Developing a tool to help states address Cyanobacteria Harmful Algal Blooms (HABs) in freshwater and drinking water

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EXECUTIVE SUMMARY:

Cyanobacteria or blue-green algae could affect the quality of the water and be a direct risk to humans and animals. Some can produce toxins in the water that can result in nerve or liver damage in humans, pets and livestock that are exposed to them in large amounts, while other toxins have been related to promoting the growth of tumors and causing cancer. These are known as Cyanobacterial Harmful Algal Blooms (cyanoHABs). Health effects can occur when water containing high levels of toxins are swallowed (usually by pets or animals), through contact with the skin or when airborne droplets containing toxins are inhaled (while swimming, bathing or showering). Cyanobacterial blooms cause fouling of the beaches and shoreline, economic and aesthetic losses, taste and odor problems in drinking water, and direct risks to human, fish and animal health. Despite the research and developments in understanding the health impacts and treatment techniques, currently there are no federal regulations or guidelines for state and local health and environmental protection agencies to control inland freshwater cyanoHABs and protect human health. Because of the potential public health risks of cyanoHABs in recreational water and drinking water, the USEPA's (EPA) Office of Science and Technology is undertaking an effort to create resources to provide guidance on how to address cyanoHABs in freshwater and drinking water sources.

The first step in the development of this effort is to gather information on guidelines and regulations for cyanoHABs from the state and local health and environmental protection agencies participating in the CDC Harmful Algal Bloom-related Illness Surveillance System (HABISS). This information will be used to learn what the states and local environmental agencies are doing and determine what type of resources EPA could develop to help the states manage and reduce cyanoHABs in freshwater and source water used for drinking water. The second step will be to create an EPA agency wide cyanoHABs workgroup to better coordinate the efforts on providing assistance to states and to help in the development of outreach materials and resources regarding cyanoHABs for state and local health and environmental protection agencies and the public.

This information will be used to develop a cyanoHABs web page within the EPA Office of Water website. This tool will have information on cyanoHABs, will provide links to other monitoring programs such as CDC's HABISS and NOAA's HABs website and will list EPA's activities regarding cyanoHABs in freshwater.

BACKGROUND:

Cyanobacteria, also known as blue-green algae, have been on Earth a very long time, with their first occurrence dating back at least 2.7 billion years ago. They evolved under anoxic conditions and have the ability to tolerate and adapt well to environmental stress conditions including exposure to strong solar radiation, high temperatures and abundant nutrients. These stress conditions could be triggered by climate changes caused by regional and global warming providing this species with better environmental conditions for optimal growth.

Cyanobacteria are photosynthetic bacteria that share some properties with algae and are found naturally in lakes, streams, ponds, and other surface waters. Similar to other types of algae, when conditions are favorable, cyanobacteria can rapidly multiply in surface water and cause "blooms." Several types of cyanobacteria have gas-filled cavities that allow them to float to the surface or to different levels below the surface, depending on light conditions and nutrient levels. This causes the cyanobacteria to form dense, floating accumulations of cells on the water surface, causing the typical pea-soup green color or blue-green "scum." Some cyanobacteria are primarily associated with the bottom sediments, only floating to the surface waters when they are released by storm events. Other cyanobacteria blooms may remain dispersed through the water column leading to a generalized discoloration of the water.

Factors that affect cyanobacterial bloom formation and persistence include light intensity and total sunlight duration, nutrients (nitrogen and phosphorus), availability, water temperature, pH, rainfall pattern, water flow (whether water is calm or fast-flowing), and water column stability. Although blooms conditions in much of the U.S. are more favorable during the late summer, the interrelationship of these factors causes large seasonal and year-to-year fluctuations in the cyanobacteria levels. Some toxin-producing strains can occur early in the season where others are only found during late summer.

