Electronic Journal of Biology, 2005, Vol. 1(2): 27-30

The Ecological Engineering of HAB: Prevention, Control and Mitigation of Harmful Algal Blooms

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Abstract

The public and government faced with the negative impacts of harmful algal blooms, nowadays we minimize those impacts through routine monitoring programs, harvesting closures, or other related activities, yet relatively little effort is devoted to direct research on control or mitigation strategies. This article will summarize various methods to prevent, control, or mitigate HAB and their impacts, furthermore, summarize the current international methods to prevent red-tide - physical, chemical and biological methods, Some of these are reasonably well advanced and are in use in the coastal waters of some countries. Other methods, such as the use of algicidal bacteria, show promise for bloom control, but are further from implementation. This article will also highlight less controversial approaches to HAB prevention, control, and mitigation (PCM), such as large-scale nutrient reductions, bloom prediction, collection and disposal of contaminated shellfish, early-warning system to protect public health, and even the creation of effective communication networks.

Keywords: HAB, Prevention, Mitigation

1. Why prevent, control and mitigate HAB

With the high development of the industry and economy, the HAB (Harmful Algal Bloom) problems gradually become cosmopolitan marine disaster, which endangers the health of the people and the fishery ecosystem. The apparent global increase in the occurrence of HAB has been accompanied with the enlargement of HAB area and more harmful to ecological environment and human body [1-4].

The coast of China, especially East China Sea, also faces the eutrophication and harm of HAB, which endangers the coastal aquaculture, fishery resources, the quality of shellfish product, ecological environment and public health. There are more than 80 HAB incidents occurred in East China Sea in 2003 with a tendency of the increased occurrence of HAB incidents especially toxic algal bloom. 2004 monitored a large scale HAB (caused by *prorocentrum dentatum* and *Alexandrium spp*) which covered more than 8000 kilo-meter square in the coast of Zhejiang province. There were several other toxic algal blooms in East China Sea and Bohai Sea on the following months. Several poisoning incidents by consuming shellfish occurred in Fujian province in June soon after harmful algal bloom. Although there are no authentic proofs to reflect the direct correlation between the HAB and the shellfish poisoning incidents, undoubtedly, the public and government faced with the negative impacts of HAB. HAB occurrence frequently places molluscs at greater risk of HAB toxin contamination, which affect seafood trade badly. It has been an instant problem that how to manage and abate or even prevent HAB efficiently, it is also worthy to find ways for preventing, controlling, and mitigating the HAB not only benefiting for soothing detrimental influence but also for the sustainable development of marine economy and social progress.

HAB science has made impressive progress in China, The national basic research programme "China Ecology and Oceanology of Harmful Algal Bloom (CEOHAB)" has been undertaken since 2002, which mainly focuses on 10 items as below:

1.) biological diversity and character of population distribution of HAB species in the main HAB area of China;
2.) life history features and interspecific interactions of key HAB species in particular HAB area of China;
3.) resource, cycling of key nutrients and their influences on red-tide occurrence in East China Sea;
4.) physio-ecological responses of key harmful algal species to nutrients;
5.) key physical processes of HAB;
6.) the numerical simulation in the process of biology, chemistry, physics in typical alga bloom area;
7.) comparative study on three area with frequent HAB;
8.) bio-optical studies and remote sensing algorithms in HAB area of China Seas;

9.) the harmful effect and its mechanism study of HAB in China;
10.) control mechanism and method study for HAB in typical Areas of China.

Some periodical progresses have been made in all these fields that are all important in the Chinese HAB problems.

2. How can we prevent HAB

2.1Establish early-warning system to protect public health

Customarily the need for marine protein cannot be substituted, as the seafood takes up large proportion of daily food for coastal inhabitants. There are a variety of toxins that come from various algal species. Recently Paralytic Shellfish Poisoning (PSP) and Diarrhetic Shellfish Poisoning (DSP) are found in shellfish during shellfish harvest season (summer and autumn) in China.

