# Harmful Algae Blooms In Drinking Water Removal Of Cyanobacterial Cells And Toxins Advances In Water And Wastewater Transport And Treatment

Scientific research indicates that in recent years, the frequency and geographic distribution of harmful algal blooms (HABs) have been increasing nationally and globally. Because the impacts of HABs can be severe and widespread-often with interstate implications-these issues have been a perennial interest for Congress. While algal communities are natural components of healthy aquatic ecosystems, under certain conditions algae may grow excessively, or "bloom," and produce toxins that can harm human health, animals, aquatic ecosystems, and the economy. In 2014, a cyanobacterial HAB in Lake Erie affected the drinking water for more than 500,000 people in Toledo, Ohio. In 2016, a massive HAB in Florida's Lake Okeechobee negatively impacted tourism and aquatic life. HABs have been recorded in every state and have become a concern nationwide. Many types of algae can cause HABs in freshwater systems. The most frequent and severe blooms involve the proliferation of cyanobacteria. Some cyanobacteria species can produce cyanotoxins that can cause mild to severe health effects in humans and kill aquatic life and other animals. HABs can also contribute to deteriorating water quality and ecosystem health. As masses of cyanobacteria or other algae die and decompose, they consume oxygen, sometimes forming "dead zones" where life cannot survive. These areas can kill fish, crabs and clams, and have detrimental economic effects. Scientists widely consider nutrient enrichment to be a key cause of HAB formation. While nutrients are essential to plants and natural parts of aquatic ecosystems, excessive amounts can overstimulate algal growth. Sources include point sources (e.g., municipal wastewater discharges) and nonpoint sources (e.g., fertilizer runoff from agricultural and urban areas). Congress, federal agencies, and states have taken steps to address HABs and nutrients that contribute to their occurrence. The Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 established an interagency task force, required the task force to prepare reports and plans addressing marine and freshwater HABs, and authorized funding for research, education, monitoring activities, etc. In December 2016, the Environmental Protection Agency (EPA) used its authority under the Clean Water Act (CWA) to propose water quality criteria for two algal toxins in waters used for recreational purposes. States use such criteria when developing water quality standards-measures that describe the desired condition or level of protection of a water body and what is needed for protection. Further, EPA has emphasized the need to reduce nutrient pollution from all sources to reduce public health and environmental impacts associated with HABs. The CWA does not authorize EPA to regulate all sources. It authorizes EPA to regulate point (direct) sources of nutrients but does not authorize EPA to regulate nonpoint (diffuse) sources of nutrient pollution. Some states have developed guidelines for algal toxins, primarily for use in guiding swimming advisories. Also, states have listed waters as impaired, or not meeting water quality standards, for algal blooms or algal toxins. Some of these states have begun to develop Total Maximum Daily Loads (TMDLs)-essentially pollution budgets-to address them. Most states have identified nutrient-related pollution as a priority to be addressed by

their TMDLs and/or alternative restoration plans. States rely heavily on financial assistance from EPA in implementing these plans and, more broadly, in addressing nonpoint source pollution that leads to degraded water quality and HAB formation. Congress has long provided financial assistance through EPA for regional, state, and local programs through CWA Sections 106 and 319 planning grants, geographic programs (such as the Chesapeake Bay and Great Lakes), and other sources. The President's FY2019 budget request for most of these programs is either eliminated or significantly reduced.

