REMISSION OF ALGAL BLOOM IN AQUATIC LAKE AND POND RESERVOIRS VIA INDIGENOUS ALGICIDAL MICROORGANISMS

Abstract

Eutrophication is referred as uncontrollable and undesirable growth of algae which case detrimental effect on human and animals. Moreover, it is polluting our aquatic environment to the greater extent. In eutrophication abundant germination of algae on the surface of the lake, pond or any aquatic reservoir. The natural source for increasing the algal content included, warmer temperature, abundant light and stable wind conditions. The man-made action causes the increases the level of nutrients in the water ecosystem which leads to the aggregation of these nutrients. Likewise, the most predominant source of these nutrients are improper fertilizers and manure usage, sludge from waste water treatment plant, septic systems, urban runoff or animal waste entering in the water reservoirs. These are affecting the lakes eco-system as well as the beneficial microbes. eutrophication forms mat like formation on the lake surface and subsequently, close the lake surface completely. Algal bloom affects the ecosystem by demisting the oxygen concentration and by releasing toxins into the ecosystem for instant, cynotoxins, brevetoxin, saxitoxin, micricystin and so on. The toxinsmay affect humans, animals, fish and beneficial microorganisms which are present in lake and pond reservoirs. Consequently, algal bloom toxins cause liver cancer and tumors via inhibiting the activities of protein phosphatases in humans and animals. Moreover, also peril effect like, reproductive toxicity, neurotoxicity, immunotoxicity, and other toxicities. For this threat there is a potential source to

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mitigate the abundant of the eutrophication of algae is bioremediation. The candidate which has the efficiency to remediate the algal concentration in the ecosystem was termed as "algicidal bacteria". This review highlights the formation and toxicity of algal bloom and mechanism of algicidal bacteria.

Keywords: algal bloom, eutrophication, algicidal bacteria, phosphorus, nitrogen.

I. INTRODUCTION

Eutrophication in aquatic environments are major consequences of human activities on freshwater ecosystems, such as rivers and lakes. DBPs, which pose a serious threat to the security of the water environment, can be derived from organic substances and algal toxins produced by HABs. Exploring methods for preventing, controlling, and reducing harmful algal blooms (HABs) is a growing area of research. Therefore, it is critical to create an effective, long-lasting, and eco-friendly algae management method. According to numerous laboratory studies, bacteria, which are the main anti-cyanobacterial microorganisms, are crucial for maintaining a healthy flux of cyanobacterial biomass. Through nutrient regeneration, endosymbiosis, the synthesis of stimulative or inhibitory chemicals, and other mechanisms, they can stimulate or inhibit the growth of phytoplankton. It is generally acknowledged that using microorganisms with anti-cyanobacterial activity is an efficient and environmentally benign method of cyanobacterial control. Physical control, chemical control, and biological control are the three categories of modern algae control technology. A flocculant, an algaecide, and increased oxidation are examples of chemical treatments. Physical techniques include membrane separation, ultrasonic, and ultraviolet. Algae growth can be efficiently slowed down with physical and chemical restrictions, but these methods have several drawbacks, including high costs, significant ecological risks, and limited sustainability. Algicidal microbes, aquatic plants, and aquatic animals are all used in biological techniques to manage algae (Sun et al., 2018). Although aquatic plants (Zuo et al., 2014) and aquatic animals (Chen et al., 2016) can be useful tools to solve HABs, their effects can be limited. Eliminating harmful algae with algicidal bacteria possesses high efficiency, sustainability, economy and environmental friendliness. Therefore, these bacteria have a promising application prospect (Ndlela et al., 2018; Sun et al., 2022). Numerous regions have documented the environmental and health effects of cyanobacterial blooms, and numerous eutrophication control techniques, including chemical algaecides, oxidants, allelochemicals, and cyanobactericidal microorganisms, have been used to suppress cyanobacteria and algae [2,3]. Because of its effectiveness and environmental friendliness, cyanobactericidal microbial technology has recently been considered as an innovative and secure technique for eutrophic water rehabilitation. The use of yellow loess and clay, for example, has unfavorable downstream impacts on creatures that live on the ocean floor. Chemical agents frequently cause chemical toxicity and start microcystin discharge into water. Some bacteria can also cause algae to lyse. Algicidal bacteria are thought to be a viable remedy for controlling HABs and may have a significant influence in the reduction of HABs. One of the main factors promoting cyanobacterial blooms (blue-green algae blooms) is thought to be the growing input of nutrients into water bodies, particularly phosphorus and nitrogen. Hepatotoxins, neurotoxins, and lipopolysaccharides endotoxins are three major groups of lethal toxins that can be produced by cyanobacteria of the genera Microcystis, Anabaena, and Oscillatoria (Rapala et al., 1997; Carmichael, 1992; Oksanen et al., 2004). HABs are known to release significant amounts of microcystin-containing harmful algal organic matter (AOM) into water bodies, degrading the water quality and endangering aquatic ecosystems and human health (Cao et al. 2019; Chen et al. 2019a, 2019b; Drobac et al. 2017; Ho, Sawade, and Newcombe 2012a; Ho, Tang, and Monis 2012b; Liu et al.) Technologies that can lessen HABs' negative effects on the environment and human health are urgently needed. To lessen the amount of hazardous blooms, a variety of techniques have been employed in the past, including the use of materials like clay (Hagestrom and Graneli 2005; Sengco and Anderson 2004), copper sulfate (Qian, Yu, and Sun 2010; Tsai, Uzun, and Chen 2019), and others.