Increased national and international transport of seafood and international travel by seafood consumers means that virtually nobody is completely free of risk from biotoxins which are originated from marine toxic algae. There is a general lack of understanding in the medical profession about the symptoms of algal poisoning, even in areas where toxic blooms are common. So early warnings of known and unknown toxins are required to protect consumers and industry.

To conduct shore-line sanitary surveys and monitor biotoxin in growing areas and markets is a good way for early warming. Long term monitoring of vast areas of coastline for HAB and marine biotoxins in seafood will continue to be the responsibility of coastal province. There needs more concerted effort to work with national monitoring programs to develop and evaluate practical early warning tools to provide better public health protection. The incidence of mortality and serious illnesses still exist in China due to the incomplete procedures used to protect public health from exposure to algal toxins. Nevertheless, the medical system should be better informed and prepared to treat individuals suffering HAB toxicity.

2.2 Better management on growing area and market

Some epidemic disease such as China's SARS and some food-born hazards (such as milk powder events in China) make us realize the essentiality to improve human health through safer food. People usually get PSP through eating raw or cooked shellfish, such as mussels, clams, oysters, scallops. Biotoxin can be prevented by large-scale proactive monitoring programs and rapid closures to harvest of suspect or actual areas that contain the toxin. To minimize the risk require commercially harvested shellfish to detected or to be delivered to a certain registered shellfish processing plant prior to distribution. Affirmed biotoxin contaminated seafood should be destroyed and the originated Shellfish Harvesting Areas (SHA) should be closed when the analysis result for a shellfish sample exceeds an action level.

2.3 Establish useful and cost-effective methods for rapid assays of toxin in shellfish

The only way to tell if fish or shellfish contains biotoxin is through laboratory testing. Mouse assay (1980 MAF-FDA MOU) is common to detect biotoxin of shellfish in China. At present monitoring of coastal waters and seafood products for known algal toxins is expensive and inefficient, so useful and cost-effective methods for rapid field assays of fish or shellfish are needed, another urgent issue is to prepare toxin standards and to develop bio-monitoring method for marine toxin intoxication.

2.4 Diminish biotoxin and medical treatment

Medical treatment in biotoxin poisoning incidents should be improved. Vitamins, antihistamines, anticholinesterases, steroids and tricyclic antidepressants have been tried with limited results. There are very few effective ways to remove the biotoxins in shellfish, some popular ways include self decontamination, temperature irritation, ozone disposing and cooking etc. Shellfish can be detoxified after a minimum of 14 days to permit natural cleansing, but effective method should be further developed to diminish toxin on shellfish. Due to no effective method to detoxify shellfish up to now, seafood should be destroyed when the analysis result for a shellfish exceeds an action level.

3. The mitigation strategy for HAB

Some possible mitigation strategy (e.g. reduce nutrient input, better waste water treatment) can be considered to reduce the HAB occurrence. HAB mitigation efforts should be proposed in view of their economic value.

3.1 Control the eutrophication of coastal ocean areas

Although there is still no definitive proof, most scientists consider that increases in HAB are somehow linked to eutrophication of coastal ocean areas. CEOHAB also deal with study on the nutrients management in HAB prevention, the results indicate the nutrients input affect HAB occurrence and toxic level caused by harmful algae. For HAB, reducing nitrogen release is especially important; however, this is also one of the most difficult pollutants to control as it comes from a wide range of widely used agriculture chemicals such as fertilizers and fossil fuels. Developing miscellaneous breed especially kelp with shellfish in aquaculture area is considered a good way to reduce nutrient absorption. Another solution is to protect and utilize natural wetland sufficiently and even to construct wetlands to absorb nutrient.

3.2 Control the invasion of alien harmful algae

The introduction of harmful algal species into new environments by ships ballast water has been identified as one threat to the world oceans. The algal seed brought by ballast water can proliferate and even form algal bloom in favourable condition. Chinese government has initial a program to survey and study algae and pathogens carried in ships ballast water, and baseline around some ports. This is far from enough to prevent and diminish the HAB caused by algae brought by ballast water from other sea area, establishing rule of law to forbid let out of the ballast water at the prescribed sea area and developing regular monitoring of alien algae in ballast water should be schedule for controlling the introduce of alien harmful algae by ballast water.

