



**Providing Guidance to Massachusetts Public Water Suppliers on Cyanobacteria
Contamination of Public Drinking Water**

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ABSTRACT

The effects of climate change are believed to be increasing the frequency and severity of cyanobacteria blooms, which produce toxins that are harmful to human health. The goal of our project was to inform public water suppliers on how to prevent cyanobacteria contamination of Massachusetts's groundwater-under-the-influence wells. To complete this goal, we surveyed state water officials and MA public water suppliers to gauge their informational needs. We then developed informational materials for MA public water suppliers and identified water bodies that may be at risk of contaminating groundwater wells. The Massachusetts Department of Environmental Protection sponsored this project and our group recommends that they continue to raise awareness about the dangers of cyanobacteria and the actions that can be taken to prevent water contamination.

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Finally, we would like to thank the representatives from the Association of State Drinking Water Administrators (ASDWA) who responded to our survey and public water suppliers who volunteered their time to speak with us.

EXECUTIVE SUMMARY

Access to clean drinking water is a problem faced worldwide. According to the World Health Organization (WHO), 1.1 billion people lack access to improved drinking water sources (WHO, 2014). Unfortunately, symptoms of global warming are only worsening this issue. One particular symptom is increased rainfall, which leads to more runoff in surface water bodies. When you combine this with increased pollutants from industrial processes, you get more contamination in drinking water.

The pollutants from runoff can contain high concentrations of nitrogen and phosphorus, which is a main contributor to the formation of harmful algal blooms called cyanobacteria. When cyanobacteria cells die, harmful toxins are released. There are two main types of toxins that cyanobacteria produce: neurotoxins and hepatotoxins. Neurotoxins cause damage to the nervous system, and hepatotoxins cause damage to the liver and kidneys (Paerl & Otten, 2013). A common sub-type of hepatotoxins is microcystin. In a recent outbreak in Toledo, Ohio, 500,000 residents were without water due to microcystins present in their drinking water. In addition, over 100 residents went to emergency rooms in the area complaining of dizziness and nausea (Zimmer, 2014). As shown by the Toledo incident, these toxins can have harmful effects on consumers if they end up in drinking water.

One way cyanotoxins can enter drinking water is when there is a surface water body near a well, also known as a groundwater-under-the-influence (GWUI) well. Cyanobacteria contaminated water can seep through the ground or travel through cracks in the soil and infiltrate a well. If one is not aware of activity occurring in the surface water influencing the well, cyanotoxins can end up in the drinking water.

There are few regulations in place for cyanobacteria in Massachusetts. Although the state has developed basic guidelines for cyanobacteria in recreational water bodies, the state has not developed similar guidance regarding drinking water. The Massachusetts Department of Environmental Protection (MassDEP) feels cyanobacteria could become a significant problem in Massachusetts if it is not addressed soon, so they are trying to raise awareness of the problem through this project.

The goal of this project was to help the Massachusetts Department of Environmental Protection further develop their Drinking Water Program to assist the

Commonwealth's water suppliers in addressing the potential threat of cyanobacteria in groundwater-under-the-influence wells. Through completion of this project, we will investigate other states' experiences with cyanobacteria contamination in GWUI wells, determine Massachusetts water suppliers' level of understanding of cyanobacteria and the best ways to address their informational needs, and develop informational materials for public drinking water suppliers and the MassDEP.

Methods

To accomplish the goal of our project, we completed the following objectives:

Objective 1: We identified corresponding surface water bodies for wells designated as under the influence of surface water in MA.

We obtained a list from the MassDEP of all the wells in Massachusetts that are classified as ground water under the influence (GWUI) wells. By using MassGIS, we located all the surface water bodies that are within 0.25 miles of each well on the list. After obtaining this information, we created a spreadsheet that contained the well ID number, all the nearby surface water bodies and their distances from the well, as well as the public water suppliers contact information.

Objective 2: We investigated other states' experiences with cyanobacteria in GWUI wells.

