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Harmful Algal Blooms: Counterbalancing Aquatic Ecosystem

Piyoosh Kumar Babele*, Ajaya Kumar Rout, Ashutosh Singh, Bijay Kumar Behera and Ashok Kumar Singh
Rani Lakshmi Bai Central Agricultural University Jhansi 284003 Uttar Pradesh India
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Cyanobacteria and phytoplankton are essential to the functioning of aquatic ecosystems. However, under extreme environmental conditions, they can proliferate rapidly and cause HABs. Toxins produced by HABs can cause severe injury to humans, fish, animals, and other aquatic ecosystem components. Urgent action and management policies are required to halt the epidemics.

What is harmful algal and/or cyanobacterial bloom?

Cyanobacteria (prokaryotes) and algae (eukaryotes) are an ancient group of photosynthetic organisms that occur in almost all habitats, including water (fresh and brackish water, oceans, and hot springs), terrestrial environments (soil, deserts, and glaciers), and symbioses (with plants, lichens, and primitive animals). They are important primary producers in aquatic environments and valuable indicators of ecosystem conditions because they respond quickly both in species composition and densities to a wide range of water conditions due to changes in water chemistry. However, excessive growth of certain cyanobacteria and algae results in harmful algal blooms (HABs). HABs affect our oceans and form in bodies of fresh water, making lakes, ponds, or your favorite swimming hole smelly and slimy. HABs are linked to 'overfeeding' of nutrients and an abundance of pollutants in water bodies. A cyanobacterial bloom can change the color of the water to blue, green, brown, yellow, orange and red. Some blooms are easy to spot, but others that present below the water's surface are hard to see. Depending on the type of cyanobacteria or algae that cause it, HABs may produce bad-smelling scum, foam, froth, or a paint like slick. HABs release cyanotoxins and are becoming more popular due to public safety concerns, adverse effects on coastal living resources, and economic losses from reduced tourism, recreation, or seafood industries.

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The Most Common Types of Freshwaters HABs

Several cyanobacterial or algal species can proliferate into a HAB under favorable conditions. Most freshwater HABs are produced by cyanobacteria. Cyanobacterial blooms are the most common type of HABs in lakes, ponds, and other freshwater systems. Some, though not all, types of cyanobacteria can produce dangerous cyanotoxins. The most frequently reported types of bloom-forming cyanobacteria are *Microcystis*, *Dolichospermum, Aphanizomenon, Nodularia* and *Planktothrix*. Cyanobacterial blooms can grow on rocks beneath the water. Common toxins made by cyanobacteria are microcystin, cylindrospermopsin, anatoxin, guanitoxin, nodularin and lyngbyatoxin. Golden algae blooms are most commonly found in oceans, however, golden algae (*Prymnesium parvum*) are an emerging problem in freshwater rivers, reservoirs, and lakes, particularly those with higher salinity due to higher mineral content. While a bloom of golden algae can cause massive fish kills, it has not been shown to pose a health threat to humans. Common toxins made by dinoflagellates brevetoxin, azaspiracid, ciguatoxins, okadic acid saxitoxin and dinophysistoxin.

What Causes Freshwater HABs?

HABs occur in more locations than ever, and new findings are reported regularly. Several researchers have argued that this trend is due to increasing eutrophication worldwide, and several classic examples connect HAB incidence to anthropogenic activities. Additionally, climate change, such as rising temperature and inorganic pollution, is massively increasing the frequency, prevalence, and toxicity of HABs. The following are some of the main freshwater algal bloom causes:

1. Nutrient runoff or nutrient pollution

HABs are mostly caused by large amounts of nitrogen (N) and phosphorus (P) in water. N and P are essential to plant growth and natural part of underwater ecosystems. These nutrients are excessively used in farms through synthetic fertilizers. Nevertheless, excessive amounts of these elements can create nutrient pollution when they run off urban and rural surfaces and flow into a river, lake, pond, or reservoir. They can enter waterways via agricultural runoff, particularly from animal manure and chemical fertilizers that are washed from farms by rain. Together with the N and P dead organic matter propagates the growth of cyanobacteria and algae leading to HABs.

