the causes of health diseases and the occurrence of cyanobacteria bloom. The death or weakness of animals associated with toxic cyanobacteria is a sign of the probability human health problem (Hilborn and Beasley, 2015b) .In 1778, the first cases of toxicity of a harmful cyanobacteria bloom were recorded by Francis. After mass livestock deaths in Lake Alexandrina in Australia, he administered a sample of the Nodularia spumigena blooms material from the lake to a sheep. He then compared necropsy results of the animal experimentally exposed with sheep that had died following natural exposure to the bloom and concluded that cyanobacteria were the source of the toxic effects. In addition, the first published report believed to document a harmful cyanobacteria bloom was by Hald to the Danish government in 1833. Hald described cattle and fish deaths associated with 'sick' lakes where green material covered the surface of the water. from 1878 to 1690, most animals such as wildlife, livestock and companion animals have been affected by harmful cyanobacteria bloom (Figure 3). Over 65 animal death cases linked with toxic cyanobacteria bloom have been studied from Europe, North America, South America, Australia, Africa and Asia. The presence of harmful cyanobacteria bloom that impacts animal or around aquatic environment is essential to control a new health problem. Hence, risks of human health can be avoided through appearance of cyanobacteria bloom, leading to animal death (Hilborn and Beasley, 2015a). Moreover, ingestion of these cyanotoxins causes widespread and severe animal and human health problems, including liver, digestive and skin diseases, neurological impairment, and death (Paerl and Huisman, 2009b). There is also increasing and robust evidence for their adverse impacts on human and animal health because cyanobacteria can produce numerous secondary, bioactive metabolites, including cyanotoxins, which are harmful to other organisms (Figure 4).

Figure 3: The global occurrence of Microcystis blooms and microcystin as determined through literature searches for records of Microcystis blooms from 257 countries and territories. White indicate no record of bloom or microcystin, blue indicates a record was found for the occurrence of a bloom, and green indicates countries or territories where there was a record of both bloom and microcystin. Adapted from (Harke et al., 2016).

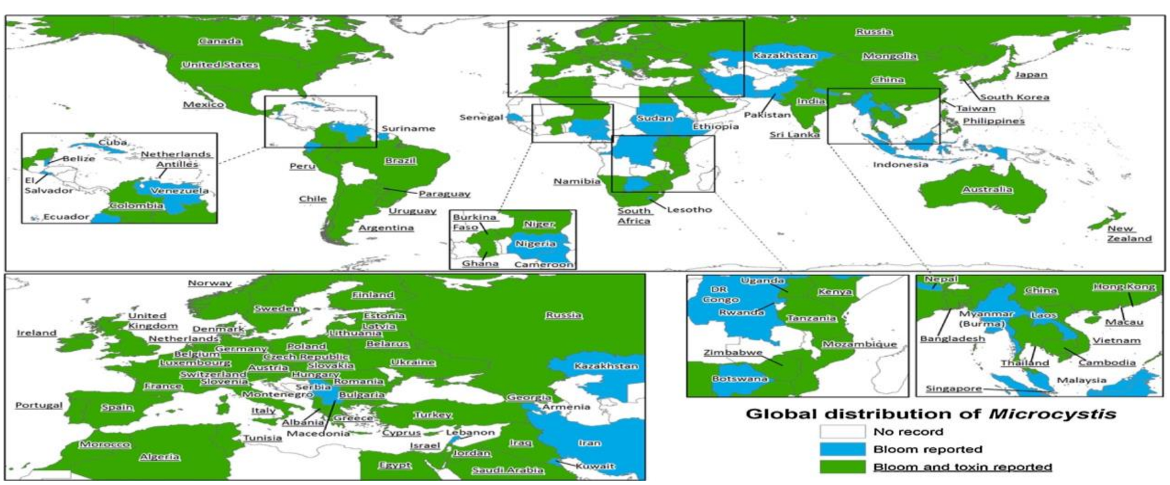
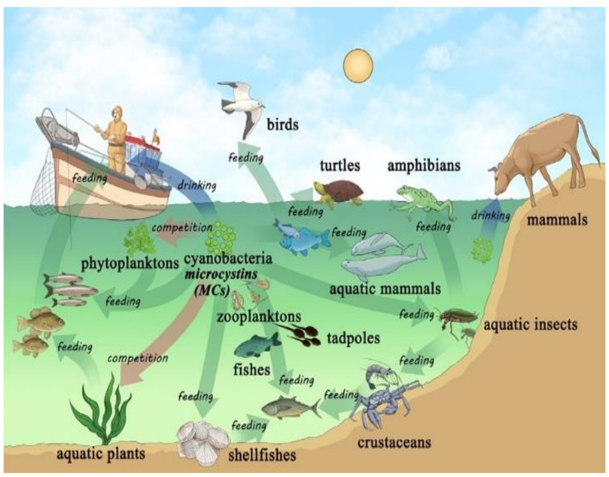