Water is an essential resource for all living organisms and cyanobacteria-dominated harmful algal blooms (cHABs) jeopardize access to this vital resource. This work aimed to construct a multi-tiered approach for both short-term and long-term management of cyanobacteria and cHABs in a drinking water reservoir, Lake Rockwell. This work investigated four different algaecide products for use in a drinking water source to address cyanobacteria growth. Bench scale experiments determined the optimal dose of each product given Lake Rockwell's indigenous population and reservoir-specific characteristics. The bench-scale experiments determined the optimal dose of Cutrine is a quarter dose, which corresponds to a 0.125 mg/L Cu concentration. The optimal dose for EarthTec was determined to be a half dose, which corresponds to 0.25 mg/L Cu concentration. The PAK27 optimal dose was determined to be a half dose, which corresponds to a 6.2 mg/L H2O2 concentration. Of the three copper based products (EarthTec, Cutrine Ultra, and SeClear), EarthTec and Cutrine Ultra facilitated a similar overall response in the cyanobacteria population. When treated with EarthTec or Cutrine Ultra the cyanobacteria population was predominately suppressed in the initial 2 days following treatment and was a function dose, followed by an increase in the cyanobacteria population between 7 and 14 days after treatment (i.e. rebound), which was a also a function of dose (e.g. lower dose, larger increase). SeClear induced a different response in the cyanobacteria population, which was suppressed in the initial 2 days after treatment. However, the cyanobacteria population treated with SeClear rebounded between 2 and 7 days after treatment, whereas cyanobacteria population treated with EarthTec and Cutrine Ultra rebounded between 7 and 14 days after treatment. The hydrogen peroxide based product, PAK27, exhibited distinctly different trend than the copper-based products. When treated with PAK27, the cyanobacteria population was suppressed within 2 days of treatment, and no rebound was observed. Based on the bench scale experiments, a field application of Cutrine Ultra at a quarter dose was performed. The in-situ application of a quarter dose of Cutrine Ultra was successful in suppressing cyanobacteria. However, the treatment affects were temporary and lasted approximately 14 days. This was expected largely due to hydrological conditions in Lake Rockwell.Experiments were designed to mimic a storm-driven, pulse-input of phosphorus to the littoral zone of Lake Rockwell. A variety of conditions were investigated ultimately to simulate a higher intensity precipitation event and a lower intensity event. These experiments highlighted a key interaction between the dissolved reactive phosphorus (DRP), which was provided by the phosphate dose, and the sediment. The interaction subsequently reduced the total reactive phosphorus (TRP) concentration within the initial 7 days, which ultimately reduced the bioavailability. The trend was observed across cyanobacteria composition #1 and #2, as well as the abiotic controls. The experiments also highlighted soil as viable source of

phosphorus and micronutrients. These experiments also suggest that there is an optimal concentration range of TRP that prompts excessive cyanobacteria growth, as increasing the phosphate dose (i.e. DRP) did not prompt the same type of growth. For example, reactors augmented with 2 mg/L PO4 and 50 g soil had a mean cyanobacteria population of 70,206 cells/mL after 28 days for reactors containing a mixed cyanobacteria population dominated by species from the diazotrophic genus of Anabaena (i.e. composition #2). Whereas, the mean cyanobacteria population increased in reactors augmented with 1 mg/L PO4 and 50 g soil to 392,206 cells/mL after 28 days for reactors containing a mixed cyanobacteria population dominated by species from the diazotrophic genus of Anabaena (i.e. composition #2).

With the ever-increasing incidence of harmful cyanobacterial algal blooms, this monograph has added urgency and will be essential reading for all sorts of researchers, from neuroscientists to cancer research specialists. The volume contains the proceedings of the 2005 International Symposium on Cyanobacterial Harmful Algal Blooms, and has been edited by H. Kenneth Hudnell, of the US Environmental Protection Agency. It contains much of the most recent research into the subject.

Benthic cyanobacteria that inhabit drinking water facilities can create toxic conditions and form harmful algae blooms (HABs). To maintain a healthy water supply at the Barberton Water Treatment Plant, three algaecides were tested to determine the optimal source and dose required to reduce benthic cyanobacteria populations without effecting chlorophyll-a. The full dose, half dose and a quarter dose of EarthTec, Cutrine Ultra and PAK 27 were tested in triplicate over 14 days to determine the optimal dose. The full dose of PAK 27 was determined to be the optimal dose and source showing a significantly low cyanobacteria rebound ($p = 0.0050$) coupled with a high rebound of chlorophyll-a ($p = 0.0056$). Given that PAK 27 is distributed in granule form, it sinks to the bottom of the reservoir where the benthic cyanobacteria accumulate. Small and large scale settling experiments determined PAK 27 would take an estimated 8 minutes to reach the maximum depth of Barberton reservoir at 22 ft. In the best effort to mimic the unique characteristics of the Barberton reservoir, future experiments should measure the level of light at depths where algae is found in the reservoir to ensure proper light replication in a mesocosm experiment. Considering that benthic algae may have different reproductive strategies at different times of the year, it is recommended that future algaecide experiments be run simultaneously to minimize temporal variance.

