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Harmful Algal Blooms in Ocean Verses Lake and its Impact on Fishery Industry: A Review

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Abstract- Harmful algal blooms (HABs) represent natural incidents that can also be exacerbated by human-induced pressures on aquatic ecosystems. Certain HABs adversely affect aquatic fauna, including both wild and cultivated fish, as well as their habitats, resulting in subsequent impacts on human well-being. Other HABs are instigated by species that naturally produce toxins, leading to human health issues upon ingestion of contaminated seafood, direct contact with water, or inhalation of aerosolized toxins. The aim of this review article is to examine the multifaceted consequences of algal blooms, with a particular focus on their economic impact, effects on human health, implications for commercial fisheries, and consequences for tourism and recreation. It also provides an in-depth analysis of the various impacts of algal blooms on ocean and lake ecosystems, highlighting the importance of proactive management and mitigation strategies to safeguard both environmental and economic interests. Understanding these far-reaching consequences is crucial for policymakers, researchers, and industries to develop effective strategies for minimizing the negative effects of algal blooms on our ecosystems and societies.

Keywords- Algal, Bloom, ecosystem, ocean, aquatic, economic

I. INTRODUCTION

The natural process of mass proliferation of phytoplankton in water bodies be regarded as harmful algal blooms. Diatoms, dinoflagellates and cyanobacteria are important organism for algal bloom production (Paerl, H.W.,2009). In 1908 Hornell firstly observed algal blooms in Indian ocean.(J. Hornell,1997).300 species of phytoplankton produced blooms out of 5000 species and out of which 8 species produced toxin (Hallegraeff, G. M. (1993).The blooms of cyanobacteria influence the health of aquatic animals and life of human (Mishra et al., 2020). Noctiluca scintillans/miliaris, Trichodesmium erythraeum, and Cochlodinium polykrikoides species are responsible for forming algal blooms near Indian Ocean (Paerl et al., 2011).

Warm temperature and highly nutritional water help in formation of bloom (Falconer, (1998). The different factor such as temperature, nutrients, salinity etc are helpful in procreation of microalgal into blooms (Anderson et al., 2012).The speedy growth of microalgal are responsible for visible discoloration of water such as foam production and red tide (Smayda, T. J. (1997). Dangers blooms of algae are a significant environmental catastrophe, with severe impacts on both local and worldwide levels. They disrupt the balance of nutrients in ecosystem and change the biogeochemical process (Zhang et al., 2018). The action and physical reaction of tiny organism influence ecological activity within biogeochemical patterns. Earlier examination of gene activity and protein makeup of a group of bacteria in the water, occurring at the same time as surge in diatoms growth, showed increased metabolic engagement linked to rhodobacteraceae and the SAR 92 group (Klindworth et al., 2014) .The way algal blooms react to too many nutrients and shifts in climate varies from lake to lake. Initially, this reaction relies on how long water stays in the lake and the amount of nutrition in it, determine by where the lake sits in the water system. Moreover, specific feature of each lake, like how deep it is, how big it is, the amount of light it gets, and its water temperature, affect how much algal bloom in that lake are affected by too many nutrients and change in climate (M Scheffer et. al., 2007). A different consequences of harmful algal bloom arises when toxic algae release harmful substances into the water ,leading to the death of marine plants and creatures harmful algal bloom also result in the death of fish and wild life (such as sea birds ,wheels, dolphins and other sea life),usually due to the moment of poisons through the food chain or when aquatic toxins are consumed or pas through gills (JH Landsberget. al., 2014).Most people in India have a strong like to the water around them, which is crucial for their way of life. This could be through jobs like fishing and farming, or in their daily activities like bathing, cooking, and spiritual practice connections come with well known adverse effects on health. These blossoms carry the potential to pose a significant public health threat in a year impacted by blooms. Regular contact with cyanobacteria harmful algal blooms can lead to sea food intoxication, queasiness, shortness of breathing, aliments caused by neurotoxins and hepatotoxins like cognitive decline, Alzheimer's and other neurological issues, gastrointestinal and breathing complications well as detrimental effects on liver and kidney functionally (Carmichael et al,1995). Phytoplankton, fundamental as primary producers reliant on photosynthesis, play a vital role in driving biogeochemical cycles, shaping food web dynamics, and ensuring the viability of aquatic ecosystems across a spectrum extending from initial water sources to the coastal expanses. The burgeoning human populace, in conjunction with its linked expansion in agriculture, urbanization, and industry, has resulted in nutrient inflows surpassing the levels required to maintain optimal primary productivity along this spectrum. This excess of nutrients and an abundance of organic matter at the foundational level of the food web have caused a phenomenon known as "cultural eutrophication," characterized by unwelcome biogeochemical and ecological repercussions. Among these, the most conspicuous and problematic consequence is the proliferation of harmful phytoplankton, commonly referred to as "blooms" (Halpern, B. S et.al 2008).Illustrative schematic illustrating the intertwined influences of physical, chemical, and biological factors on the emergence and propagation of harmful algal blooms spanning the transition from freshwater to marine environments (Paerl, H. W et.al 2018).Harmful algal blooms featuring characteristic species from primary taxonomic algal categories across the spectrum from freshwater to marine ecosystems (Paerl, H. W et.al 2018). When favorable environmental and climatic circumstances align to trigger harmful algal blooms (HABs), phytoplankton species possess the ability to generate dangerous toxins that can permeate various trophic levels (such as crustaceans and mollusks) and eventually enter the human food chain, leading to illnesses and, in severe cases, fatalities. Diverse physical, chemical, and biological elements contribute to the occurrence of HABs and the subsequent production of toxins. These factors encompass an escalation in temperature, heightened instances of rainfall, and an excessive discharge of nutrients into aquatic environments. Toxins are typically released during the decline of an algal bloom, as the cell membrane ruptures, causing the dispersion of the produced toxins in water bodies, which are then absorbed by organic matter within the water column. Nonetheless, live algal cells can also discharge toxins into the water (EPA, U et.al 2014).During HAB occurrences; the presence of harmful algae does not always directly correspond to the actual production of noxious toxins. Additionally, a specific toxin can be generated by various algal species, and a single algal species has the capacity to produce multiple types and variations of toxins. Toxicity levels sufficient to pose a danger can be reached even with low cell densities. Furthermore, toxins present in water or seafood are devoid of odor and taste, and they cannot be eliminated through cooking or freezing Marine toxins are categorized into five groups based on the effects they exert on organisms: Paralytic Shellfish Poisoning (PSP), Diarrhetic Shellfish Poisoning (DSP), Amnesic