Some cyanobacteria can produce toxins in the water that can result in adverse environmental impacts and highly deleterious health effects in humans, pets and livestock that are exposed to them. These are known as cyanobacterial Harmful Algal Blooms (cyanoHABs). While the conditions that cause cyanobacteria to produce cyanotoxins are not well understood, it is known that some strains with the ability to produce toxins may not produce it under all conditions. These species are often members of the common bloom-forming genera. Both non-toxic and toxic varieties of most of the common toxin-producing cyanobacteria exist and it is impossible to tell if a strain is toxic or not toxic by looking at it. Molecular tests are available to determine if the cyanobacteria, Microcystis for example, carry the toxin gene. Also, water contaminated with low levels of cyanobacteria can have taste and color problems due to nontoxic compounds but toxic cyanobacteria can occur without associated taste and odor problems.

There is widespread agreement within the scientific community and resource managers that the incidence of cyanoHABs is increasing in the U.S. As an example, during the months of June and July 2010, cyanoHABs were seen in eight lakes in Ohio, including Lake Erie. Under the right combination of factors that affect bloom formation (e.g. high water temperature, low water depths, calm stable water conditions, and high nutrients levels) cyanoHABs can dominate the algal community of a freshwater lake and be present in high concentrations. As water

Figure 1 Algal bloom at Grand Lake St. Mary's, Ohio, 2010. Ohio EPA Photo

temperatures increase in the summer and with increasing risks of higher temperatures due to global climate change, the incidence of cyanoHABs is only expected to rise.

Cyanobacteria could affect the quality of the water and be a direct risk to humans and animals. Dense cyanoHABs can block sunlight and use up all the oxygen in the water, killing other plants and animals. These bloom biomasses adversely affect the aquatic life and water quality and can lead to massive fish kills caused by hypoxia and/or toxin secretions when the cells die and decay. Recreational activities such as swimming, wading or showering in affected bodies of water can increase risk of exposure to these toxins. Adverse health effects can occur when surface scum or water containing high levels of toxins are swallowed (usually by pest or animals), through contact with the skin or when airborne droplets containing toxins are inhaled (while swimming, bathing or showering). Cyanotoxins may cause illness within minutes to days after exposure. The cyanotoxins include neurotoxins (affect the nervous system), hepatotoxins (affect the liver), and dermatoxins (affect the skin). Symptoms can range from mild like skin rashes, headaches, to moderate (nausea, muscular pains, central abdominal pain, diarrhea and vomiting) to sever like seizures, liver failure, respiratory arrest – even death, although this is rare. There is evidence that long-term exposure to some cyanotoxins can promote the growth of tumors (microcystins) or cause cancer (cylindrospermopsins). The severity of the illness is related to the amount of water ingested, and the concentrations of the toxins.

There have been many documented reports of livestock deaths throughout the world as the result of consumption of surface water with cyanobacterial blooms. Infrequently, human deaths have also been documented such as the outbreak in a kidney dialysis center in Brazil in 1996 in which 50 patients exposed intravenously to water containing microcystins died. Clearly, cyanotoxins

can be a human health risk, but the actual risk to toxins at low levels in drinking water and the long-term effects to the exposure to the toxins in the U.S. are uncertain.

No federal regulatory guidelines for concentrations of cyanobacteria or their toxins in drinking water and recreational waters exist at this time in the United States. The Safe Drinking Water Act (SDWA) requires the EPA to publish a list of unregulated contaminants that are known or expected to occur in public water systems in the U.S. that may pose a risk in drinking water and for which the EPA conducts research to make decisions about whether regulations are needed. This list is known as the Contaminant Candidate List (CCL). Cyanotoxins have been included in the three CCL published so far. The most recent CCL focuses research and data collection on three cyanotoxins: microcystin-LR, anatoxin-a, and cylindrospermopsin. Microcystin-LR is one of at least 80 known microcystins and is generally considered one of the most toxic microcystins. More than a dozen countries (including Canada, Brazil, New Zealand, and Australia) have developed regulations or guidelines for microcystins in drinking water, while other countries have developed guidelines for recreational waters. Most of these guidelines are based on the World Health Organization (WHO) guideline value of 1.0 µg/L microcystin-LR for drinking water. Many states in the U.S. have included cyanotoxins in their freshwater beach-monitoring programs and have developed their own guidelines from available data using risk assessments methods and the guidelines provided by WHO. EPA have not made regulatory determinations or established any guidelines for cyanobacteria and their toxins in drinking water due to the absence of certified toxin standards to support analyses, lack of capacity to deal with multiple toxin congeners, and also the absence of robust analytical methods for compliance monitoring.