Figure 4: Microcystins (MCs)in the aquatic environment. The cyanobacteria compete with other phytoplankton (algae) and aquatic plants,and the MCsproduced and released into water by toxic cyanobacteria are harmful to other aquatic organisms, including zooplankton, shellfishes, crustaceans, fishes, and turtles. MCs can also be accumulated in aquatic organisms and transferred to higher trophic levels through the food chain. The presence of MCs in drinking water and aquatic products may pose a threat to humans. (adapted from (Chen et al., 2016)



On environment

Cyanobacteria are known as oxygen-evolving photosynthetic microorganisms and have had significant effects on our plant. These have provided cyanobacteria advantages to survive and be resistant as important primary producers during numerous geochemical and climate changes that have taken place on earth during 3.5billions years. The development growth of cyanobacteria ‘bloom’ causes oxygen depletion and harms the ecosystem. Cyanobacteria can adapt to various environments, including natural aquatic environments undergoing human-induced and environmental changes. A wide variety of ecosystems, ranging from oligotrophic oceans to eutrophic lakes, and from the tropics to polar regions, are suitable for forming cyanobacteria bloom. The domain of harmful cyanobacteria blooms leads to raising the turbidity of eutrophic lakes, reservoirs, lagoons and brackish water such as the Baltic Sea (Figure 5). This inhibits aquatic macrophytes’ growth, thereby negatively impacting the aquatic habitat for many invertebrates and fish species. Furthermore, dense cyanobacterial bloom cause night-time oxygen depletion, which can result in fish kills. Cyanobacterial bloom can lead to distinct odor problems by the production of geosmin and other musty chemicals (Figure 6) (Paerl and Huisman, 2009b).

Additionally, the harmful cyanobacterial bloom could be connected with global warming. Increasing temperature is favorable to harmful cyanobacterial bloom in various ways. In general, cyanobacteria’s optimal growth rates occurs at high temperature, usually in excess of 25°C. at these high temperatures, the competition between cyanobacteria and other eukaryotic primary producers such as diatoms, chlorophytes, cryptophytes, and dinoflagellates is raised. That means the growth rate of cyanobacteria is the most highest of other organisms with high temperatures. Moreover, the direct impacts of increasing temperature on cyanobacteria growth are warming of surface water and intensifies vertical stratification. Global warming lengthens the period of stratification. There is a tendency for many lakes in the temperate zone to stratify earlier in spring. The stratification is maintained throughout summer, and destratification of lakes is postponed to later in autumn. Therefore, rising temperatures decrease the water’s resistance to vertical migration of phytoplankton. This will facilitate the formation of surface blooms by buoyant cyanobacteria, and will favor rapid vertical adjustment of migrating cyanobacteria to optimize their nutrient and light acquisition (Paerl and Huisman, 2009b). Cyanobacteria bloom strongly impact on the water quality that uses in different purposes such as, drinking, entertainment, aquatic system, and cultivation. The occurrence of effects on environment duo to cyanobacteria producing to cyanotoxins which are toxic to organisms and its habitat. To illustrate this, after cell death and degradation, cyanobacteria release toxins into the aquatic system causing differences on water quality and then consuming by drinking water or recreational activity. Moreover, these contaminated water can be harmful to microorganisms which inhabit in or surrounding aquatic environment (Mohamed, 2011a). Some cyanobacterial bloom species release toxic peptides and alkaloids, which are considered a basic threat to the use of freshwater ecosystems and reservoirs for drinking water, irrigation, fishing and swimming (Paerl and Huisman, 2009b).