Shellfish Poisoning (ASP), Neurotoxic Shellfish Poisoning (NSP), and Azaspiracid Shellfish Poisoning (AZP) PSP, DSP, NSP, and AZP have all been linked to the consumption of shellfish contaminated with toxins produced by dinoflagellates, while ASP results from the ingestion of toxins released by diatoms (Camacho, F. G et.al 2007).

II. ALGAL BLOOMS IN OCEAN AND LAKE

Red tides are inherent oceanic calamities that impact coastal ecosystems, fisheries, and recreational marine activities (Lee, J. H.et.al (2020). Red tides are the prevalent form of harmful algal blooms (HABs), resulting from the rapid growth of phytoplankton, predominantly dinoflagellates and certain diatoms, which impart a reddish or brownish hue to the ocean (Lu, S., & Hodgkiss, I. J.et.al (2004).Certain harmful algal blooms (HABs) generate toxins that contaminate shellfish, fish, and marine mammals. However, even in the absence of toxin production, red tides can have detrimental effects, including inducing hypothermia in seabirds by neutralizing their inherent water repellency and insulation, as well as suffocating fish by adhering to their gills (Kudela, R. M. et.al(2009). Potential causes of the increasing red tide events are climate change, other anthropogenic impacts, and rapid changes in the marine environment. For example, a Karenia brevis bloom occurred to the west of Florida in 2017 and persisted for more than a year. Such persistent red tide, which had not occurred before, resulted in massive mortality of marine wildlife and a ban on marine leisure activities. A recent study reported that anthropogenic forcing (N-enriched discharge) was the key factor in the red tide west of Florida (Medina, M et.al 2022). In Chile, the most devastating occurrence of aquaculture fatalities transpired during two consecutive red tides in 2016. The initial event was a bloom of Pseudochattonella verruculosa spurred by unusually warm water temperatures and significant water column stratification. Moreover, an immense quantity (40,000 tons) of salmon perished as a result of the red tide. The disposal of deceased salmon triggered the subsequent Alexandrium catenella bloom, leading to the production of paralytic shellfish toxins. These red tides extended across 2,000 km of the coastline, resulting in the death of additional salmon and numerous bivalves. The economic impact due to the loss of salmon was highly significant, amounting to an estimated 800 million USD (Hallegraeff, G. M. et.al(2021).Lake of the Woods (LoW) is a boreal lake that spans across international borders, situated within the Canadian provinces of Ontario and Manitoba, as well as the U.S. state of Minnesota. It grapples with substantial challenges in water quality owing to excess nutrient levels and recurrent occurrences of severe cyanobacterial harmful algal blooms (cHABs) (Pascoe, T.et.al (2023). The lake holds significant socio-economic and cultural value as a primary fishing and tourism spot, a generator of hydroelectric power, and a crucial drinking water source for numerous communities in the area. Despite being historically abundant in aquatic life, informal accounts have indicated a rise in the severity of blooms in the lake in recent decades. This assertion is supported by paleolimnological analyses conducted on sedimentary cores, revealing evident upticks in phytoplankton indicator pigments during the latter years of the 20th century (Paterson, A. M.et.al 2007).Phosphorus is a primary limiting factor for phytoplankton biomass in lakes situated on the Precambrian Shield. (Schindler, D. W. (1974).Nevertheless, the overall external phosphorus inputs to the lake have substantially decreased over the past four decades, largely attributed to reductions in point-source discharges from the pulp and paper industry and local sewage treatment facilities(Hargan et al., 2011).