Figure 2 Microcystis Bloom at Ohio River, 2008. Ohio EPA Photo

The *Harmful Algal Bloom and Hypoxia Research and Control Act (HABHRCA)* originally enacted in 1998 mandated that the National Oceanic and Atmospheric Administration (NOAA) establish a National Coastal HAB Research Plan and control program for water bodies within their purview, the oceans, estuaries and the Great Lakes. NOAA has done an excellent job of establishing and administering three HABHRCA competitive research-grant programs; the Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) Research Program, the Monitoring and Event Response for Harmful Algal Blooms (MERHAB) Research Program, and the Prevention, Control, and Mitigation of Harmful Algal Blooms (PCM HAB) Research Program. HABHRCA was reauthorized in 2004, to include all water bodies. The bill, *Freshwater Harmful Algal Bloom Research and Control Act (FHAB Act)*, was proposed in 2010 and will mandate the EPA to establish a National Freshwater Harmful Algal Bloom Research Plan (FHABRP). The plan will help obtain the scientific information required by the EPA to make regulatory determinations and established federal policy for cyanoHABs in freshwaters. The proposed act funds would be administered through the three competitive, research grant programs established by NOAA - ECOHAB, MERHAB & PCM HAB. At this moment, the EPA has not received a mandate or funding.

Cyanobacterial blooms cause fouling of the beaches and shoreline, economic and aesthetic losses, taste and odor problems in drinking water, and direct risks to human, fish and animal health. Estimates performed previously estimated that the economic costs of cyanoHABs and eutrophication in the U.S. freshwaters are $2.2 billion to $4.6 billion annually. Although establishing guidance values for cyanoHABs in freshwater is challenging, state and local health and environmental protection agencies should take a proactive approach to manage and prevent the harmful effects of algal toxins in drinking water and recreational waters.

Problem Statement:

Despite the research and developments in understanding the health impacts and treatment techniques, currently there are no EPA programs or guidelines that provide assistance to state and local management agencies in adopting measures to prevent and mitigate freshwater and protect human health. Because of the public health risks of cyanoHABs in recreational water and drinking water, the EPA is undertaking an effort to create resources, search for opportunities and develop partnerships to provide guidance on how to adopt measures to prevent and mitigate cyanoHABs in freshwater and drinking water sources.

