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REVIEW

HARMFUL CYANOBACTERIAL BLOOMS AND DEVELOPED CYANOPHAGES AS A BIOLOGICAL SOLUTION

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ABSTRACT

Cyanobacterial Harmful Algal blooms (CHABs) cause devastating impacts to fisheries, tourism, public health and ecosystem around the world, and have increased in frequency. Cyanobacterial blooms occur in fresh water and marine environments, producing a variety of toxins, and poisoning risks to humans and animals. Chemicals can be used to kill cyanobacteria. Unfortunately, many of these chemicals are toxic to other forms of life, including fish and organisms they eat. The use of chemicals in natural lakes could create more problems than they solve, is not permitted. Cyanophage is a double-stranded DNA virus that infects cyanobacteria and is detected in both freshwater and marine environments as a biological solution developed Cyanophages can use for long term treatment options.

Keywords: Cyanobacterial Harmful Algal blooms, Cyanophage, DNA Viruses

INTRODUCTION

Cyanobacteria are unicellular organisms that live in marine waters, freshwater and brackish water **(Carmichael, 2001)**.When these bloom become harmful it known as the cyanobacterial harmful algal blooms (CHABs) **(Schmidt *et al*., 2014)**. CHABs naturally occurring in aquatic environment according to the pH level, water temperature, law water flows, light level, nutrition level **(Sellner *et al*., 2003)**. Many types of algae have an optimal growth temperature between 12°C and 15°C. However, the optimal temperature for most cyanobacteria growth is 25°C. When water is warmer than 25°C cyanobacteria can grow faster than other types of algae (diatoms, green algae). Some algal bloom and green plants growing fast when the high concentration of N and P present in aquatic environment and others die. The dead organic matter will be decomposed by bacteria. The bacteria increased in number and use up devolved oxygen in the water. According to that condition many fish and other living animals in water cannot survive results in dead aquatic environment **(O'Neil *et al*., 2012)**. Algal bloom colors can be green, yellowish-brown, or red, Bright green blooms in freshwater caused by different types of cynobacteria or green blue algae and can have different appearances. Not all cyanobacteria species caused CHABs **(Carmichael, 2001)**.

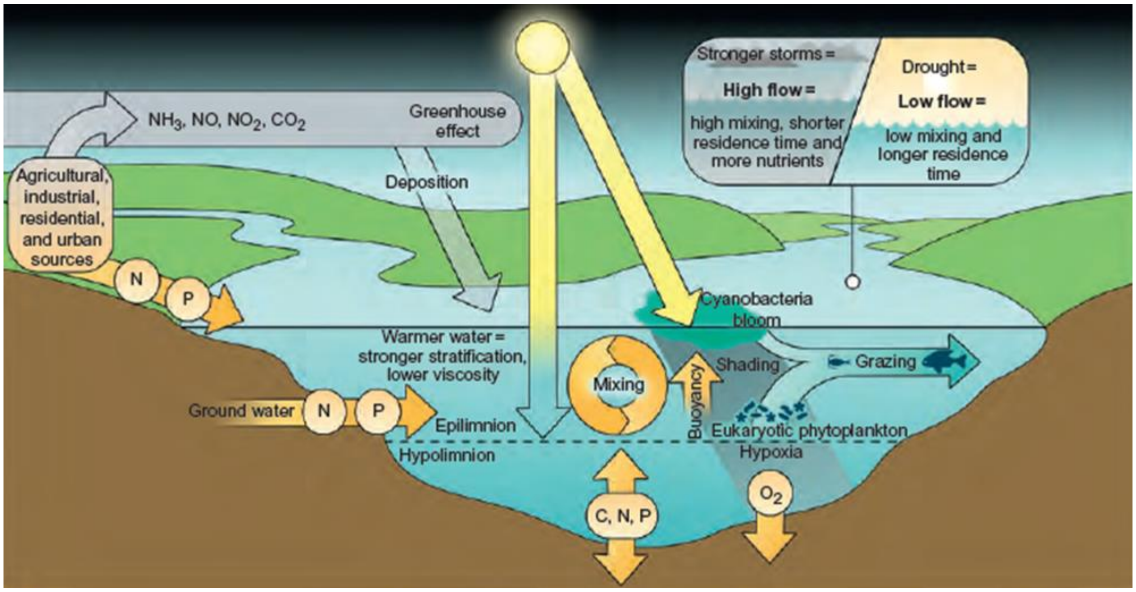

Figure 1 External and internal factors controlling growth of cHABs **(Source: Watson et al., 2015)**