However, because copper sulfate is not biodegradable, its widespread use in reducing hazardous blooms could lead to secondary metal complex contamination. To develop the bacterial biological control of algal blooms, the algicidal activity in various microbial assemblages needs to be extensively investigated. When the situation is ideal, cyanobacteria can multiply and take over the phytoplankton in a body of water to create a bloom [2]. Toxins that are harmful to both human and animal health can be produced by the cyanobacteria that are part of the bloom. Hepatotoxins (toxins that target the liver) and neurotoxins (toxins that target the nervous system) make up the bulk of freshwater cyanobacteria toxins [3]. Numerous species of cyanobacteria belonging to the genera Microcystis, Planktothrix, Anabaena, and Oscillatoria generate the hepatotoxin microcystin [3]. The most prevalent and common cyanotoxin in Kansas lakes is microcystin, which is also widely distributed throughout the world [4,5]. The effects of microcystin poisoning depend on the method of exposure (for example, ingestion, inhalation, or direct touch) and the dose of toxin received by the person or animal. After exposure, signs and symptoms may appear minutes to hours later. Both in animals and people, acute microcystin poisoning can cause non-specific clinical signs and symptoms such as nausea, vomiting, diarrhea, coughing, sore throat, rash, and liver damage. The majority of people who are exposed to cyanobacteria in recreational water recover without any long-term effects, whereas most canines die as a result.

II. ALGAL BLOOM

Similar to plants, algae are tiny creatures that inhabit aquatic settings and use photosynthesis to harness the energy of the sun. All natural waters, including salt water, fresh water, and brackish water (a mixture of salt and fresh water), include algae. Some varieties of algae release poisons. Environmental elements like light, temperature, salinity, pH, and nutrient levels have the ability to trigger the production of toxins in these algae. Algal toxins that are discharged into the nearby water or air can have a major negative impact on people, animals, fish, and other ecosystem components. Depending on the type of algae, the excessive growth, or algal bloom, is apparent to the human eye and can be green, blue-green, red, or brown. (https://www.niehs.nih.gov/health/topics/agents/algal-blooms/index.cfm). While some blooms are simple to see, others are difficult to view because they grow close to the bottom of bodies of water. A water body's presence of a hazardous bloom cannot be determined just by looking at it. HAB production can be influenced by a number of variables, including increased nutrient levels (e.g., eutrophication) and an appropriate temperature, light intensity, and species mobility [18,19]. The consequences of increased nutrient loading in aquatic settings are modulated by eutrophication and other physical, biological, and chemical variables, which affect HAB population dynamics (Kazmi et al.,2022)