2. Warm and stagnant water

Rise in earth's temperature due to greenhouse effect is one of the main reasons HABs are thriving at a fast rate. Conducive temperature is required for certain cyanobacteria to thrive both in and out of water. The exceedingly high temperatures experienced due to global warming have led to rapid decomposition of nutrients such as nitrates and ammonia, which are easier forms for cyanobacteria to use up and grow in quantity. Higher temperatures and warm water give cyanobacteria a competitive advantage over other benign algae. As blooms grow thicker, the dark surfaces of the algae mats absorb more sunlight, which leads to warmer water and more HAB growth. Similarly, slow-moving or stagnant water can cause low turbidity, allowing suspended particles to settle out of the water column. When turbidity is low, more light can penetrate the water column, creating optimal conditions for algal growth. Moreover, static water can also become thermally stratified, meaning that a layer of warm water, which favors cyanobacterial and algal blooms, floats on top of cooler water. In return, growing algae creates a turbid environment that contributes to decreased water flow.

3. Climate change

Climate change is both increasing the frequency and duration of droughts in many parts of the country and intensifying extreme storms. Periods of drought interspersed with strong precipitation increase runoff from agricultural lands, lawns, and other sources, leading to higher nitrogen levels in rivers and, therefore, HABs. Burning fossil fuels, deforestation, and land development are increasing the amount of carbon dioxide in the atmosphere. This fuels HABs because cyanobacteria can feed on the carbon dioxide not only present at the surface of a water body but also dissolved in the water. When algae die and sink to the bottom of a freshwater body, they decompose and release once sequestered carbon, providing more fuel for cyanobacteria growth. Climate change and more severe droughts also modify the flow regime in freshwater bodies and can increase competition for ever-scarcer freshwater supplies. Reduced flows in waterways mean the remaining water will be warmer and more stagnant, creating conditions ripe for algal blooms.

Effects of HABs on Aquatic Ecosystems

1. Endangerment to Human Health

People can be exposed to HAB toxins by swallowing or swimming in affected waters, eating poisoned fish or shellfish (even when food is cooked, algal toxins remain), or inhaling airborne droplets of affected water. Depending on the level of exposure and the type of algal toxin, health consequences may range from mild to severe to fatal. HABs produce toxins that reduce the suitability of water for human consumption. People often get sick by eating shellfish containing cyanotoxins. Their large presence in the water and their well propagating sequences lead to quick contamination of water, thus posing a health hazard to humans. Strong irritation, itching, and even skin diseases are experienced when such contaminated water encounters the human skin. Some cyanotoxins are known to cause acute illness in humans, such as allergic reactions, gastrointestinal upset, eye irritation, respiratory distress and flu like symptoms. Long-term effects after ingesting cyanotoxins include liver cirrhosis, neurogenerative diseases, etc. Pets and wildlife are also susceptible to cyanotoxins. Freshwater blooms have not only shut down local water sources but have also been blamed for the death of dogs that had been swimming in them.

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2. Death of Aquatic Life and disturbance in Food Chain

For any living organism to survive, they need oxygen for respiration. Fishes and other aquatic life depend on the oxygen dissolved in water. HABs consume oxygen and block sunlight from underwater plants. HABs can deplete oxygen in water and lead to low dissolved oxygen levels. When masses of algae die and decompose, the decaying process can deplete oxygen in the water, causing the water to become low in oxygen and when oxygen levels become too low, fish suffocate and die. More death of aquatic animals means more food for the algae, leading to faster propagation and, in the end, deterioration of aquatic life. Toxins produced by HABs are detrimental to fish and other animals. These toxins can be transferred through the food web, affecting and even killing the higher forms of life, such as zooplankton, shellfish, fish, birds and larger animals like sea lions, turtles, and dolphins. Even if algal blooms are not toxic, they can negatively impact aquatic life by blocking out sunlight and clogging fish gills. In 2015, a bloom of various dinoflagellates off the coast of South Africa led to low-oxygen conditions, known as eutrophication, killing 200 tons of rock lobster.