Figure 5: Examples of large water bodies that have experienced recent increases in frequencies, magnitudes and duration of CyanoHABs. Left to right, starting at top: Neuse River Estuary, North Carolina, USA; Lake Volkerak, the Netherlands; Lake Taihu, China; St. Johns River, Florida, USA (courtesy of J. Burns); Lake Ponchartrain, Louisiana, USA (courtesy of J. Burns); Baltic Sea-Gulf of Finland (courtesy of Finnish Border Patrol and Institute of Marine Research, Helsinki, Finland). Adapted from (Paerl and Huisman, 2009b)

Figure 6: Microcystis aeruginosa bloom near the reeds in the north shore of the Gonghu Bay in Lake Taihu, China. (adapted from (Chen et al., 2016))

Economy

Cyanobacterial blooms can have substantial economic and social impacts because of damage to the drinking water industry, recreation and tourism, aquaculture, and agriculture. The implications of toxics cyanobacteria in water supply system become a serious problem around the world. And also, the protection of water supplies from cyanobacteria becomes more challenging. For example, in Toledo, Ohio, the water supply system shut down for three days and impacted over 400,000 residents during the summer of 2014(He et al., 2016). According to the World Health Organization (WHO) guidelines for the drinking water, the critical concentration of some cyanotoxins such as microcystin-LR (MC-LR) is even < 1 μg/L. Cyanotoxins and their metabolites are persistent in the environment and hence can directly enter the drinking water supply system. For instance, the half-life of microcystin- LR (MC-LR) (secreted by Microcystis aeruginosa), is around 90 days and is known to be among the most toxic cyanotoxin present in the natural environment (Kumar et al., 2018). On the other hand, decreasing the water quality, the capital and operating costs for water treatment plants and industrial water users are increasing. Moreover, algal bloom can negatively impact a range of recreational activities including, boating, fishing, swimming, hunting and wildlife viewing (Smith et al., 2019). These blooms and toxins involve substantial economic costs due to intensive water treatment requirements, decreased tourism and recreation revenue, and lowered property values (Xiao, 2018).

The most factor that causing harmful cyanobacteria Microcystis bloom:

climate

One of the main reasons leading to the formation of cyanobacteria bloom is climate change. Consequently, changing such as temperature, rainfall, solar power and drought affect the nature of the environment, causing harmful microcystis bloom. High temperatures and low circulation that result from drought lead to appearing microcystis bloom (Kurobe et al., 2018). Besides, raising the water exchanging frequency and strengthened the freshwater current during flood seasons is a reason of forming Microcystis bloom (Wang et al., 2016). The shortage of light and decreasing temperature are among the clearest reason for the disability of Microcystis growth in the benthic environment (Feng et al., 2019). It can be seen that the formation of Microcystis bloom is affected by the typical seasonal pattern of the temperature climate. To illustrate that, rainfall and seasons can impact water temperature, water volume, and PH (Fernández et al., 2015). Microcystis bloom often occurs in summer in eutrophic temperate lakes and causes various problems, such as reduced transparency, decreased biodiversity, the potential occurrence of oxygen depletion, odor and taste compounds, as well as the production of toxins hazardous to animal and threaten human health (OU, 2004). The aquatic ecosystem temperature reaches 15°C leading to Microcystis bloom formation (Harke et al., 2016). Temperature is one of the main factors in the outbreak of cyanobacteria. Temperature changes lead directly to changes in water temperature, and these changes affect various physical and chemical properties, reaction rates, and biological activities of river waters. Suitable water temperature affects the metabolism and reproduction of algae, thereby accelerating the process of eutrophication and increasing the risk of blooms. The effects of short and long-term climate change on phytoplankton dynamics in aquatic ecosystems have received widespread attention in the past few decades. Temperature changes have a significant impact on the growth and distribution of aquatic organisms. Within a specific temperature range, algae's metabolic rate accelerates, and the growth and reproduction rate increases. Many studies have confirmed that the meteorological factors likely to have an essential impact on cyanobacterial growth and bloom formation include temperature. Jeremy et al. (2018) found that the biomass of cyanobacteria increased with temperature. When the water temperature was higher than 18°C, cyanobacteria's biomass decreased rapidly with the increase of temperature, and the algal toxin increased gradually at high temperatures (Walls et al., 2018). Xia (2014) argued that different species of planktonic algae were affected by environmental factors, such as water temperature, and that chlorophyll a is only related to abundance when the dominant algae species are stable and single. Based on frequent, long-term field observations of large areas of Taihu Lake, Li et al. (2016b) found that moderate temperatures were beneficial to the formation of cyanobacteria blooms. Petra et al. (2016) pointed out that the growth rate of cyanobacteria increased significantly when the temperature exceeded 25 °C, and that its optimum growth temperature is 27°C to 37°C (Bing et al., 2020, Visser et al., 2016).