Some blue green algae produce toxins (Cyanotoxins) which is toxic for humans, animals, aquatic environment. Examples for cyanotoxins are Hepatotoxins, Neurotoxins, Endotoxins, Dermatoxins **(Zanchett and Oliveira-Filho, 2013)**.
The current treatment options available for Cyanobacterial Harmful Algal Blooms (CHABs) are mechanical, physical/chemical, and biological control. Mechanical control are the use of filters, pumps and barriers to remove or exclude CHAB cells or other materials related to the proliferation of contaminated water **(Nienhuis and Gulati, 2002)**. Chemical control are the use of chemical compounds to kill, inhibit, or remove CHAB cells. Biological control involves the use of organisms or pathogens (e.g.: viruses, bacteria, parasites, zooplankton, crustaceans) that can kill, dissolve or remove CHAB cells. These options are short term treatment **(MacKay *et al*., 2014)**.The idea of developed Cyanophages introduce as a long term biological treatment option for the Cyanobacterial Harmful Algal blooms **(Watson *et al*., 2015)**.

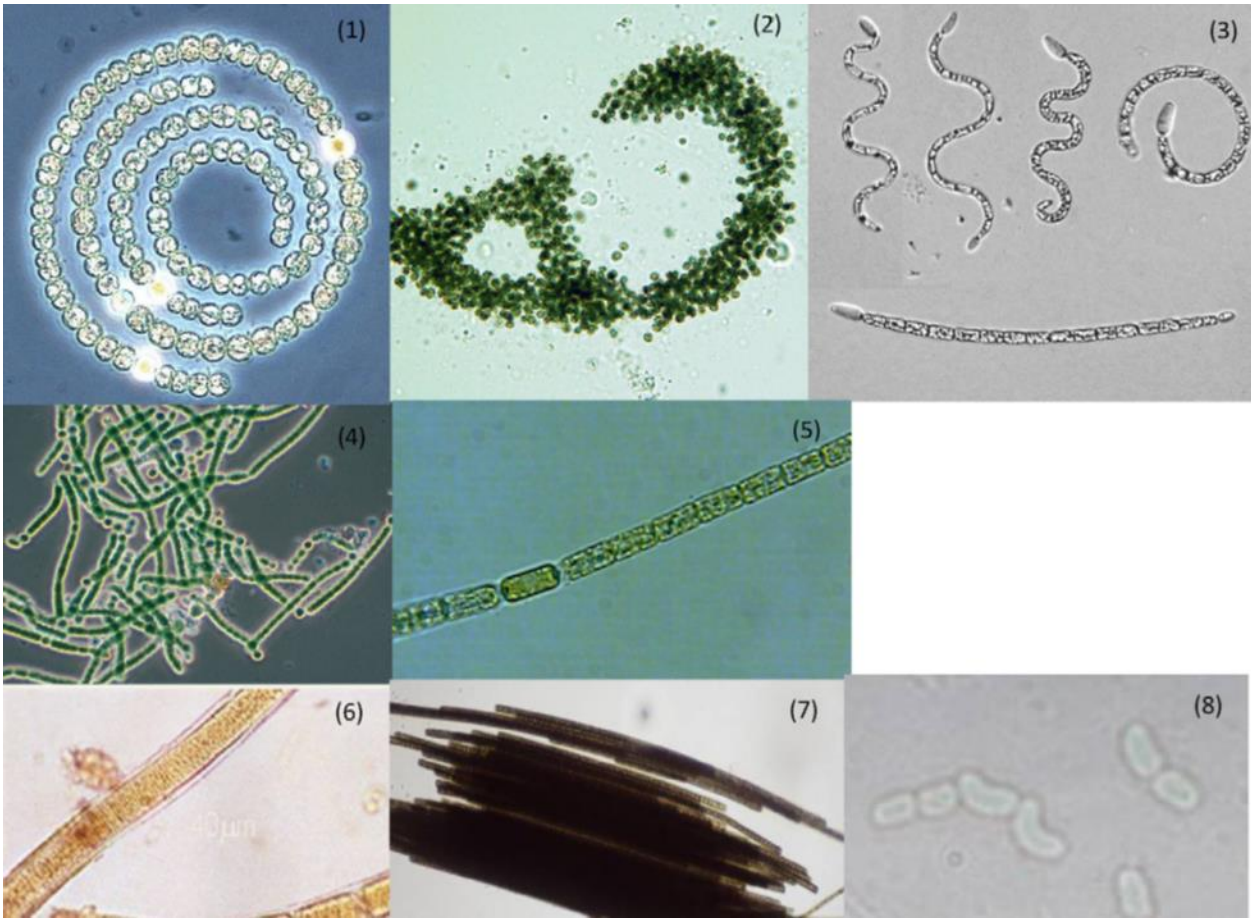

Figure 2 Major types of cyanobacterial genera (1) Anabaena (2) Microcystis (3) Cylindrospermopsis (4) Nodularia (5) Aphanizomena (6) Lynbya (7) Trichodesmium (8) Synechococcus **(Source: O'Neil et al., 2012)**