Behavior Over Time Graph

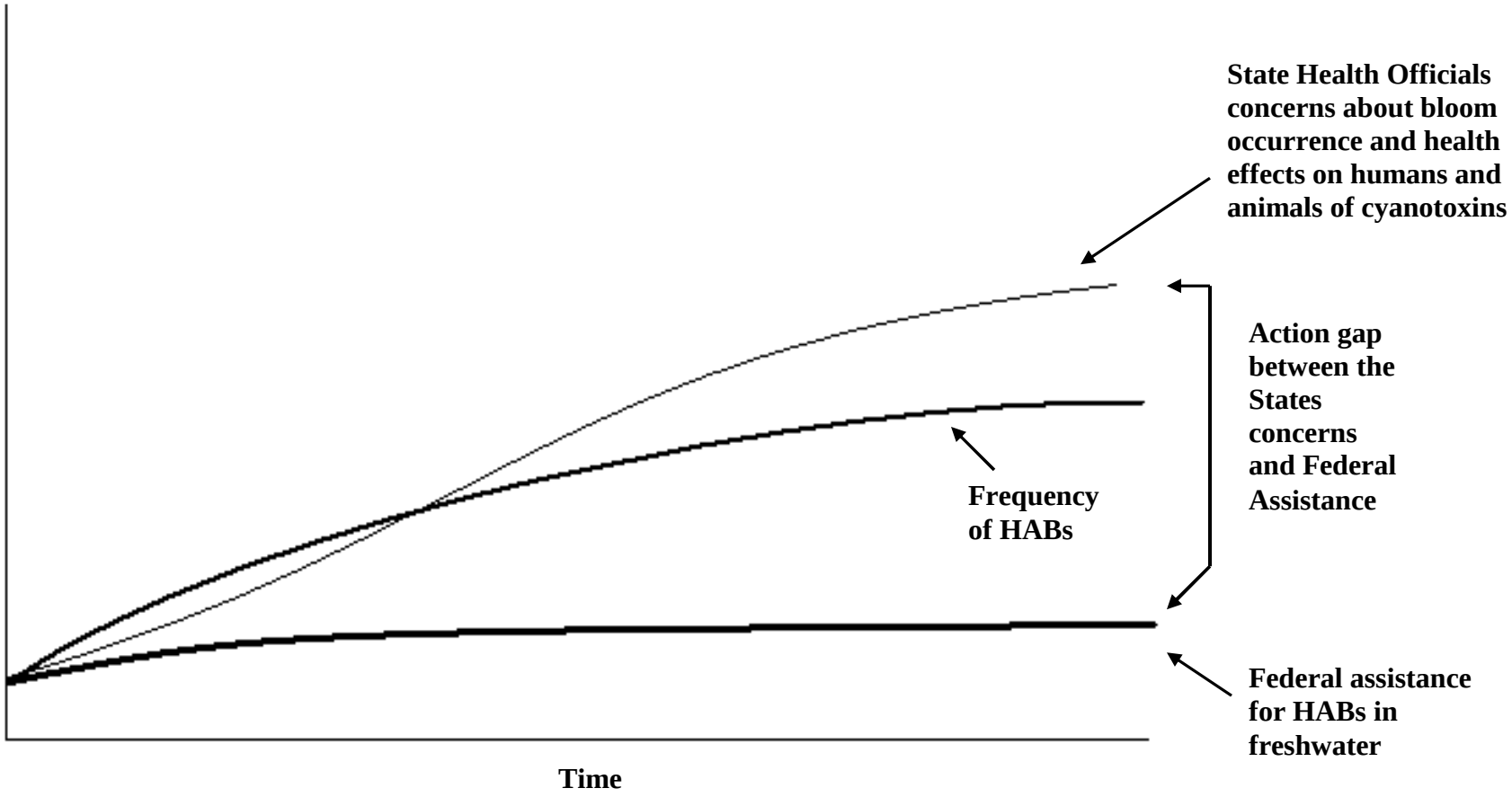


Figure 3 CyanoHABs Events, Concerns and Response Over Time

Concerns about the occurrence and health impacts of cyanotoxins have increased among state health officials, but not for the federal government to provide assistance and guidance. This graph over time represents the gap between the concerns of state health officials and the federal assistance.