3.3 Forecast and prediction of HAB

Forecast and prediction of HAB is one of the most important areas for future research. Early warning can provide managers and aquaculturists with the means to make informed decisions regarding public health and potentially save considerable effort and money. Early warning could help adjusting season openings and taking actions with sufficient time.

There are several methods could be used as a tool to predict the occurrence of HAB. Some are based on chemical character (i.e., water temperature, pH, and specific conductance), others are based on oceanographic events and meteorological times series, biomass of algae, numerical simulation, and satellite imagery interpretation etc. The Chinese key programme “Forecast Technology for Harmful Algal Bloom” try to establish forecast model based on almost all above methods; periodical result show that the last one may be an promising way to predict HAB.

3.4 communication and education

A network of centralized locations for communication should be established, maintained and broadly communicated throughout country. It is a national strategy for surveillance of seafood poisoning, and for efficient gathering and exchange of information in and between provinces. The rapid response effort was critical to maintaining ties to the managing agency and the public on the potential threats to public health and possible economic impacts were avoided. Education and public outreach could also be effective mitigation strategy.

4 How to control the HAB

As the principle to develop a controlling technique, it should effectively control HAB, cost benefit, use conveniently and put no harm on other organism and ecosystem. Although the controlling technique is just developed recently, there are some progresses in application. People often control HAB using chemicals, fine clay particles or biological agents but not as common as herbicide in land based agriculture [5-9]. Although the potential dangers of chemical or biological agents are known, they are still used as fast and sensitive algaecides in emergency treatment for the sake of no ideal technique up till now.

One kind of techniques is based on physical principle, such as isolation by transferring protected target or set barrier, destroy by ultrasonic or electromagnetic wave, reclaim by pump on board etc. Another kind of techniques is based on chemical principle, such as killing harmful algae directly by inorganic medic (bluestone, potassium permanganate, javel, chlorine, ozone etc) or organic detergent (organic amic), depositing algae by flocculant (inorganic flocculant, macromolecule flocculant and microbe flocculant), or precipitating algae by natural mineral. Dispersal of fine clay particles over a bloom has seen some success, as the clay aggregates with itself and with other particles in the water (including HAB cells) and pulls the harmful algae to bottom sediments. Other kind of techniques is based on biological principle, such as controlled by algicidal bacteria, predator or limited by nutrition competition. CEOHAB programme have made progress on biological and coagulation mechanism and method for HAB control. Anti-algal bacteria and two species of macro-algae (Gracilaria lemaneiformis and Ulva pertusa) found be effective, modified clay by organic hexadecyltrimethyleamine bromide (HDTMA) can coagulate HAB cells which proved by field work on Bohai Sea in 2003. At present all these different treatment methods are not economic or harmless and may not be feasible over large areas, but might be useful in emergency situations in specialized situations. The research is still continue even though the costs may be high, as there are likely control methods that not even been thought of yet that may be inexpensive and environmentally benign. This field is relatively young and still needs years of funding to reach the optimal goal of a possible mitigation tool.

5 Conclusion

At present several potential HAB control strategies have been developed. Among them, only control by modified clay is developed to the point of open water application. Critical evaluation of different approaches, including considerations of possible "collateral damage" and extensive adverse economic impacts of certain HAB, need to continue research. It seems mitigation and prevention are more important than control of the HAB. Scientists need to be encouraged to investigate HAB control and mitigation strategies. Sometimes it is easier to pursue basic or fundamental science, rather than taking on the challenging and highly visible practical research that tries to control blooms. There are surely technologies that we have not even considered yet that will be effective if scientists and engineers are given the resources and encouragement to pursue control and mitigation research. In this sense, there is much to learn from those who practice pest control in agriculture, which has a long history of successful chemical and biological mitigation.

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ISSN 1860-3122