III. TOXINSPRODUCED BY ALGAE

The types of algae known as toxic algae are those that produce strong poisons. Diatoms and dinoflagellates are two algae species that contain strains or variants that can occasionally be fatally poisonous. When there are high nutrient levels, lots of sunshine, and warm temperatures, this typically happens under heavy bloom conditions (Lawler, 1998). Hepatotoxins, neurotoxins, and lipopolysaccharides endotoxins are three major groups of lethal toxins that can be produced by cyanobacteria of the genera Microcystis, Anabaena, and Oscillatoria (Rapala et al., 1997; Carmichael, 1992; Oksanen et al., 2004). A variety of hepatotoxins collectively known as microcystins have been reported (Sivonen and Jones, 1999; NRA, 1990; Carmichael, 1992; AWWA, 1995; Chorus, 2001; Sivonen and Jones, 1999; Carmichael, 1992; Ressom et al., 1994); there have been at least 76 different microcystin variations found in cyanobacterial blooms. Microcystin-LR, a well-known extremely acute hepatotoxin, is the most common form. By inhibiting protein phosphatase, it causes liver bleeding within a few hours and promotes the growth of tumors (Wiegand and Pflugmacher, 2005; Cohen and Cohen, 1989; Carmichael, 1992; Bourne et al., 1996). There are two types of hazardous algae: freshwater toxic algae and marine toxic algae. Under marine toxic algae, brackish and estuarine species are covered (Gorham, 1988). Cyanophyta (blue-green algae) are the primary cause of almost all freshwater blooms. Due to their high-density blooms, freshwater toxic algae rarely cause issues other than problems with oxygen loss.Anabaena, Microcystis, and Gonyaulax species among others are toxin-producing in freshwater settings. Examples include Microcystis aeruginosa, Anabaena cylindrical, Anabaena doliolum, and Anabaena Aphanizo (Kumar, 1979).

IV. VARIOUS METHODS TO MITIGATE ALGAL BLOOM

The three types of current algal control methods include physical control, chemical control, and biological control. Chemical treatments include flocculant, algaecide, and enhanced oxidation. Physical techniques include membrane separation, ultrasonic, and ultraviolet. Algae growth can be efficiently slowed down with physical and chemical restrictions, but these methods have several drawbacks, including high costs, significant ecological risks, and limited sustainability. Algicidal microbes, aquatic plants, and aquatic animals are all used in biological techniques to manage algae (Huang et al. 2016, Sun et al., 2018). Aquatic plants and animals can be useful tools to combat HABs, but their impacts might be limited. For the removal of dangerous algae, algicidal bacteria have a high level of effectiveness, sustainability, economy, and environmental friendliness (Zuo et al., 2014; Chen et al., 2006). These microbes therefore have a promising future in the application field (Ndlela et al., 2018; Sun et al., 2016). There is an urgent need for technologies that can mitigate CyanoHABs' detrimental impact on the environment and human health. To lessen the amount of hazardous blooms, a variety of techniques have been employed in the past, including the use of materials like clay (Hagestrom and Graneli 2005; Sengco and Anderson 2004), copper sulfate (Qian, Yu, and Sun 2010; Tsai, Uzun, and Chen 2019), and others. However, because copper sulfate is not biodegradable, its widespread use in reducing hazardous blooms could lead to secondary metal complex contamination. Karenia brevis blooms were collected using clays, which were then blended with the toxic algal blooms. The transmission of this mixture to tellinid bivalves and shellfish was later demonstrated. However, ingesting shellfish that had been contaminated with the clay-bloom mixture resulted in neurotoxic shellfish poisoning, which is a public health issue (Haubois, Bricelj, and Naar 2007; Plakas et al. 2002; Poli et al. 2000). Despite the fact that the blooms were successfully eradicated by this method.

V. ECO-SYSTEM OF ALGAL BLOOMED RESERVOIR

Living things and their surrounding natural environment make up ecosystems. An ecosystem includes people, animals, and local habitats. Ecosystems can be impacted by harmful algae and cyanobacteria in a variety of ways.Fish and other aquatic life may have a harder time finding food as a result of algae blooms, and whole populations may move away or even perish as a result.Thick, green muck produced by harmful algal blooms has an adverse effect on clear water, leisure activities, companies, and property values.Aquatic ecosystems suffer as a result of hazardous algal blooms that are fueled by nutrient pollution.Aquatic life cannot thrive in dead zones, which are regions of water with little or no oxygen. These regions, sometimes known as hypoxic zones, are brought on by algae blooms that deplete oxygen.

