

Red tides in Indian coasts: Impacts and management

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Abstract

Red tides caused by harmful algae are a major concern worldwide because of its negative effect on marine biodiversity and to people dependent on marine resources for their survival. Since 1980's, many algal bloom incidents have happened in India and their impacts led to the fish kills and hospitalization of human beings. The review delineates the type of Harmful Algal Blooms found in Indian coasts, and associated diseases in shellfishes and harms to people. Moreover, causes for the appearance of red tides are elaborated and preventive measures to lessen the blooms are suggested.

Keywords: Mortality, public health, nutrients, pollution, mitigation

Introduction

Of the remarkable diversity of phytoplanktons in the world, 7 % are about to cause algal blooms. They lead to discolouration of sea water known as red tides. Certain types of algae show sudden excessive growth in marine and freshwater, detrimental to the aquatic life are known as Harmful Algal Blooms (HABs). Their sustenance in marine water is brought about by the interaction of physical, chemical and biological factors that are often quick and unpredictable (Gilbert, 2005). Harmful Algal Bloom (HAB) proliferation in the seas can cause massive fish kills, contaminate seafood with toxins, and alter ecosystems in ways that become toxic to humans (Sharma *et al.*, 2024) [13]. HABs show high diversity regarding causative organisms, bloom dynamics and type of impact (Padmakumar *et al.*, 2012) [8].

Coastal habitats of India are sensitive to changes in environmental conditions because of susceptibility to variations in sea surface temperature, salinity, nutrient input, pollution and ongoing developmental activities. The HAB's have negative impacts on fisheries due to the vulnerability to red tides and harmful microalgae (Zingone and Enevoldsen, 2000) [20]. The algal blooms reports have been found to increase after 1980's in India. Between 1998–2010, eighty algal blooms were recorded, of which 31 were dinoflagellates blooms, 27 cyanobacterial blooms, and 18 by diatoms. Among these three blooms constituted raphidophytes and one haptophyte bloom (Padmakumar *et al.*, 2012) [8]. Besides, studies from the Indian coast showed the presence different algal species were responsible for causing blooms in Indian waters (D'Silva *et al.* 2012) [2]. *Noctiluca* (Dinophyceae) and *Trichodesmium* (Cyanophyceae) are major contributors to the bloom forming taxa. This review highlights past incidents of red tides, the importance of mitigation measures to prevent harmful algae that are involved in bloom formation.

Types of HABs and their effects on aquatic organisms.

Many of the microalgae including diatoms and dinoflagellates can produce toxins effecting the marine biota. Recently, the incidences of HAB's are increasing worldwide and also in India. *Cochlodinium polykrikoides* and *Gymnodinium catenatum* blooms were seen during a monsoon break (July 2000) at Goa and fish mortality was observed in the subsequent year (D'Silva *et al.* 2012) [2]. The bloom-forming algal species can be categorised into three groups

1. The harmless algal species namely the dinoflagellates (*Noctiluca scintillans*, *Gonyaulax polygramma*, *Trichodesmium erythraeum*) lead to water discolorations. These algae under certain circumstances, when undisturbed waters proliferate to maximum extent resulting in mortalities of fish and invertebrates. This proliferation leads to oxygen depletion becoming fatal to the marine organisms (He, 2015).
2. Some algal species produce toxins that can enter the food chain inducing many gastrointestinal and neurological diseases in humans (Table 1). The potentially toxic microalgae are recorded from the Indian coasts namely, *Alexandrium* spp., *Gymnodinium* spp., *Dinophysis* spp., *Coolia monotis*, *Prorocentrum lima*, and *Pseudo-nitzschia* spp (Padmakumar *et al.*, 2012) [8]. Dinoflagellates are most toxic, whereas diatoms and cyanobacteria known to produce harmful chemicals. The cyanobacteria produce neurotoxic and hepatotoxic metabolites accumulates in fish livers and kidneys (Sonak *et al.*, 2018) [18]. Knowledge on these toxins in aquatic environments is important for the sustainability of healthy aquatic ecosystems and human populations (Rastogi *et al.*, 2015) [10].

Table 1: The type of toxins produced by algal blooms and associated problems.

