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厦门大学

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有 害 藻 华 的 防 治

Prevention of Harmful Algal Bloom

Musabyemariya Jeannette

指导教师姓名：黄凌风 教授

专 业 名 称：海 洋 事 务

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答辩委员会主席：洪华生 教授

评　　阅　　人：彭本荣 副教授，陈斌 博士

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Dedication

This work is dedicated to my beloved family and to all those who encouraged and supported me in my study

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摘 要

近年来在沿海以及河口等地区有害赤潮频频暴发。由于赤潮暴发会导致水体藻类大量增殖和有害毒素的产生，这严重破坏了水生生态系统，并且影响了地区经济，周边居民的健康以及休闲娱乐活动。因此，控制和预防沿海赤潮暴发迫在眉睫。

本研究重点论述在河口区域如何有效预防 HABs（单细胞微生物的迅速增长导致危害）以及所带来的负面效应。建立有效的预防措施，我们首先必须充分理解引起 HABs 的各种原因。针对沿海河口特殊的地理环境，污染物来源比较复杂，工业废水、城市生活污水、农业养殖业废水和大气沉降水等都成为 HABs 的主要根源。本文根据这些原因阐述相应的有效预防措施。

首先政府应该根据清洁水法案的规定和标准来严格控制工业污染物的排放，在工业废水排放之前必须经过污水处理厂的预处理，以便降低污染物的排放量。

农业养殖业污染已经成为最大的污水来源，包括农田牧场的废水以及动物和鱼类的废弃物。为了降低农业污染引起的负面影响，在排放污染之前，我们可以运用最佳管理措施（BMPs）方案，同时利用动物的废弃物制造电力，控制动物和鱼类的饲料投放量，建立滨海缓冲带。

防止城市污染的排放，首先需要改变我们的生活方式以及与周围环境的处理方法，包括保持城市清洁，规划城市建设，降低雨水排入的速度，利用再生池、湿地公园和植草沟中的植物移除污染物等。

控制大气污染沉降的方法有：减少工业废气排放，出行尽可能利用电动车、自行车、公交车和步行的方式，用紧凑型荧光节能灯代替白炽灯，回收利用报纸和铝等材料，种植绿色植物，执行更严格的清洁空气法律和国际条约。

前置库，即暂时储存雨水的处理池，它的应用也是防止污染物排放的有效措施之一。如果水质符合标准即可排放，否则必须经过处理。

传统的方法比如机械的、电力的和化学的方法，在一定程度上可以作为移除部分有害藻类的应急措施。虽然在过去这些方法使用比较普遍，但是不能从根本上解决和控制赤潮暴发。

目前植物修复技术作为一种最重要的可持续发展策略，是利用天然植物吸收

和移除水体污染物的技术。本研究主要论述植物通过浮床系统而达到修复水体的效果。

本文筛选了 5 种挺水植物：水烛香蒲（*Typha angustifolia* L.）、鸢尾（*Iris tectorum*）、雍菜（*Ipomoea aquatic*）、芦苇（*Phragmites australis*）和大花美人蕉（*Canna generalis* Bailey）的植物修复作用，研究分别从对 N、P、BOD_5 、COD 和 6 种重金属（Cu、Hg、Cd、As、Cr、Zn）等方面阐述植物修复技术的可行性和可持续性。

研究表明所有这些植物都能吸收和移除各种污染物，但是修复能力略有不同，受到培养介质、植物特性和持续时间的影响。在 5 种植物中，鸢尾表现出最强的修复能力和环境胁迫耐受能力。总之，所有这些植物都可被优先选择作为植物修复的材料。

除了以上各种方法之外，为了保证能够有效控制 HABs，政府必须制定相关的海洋政策。1982 和 1992 年分别制定的海洋公约和生物多样性公约都应该用于保护海洋生态系统以及预防控制 HABs。同时，政府部门应该加强公众教育，宣传普及引起海洋污染的环境因素和有害生物，提高公众对预防 HABs 的意识。

关键词：有害藻华；防治策略；河口区；污染；植物修复；政策

Abstract

In the last few decades an excessive increase of harmful algal blooms (HABs) the rapid increase of microscopic single-celled organisms that cause harmful effect occurred in coastal areas and in estuaries as well. Due to production of high biomass and toxins, the occurrence of HABs leads to deterioration of aquatic ecosystems and negative effects on economy, people health and recreation activities. To overcome these problems, prevention of harmful algal bloom in estuarine water is urgent.

The aim of this study is to show successful strategies to prevent HABs and their negative effects in estuarine water as a coastal place which receives many pollutants from different sources.

Successful prevention strategies are built on an understanding of the causative factors. In this study, pollutants from industries, urban places, agriculture/aquaculture and atmosphere are proved to be causative factors of estuarine HABs. Then, successful prevention should start with the prevention of pollutants from these sources.