VI. TOXIC EFFECTS OF HUMANS, ANIMALS AND BIRDS

HABs have the potential to impair tourism, reduce wild or farmed fish stocks, and cause intoxication in humans through the consumption of tainted seafood. It is critical to develop methods for reducing algal proliferation in these circumstances (Zhang et al., 2020). Since a very long time, there have been sporadic reports that HABs in freshwaters and oceans have killed livestock, humans, and aquatic animals, but these reports have only ever been local in scope and have not garnered much attention internationally (McBarron and May 1966). The fast growth of the coastal aquaculture business until the end of the 20th century caused eutrophication in the water, which provided enough nutrients for HABs. When there was a global surge in HABs and reports of infections in humans, cattle, and fish, researchers began to pay attention to the risks and causes of HABs. Toxins have toxic consequences when they are discharged into water during harmful algal blooms (HABs). Sanseverino et al., 2016 denoted as ,eating of contaminated water or scum, inhalation of dried algal material through aerosols or wind-dispersed particles, eating of contaminated seafood, and direct skin or conjunctival contact are some of the ways that are thought to cause the disease in people. The following ailments are the most common ones brought on by marine toxins in humans: Amnesic Shellfish Poisoning (ASP), Paralytic Shellfish Poisoning (PSP), Diarrhetic Shellfish Poisoning (DSP), Neurotoxic Shellfish Poisoning (NSP), and Ciguatera Fish Poisoning (CFP). These illnesses can affect people in varied degrees of severity, and treating the symptoms they display incurs costs for the healthcare industry. Hospitalizations and illnesses brought on by intoxication episodes incur costs for medical care, illness research, emergency transportation, as well as the loss of personal productivity. Cyanobacteria are microscopic creatures that can take the form of white, blue-green, brown, red, or green scum on the water's surface. They are not clearly filamentous and can be found in the water column, together with symbiotic plants, in sediments, at the surface, on the coast, as crusts in recently flooded places where the water has receded, or in crusts on the ground. In the water column, cyanobacterial blooms typically develop when nitrogen concentrations are elevated. FHABs are a result of nitrogen and phosphorus contamination. When the water is warmer than 15°C and there is enough sunlight, blooms usually happen. Water bodies that stagnate are frequently impacted. However, because many of the toxic species have gas vesicles that affect buoyancy, they may not be visible because they can be at any level of the water column. Blooms are occasionally seen on surfaces of lakes or ponds where they can concentrate downwind. Some toxigenic cyanobacteria species can produce many cyanotoxins, and not all cyanobacteria species are toxic. Furthermore, not all toxigenic strains of cyanobacteria produce cyanotoxins. The genera that cause FHABs vary seasonally, and blooms might consist of one dominating species, multiple co-occurring species, or mixed assemblages of toxigenic and nontoxigenic species. Cyanotoxin interactions could result from blooms that release several different toxins. According to the species of affected animal(s), the cyanotoxins involved, and the quantity of exposure, clinical symptoms and lesions caused by cyanotoxin poisoning vary in their onset, severity, and kind. Although cutaneous and pulmonary exposures have been documented in humans, oral exposure is the most frequently recognized cause of cyanotoxin poisoning in domestic animals. Coughing, throat irritation, and nasal discharge are all possible signs of cyanobacteria inhalation in addition to skin irritation. Occasionally, dietary supplements containing cyanobacteria have been linked to negative consequences. This is probably because to poor quality control and incorrect identification of the supplement's organisms. For instance, a dog that had repeatedly taken dietary supplements containing microcystins eventually recovered after receiving intensive supportive care, while a horse that had developed hepatoencephalopathy like symptoms before dying from liver damage. The intra peritoneal (IP) exposure route has been employed in algal toxin testing as a practical and cost-effective way to reduce the amount of test material required for toxicological analyses, although being environmentally unfeasible. Studies on Japanese quail (Coturnix japonica) and mallards (A. platyrhynchos) indicate that the acute IP toxicity of two MCs (congeners LR and RR) is similar to that seen in mammals (Takahashi and Kaya, 1993; Li et al., 2012; see supplementary materials section for details). While 10.9 mg of MC-LR/kg of BALB/c mice has been reported as the acute oral LD50 (Yoshida et al., 1997), MC-LR doses in crude extracts (up to 8.9 mg; Li et al., 2012; Kral et al., 2012) or highly purified material (up to 17.5 mg; Bong, 2020) failed to cause lethality in mallards and quail. Toxin purity, congener composition, dosing processes, and observation length are a few examples of testing method discrepancies that prevent a conclusive statement about interspecies variances in sensitivity. Activation of cytochrome P450 detoxification systems, oxidative stress, histological abnormalities in the liver and other organs, changes in blood plasma chemistry profiles, and certain indications of reproductive impairment have all been reported in oral MC dosage experiments in birds (Rattner et al., 2022).