After decades of regulation and investment to reduce point source water pollution, OECD countries still face water quality challenges (e.g. eutrophication) from diffuse agricultural and urban sources of pollution, that is disperse pollution from surface runoff, soil filtration and atmospheric deposition. The relative lack of progress reflects the complexities of controlling multiple pollutants from multiple sources, their high spatial and temporal variability, associated transactions costs, and limited political acceptability of regulatory measures. This report outlines the water quality challenges facing OECD countries today, presents a range of policy instruments and innovative case studies of diffuse pollution control, and concludes with an integrated policy framework to tackle diffuse water pollution. An optimal approach will likely entail a mix of policy interventions reflecting the basic OECD principles of water quality management – pollution prevention, treatment at source, the polluter pays and beneficiary pays principles, equity, and policy coherence.

This proceedings book focuses on advanced technologies to monitor and model urban soils, vegetation and climate, including internet of things, remote sensing, express and non-destructive techniques. The Smart and Sustainable Cities (SSC) conference is a regular event, organized each second year in RUDN University (Russia) and providing a multidisciplinary platform for scientists and practitioners in urban environmental monitoring, modeling, planning and management.

For the first time in history, humans have exceeded the sustaining capacity of Earth's global ecosystems. Our expanding footprint has tremendous momentum, and the insidious explosion of human impact creates a shockwave that threatens ecosystems worldwide for decades-possibly centuries. Walter K. Dodds depicts in clear, nontechnical terms the root causes and global environmental effects of human behavior. He describes trends in population growth, resource use, and global environmental impacts of the past two centuries, such as greenhouse effects, ozone depletion, water pollution, and species extinctions and introductions. Dodds also addresses less familiar developments, such as the spread of antibiotic resistant genes in bacteria and the concentration of pesticides in the Arctic and other remote ecosystems. He identifies fundamental human activities that have irreversible effects on the environment and draws on recent social science and game theory results to explain why people use more than their share. Past behavior indicates that as resources grow scarce, humans will escalate their use of what remains instead of managing their consumption. Humanity's Footprint paints a lively but ultimately sobering picture of our environmental predicament. Dodds calls for a consilient approach to socioenvironmental restoration that draws on new thinking from across disciplines to develop sustainable solutions to global environmental problems.

An integrated approach to understanding and mitigating the problem of excess nitrogen Human activities generate large amounts of excess nitrogen, which has dramatically altered the nitrogen cycle. Reactive forms of nitrogen, especially nitrate and ammonia, are particularly detrimental. Given the magnitude of the problem, there is an urgent need for information on reactive nitrogen and its effective management. Nitrogen Overload: Environmental Degradation, Ramifications, and Economic Costs presents an integrated, multidisciplinary review of alterations to the nitrogen cycle over the past century and the wide-ranging consequences of nitrogen-based pollution, especially to aquatic ecosystems and human health.

This book describes essential principles of and approaches to monitoring and modeling algal blooms. Freshwater algal blooms have become a growing concern worldwide. They are caused by a high level of cyanobacteria, particularly Microcystis spp. and Cylindrospermopsis raciborskii, which can produce microcystin and cylindrospermopsin, respectively. Since long-term exposure to these cyanotoxins may affect public health, the reliable detection and quantification of these harmful algae species has become a priority in water quality management. The book utilizes an advanced monitoring approach to identify and quantify cyanobacteria species and various cyanotoxin-producing genotypes. Further, it uses a modeling approach to forecast the occurrence of the phytoplankton that causes algal blooms in freshwater reservoirs, providing a comprehensive picture of currently available micro- and macro-techniques for studying the problem of algal blooms. As such, it offers a valuable guide for researchers, graduate students and professional engineers engaged in monitoring

and modeling water quality in lakes and reservoirs. Dr. InChio Lou is an Assistant Professor at University of Macau, Macau, China. Dr. Boping Han is a professor at Jinan Universtiy, Guangzhou, China. Weiying Zhang is a researcher of Environmental Engineering in the area of freshwater phytoplankton at University of Macau, Macau, China.

The increasingly widespread production of toxins by marine and freshwater microalgae raises serious concerns regarding seafood and drinking water safety. This book compiles studies on the influence of climate change on the spreading of toxin-producing species in aquatic systems. The chemistry and biology of toxin production is revised and an outlook on control and prevention of the toxins' impact on human and animal health is given.