Causal Loop Diagrams and Applicable Archetypes

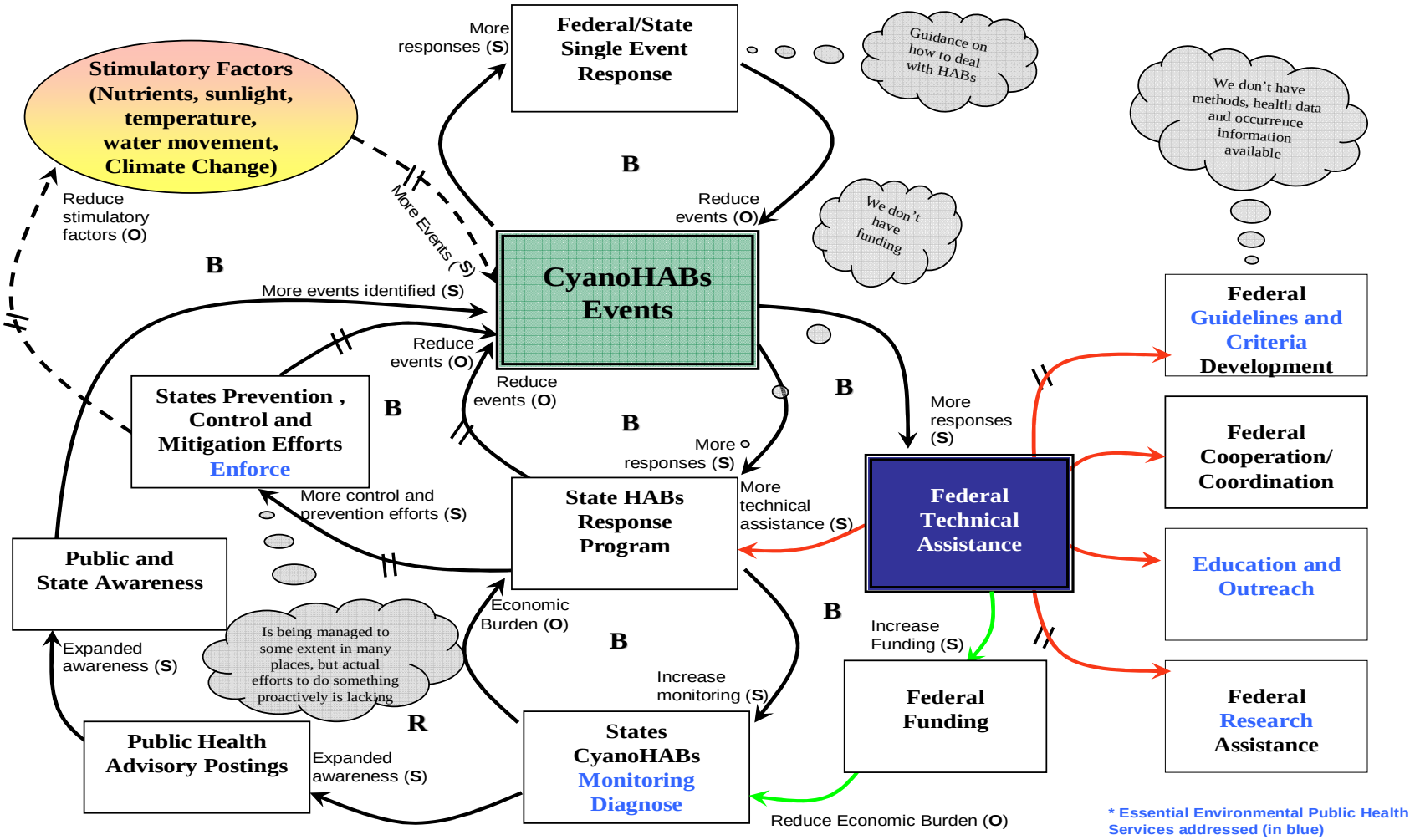


Figure 4 Causal Loop Diagram

10 Essential Environmental Health Services:

This project seeks to fulfill six of the ten Essential Environmental Health Services (Figure 3). These services are:

1. Essential Service #1: ***Monitor*** *environmental and health status to identify and solve community environmental health problems.* This project will provide tools that could help state and local health and environmental protection agencies monitor the environmental presence of cyanotoxins in freshwater sources.
2. Essential Service #2: ***Diagnose*** *and investigate health problems and health hazards in the community.* By supporting programs like CDC's HABISS and by providing tools to enhance states monitoring capabilities will be possible to better understand the effect of cyanoHABs on the health of the general public and the environment.
3. Essential Service # 3: ***Inform, educate****, and empower people about health issues.* Educational material posted in the cyanoHABs web page will help inform and educate state and local health and environmental protection agencies and the public on cyanoHABs issues.
4. Essential Service # 5: ***Develop Policies*** *and plans that support individual and community environmental health efforts.* Development of guidance documents such as health advisories regarding levels for cyanotoxins in finished drinking water and recreational waters will ensure the protection of human and animal health and the environment.
5. Essential Service # 6: ***Enforce*** *laws and regulations that protect health and ensure safety.* Guidance levels in recreational waters could help develop control and mitigation efforts to control some of the causal factors of cyanoHABs.
6. Essential Service #10: ***Research*** *for new insights and innovative solutions to environmental health problems and issues.* Conducting research will help in gaining knowledge regarding cyanotoxins health/ecological effects, new standards and methods of detection and treatment techniques.