VII. EFFICIENCY OF ALGICIDAL BACTERIA TO LYSE ALGAL BLOOM

Physical and chemical methods may be used to reduce algae blooms in lake reservoirs, but they will also lead to further contamination of the ecosystem. Kathryn J. Coyne,2022 marked as “A variety of results have been observed in algae species for a number of time intervals from minute to day following exposure to antimicrobial bacteria”. In the case of algal cell lysis, these actions can result in the irrevocable death of cells or in the temporary creation of algal cysts. Additional effects could include algaetic effects, which would suppress algae growth in reaction to algicidal chemicals such cell cycle inhibitors. Possibly the most typical result of algicidal interactions is the lysis or rupture of the algal cell (Zhang et al., 2017; Jeong and Son, 2021). If physical or chemical interactions result in the loss of membrane integrity without prompting the algal cell to respond metabolically or physiologically, lysis may be an externally driven process (necrosis) that occurs (Franklin et al., 2006). As an illustration, mycosubtilins produced by Bacillus bacteria interact with the cytoplasmic membrane, causing an increase in ion permeability and the lysis of species of raphidophyte and dinoflagellate (reviewed by Jeong & Son, 2021). Algicidal *Thalassospira sp.* produced benzoic acid that resulted in cell lysis in the HAB dinoflagellate *Karenia mikimotoi*, likely via breaking through the cell membrane and acidifying the algal cytoplasm (Lu et al., 2016). On the other hand, prolonged exposure could cause lysis, which is the outcome of internally motivated mechanisms (Wang et al., 2020a). For instance, algicidal compounds might promote the production of reactive oxygen species, which would lead to the peroxidation of membrane lipids and cell lysis (Coyne et al., 2016). Through genome analysis of the algicidal Rhizobium against *M. aeruginosa*, for example, it was found that the genetic capacity for algal cell wall polysaccharide destruction, which is responsible for the algal lytic capabilities, as well as metabolic pathways for microcystin detoxification. Another instance featured *M. aeruginosa* flocculation and the degradation of photosynthetic pigments, which resulted in the fragmentation of algal cells and a subsequent decrease in toxin concentrations thanks to the activity of the bacterium *Raoultella sp*. S1 (Li et al., 2021a). Some algae can form protective cysts that allow them to avoid or at the very least delay cell death. According to research (Bravo and Figueroa, 2014; Jung et al., 2018), 200 of the 2,000 dinoflagellate species are known to produce cysts as a natural component of their life cycle or in reaction to adverse environmental conditions. Both thick-walled "resting" cysts and thin-walled "pellicle" cysts have been described in dinoflagellates; nevertheless, the functions of the several morphological types of cysts are complex and not fully known for all species (Bravo and Figueroa, 2014). noted the presence of cyst-like cells when K. brevis was cultured with algicidal bacteria from the Cytophaga/Flavobacterium/Bacteroidetes (CFB) group, showing that algicidal bacteria may encourage a transition to the cyst stage in dinoflagellates It is more plausible that this trait is a dinoflagellate defense mechanism in reaction to algicidal activity than that it is directly related to the behavior of certain bacteria. In one instance, when exposed to Proteobacterium *Pelagibaca abyssi*, *Pyrodinium bahamense*, a deadly dinoflagellate, also generated pellicle cysts (Dungca-Santos et al., 2019). P. abyssi had a chance to enter the cyst through its thin membrane while pellicle cysts, on the other hand, developed because the theca was gone. This gave rise to the cyst's disaggregation (Roth et al. (2008b). A recent study by Prasath et al. (2021) suggests that some algicidal bacteria may also prevent cysts from developing. Researchers described the outcomes of removing *Gymnodinium catenatum* vegetative cells and preventing the germination of this species' cysts using polyaluminum chloride as a coagulant in combination with fermentation broth from *Bacillus nitratireducens*. (Kathryn J. Coyne et al., 2022)