III. IMPACT OF ALGAL BLOOMS

1. Economic Impacts of Algal Blooms

Harmful Algal Blooms (HABs) pose a natural risk in both freshwater and marine environments, and their occurrences are linked to a substantial influence on both socio-economic systems and human well-being. Across the globe, millions of individuals rely on freshwater or marine sources for essential resources and services, the availability of which is closely tied to the safeguarding of water bodies. The combined impact of climate shifts and human-induced factors collaboratively exerts adverse effects on aquatic environments, leading to modifications in their physical, chemical, and biological characteristics. These alterations can carry notable socio-economic consequences, affecting key sectors such as public health, commercial fisheries, tourism, recreational activities, as well as monitoring and management efforts. Harmful Algal Blooms (HABs) are distinguished by the rapid growth of algal populations or the production of detrimental toxins. The biological consequences of HABs encompass fish fatalities, contamination of seafood, and illnesses in humans resulting from the consumption of tainted shellfish or fish. These occurrences directly or indirectly impact the economy. Direct impacts include financial losses in the marine industry due to shellfish closures, medical treatment expenses for human illnesses, costs for algae and dead fish removal from water and beaches, as well as investments in HABs prevention and monitoring. Indirect effects involve a substantial decline in tourism to regions affected by HABs, reduced revenue for businesses in the hospitality sector, decreased recreational use of lakes, seas, and oceans, along with increased expenditures by residents (Anderson, D. M et.al 2000).

2. Impact on Human Health

When toxins are discharged into water during harmful algal blooms (HABs), their harmful effects on humans are believed to manifest through diverse pathways: ingestion of contaminated seafood, inhalation through aerosols or wind-carried particles of desiccated algal material, consumption of water or scum, and direct contact with the skin or conjunctiva. The primary ailments induced by marine toxins in humans encompass the aforementioned Amnesic Shellfish Poisoning (ASP), Paralytic Shellfish Poisoning (PSP), Diarrhetic Shellfish Poisoning (DSP), Neurotoxic Shellfish Poisoning (NSP), and Ciguatera Fish Poisoning (CFP) .These health conditions can vary in severity among affected individuals, and treating the exhibited symptoms incurs costs for the healthcare sector. Hospitalizations and sickness resulting from instances of intoxication lead to expenses related to medical treatments, illness investigations, emergency transportation, and contribute to the loss of individual productivity (Todd, E. C. D. 1995).While the detrimental health impacts of exposure to Harmful Algal (HA) toxins have been recognized for many years (particularly for certain cyanobacterial toxins) or even longer (such as brevetoxins linked to Florida red tides), there has been a notable lack of comprehensive epidemiological studies aimed at thoroughly evaluating these effects. This deficiency has impeded efforts by the Intergovernmental Panel on Climate Change (IPCC) to make accurate predictions regarding the influence of climate change on illnesses associated with Harmful Algal Blooms (HABs) (Hanson, C. E. et.al (2007).