Errors of chemical control

Photosynthetic organisms, including algae and cyanobacteria (blue-green algae), produce new particulate organic matter in the water system. When these organisms come into contact with water treatment chemicals in either the reservoir or the treatment plant, damage to the cells can result in the release of cell contents as dissolved organic matter **(Codd *et al*., 1989)**. The release of dissolved organic material from cyanobacteria is particular concern. Cyanobacteria, in many cases, dominate freshwater phytoplankton in surface water of eutrophic systems, is the major producer of toxins **(Kenefick *et al*., 1992)**.

Two of these compounds, geosmin and methylisoborneol, have been identified as major agonists of soil musty odour common in aqueous systems **(Kenefick *et al*., 1992)**. These odorants are saturated cyclic tertiary alcohols which are resistant to oxidation by conventional water treatment chemicals **(Izaguirre *et al*., 1982)**.The production of these odorous compounds was the main reason for inclusion of granular activated carbon (GAC) reactors in water treatment plants. Cyanobacteria also produce several other organic compounds that can react with chemical disinfectants to form byproducts of interest. Dissolved organics of cyanobacterial origin produce chloroform per unit mass of carbon, like humic acid and fulvic acid when in contact with chlorine. Release of organic compounds by phytoplankton occurs spontaneously during active growth and decay of cells **(Baines and Pace, 1991)**. Deterioration of physiological condition is associated with geosmin release **(Rosen *et al*., 1992)**.

However, chemically induced cellular damage can cause sudden release of organic compounds within the cell. Prechlorination in a water treatment plant leads to the release of geosmin to the water **(Ashitani *et al*., 1988)**. Water treatment with copper sulphate can leads to release of toxin, microcystin-LR **(Kenefick *et al*., 1993)**.

The release of dissolved organic compounds by cyanobacteria presents the risks to consider before using chemical plants or groundwater reservoirs. To avoid this risk, it is important to note chemicals that cause this reaction in cyanobacteria **(Matsumoto and Tsuchiya, 1988)**.

Cyanophages

Cyanophages are double-stranded DNA viruses. They can infect cyanobacteria and able to detected in freshwater and marine water. They have a complex pattern of host range and play an important role in controlling the cyanobacteria population. It is divided into three families, Myoviridae, Siphoviridae, and Podoviridae (Table.1). Major types are LPP−1, N−1, AS−1, and SM−1 (Fig.2) **(Xia *et al*., 2013)**.

Table 1 Types of freshwater Cyanophages **(Source: Xia *et al*., 2013)**

Family	Morphology	Phage species	Host	References
Myoviridae	Contractile tail	AS-1	*Aancystis nidulans, Synechococcus cedrorum*	Safferman R S, et al., 1972
		N-1	*Nostoc muscorum*	Adolph K W, et al., 1971
		Ma-LMM01	*Microcystis aeruginosa*	Yoshida T, et al., 2006
	Long, non-contractile tail	SM-2	*Synechococcus elongates,Microcystis aeruginosa*	Fox J A, et al., 1976
Siphoviridae		S-2L	*Synechococcus sp. 698*	Khudyakov I Y, et al., 1978
		S-4L	*Synechococcus. elongatus*	Khudyakov I Y, et al., 1982
		LPP-1	*Lyngbya, Plectonema, Phormidium*	Sherman L A, et al, 1970
Podoviridae	Short tail	SM-1	*Synechococcus elongatus*	Safferman R S, et al., 1969
		Ma-LBP	*Microcystis aeruginosa*	Tucker S, et al., 2005
Unassigned	Tailless	PaV-LD	*Planktothrix agardhii*	Gao E B, et al., 2009