Our group, with the help from the MassDEP, designed a set of survey questions which we sent to the fifty public water administrators who make up the Association of State Drinking Water Administrators (ASDWA). In these surveys, we asked administrators whether their states have had past experience with cyanobacteria in their GWUI wells and for the contact information of the water supplier who responded to the incident. We used the information we received to determine whether or not other states had experienced cases of cyanobacteria contamination in their GWUI wells. We later followed up with each administrator who responded to our survey to help us determine why each respondent answered the way they did.

Objective 3: We determined MA water suppliers' level of understanding of cyanobacteria and the best ways to address their informational needs.

We conducted interviews with the Massachusetts public water suppliers who have at least one GWUI well in their public water system. We used these interviews to gauge public water suppliers' knowledge of cyanobacteria, their perception of cyanobacteria, their experiences with cyanobacteria, their knowledge of their system's GWUI wells and surface water bodies, and any procedures they have in place for responding to cyanobacteria blooms. To figure out how to address these suppliers' informational needs, we asked the members of ASDWA what cyanobacteria-related topics water suppliers should know about, and what format of informational materials the administrators thought suppliers would find the most useful. We verified the responses we received from ASDWA during our interviews with MA public water suppliers.

Objective 4: We developed informational materials for public drinking water suppliers and the MassDEP.

We designed informational materials for public water suppliers based on our background research, findings from our surveys of the members of ASDWA and our interviews of MA public water suppliers.

Findings

Below are our findings from the following parties: Public water administrators and Massachusetts public water suppliers.

Findings from Public Water Administrators

Finding 1: There were no reported instances of cyanobacteria in GWUI wells in the states that responded to the ASDWA survey.

Finding 2: Public water administrators thought public water suppliers would want to learn more about treatment and prevention plans.

Finding 3: Public water officials believe that suppliers wish to receive online content about cyanobacteria.

Findings from Massachusetts Public Water Suppliers

Finding 4: Most of the MA water suppliers we interviewed are aware of what cyanobacteria are.

Finding 5: MA water suppliers do not believe they have had any instances of cyanobacteria contamination in their water systems.

Finding 6: Public water suppliers are not particularly concerned about cyanobacteria contamination in their public water system.

Finding 7: Most public water suppliers expressed an interest in learning about potential threats to their drinking water.

Finding 8: The state lacks a clear process for water suppliers to respond to cyanobacteria blooms.

Finding 9: Most suppliers were aware of the surface water bodies located near their GWUI wells.

Finding 10: Water suppliers that we interviewed that did not own the surface water(s) influencing their wells do not communicate with those who oversee the surface water.

Finding 11: Some water suppliers were aware of the activities that occurred around the nearby surface water bodies.

Recommendations for Public Water Suppliers

We developed two sets of recommendations: one for public water suppliers in Massachusetts and one for the MassDEP. The recommendations for both parties are presented below.

Recommendation 1: Public water suppliers with GWUI wells in their system should identify which surface water bodies are capable of influencing their wells.

It is important for public water suppliers to be aware of which surface water bodies are nearby their GWUI wells so they are aware of which water bodies can possibly contaminate their ground water.

Recommendation 2: Public water suppliers with GWUI wells should identify potential hazards to the surface water bodies that can influence their GWUI wells.

Public water suppliers should be aware of the activity surrounding their surface water body. They should be aware of the type of runoff these hazards can produce and produce

action plans to deal with these hazards so they can effectively combat cyanobacteria blooms.

Recommendation 3: *Public water suppliers with GWUI wells should communicate regularly with those whose activities are determined to be a potential hazard to their surface water bodies.*

We recommend that public water suppliers communicate with these other groups about taking steps that will prevent cyanobacteria contamination in the drinking water. We encourage the water suppliers to distribute educational materials on source water protection to the various parties, and encourage them to report problems with the surface waters.