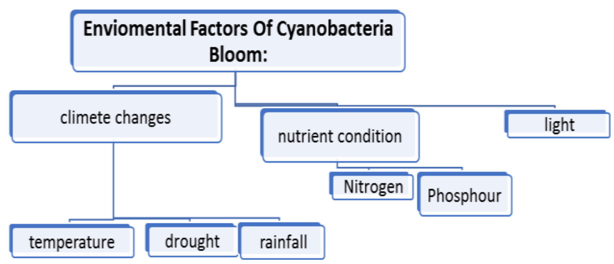
Nutrient

There are plenty of researches that prove the strong relationship between nutrients and the development of Microcystis sp (Bing et al., 2020). Modes of nutrient supply and increasing of nutrient on the environment are a critical factor of Microcystis appearance. The concentration of phosphor, nitrogen and iron plays fundamental role in microcystise growth. N is necessary on the structure and function of macromolecules such as protein and nucleic acids. And also, phosphor is critical part of the building blocks of nucleic acids, phospholipids and complex carbohydrates. Iron regulates most of the biochemical processes of microalgae. These nutrients take part in the fundamental process such as the biosynthesis of protoporphyrin precursor, &-aminolaevulinic acid, and chlorophyll formation. Photosynthetic electron transporter ferredoxin needs these elements. Nitrogen is considered an essential element in nitrogen assimilation and nitrate reduction. Besides, it can be an activator of peroxidase and catalase enzyme to protect cells against the harmful impact of peroxide (JIANG, 2004). Different cellular mechanisms like buoyancy regulation, cellular storage, high-affinity transporters, and coloniality are regulated via nitrogen Although most of cyanobacteria genera are considered N fixer, such as Dolichos- permum/Anabaeana, Aphanizomenon, Cylindrospermopsis, Nodularia that demand their requirements of nitrogen via N2 fixation, Microcystis sp. are known as non-N fixers, which is essential for its growth. Microcystis sp. rely on external N resources such as environmental pollution or other N sources through forming combined N forms. Microcystis oxides nitrogen (nitrate/ nitrite) to reduced nitrogen (ammonia) that increase reduced nitrogen concentration on freshwater ecosystem producing bloom formation. Microcystis utilize the strategy of regulating the buoyancy and vertically migrate in order to reach nutrient-rich down water by sinking and optimal light amount on the water surface (Harke et al., 2016). In addition, the phosphor is necessary for Microcystis ability to drift vertically even in low concentration. Microcystis can store phosphor in the form of polyphosphate inside its cells, which aid surviving cells during the period of phosphor deprivation. Under low P concentration, Microcystis sp. has the ability to synthesize high-affinity phosphate transporters and alkaline phosphatases and phosphor. On the other hand, the nitrogen compound was an important factor in Microcystis growth than phosphor and iron. It proves that the reason for the dominate of Microcystis sp. on the lake was nitrogen concentration (Harke et al., 2016). It found that the higher content of PO43□-P in water is beneficial to microcystis as the dominant algae, and to the bacteria associated with cyanobacterial outbreaks (Bing et al., 2020). In summary, they pointed out that the effect of temperature and nutrients is associated with the development of Microcystis blooms. Cyanobacteria blooms increase with high temperature at hyper-eutrophic environment fig.(8) (Fernández et al., 2015).