3. Impacts on Commercial Fishery

Harmful Algal Blooms (HABs) are strongly linked to financial losses within the fish market. When HABs occur, toxins released by algae can be absorbed by fish, leading to the closure of fish trade. Concurrently, the proliferation of algae may deplete oxygen in water bodies, resulting in fish mortality. The subsequent rise in fish prices and decreased consumer demand, particularly during HABs, are just a few of the economic ramifications in the commercial fishery sector. The suspension of commercial fishing directly impacts producers economically. Furthermore, when harvested fish cannot reach the market due to high toxicity levels, the economic impact must also factor in harvest costs. HABs can also affect aquaculture facilities, necessitating additional investments to secure commercial operations. Given the considerable public concern regarding seafood safety, understanding the economic impact on both commercial and recreational fisheries is crucial in gauging public responses to the challenges posed by HABs (Neilan, B. et.al (2010).

4. Impacts on Tourism/Recreation

Economic impacts observed during harmful algal blooms (HABs) episodes are shaped by various factors, with tourism and recreation representing a significant influence. The financial ramifications of blooms encompass losses from the closure of fishing activities for recreational fishers, diminished recreational and leisure experiences for beachgoers, and a decline in visitors to hotels, restaurants, and rented holiday homes. The economic effects within the tourism and recreation sectors are heavily affected by alterations in the coastal or freshwater environment triggered by a bloom. These alterations include changes in water color, the accumulation of deceased fish on beaches, and the odors emanating from algae decomposition. When estimating the local economic impact on these sectors, it is crucial to consider a redirection of tourism-related business, as other activities may experience a boost due to the manifestations of HABs(Thornbrugh, D. J. et.al (2009).

IV. KEY OBSERVATION

The HABs are often linked to environmental factors such as rising water temperatures and nutrient pollution as well as it impact in the fishery industry includes fish mortality ,fish health, fishery closures, economic loss, long term ecosystem changes. HAB can lead to mass fish mortality events due to toxins produced by certain algal species. Observing the extent of fish kills during HAB events is crucial Even if fish survive, exposure to HAB toxins can affect their health and market values of the catch. HAB- related contamination may lead to temporary or permanent fishery closure, affecting the livelihood of fisherman and the availability of seafood products. The economic impact on the fishery industry can be substantial, including revenue loss, reduced catch quality and increased monitoring and management costs. Repeated HAB events can disrupt food webs and alter the structure of aquatic ecosystems, potentially leading to shifts in fish populations. Among all the sectors examined in this report, determining economic losses related to human health proves to be exceptionally intricate due to challenges in assessing the direct effects of toxins on human health, given the wide range of symptoms they can induce. European data are included selectively in specific categories, primarily the section covering monitoring and management costs, potentially due to a scarcity of publicly available reports or data regarding the economic impact of HABs in Europe. Conversely, the United States of America (USA) has well documented cost estimates for HAB events in various scientific reports.

Enhancing transparency in economic data and accurately evaluating the costs of measures taken to ensure good water quality are vital for identifying the most effective actions and determining the economic losses caused by HABs. This report serves to provide critical information on monetary losses necessary for cost-benefit analyses, aiding policy guidance concerning HABs. Additionally, it serves as a valuable resource to familiarize readers with HAB events, assess methods for estimating the economic impact of HABs, and identify the most cost-effective approaches in term of costs and benefits.

Disseminating information to the public about HABs and advocating for management processes to mitigate their occurrences are crucial measures for reducing negative impacts associated with blooms. Thus, promoting greater public awareness of HAB episodes and encouraging effective monitoring and management of HABs are essential to recognize these phenomena, comprehend their origins, predict their occurrences, and mitigate their repercussions. Leveraging molecular-based technologies and data integration into predictive models will play a pivotal role in achieving these objectives.

V. CONCLUSION

Harmful Algal Blooms (HABs) refer to a significant proliferation of phytoplankton species, whether toxic or non-toxic, within aquatic ecosystems. These occurrences are natural but carry substantial economic implications across various sectors. This technical report offers a detailed account of prevalent phytoplankton organisms causing HABs and compiles information from diverse sources, including scientific reports, papers, and books, concerning the economic losses attributable to HABs. The data encompass both marine and freshwater HABs, focusing on their impact on human health, fisheries, tourism, and the monitoring and management processes aimed at HAB prevention

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