Harmful Algal Blooms: A Compendium Desk Reference provides basic information on harmful algal blooms (HAB) and references for individuals in need of technical information when faced with unexpected or unknown harmful algal events. Chapters in this volume will provide readers with information on causes of HAB, successful management and monitoring programs, control, prevention, and mitigation strategies, economic consequences of HAB, associated risks to human health, impacts of HAB on food webs and ecosystems, and detailed information on the most common HAB species. Harmful Algal Blooms: A Compendium Desk Reference will be an invaluable resource to managers, newcomers to the field, those who do not have easy or affordable access to scientific literature, and individuals who simply do not know where to begin searching for the information needed, especially when faced with novel and unexpected HAB events. Edited by three of the world's leading harmful algal bloom researchers and with contributions from leading experts, Harmful Algal Blooms: A Compendium Desk Reference will be a key source of information for this increasingly important topic.

This AWWA manual of practice provides water professionals with solutions to algae-related problems. Topics covered include identification of algal species, monitoring programs, and best management and treatment strategies.

Biomonitoring of water quality is very much essential for assessing the overall health of water bodies and safe supply of drinking water. The chemical nature of toxicant is highly dynamic in environment with time and space whereas biological system can integrate all environmental variables over a large period of time in terms of effect that can be easily measured and quantified. In view of the above, there is a pressing need to determine the water quality of natural resources as well as drinking water based on the standard protocols and guidelines from regulatory agencies. It is clear that the synthetic chemicals are essential for our society to maintain the health and well being of the people. However, there has been a range of detrimental effects on human health and natural environment. In general, we need to improve our management of waste chemicals discharged into the air, water and soil environments. New techniques are needed to predict adverse effects before they occur and for the treatment of wastes. In addition, a range of social, political and economic factors will be needed to be taken into

account in order to achieve success.

Harmful Algae Blooms in Drinking WaterRemoval of Cyanobacterial Cells and ToxinsCRC Press

Red tides in the sea and bright green lakes and rivers are becoming features of our degraded world environment. These events, caused by algae and the toxins they produce, are often associated with poisoning of people or livestock resulting in injury to health and economic loss. This volume provides definitive information on the identification of toxin marine and freshwater algae, the routine analysis and effects of algal toxins, their veterinary and public health impact, and on control measures in current use. Professionals in the food and water industry, and those working in public health and environmental ecology will find this book extremely useful.

Cyanobacteria are Gram-negative photosynthetic bacteria capable of producing toxins responsible for morbidity and mortality in humans and domestic animals. Many are capable of forming concentrated blooms that impact the environment by limiting the growth of sub-surface plants and phytoplankton. Harmful algal blooms (HABs) are also capable of producing multiple types of toxins, creating a potential hazard to recreational water users and animals drinking water from or near a bloom. Characterization of HABs is necessary to prevent these human and animal exposures and includes classifying of the type of cyanobacteria present and whether or not they are capable of toxin production, and the exact type of cyanotoxin that is actually present in bloom. Current methods used to classify cyanobacteria and cyanotoxins include microscopy, bioassays, ELISA, PCR, HPLC, and LC/MS. All of these methods, however, have limitations that include time, labor intensity, or cost. Fourier-Transform Infrared Spectroscopy (FTIR) is another potential tool for cyanobacterial classification that is not limited by these factors. To examine the practicality of this method, library screening with default software algorithms was performed on diagnostic samples received at the Kansas State University Veterinary Diagnostic Lab, followed by PCA of samples meeting minimum quality requirements to produce cluster analyses and dendrograms. Both spectrometers and software packages used were successful at distinguishing cyanobacteria from green algae in clean samples with 89.13% agreement. PCA resulted in clear classification of cyanobacteria or green algae demonstrated by a large order of magnitude difference produced by average Euclidian distance dendrograms. While this method is only capable of differentiating cyanobacteria from green algae or other aquatic environmental constituents, its simple, rapid use and low cost make it a beneficial screening tool when coupled with toxin-detection methods to characterize HABs.