The principal instrument that estuaries' countries should use to prevent industrial pollutants is the Clean Water Act established by lawmakers to help in reducing the amount of pollutants entering wastewater treatment plants and, consequently, reduce the amount of pollutants flowing from these plants into the estuary.

Agricultural/aquaculture runoff from cropland, pastureland, and animal and fish waste has been identified as the single largest source of water pollution. Here the application of best management practices (BMPs), the use of animal waste as fuel for the production of electricity, the control of animal and fish feeding and the use of riparian buffers, could substantially reduce the negative impact of agricultural/ aquaculture pollutants to estuarine water.

Urban pollutants can be prevented first of all by changing our way of living, and the way we interact with our surrounding which means keeping our places clean,

urban planning, and stormwater control in order to reduce its velocity and remove some pollutants using plants in recharge basins, wet parks and vegetated swales.

Atmospheric pollutant deposition can be prevented by controlling industrial emission, such as using electric vehicles, walking, cycling, using mass transportation when possible, replace incandescent light bulbs with compact fluorescent bulbs, recycle newspapers, aluminum, and other materials, plant trees and support much stricter clean air laws and enforcement of international treaties.

Pre-reservoirs are also useful for pollutant prevention because they are constructed in the entrance of the estuaries where storm water is temporarily stored. The water quality is checked after the storm. If the quality is acceptable, then the water is allowed to enter the estuaries through a pipeline, if it is not acceptable, then treatment is required.

In estuarine water, some techniques such as mechanical, electrical and chemical so called traditional techniques are useful in the case of emergency to remove or kill some harmful algae even though they are generally not selective and they cannot intrinsically resolve the problem.

The most important and sustainable strategy is phytoremediation because it uses natural plants to uptake and remove pollutants in water. In this study, we talked about floating bed as one kind of phytoremediation using floating rafts to support plants.

Five emergent plants have been chosen such as *Typha angustifolia, Iris tectorum, Ipomoea aquatic, Phragmites australis* and *Canna generalis* to show how the use of plants for water pollutants uptake is possible and sustainable. Nitrogen (N), phosphorous (P), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), Copper (Cu), Mercury (Hg), Cadium (Cd), Arsenic (As), Chromium (Cr) and Zinc (Zn) are the pollutants chosen to show that these plants can uptake them in water.

The study showed that all these plants are able to uptake and remove all these nutrients/pollutants in water at different rates because of medium factors, plant preference and duration. *Iris tectorum* has been proved to be the best of all pollutants

uptake, stressed environmental tolerance and environmental adaptation. In conclusion, all these plants are recommended because their uptake capacity is good.

In order to prevent HABs successfully, marine policies are also needed. Law of Sea (LOS Convention) established in 1982 and the 1992 Convention on Biological Diversity (CBD) are the most needed by countries with estuaries to protect their water against new introductions of HABs or pollutants. Education of population about HABs prevention is required in order to protect the population against HABs consequences on the one hand, and protect estuarine water from pollutants and introduction of new harmful species on the other hand.

Keywords: harmful algal blooms; prevention strategy; estuary; pollutions; phytoremediation; policy

Abbreviations

ARS: Agricultural Research Service

ASP: Amnesic Shellfish Poisoning

BATNEEC: Best Available Techniques Not Entailing Excessive Costs

BMPs: Best Management Practices

BOD: Biological Oxygen Demand

CBD: Convention on Biological Diversity

CFP: Ciguatera Fish Poisoning

C-HABs: Cyanobacterial Harmful Algal Blooms

COD: Chemical Oxygen Demand

COP: Conference of the Parties

DFT: Deep Flow Technique

DSP: Diarrhetic Shellfish Poisoning

DW: Dry weigh

ECOHAB: Ecology and Oceanography of Harmful Algal Blooms

EPA: Environment Protection Agency

FAO: Food and Agriculture Organization

GEOHAB: Global Ecology and Oceanography of Harmful Algal Blooms

HABs: Harmful Algal Blooms

IMO: International Maritime Organization

IPC: Integrated Pollution Control

IUCN: World Conservation Union

LOS: Law of Sea

MEBC: Ministry of Environment British Colombia

N: Nitrogen

NOAA: National Oceanic and Atmospheric Administration

NRCS: Natural Resources Conservation Service

NSP: Neurotoxic Shellfish Poisoning

P: Phosphorus

PPM: Part Per Million

PSP: Paralytic Shellfish Poisoning

TCE: Trichloroethylene

TN: Total Nitrogen

TP: Total Phosphorus

TTGSWMC: Ten Towns Great Swamp Watershed Management Committee

UNCLOS: United Nations Convention on the Law of the Sea.

US: United States

USDA: United States Department of Agriculture