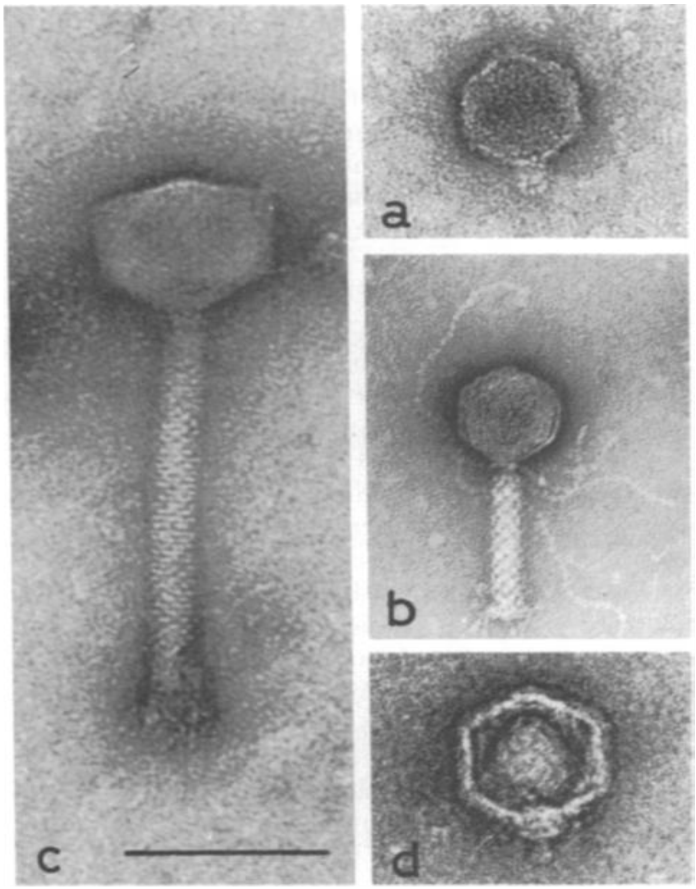

Figure 3 Types of Cyanophages (a) LPP−1 species of cyanophage (b) N−1 (c) AS−1 (d) SM−1 **(Source: Etana and Moshe., 1973)**

Cyanophage-Cyanobacterial interaction

Cyanophage nucleic acids contain only a few genes necessary for the synthesis of new viruses, their structural components such as capsid proteins, and enzymes used in the phage life cycle. The synthesized enzyme is involved in the complete replication or processing of the nucleic acid and functions only when the phage is in the host cell **(Sandaa, 2009)**.

In order to synthesize phage, proteins and enzymes, ribosomes, transfer ribonucleic acid (t-RNA) and energy production are supplied by host cells **(Hyman and Abedon, 2009)**.

Their existence in the host cells after viral infection and their electronic tomographic analysis for molecular degradation are useful for understanding viral infection mechanisms and therefore for studying the development of cyanophage or other phage within host cells it turned out to be. The two main modes of phage propagation are the lysis cycle and the lysogen cycle **(Hanlon, 2007; Peduzzi and Luef, 2009; Hyman and Abedon, 2009)**.

Cyanophage is remarkably similar to T phage in terms of morphological attributes and life cycle patterns **(Herskowitz and Hagen, 1980)**. The lysis cycle is terminated by lysis and death of the host cells. The lytic cycle is highly dependent on the activity and efficacy of the enzyme lysozyme produced by the cyanophage itself In the case of non-production of lysozyme, it has been found that respiration and metabolism of the host are affected and may be stopped, but until induction of the dissolution process takes place in both cases It is certain that there is nothing **(Herskowitz and Hagen, 1980)**.

Role of Cyanophages

Cyanophage plays an important role in the evolution of cyanobacteria. It controls the abundance of cyanobacteria, the dynamics of populations, and the structure of nature. Cyanophage is a global reservoir of genetic information. They transfer genes, confer cyanobacteria with novel properties, and act as vectors that affect the rate and direction of the evolution process **(Xia *et al*., 2013)**.

Lysogeny makes an important contribution to the maintenance of the cyanobacterial gene pool and ecological adaptation. The incorporation of many cyanobacterial genes into the cyanophage genome indicates that genetic transmission occurs between the host and the phage. Such gene transfer plays a driving function in adaptive microscopic evolution **(Xia *et al*., 2013)**.

Unlike bacteriophages, which usually have a host-specific host range, cyanophage generally has a host in more than one genus **(Singh1 *et al*., 2012)**. Recently, the role phage plays in the ecological dynamics of poisonous bloom-forming Pseudomonas aeruginosa has been studied **(Yoshida *et al*., 2008)**.

CONCLUSION

Reports on various systems in which gene recombination or gene exchange are performed between phage and cyanobacteria are regularly conducted. The structure need to be further evaluated, focusing on the use of molecular biology.

An important role can be played in the field of new evolving molecular evolution for Cyanophage in different ecosystems like lakes, ponds, rivers, marine environment.

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