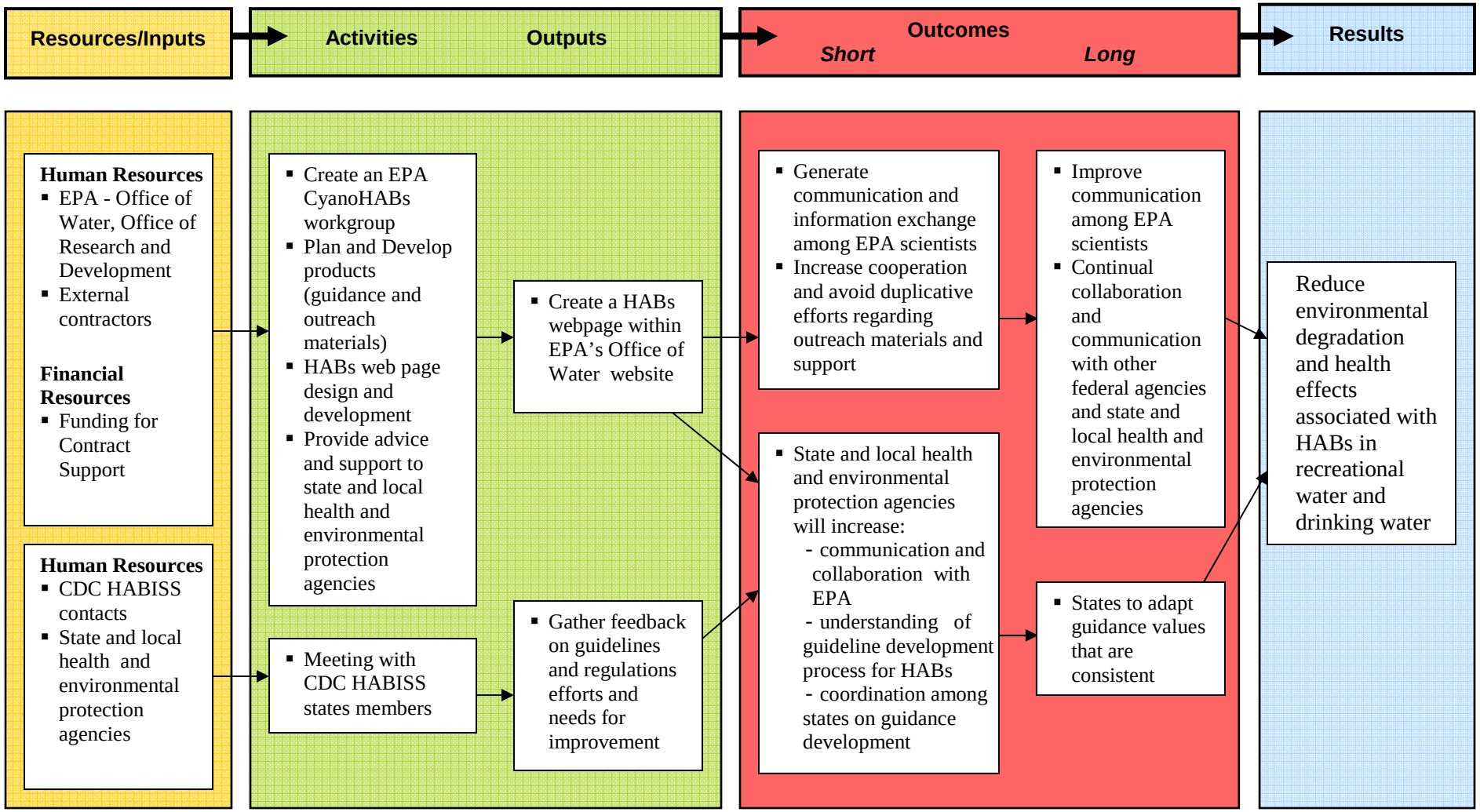
Figure 5. Ten Essentials of Public Health. National Center for Environmental Health, CDC