Name	Type of toxins	Through	Disease and its reports	Remarks
<i>Gymnodinium catenatum</i> , <i>Alexandrium</i> spp., <i>Pyrodinium bahamense</i>	Saxitoxins, gonyautoxins, neosaxitoxin, C-Toxin	Consumption of contaminated shellfishes and fishes like sardines, etc.	Paralytic Shellfish Poisoning (East and west coasts)	Tingling in the lips, tongue, and fingertips, lead to respiratory failure and death
<i>Dinophysis</i> spp., and	Okadaic acid and its	Consumption of	Diarrhetic Shellfish	It is characterised by

<i>Procentrum</i> spp.	derivatives (Lipophilic toxins)	contaminated shellfishes	Poisoning (Karnataka)	gastrointestinal symptoms
<i>Nitzschia</i> spp.	Domoic acid	Consumption of contaminated shellfishes	Amnesic Shellfish Poisoning	Causes gastrointestinal and neurological disorders
<i>Prorocentrum</i> sp., <i>Ostreopsis</i> spp., <i>Amphidinium</i> sp., <i>Thecadinium</i> sp.	Ciguatoxins/ Mitotoxin	Consumption of contaminated small algae-eating fish	Ciguatera fish poisoning	Characterized by cardiovascular and neurological symptoms
<i>Kerenia brevis</i>	Brevetoxins	Consumption of contaminated shellfish and seagrasses	Neurotoxic shellfish poisoning (Bay of Bengal)	Affects aquatic animals and humans. Also, leads to massive fish kills.

Source: Vaisakh 2024^[17].

3. The algae such as *Gymnodinium mikimoto*, *Chrysochromulina* spp., *Chaetocero* ssp., and *Prymnesium* spp. harmless to humans, but harmful to fish and invertebrates by causing gill blockage. The incidence of the blooms is detrimental to sheltered bays and aquaculture systems. They affect the feeding responses and respiratory mechanisms in animals

Causative factors responsible for algal blooms

1. Currents, Upwelling and long-term climate changes

Coastal upwelling, currents and climate change patterns influence the algal blooms in Indian coasts (Peter *et al.*, 2024)^[9]. The changing climate leads to changes in composition of the water column and increased stratification which favours the occurrence of red tides. The shifts in precipitation patterns, rise the nutrient loading, accelerate the algal blooms causing eutrophication. Post-monsoon and pre-monsoon are favourable for bloom formation when the required sea water temperature is available (Zingone and Enevoldsen, 2000)^[20]. HAB's have been observed to intensify as water temperatures reaches the level of maximal algal growth. The blooms of *skeletonema* (preferring low salinity) and the raphidophyte *Chattonella marina* (preferring low temperature) were found in summer at Kerala, because summer was the favourable season for blooms (Vaisakh, 2024)^[17]. The monsoonal break helps phytoplankton species like *Cochlodinium* sp. and *Gymnodinium* sp. to bloom. With the beginning of the northeast monsoon, the sea water of lower salinity from Bay of Bengal enters into the coastal regions of southwest India promoting the growth of specific bloom-forming species (Vaisakh, 2024)^[17].

2. Coastal pollution

Release of domestic and industrial effluents, to the sea is major contributor to toxic algal blooms resulting in Eutrophication. The excessive accumulation of nitrogen and phosphorous occurs in the sea. Fluctuating N-P ratio and water temperature helps in the growth of cyanobacteria and several dinoflagellates.

3. Dust storms and heavy metals

Certain types of *Trichodesmium* sp and other cyanobacteria, use iron as source from dust particles and convert them into atmospheric nitrogen as usable form in marine environments. Hence, this helps in the proliferation of toxic algae and the formation of red tide. The deposition of dust induces changes in water temperature, leading to

stratification of water column triggers the growth of harmful algae, enabling them to compete with less harmful species. The *Lyngbya* species are observed to bloom when the iron and phosphorus concentration is higher, enhancing their photosynthetic activity (Igwaran *et al.*, 2024)^[5]. Moreover, untreated effluents from aquaculture are rich in heavy metals like cadmium (Cd) and lead (Pb) gets deposited in water bodies causing algal blooms.

4. Introduction of new algal species into inshore areas through ship ballast water exchange or aquaculture: The algal species responsible for causing HAB's invade from other countries through different ways. The ballast water from the ships sink into the ocean leading to the growth of harmful algae (Vaisakh, 2024)^[17].