Light:

one of the most important environmental factors of the formation of cyanobacteria bloom is light. It found that suitable light is a fundamental reason for increasing algae growth. Light radiation provides metabolic energy for algal photo- synthesis, affects the rate of photosynthetic carbon fixation, and also affects algae cell respiration intensity and energy levels. In addition, light induces the formation of specific products such as carotene in cells. Plenty of studies have confirmed that the growth of phytoplankton and cyanobacteria in water is greatly affected by light intensity (Bing et al., 2020, Domingues et al., 2017, Domingues et al., 2015). Therefore, Illumination is an important indicator for phytoplankton photosynthesis and evaluations of water environment quality. Phytoplankton, in which algae plants use photosynthesis to absorb and transmit light energy through chlorophyll, plays a vital role in energy conversion and materials circulation in lake ecosystems. The light intensity has a direct relationship with the formation of water blooms. Many studies have shown that the light is primarily reflected by changes in the photosynthetic rate of algae with light intensity. Different types of algae have different photosensitivity levels to light intensity (Bing et al., 2020).

Figure 7: Schematic diagram of factors affecting the blooms



Treatment

Cyanotoxins can be eliminated from water by various strategies such as flocculation, membrane filtration, and adsorption on activated carbon, oxidation by permanganate, ozonation, and chlorination (He and Wert, 2016). However, the use of these techniques unable to eradicate cyanotoxins and expensive process (Kumar et al., 2018). Nowadays, the utilization of nanomaterials has become a topic of widespread discussion amongst researchers. It is a novel device that is smaller, cheaper, lighter and faster with more high function than physicochemical treatment methods. Moreover, using few raw materials and consuming less energy. Natural or man-made nanomaterials (NMS), with at least one dimension of 100nm or less, are utilized in many fields such as industry, medicine, or the environment. The most distinguishing characteristic of NMs is their size, which is an essential determinant of their physicochemical properties with respect to the ease of uptake of these compounds as well as their interaction with biological tissues. These particles have been proven to induce oxidative stress and distal organ involvement.

Use of nanoparticles in water treatment:

The inhibition of algae growth and stimulate lipid peroxidation by nanomaterials is proven. It is found that titanium dioxide (TiO2) and other nanoparticles can cause cell growth inhibition, lipid peroxidation and photosynthesis inhibition in algae. The degree of toxicity depends on concentration and particle size, even in bulkier inert material (as in carbon black and TiO2) (Chen et al., 2018). Some research indicates that nanoparticles' function in organisms is mediated by reactive oxygen species (ROS) production, which can cause cell damage and lipid oxidation. Moreover, the direct contact between f-MWNT and algal cell surface (algal cell/nanoparticles aggregation) was likely responsible for reduced PSII functional cross-section and oxidative stress during exponential growth. There was noticeable algal cell/NiO aggregation, which may cause a reduction in the light available to those cells and thus inhibiting their growth. Nanoparticles inhibit the growth and photosynthetic abilities of algae, alter enzymatic activity [e.g., malondialdehyde (MDA), superoxide dismutase (SOD), catalase (CAT), and glutathione (GSH)] in algal cells, and cause DNA damage. The indirect effects of nanoparticles are caused mainly by physical restraints or the release of toxic ions (e.g., metal nanoparticles) or the production of reactive oxygen species (ROS). Physical restraints can cause toxicity because of the addition of nanoparticles, such as the shading effect. The production of nanoparticles on the surface of algal cells might reduce light availability for photosynthesis. Aggregation of nanoparticles on the surface of algal cells increased cells' weight by two- to three-fold. Nanoparticles on the surface of cells might block the cell wall and prevent nutrient molecules from entering cells (Miazek et al., 2015). Recent research also showed that nanoalumina promote the horizontal transfer of multi-resistance genes mediated by plasmids across genera. Table 2 explains the effect of nanomaterials on toxic algae (Chen et al., 2012b).