National Goals Supported

This project supports:

1. CDC Health Protection Goal for Healthy People in Healthy Places by improving the quality and safety of our freshwater sources and by protecting the health of all persons in contact with drinking water and recreational waters.
2. Healthy People 2010 Objective #8 to Promote health for all through a healthy environment by 1) increasing the proportion of assessed rivers, lakes, and estuaries that are safe for fishing and recreational purposes, and 2) increasing the proportion of days that beaches are open and safe for swimming.
3. CDC's National Strategy to Revitalize Environmental Public Health Services Goal 1 (Build Capacity) by assisting state and local health and environmental protection agencies to better prevent or respond to cyanoHABs events; Goal 2 (Support Research) by developing guidelines based on current research; and Goal 4 (Communicate and Market) by recommending and disseminating guidelines and resources to engage and empower state and local health and environmental protection agencies.

Project Logic Model:



PROJECT OBJECTIVES/DESCRIPTION/DELIVERABLES:

Program Goal: The EPA Office of Science and Technology (OST) is one of five water offices at the EPA with the mission of providing the latest water pollution science and best available control technologies to keep the nation's waters safe and clean. Together with other EPA Offices and the regions, OST provides the tools and the training that states need to develop and maintain strong scientifically-based water pollution control programs. This leadership project represents one of the ways that OST contribute to the collective efforts of all water offices, other federal agencies and states to achieve OST 's goal to address the ecological and human health adverse impacts of CyanoHABs in freshwater and drinking water.

Health Problem: Data from epidemiology and toxicology studies clearly links cyanobacterial toxins to adverse heath effects, particularly gastrointestinal illness, liver disease, neurological effects, and skin reactions. Exposure to CyanoHABs occurs by drinking water with cyanotoxins, which will be a high-level exposure, or when exposed to recreational water with cyanotoxins. In severe cases the exposed person could experience respiratory distress, flu-like symptoms, fatigue, muscle and joint pains, and severe neurologic symptoms. In addition, some cancers have been associated to specific cyanotoxins.

Outcome Objective: Reduction in the adverse health effects caused by exposure to cyanoHABs in recreational waters and drinking water.

Determinant: Health problems associated with exposure to cyanoHABS could be measured by tracking the data on human and animal health and on the environmental effects of harmful algal blooms collected in the CDC's Harmful Algal Bloom-related Illness Surveillance System (HABISS).

Impact Objective: The objective is to provide federal guidance regarding health effects, prevention and mitigation efforts and drinking water treatment of cyanoHABs in recreational water and drinking water.

Contributing Factors: Both natural forces and human activities promotes cyanoHABs through habitat alteration. The major contributors to the development of algal blooms are nutrients (nitrogen and phosphorus), increase sunlight, high temperatures, and lack of water movement. It is very likely that cyanobacteria will probably thrive under environmental conditions associated with global warming therefore increasing the health and ecological harms associated with acute and chronic exposure to cyanobacterial toxins in recreational and drinking water. With climate change there is the possibility of an increase in the frequency of large storms (i.e., hurricane, floods and droughts) and the intensities that could have an impact in the nutrient and hydrologic regimes. Also raises in water temperatures could alter hydrologic conditions and promote bloom formation.

Process Objectives:
Develop a cyanoHABs web page within the EPA's Office of Water website that could be used as a tool for states and local environmental agencies to find information regarding health effects, prevention and control measures, research and activities the EPA are conducting and links to other sites with information on algal toxins in freshwater.

METHODOLOGY:

EPA's Office of Science and Technology is seeking to create a tool comprising information on cyanoHABs in recreational and drinking water.

The first step in the development of this effort is to gather information on guidelines and regulations for cyanoHABs from the state and local health and environmental protection agencies participating in the CDC Harmful Algal Bloom-related Illness Surveillance System (HABISS). This information will be used to learn what the states and local environmental agencies are doing and determine what type of resources the EPA could develop to help the states manage and reduce cyanoHABs in freshwater and source water used for drinking water.

