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HARMFUL ALGAL BLOOMS

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What is Harmful Algal Bloom

Harmful algal bloom (HAB) are those algal species which produces toxin, lethal to biotic environment of an aquatic ecosystem. It is observed that most algae are harmless, but certain ones produce toxins which are posing threat to water bodies and human health. These toxins producing algal blooms are termed as Harmful algal blooms, often termed as "Red tide or Green tide". This natural occurrence gained a significant worldwide attention due to its frequent massive occurrences and vast severity in the recent years which concerns the environmentalists.

What results in HAB

Deterioration in water quality parameters due to introduction of excess nitrogen and phosphorus into the water bodies from agricultural run-off, results in proliferation of toxin producing algae which in turn disturbs the ecological balance of environment. This is mainly affecting the food chain, oxygen depletion, dead zone creation in water bodies and mass mortality of fishes and other marine organisms. Climatic changes also alter the water temperature, ocean current patterns and rainfall, which create favourable conditions for the harmful algae to sustain and flourish.

Organisms responsible for HAB

Simple phytoplanktons like diatoms, dinoflagellates and cyanobacteria are the main organisms which causes HAB. Blue green alagae (Cyanobacteria) are the algal species which causes blooms in freshwater, producing toxins like microcystin, anatoxins etc. other problematic algae in aquaculture sectors (freshwater as well as inland saline) are *Microcystis aeruginosa*, *Euglena* spp, *Anabaena* spp (filamentous in nature), *Prymnesium parvum* (golden algae), *Chlorella vulgaris* and *Scenedesmus* spp

Certain species like *Karenia brevis, Chattonella marina* produces brevetoxins that can lead to red tide events, affecting the shellfishes. The poisoning is called Neurotoxic shellfish poisoning. Ciguatera fish poisoning is caused by *Gambierdiscus toxicus* producing ciguatoxins which affect the coral reef fishes. Similarly, Paralytic shellfish poisoning is caused by *Alexandrium* spp, *Gymnodinium* spp and *Pyrodinium* spp which produces saxitoxins affecting the shellfishes. *Dinophysis* spp and *Prorocentrum* spp produce the okadaic acid and dinophysis toxin. While, *Pseudo-nitzschia* produces domoic acid affecting the shellfishes, crabs as well as anchovies.

Physico-chemical and biological factors responsible for algal blooms

In an aquatic environment, excessive abundance of nutrients like phosphorus and nitrogen promotes the algal growth. Other factors like light penetration, warmer temperatures, optimum pH levels, sedimentation rate, stagnant waters and other biological organisms like abundance of bacteria or absence of zooplanktons promote more algal concentrations. Besides these, blooms follow seasonal abundance with respect to seasonal fluctuations in the physico-chemical parameters of the environment.

Environmental Impact of HABs

The environmental impact of HABs can be very severe in freshwater, brackish water as well as marine environment. Mostly, this severity is observed indirectly in terrestrial areas too. The potent toxins produced by the algal species are fatal to marine biota reaching up to human life. This leads to massive fish kills and affect other marine organisms. Another drastic impact is on coral reef and seagrass beds as the excessive concentrated algal scum as well as toxins aid in coral bleaching, affecting coral growth and seagrass species. These excessive algal growth leads to hypoxic condition like oxygen depletion zones or dead zone. Harmful algal species compete with the other phytoplanktons and harmless algae, leading to loss of biodiversity, reduced food availability to the higher trophic levels thus, disturbing the ecological balance. The decaying of these blooms can contribute to CO_2 emission through decaying processes and increase the release of green-house gases like CO_2 and methane.

1. Impact on Mariculture

HAB leads to devastating effects on mariculture activities. These include mass mortality of cultured finfishes and shellfishes. The toxin thus produced are accumulated in every niche of the aquatic environment and do get imbibed into the tissues of the cultured species. Shellfishes like mussels, oysters and clams concentrate the toxins thus produced by the HABs. These often get bioaccumulated to the higher trophic levels, reaching the humans. Another impact is HAB lead to financial crisis to the stakeholders due to mass mortalities and market restrictions. Besides these, there are increased operating cost involved in water quality management and testing of toxin levels. Certain measures in early warning of blooms may have to deploy relocation of cages which is very expensive in nature. Stakeholders dealing with semi-enclosed or closed farming practices suffer in water exchange leading to disease outbreaks. Thus, HABs create a barrier for sustainable expansion of the mariculture activities. In order to regulate and monitor, more reliance of early warning systems, satellite monitoring and regular water quality monitoring can aid in avoidance of mass mortalities to an extent.

2. Impact on Shellfish Industry

Being sessile and sedentary life, the shellfishes are more prone to HABs due to bioaccumulation of toxins. Globally, intense severity is very visible in shellfish culture farms. HABs can have negative impact on the shellfish especially the physiology of the species, thereby economic losses to the stakeholder. Though, early detection and rapid response to mitigate the impacts of HAB in shellfish industry are possible with satellite monitoring, toxin testing and continuous water quality management, however these measures do not guarantee the complete protection and prevention of shellfishes from the impact of HABs and also involves increased operational cost.

3. Impact on Human biota

Impact of HABs on human can range from direct or indirect consequences resulting from acute to everlasting chronic health hazards. Direct contact with HABs can lead to skin and eye irritations and can be fatal if ingested in high levels. HAB have impact on human beings as amnesic shellfish poisoning (ASP), paralytic shellfish poisoning (PSP), diarrhetic shellfish poisoning (DSP). It is studied that saxitoxins (toxins from PSP) leads to neurological and respiratory disorders, domoic acid (ASP) can result in loss of memory and even death, Okadaic acid (DSP) leads to gastrointestinal disorders and brevetoxins (NSP) can result in gastrointestinal and neurological and gastrointestinal distresses.