Impact of algal blooms:

- Harmful algal blooms (HABs) cause ecological, socioeconomic, public health and sustainability issues. The rapid growth of harmful algae can give rise to hypoxic conditions in the water, decreasing the population of fish and other aquatic organisms, thus disrupting the ecological balance of aquatic ecosystems. This disruption can bring about negative effects on the entire food web, impacting ecosystem health.
- Fisheries and Aquaculture: Red tides can impact the economy of the country and coastal fishing industry by the massive fish kills (Anantharaman *et al.*, 2010)^[1]. Fishing gets hampered due to the algal blooms affecting the livelihoods of people dependent on fisheries and aquaculture. HAB's pose threats to aquaculture with the incidence of bloom related fish deaths by the damage of gills (Lenzen *et al.*, 2021)^[6].
- Public Health Concerns: HABs need to be monitored to ensure the safety of seafood and in protecting public health. To date, there have been four cases of Paralytic Shellfish Poisoning (PSP) that have been identified from Tamil Nadu by the consumption of shellfishes collected from polluted waters affected with red tides (Table 2). Few cases of Ciguatera Fish Poisoning and *Gamberdiscus* sp. infection are reported from Mangalore and Kerala which envisaged hospitalisation of people and children (D'Silva *et al.*, 2012)^[2]. Furthermore, several incidents of algal blooms have been reported from, off Goa, Gujarat, and Kochi causing health effects (D'Silva *et al.*, 2012; Oyeku *et al.*, 2021)^[2, 7].

Table 2: Incidents of red tides in India and their consequences on human health.

State	Year	Incident	Plankton sp	Remarks
Tamil Nadu (Valayar village)	1981	PSP like – death of 3- people, 35 hospitalisations	Not identified	Consumption of <i>Meretrix casta</i>
Kerala (Vizinjam)	1997	PSP like – 7 death and 500 hospitalisations	Not identified	Consumption of <i>Perna indica</i>
Kerala (Malabar coast)	2005	Unpleasant odour from sea – 200 children hospitalised	<i>Heladosphaera</i> sp., <i>Karenia brevis</i>	Neurotoxin
Karnataka (Mangalore)	2015	Gamberdiscus sp. (suspected)	<i>Gamberdiscus</i> sp. (suspected)	Consumption of snapper
Kerala (Triavndrum)	2016	Ciguatera fish poisoning – 6 hospitalisations	<i>Gamberdiscus</i> sp. (suspected)	Consumption of snapper

*Source: Rastogi *et al.* 2013.

4. Tourism Impact: Coastal tourism is an essential part of India's economy. Red tides lead to the water discoloration, foul odours, and the harmful toxins, alter the coastal areas. This can decrease the coastal tourism and have economically negative consequences for communities dependent on tourism (Igwaran *et al.*, 2024)^[5].

Prevention and management of HAB's

Algal blooms prevention and management strategies for are required to tackle their adverse effects. The measures need to focus on minimizing algal growth by limiting the discharge of nutrients into the seas and water bodies (Summers and Ryder, 2023)^[15]. This can be achieved by sewage treatment and the control of industrial discharges, agricultural runoff entering the sea. Thus the amount of nitrogen and phosphorus, the primary nutrients responsible for algal growth, can be prevented from entering the water.

Biological methods can be employed by introducing natural competitors or grazers of algae which can help maintain a balance in the ecosystem. Integrated approaches to prevent red tides could yield better results. Algal blooms can be prevented by creating public awareness and education. Avoiding excessive use of fertilizers and proper waste disposal, would be the long-term prevention efforts (Tian *et al.*, 2022; Summers and Ryder, 2023)^[15, 16].

Use of novel technologies, viz. autonomous underwater vehicles and drones, help in real-time monitoring and data collection, aiding in more precise management interventions (Peter *et al.* 2024)^[9]. Moreover, collaboration between researchers, policymakers, and stakeholders is necessary. Sustainable agricultural practices and use eco-friendly algaecides, use of beneficial microorganisms can be employed for algal bloom control (Sanseverino *et al.*, 2016, Weir *et al.*, 2020)^[11]. By employing advanced remote sensing techniques, such as satellite imagery and hyperspectral analysis, scientists can accurately identify and monitor algal bloom regions. This enables early warning systems prompting response measures to be implemented (Xue *et al.*, 2023)^[19].

Conclusion

The harmful algal blooms have deleterious effect on aquatic organisms and to humans. The red tides occurred in the last decade caused diseases in humans leading several episodes of hospitalisations. These algal bloom incidents in Indian coasts stress on the need for monitoring, mitigation, and management strategies to minimize the red tides and related ecological and socio-economic impacts. Minimising the

nutrient input to seas, faster detection of red tides is required to lessen the potential harm associated with Harmful Algal Blooms. Use of advanced technologies like autonomous underwater vehicles, drones and Remote sensing, collaborative research and outreach, would be useful to mitigate the harmful impacts of algal blooms and to safeguard marine ecosystems.

Acknowledgements: Author is thankful to SJU, Bangalore for the support.

Conflicts of interests: Author does not have any competing interests.

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