Recommendations for the Massachusetts Department of Environmental Protection (MassDEP)

Recommendation 4: *The MassDEP should continue to raise awareness of cyanobacteria among public water suppliers.*

In our interviews, we learned that public water suppliers are not concerned about cyanobacteria contamination in their water bodies; however they are aware of the threat it can pose. This is why it is important to continue to inform public water suppliers of the harmful effects cyanobacteria can have.

Recommendation 5: *The MassDEP should continue to investigate monitoring and treatment techniques for cyanobacteria through their Office of Research and Standards.*

Although cyanobacteria has yet to affect public drinking water in Massachusetts, it is important that the MassDEP develop the tools that suppliers can use to combat a harmful bloom should one arise.

Recommendation 6: *The MassDEP should work with water suppliers to conduct a study on cyanobacteria vulnerability in at-risk water systems.*

This study could create a scale that assigns each surface water body a quantitative relative risk rating. Once each of the surface waters in each GWUI system are scored, the MassDEP could better focus their outreach and prevention efforts to those GWUI wells and surface water bodies most vulnerable to cyanobacteria contamination.

Recommendation 7: *The MassDEP should create and distribute information on a uniform process for responding to cyanobacteria blooms.*

Although many suppliers knew to contact the MassDEP for assistance in the case of a bloom in their water system, there is not a clear process in place for responding to cyanobacteria blooms, as discussed in Finding 8. It would be ideal if the MassDEP would provide a list of actions that public water suppliers could take before contacting the MassDEP.

Conclusion

By completing our background research, distributing surveys to public water administrators via ASDWA, and conducting interviews with Massachusetts public water suppliers, we were able to develop informational materials in the format of a fact sheet for Massachusetts public water suppliers and the MassDEP. Educating public water suppliers, who are the first line of defense in the protection of public drinking water, is crucial as cyanobacteria blooms may one day pose a threat to Massachusetts. Informing this particular set of water suppliers who oversee GWUI wells is important because no states that responded to our survey have experience with this situation. An important initial action that these public water suppliers can take is to understand the contamination hazards that their public water system faces and to develop plans to mitigate these hazards, with which the MassDEP may be able to assist them. The purpose of our two deliverables, the well data spreadsheet and the fact sheet, is to educate the suppliers and provide them with the knowledge they need to prevent cyanobacteria contamination in their public water system.

We also provided the MassDEP and public water suppliers with a set of recommendations based on our findings from our surveys with public water administrators and our interviews with public water suppliers in Massachusetts. These recommendations may help the Department and the suppliers determine their course of action in combating the potential issue of cyanobacteria contamination. The majority of our recommendations suggest continued preventative action on the part of both suppliers and the MassDEP. Although few large scale cases of cyanobacteria contamination of drinking water have occurred in Massachusetts, or elsewhere in the United States, the effects of climate change and increased pollution could lead to more frequent or severe

toxic blooms. Given the public health consequences of cyanobacteria and its derivative toxins, it is important that the MassDEP persist in promoting readiness and prevention among water suppliers and water officials in other states. We believe that our informational materials, our findings, and our recommendations may help the MassDEP continue to take the initiative in preventing dangerous cyanobacteria blooms in public drinking water.

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CHAPTER 1: INTRODUCTION

Access to clean drinking water is a challenge faced by people worldwide. According to the World Health Organization (WHO), 1.1 billion people lack access to improved drinking water sources, which are by definition “protected from outside contamination” (WHO, 2014). The absence of improved sources can lead consumers to draw from unsanitary resources. Those who consume unsanitary water are at-risk of contracting a multitude of illnesses including gastrointestinal diseases, anemia, kidney damage, and cancer (EPA, n.d.). The WHO estimates that every year 1.6 million people die of diarrheal diseases like cholera, and 660 million people suffer from parasitic infections (2014).

The effects of climate change have compounded the extent of drinking water source contamination, putting communities with clean water supplies and adequate water infrastructure and sanitation in danger (Braks and de Roda Husman, 2013). The US Environmental Protection Agency (EPA, 2014) has claimed that climate change has caused annual precipitation volume to increase 0.5% per decade in the United States, sending more runoff into surface waters used for drinking water. The runoff can contain sediments, nutrients, pollutants, trash and animal waste, which all make the water unsafe for consumption (EPA n.d.). Runoff can cause elevated concentrations of nitrogen and phosphorus in water bodies, which can have several harmful effects. One effect of this is formation of harmful algal blooms called cyanobacteria (Falconer, 1999).