Sea and Ocean Hazards, Risks and Disasters provides a scientific approach to those hazards and disasters related to the Earth's coasts and oceans. This is the first book to integrate scientific, social, and economic issues related to disasters such as hazard identification, risk analysis, and planning, relevant hazard process mechanics, discussions of preparedness, response, and recovery, and the economics of loss and remediation. Throughout the book cases studies are presented of historically relevant hazards and disasters as well as the many recent catastrophes. Contains contributions from experts in the field selected by a world-renowned editorial board Cutting-edge discussion of natural hazard topics that affect the lives and livelihoods of millions of humans worldwide Numerous full-color tables, GIS maps, diagrams, illustrations, and photographs of hazardous processes in action will be included

"Updating the most comprehensive and complete guide to water treatment planning and design, this edition maintains the book's broad scope and reach, while reaching the working professional with additional worked problems and new treatment approaches. It covers both

the principles and theory of water treatment as well as the practical considerations of plant design and distribution. The contents have been updated to cover changes to regulatory requirements, testing methodology, and design approaches, as well as the emergent topics of pharmacological agents in the water supply and treatment strategies"--

Harmful algal blooms (HABs) occurring in freshwater, and the associated toxins they produce, are dangerous to animals and humans. Mitigating the increasing presence of HABs presents a major challenge to water managers and drinking water utilities across the world. This book explores the current research on removal of HABs and toxins from drinking water. It provides the necessary tools so that treatment plant operators, engineers, and water managers can understand the vulnerability of drinking water treatment plants to HABs and develop treatment processes to minimize the impact of these contaminants. Although conventional treatment processes can be effective for the removal of HAB cells and some HAB toxins under optimal conditions, the potential exists for significant breakthrough of toxins during normal operation. As a result, there is a recognized need for more advanced techniques. Possible advanced processes for removing HAB toxins include granular activated carbon (GAC), powdered activated carbon (PAC), or oxidative processes. This book reviews both conventional and advanced treatment processes and presents clear and easy-to-understand procedures for the design of systems for optimal cell or toxin removal.

This book is a printed edition of the Special Issue "Urban Inequality" that was published in Urban Science

Environmental Law: 2017-2018 Case and Statutory Supplement

Clean and environmentally sound disposal of animal waste in the quantities that Concentrated Animal Feeding Operations (CAFOs) produce can only be described as a challenge. Designed to provide practical information, Environmental Management of Concentrated Animal Feeding Operations (CAFOs) covers the concepts and practices involved in the operation

This new edition provides an essential resource for students and practitioners of environmental law by including the text of the major laws and executive orders shaping the field as well as significant new Supreme Court decisions. New to the 2019-20 Edition: A complete updating of the text of the major federal environmental statutes, including amendments to the Emergency Planning and Community Right-to-Know Act, the Clean Water Act, the Oil Pollution Act, and the Safe Drinking Water Act. Executive Orders from President Trump affecting the implementation of the Clean Water Act, the management of forest and rangeland resources, and federal policy to protect the oceans. New decisions from the U.S. Supreme Court interpreting the Endangered Species Act, the Atomic Energy Act, and procedures for bringing regulatory takings claims.

Environmental protection, information of federal agencies' expenditures and coordination related to harmful algae : report to congressional committees.Harmful algal blooms are an environmental problem in all 50 states, according to EPA. While algae are essential to the ecosystem, providing food for all types of animals, these blooms can produce toxins that hurt the environment and local economies. Specifically, they can cause human illness or death from the consumption of seafood or water contaminated by toxic algae; harm aquatic and other animal species through neurological or liver damage or severe oxygen depletion; and hurt the seafood industry, recreation, and tourism. Harmful algal blooms occur naturally, but their prevalence, frequency, and severity are increasing-and this increase is influenced by climate, pollution, and human activities such as agriculture and wastewater, according to an

interagency working group report.The Drinking Water Protection Act included a provision for GAO to review federally funded activities related to harmful algal blooms. This report examines (1) how much federal agencies expended on these activities from fiscal years 2013 through 2015 and (2) how federal agencies coordinate their activities with each other and with nonfederal stakeholders. GAO collected information from federal agencies by using a questionnaire and interviewing agency officials.

Toxic cyanobacteria (blue green algae) have now been reported in 27 countries and are found on all continents including Antarctica. Drinking water authorities world-wide are faced with the challenge of treating contaminated water or the possibility of a toxic bloom occurring sometime in the future. This tailored collaboration project was to provide the international drinking water industry with information to facilitate the confident application of viable treatment techniques for cyanotoxins. Assessment included toxicity of the ozonated solutions, assessment of the protein phosphate inhibition assay technique and the possibility of seeding an activated carbon filter with select bacteria for removal of microcystin-LR. This report offers valuable guidance to the water supplier to aid in deciding upon the most appropriate treatment options for a range of dissolved blue-green algal toxins.