3. Strain on Industries and Economies

The presence of HABs makes transport on waterways cumbersome, leading to more expensive means of transport, such as air, resulting in economic losses. Since HABs lead to the death of aquatic life, there can be widespread losses to fishermen who depend on fishing as an income-generating activity. HABs badly affect fishing and shellfish industries, killing fish and contaminating shellfish. Annual losses to these industries from nutrient pollution are estimated to be in the tens of millions of dollars. Besides, some industries, for example, food-processing companies, only require clean water from water bodies to drive their production. This means that the presence of HABs will cause additional water treatment costs to get clean water, leading to increased overhead costs.

4. Losses in the Tourism Industry

With the dense growth of algal blooms on natural recreational water surfaces, the tourism industry suffers greatly as the resulting foul smell and dead zones mean there are no fishes to watch, no available ways to navigate the water, and no swimming or boating activities.

5. High Water Utility Bill for Domestic Consumers

With HABs contamination or not, people still need water for consumption. The municipality will have to invest in water treatment processes that eliminate the toxins caused by algal blooms. In some cases, extensive growth of algal blooms may lead to scarcity of fresh drinking water if the town or community depends on the contaminated source as the only one for distributing consumption water. All these increase the costs of treatment and the demand for water, which eventually dramatically raises the water utility bills for domestic consumers.

Solutions to mitigate HABs

1. Proper Sewage Treatment

To decrease the amount of nitrogen and phosphorus in water, sewage water must be treated according to the standard waste treatment procedure. Implementing disinfection and tertiary treatment is important to mitigate the introduction of excessive nutrients into rivers, lakes, oceans, and streams. This involves the removal of nitrogen and phosphorus components through processes such as nitrification, followed by the appropriate treatment of resulting sludge. Also, effective water treatment procedures guarantee that people drink clean water and protect aquatic life.

2. Reduction of Pollution and Water Wastage on a Personal Level

In order to attain the global objectives of environmental conservation with a focus on reducing pollution, it is imperative to initiate individual efforts aimed at minimizing waste generation, promoting recycling practices, and embracing the concept of reusing resources as a means to preserve the natural environment. When individuals engage in this behavior at their residences, workplaces, or educational institutions, it has the potential to contribute to the reduction of the collective nutrient burden in water bodies, hence facilitating the water treatment process.

3. Better farming practices

Farmers use fertilizers to increase crop yields by supplementing deficient nutrients. Farmers are advised to consult with agricultural experts regarding the type and amount of fertilizer to use. Employing the most desirable practices and applying the proper quantities of fertilizers can ensure both optimal crop growth and a balanced level of soil toxicity or nutrient concentration. It would mean that only small quantities of chemicals are dispersed into waterways upon the onset of rain, thereby reducing the incidence of algal bloom. Do not apply fertilizer before gusty, rainy days or near waterways.

4. Green infrastructure

As mentioned above, it's not just farms that produce tainted runoff. Every year, gallons of untreated stormwater wash off paved surfaces into waterways. This runoff can contain high levels of nutrients and inorganic pollutants that can trigger HABs. The solution is to use greener infrastructure in cities. Adding green roofs, planting trees, and building gardens of rain absorbing plants all capture rainwater before it flows into waterways.

5. Ultrasound Bloom Treatment

This technology utilizes ultrasonic sound vibrations in water bodies to detect algal blooms and if found, to control their growth by up to 90 percent. This treatment monitors vast bodies of water and can determine whether algal blooms pose a threat based on the prevailing conditions. These waves are sent across the surface of water bodies to counter their buoyancy, causing them to descend and inhibiting photosynthesis. The absence of light inevitably leads to the demise of HABs.

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6. Smart water policies and conservation

Smart water management practices, which comprise planning, developing, distributing and managing the use of water resources using an array of technologies, should be designed for better monitoring and more reasonable and sustainable usage of water resources. Government agencies, local communities, and businesses should develop practical strategies for reducing excessive nutrients and pollutants from water bodies while providing alternative, sustainable water supplies for growing populations and economies.