The second step will be to create an EPA agency wide cyanoHABs workgroup to better coordinate the efforts on providing assistance to states and to help in the development of outreach materials and resources regarding cyanoHABs for state and local health and environmental protection agencies and the public.

The third step will be to develop a cyanoHABs web page within the EPA's Office of Water website with information regarding health effects, prevention and control measures, research and activities conducted at the EPA, and links to other sites with information on algal toxins in freshwater.

Events and Activities

1. By January 27, 2011, meet with CDC HABISS states members to request feedback on existing monitoring and response plans, and perceived needs for improvement.
2. By March 2011, create an EPA workgroup to coordinate efforts for outreach material and web page development.
3. By November 2011, finish ongoing projects (toxicological reviews for the three cyanotoxins listed in CCL 3 and the cyanotoxins fact sheet for drinking water operators).
4. By December 2011, distribute a draft web page for internal review and comments
5. By December 2011, start the development of health advisories for the three algal toxins listed in CCL 3.
6. By February 2012, launch the CyanoHABs web page within the EPA Office of Water's nutrients portal.

Note: activity dates may change because of the dynamic nature of this project.

EXPECTED OUTCOMES:

Out of this project, the EPA will expect that state and local health and environmental protection agencies will become more aware of the different activities that the agency is conducting regarding cyanoHABs in freshwater and source water as well as describing what the agency capabilities and limitations are to address algal toxins related issues.

The EPA also expects to increase the consistency in the guidance values for cyanotoxins in recreational waters and drinking water that exists across state lines by providing the tools needed to develop guidance levels.

The EPA expects to use this resource to increase the knowledge of the public on the potential dangers of cyanotoxins in freshwater and also to increase communication and collaboration with state and local environmental protection agencies regarding this issue. This project represents one of the ways in which the Office of Water will contribute to the EPA's strategic goal of protecting the integrity of the nation's water and the safety of the drinking water.

LEADERSHIP DEVELOPMENT OPPORTUNITIES:

Lesley Vazquez-Corian, Dr.PH, MEH

It was a pleasure to be part of the EPHLI fellowship. Throughout the year, I was exposed to activities and projects that gave me wonderful opportunities to learn valuable lessons and to develop my analytical and leadership skills. The combination of a challenging leadership project, the exposure to highly prepared and skilled public health professionals and a supportive learning environment from the coaches and mentors are the foundation of this fellowship. The EPHLI staff was very responsive facilitating my learning process. I am thankful to my mentor John McLeod for his invaluable support and collaboration all through the fellowship. He and the coaches always challenged me to look and work on my project using the systems thinking process, allowing me to develop a set of skills that I will use throughout my public health career and to gain insight into my specific area of interest. This experience was priceless. I would strongly recommend the EPHLI fellowship to any public health professional seeking to gain and develop leadership capabilities.

ABOUT THE EPHLI FELLOW

Dr. Lesley Vazquez-Coriano is a microbiologist at the US Environmental Protection Agency (EPA), Health and Ecological Criteria Division (HECD), Office of Science and Technology (OST), Office of Water in Washington, DC. As a microbiologist with OST, Lesley provides technical expertise regarding microbial contamination on the nation's drinking water under the Safe Drinking Water Act (SDWA) to other offices in the agency, to personnel from other government agencies and to non-governmental groups. In addition, she is the EPA/WHO Microbial Subcommittee Member and participates in advisory and planning conferences and meeting as a source of expertise on projects with the WHO such as the development of the Guidelines for Drinking Water Quality and the Microbial Risk Assessment Guidelines Harmonization efforts. Lesley is also the Office of Water lead in coordinating with EPA Regions and other federal partners such as the Centers for Disease Control and Prevention (CDC) on the issues related to Cyanobacteria Harmful Algal Blooms (cyanoHABs).

Lesley received her BS in Industrial Microbiology, her MS in Environmental Health and her Dr.PH with a concentration in Environmental Health from the University of Puerto Rico. In addition to working with EPA, Lesley is an Adjunct Professor of Environmental Health at George Mason University.

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