VIII. MECHANISM OF ALGICIDAL BACTERIA ON BLOOM

Algicidal bacteria are microorganisms that play a vital role in curbing the growth of harmful algal blooms in aquatic environments. They employ various mechanisms to counteract the rapid proliferation of algae and mitigate the impacts of these blooms. The strategies these bacteria use are diverse and often work in combination to achieve their algicidal effects. One of the primary ways algicidal bacteria exert their control is through the secretion of algicidal compounds. These compounds can include enzymes, antibiotics, fatty acids, and other bioactive substances. When released into the surrounding environment, these compounds disrupt algal cell membranes, interfere with their metabolic processes, and ultimately cause cell lysis. This leads to a reduction in algal cell viability and a limitation of their growth. Quorum sensing is another mechanism employed by some algicidal bacteria. This communication process allows bacteria to coordinate their actions based on population density. When the bacterial population reaches a certain threshold, they release signaling molecules that trigger the production of algicidal compounds. These compounds are then released, targeting the algae and controlling their growth. Nutrient competition is yet another mechanism by which algicidal bacteria contribute to bloom control. These bacteria can outcompete algae for essential nutrients like nitrogen and phosphorus. By consuming these nutrients, the bacteria limit the availability of resources that algae require for their growth, thereby weakening the algae and impeding their rapid proliferation. Some algicidal bacteria establish direct physical contact with algal cells. Through attachment to the algal surface, these bacteria can disrupt cell integrity and interfere with normal cellular processes. This attachment may also involve the secretion of enzymes or toxins directly onto the algal cells, causing damage and cell lysis. Furthermore, certain algicidal bacteria induce oxidative stress in algal cells. By generating reactive oxygen species (ROS), these bacteria damage lipids, proteins, and DNA within the algal cells, leading to their eventual death. Algicidal bacteria are often more resilient to oxidative stress than algae, allowing them to selectively target the algae without harming themselves. In aquatic environments, light is a critical resource for photosynthetic algae. Algicidal bacteria can form biofilms or colonies on surfaces, effectively shading the water's surface. This shading reduces the amount of available light for the underlying algae, hampering their growth and reproductive capabilities. Additionally, some algicidal bacteria possess the ability to recognize and target specific types of algae. This selective recognition allows them to target harmful or problematic algal species while sparing beneficial ones, contributing to a more balanced ecosystem. In conclusion, algicidal bacteria employ a range of interconnected mechanisms to control algal blooms. Their secretion of algicidal compounds, quorum sensing capabilities, nutrient competition, direct cell attachment, induction of oxidative stress, biofilm formation, competition for light, and algal cell recognition collectively contribute to their effectiveness in mitigating the impact of algal blooms in aquatic environments (Sukenik, A., & Kaplan, A. (2021))

IX. CONCLUSION

The greatest treatment for these algal blooms is algicidal bacterium, which lyses the cells of the algae and prevents the environment in an organic way. This approach of controlling algae has the advantages of being economical, not creating secondary pollutants, long-lasting, not harming people or animals, and primarily being safe for lake and pond-like reservoir eco-systems. Human activity has a significant negative impact on freshwater habitats including rivers and lakes, leading to eutrophication and harmful algal blooms (HABs) in aquatic ecosystems.DBPs, which pose a serious threat to the security of the water environment, can be derived from organic substances and algal toxins produced by HABs. When native microorganisms lyse the algal cell that is causing the reservoir bloom, the danger of HABs can be decreased.

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