7. Monitoring, mitigation, and collaboration

Improved monitoring and increased research into HABs are also much needed. There is no nationwide system for collecting data on and responding to HABs, and the type of information available on HABs in individual states varies greatly. Improved methods of communication to the public, across organizations, and among states could speed up emergency response to HABs, reducing harm to the environment, wildlife, and people. Knowing where HABs are occurring and whether the government is responding is a critical first step to keeping our waterways, ecosystems and population safe.

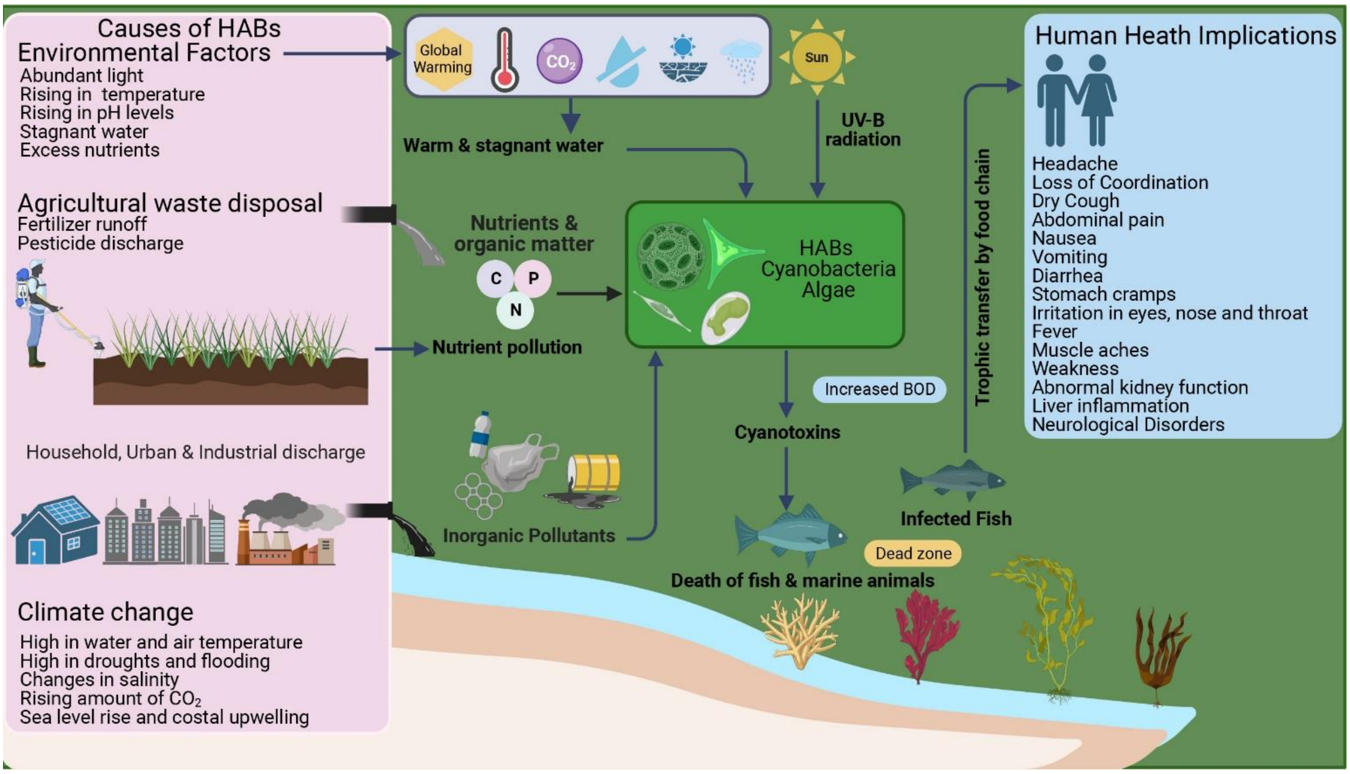

Figure: Overview of causes of HABs, ecological impacts on aquatic systems and associated human health implications.

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