In case of freshwater environment, the microcystin toxins produced by the blue green algae is the main problem as the humans mainly depend on lakes, rivers and reservoirs for drinking water supply. These toxins make the environment unsafe for human consumptions. Impacts of HABs are well noticed in fishing activities, coastal and island tourisms, recreational activities like swimming, surfing as well as affect the community well-being.

Managing the HABs: Approaches for monitoring and mitigation

Recent research observes various approaches in monitoring and management of HABs so as to protect marine environment, human life as well as their economic stability. These are mitigation measures like early detection, preventive steps and proactive actions. Use of remote sensing and satellite data to study the physicochemical parameters of the water helps in early detection of HABs. On field regular monitoring of water samples have significant role in detection of HABs. Advanced technologies like sensors can be well equipped in the early detection of these algae. Local communities and government should have a collaborative effort in detection, reporting and tracking of the HABs. Strict rules and regulation to be implemented to control excessive nutrient pollution and dumping of domestic garbage, sewage and effluents from industrial sectors into the adjoining water bodies of coastal regions. In aquaculture sectors, algicides and clay flocculation methods can be implemented in manging the bloom expansion as a last management measures. Relocation of the culture farms, alteration of the water flow, complete drying up of ponds before next culture period are certain measures to tackle at a very small extend. There should be strict monitoring in HAB affected areas and temporary closure of fishery can be implemented. Education and awareness among the public regarding the ill effects of HAB should be issued periodically. Advanced filtration methodologies to be implemented if drinking water sources are affected by the HABs. Initiation to be taken to develop HAB-resistant mariculture fish strains. It is believed that these diverse management measures can early detect, proactive monitoring programs and tackle or lessen the impact of HAB, thus protecting the aquatic environment, safeguard the community health and support the fishery dependent sectors.

Measures for reducing nutrient pollution at regional level

There should be proper disposal of household wastes so as to prevent them from entering water systems. More and more promotion of eco-friendly cleaning supplies and fertilizers can aid in prevention of blooms. Minimal usage of pesticides and herbicides in agricultural lands and aquacultural areas, implementation of best management practices like recycling and composting, proper measures to conserve and protect water bodies, involvement of local bodies in strict implementation and regulation of nutrient runoff and pollutants into adjacent water bodies as well as coastal waters can lead to overall reduction of excessive nutrient inflow and thus mitigate the frequent occurrences of HAB.

Education and Awareness creation

Education and awareness among the public can create wonders in drastic reduction of HAB occurrences. This can lead to promotion of very effective prevention as well as management strategies. Making the community involvements at regional level can create a sense of urgency at a microlevel. These practices make the public and policymakers informed about the knowledge on HABs and realize the urgency in nullifying it by taking proactive steps in minimizing their involvements in nutrient enrichment of an aquatic ecosystem.

Implementation of advanced Technologies in monitoring and mitigating HABs

Future techniques for detecting HAB are set to integrate advancements in multi-sensor technology, genomics, real-time data analysis, and predictive modelling for early detection and mitigation measures. Several emerging technologies like advanced remote sensing with artificial intelligence incorporation, satellite imagery, nano-satellite techniques, drone imagery, can be explored for HAB monitoring. Utilizing the real-time environmental DNA (eDNA) monitoring on continuous basis will help in monitoring of HAB onsets and prevalence in the aquatic environments. On field specifically portable on-site gene sequencers, environmental RNA (eRNA), utilizing of microsensors for monitoring the physico-chemical parameters can indicate the extend of receding of the algal bloom. Smart buoy arrays with sensor technologies, drone and robotic technologies helps in providing overall detailed view of the HAB. Predictive models incorporating real time as well as historical data in collaborating with AI technologies can pave a way in early warning signals. Toxin detection can be done using sensors for molecular-chemical analysis onsite. Other advanced techniques like usage of optofluidic sensors can be deployed. Public can be made aware about the dreadful effects of HABs via invention of user-friendly mobile "HAB" app, low cost HAB detection kits which in turn empower them to test water samples and report localized blooms. These data can be retrieved to the central monitoring systems. Implementation of Open database on HAB tracking with open access to all would create global collaboration in trans-boundary bloom events. These emerging technologies could help aggressively in monitoring, early detection and mitigating HABs with proactive management measures.

Conclusions

The deadly blooming of the harmful algal species creates a major threat to the aquatic ecosystem, fishing, mariculture activities, tourism and ultimately harming the human health. The frequent occurrences and severity indicate the continuous fuelling for the proliferation of algal species especially by the excessive nutrient enrichment, climatic changes and other factors. As the toxin by the HABs lead to mass fish kills, shellfish contamination and human hazards, it is the necessity to come up with urgent proactive management measures. This can be done with proper monitoring, management and mitigational measures covering on field monitoring to satellite based monitoring techniques. Collaborative efforts should be implemented with communities, stakeholders, government and international agencies to monitor the HABs on a region-specific to global level. Public should be well educated and made aware about the HABs. It is the necessity to comprehensively manage the nutrient pollution in aquatic ecosystems with proactive and innovative technologies so that we can imbibe in protecting our marine environments, safeguard the associated biodiversity and human health.

SUGGESTED READINGS

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