Examples of nanoparticles and their impacts on algae growth:

AgNP Silver Nanoparticles:

Experiments on different bacterial and fungal strains have proven that AgNP, used either only or as a compound combined, i.e., with titanium dioxide, have a biocidal effect on heterotrophic microorganisms. AgNP penetrates bacterial, fungal and animal cells and interfere with membrane proteins, activating a biochemical cascade that inhibits of cell division. When passing through the cell wall and plasma membrane by diffusion or endocytosis, nanoparticles cause a mitochondrial dysfunction increasing the reactive oxygen species (ROS) (Huang et al., 2016). The toxicity of AgNP depends highly on nanoparticle stability and mobility inside the biological systems and in the environment. Furthermore, the stability and mobility of AgNP are the results of molecules' size, concentration, interactions with inorganic and organic compounds, and many environmental parameters such as temperature, pH, and humidity. Thus, all these characteristics strongly influence the bioavailability and kinetics of AgNP molecules triggering various effects on cells (Nowicka-Krawczyk et al., 2017). Various studies on algal response to AgNP exposure concern species such as Thalassiosira pseudonana (marine diatom); Synechococcus sp. (freshwater cyanobacterium); Chlorella vulgaris and Dunaliella tertiolecta (freshwater and marine green algae respectively) or Chlamydomonas reinhardtii (green algae inhabiting small reservoirs or occurring on moist soil); or include the assessment of algal coating growth inhibition on the protected surface of the underwater historical stone (Huang et al., 2016, Ribeiro et al., 2014, Oukarroum et al., 2012). For example, the cells of aerial green algae Apatococcus lobatus collapsed while exposure to AgNP causing degradation of chloroplasts (Nowicka-Krawczyk et al., 2017).

Magnetic nanoparticles (MNPs):

Magnetic nanoparticles (MNPs) are considered a non-toxic and eco-friendly agent. MNPs have been used to clean up air, treat water from infectious and flocculants, remove organics, dyes, heavy metals... etc. (Su, 2017). The possible mechanisms include electrostatic attraction, coprecipitation, and high reductive reactivity between MNPs and contaminant molecules. MNPs can also be used in water purification as non-absorbents or immobilization carriers to enhance contaminants' removal efficiency. These applications offer significant environmental merits, e.g., higher removal efficiency (usually > 85%), faster kinetics (e.g., first- and second-order kinetics), and stronger reactivity with numerous contaminants (both organic and inorganic compounds), due to their small size at the nanometer scale, relatively large surface area (10–500 m2/g), super paramagnetism and biocompatibility with biomacromolecules (Jiang et al., 2018)

Copper-based nanoparticles (CuNPs):

Control of algal blooms through biological techniques such as altering of normal physiology, including the decrease in photosynthetic pigments, may be a promising way of ecological recovery. Copper nanoparticles are showing broad-spectrum activities. It has proven that using this material in various fields such as water purification and air antibacterial packaging. Copper-based nanoparticles (Cu-NPs) are used in water treatment and as bactericidal in replacement of nanoparticles silver. The chemicals used in the synthesis of copper nanoparticles are commonly available, cheap, and nontoxic. Toxic impacts of Cu-NPs on different criteria cells have been well documented. Copper sulphate is most commonly used to control algae in water bodies at recommended concentrations of 1–2 pp. Maximum Chlorella vulgaris growth was observed at 5 ppm Cu (II) and decreased at higher copper concentrations. The toxic component of copper sulphate is the cupric ion (Cu2+), as earlier revealed by Palmer. Copper toxicity has been reported for Chlorella sp. with the intent to prevent algal blooms in aquaculture. Furthermore, the toxic effects of Cu (II) on C. vulgaris and its chloroplast were investigated (El-Kassas and Okbah, 2017).

Conclusion

To summarize, there are various factors and environmental changes leading cyanobacterial bloom. The cyanobacterial bloom particular Microcystis sp. is considered a massive threat to many healthy and economic issues. Hence, effective cyanotoxin removal is necessary to avoid any damage of our planet. Cyanobacteria removal occur in different methods such as ozonation, chlorination, flocculation, membrane filtration, and adsorption on activated carbon, oxidation by permanganate, however, the use of these techniques unable to eliminate cyanotoxins and expensive process and possess negative impacts. In contrast, Control of algal blooms through biological techniques such as alteration of normal physiology including the decrease in photosynthetic pigments may be promising ways of ecological recovery. The use of nanoparticles in various fields such as water purification, air antibacterial packaging which are commonly available, cheap, and nontoxic. Therefore, utilizing nanoparticles on Microcystis bloom are going to be effective.

Conflict of interest

Conflicts of interest do not occur.

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