Although these bacteria are quite frequently present in most bodies of water at low concentrations, high concentrations can prove to be dangerous, particularly in drinking water sources. According to the EPA (EPA, 2012), the presence of

cyanobacteria in drinking water is known to cause an unpleasant taste and odor. More concerning, however, is that cyanobacteria in surface water bodies, such as lakes and rivers, can produce dangerous toxins, which at elevated concentrations, make the water unsafe to consume. Symptoms include dizziness, gastrointestinal upset, kidney damage, and liver damage (Paerl & Otten, 2013).

In a recent cyanobacteria outbreak in Lake Erie, a dangerous toxin associated with cyanobacteria, microcystin, was found in the drinking water. That outbreak affected 500,000 residents in Toledo, Ohio (Zimmer, 2014). During the bloom in Toledo, emergency rooms in the area had over 100 people reporting symptoms including dizziness, upset stomachs, and vomiting, which are common symptoms of cyanotoxin consumption. (Dungjen, 2014). Although the water was not shut off, the residents were warned against drinking the contaminated water. The level of microcystin present in the water was 2.5 parts per billion, far exceeding the WHO's advisory level of 1 part per billion (Leber, 2014).

Recently, federal and state government agencies have started to pay attention to the growing incidences of cyanobacteria and the detrimental effects of their resulting toxins on human health. For example, The EPA has placed three of the most prevalent cyanotoxins on its Contaminant Candidate List for regulatory consideration. These cyanotoxins are microcystin-LR, anatoxin-a, and cylindrospermopsin (EPA, 2012).

In Massachusetts the Department of Public Health (MassDPH) and Department of Environmental Protection (MassDEP) conducted a CDC-funded study to monitor cyanobacteria blooms and evaluate their health and environmental impact on Massachusetts water bodies (Yandell, 2010). The MassDPH's studies on the

cyanobacteria content of certain bodies of water in the Commonwealth found that in 2010, 33% of the water samples taken from twenty-five different bodies exceeded the advisory level of 70,000 cells/mL set for this study (Yandell, 2010). As a result, the MassDPH developed official guidelines for maximum safe levels of cyanobacteria and cyanotoxin content in recreational water bodies and monitoring and advisory posting procedures (MassDPH, n.d.).

Although Massachusetts has established basic guidelines for cyanobacteria in recreational water bodies, the Commonwealth has not developed similar guidance regarding drinking water. A number of the recommendations made in the MassDPH's guidelines are relevant to cyanobacteria presence in recreational water, but they would have to be adjusted and developed to properly address consumption through contaminated drinking water. First, without guidelines in Massachusetts' drinking water, water suppliers may not know how to properly address cyanotoxins in their drinking water. Second, since the MassDPH's study focused mainly on cyanobacteria exposure through recreational water bodies, a number of their contaminant advisory levels are based on water consumption rates while swimming (MassDPH, n.d.). Third, the advisory levels for drinking water sources may need to be altered, as the rate of exposure may differ for direct consumption versus dermal contact through swimming. Fourth, the guidelines issued by the MassDPH fail to address any potential treatment or prevention procedures that public water suppliers may use to combat cyanobacteria contamination (MassDPH, n.d.).

Due to the inconsistent regulation for cyanobacteria in drinking water, the MassDEP plans to develop their Drinking Water Program to aid public water suppliers by

researching ways to address the growing cyanobacteria problem in drinking water, specifically in public wells under the influence of surface water. Wells that are under the influence of surface water are particularly at risk because cyanotoxins that are in the surface water can infiltrate wells and be consumed by the public.

The goal of this project was to help the Massachusetts Department of Environmental Protection further develop their Drinking Water Program to assist the Commonwealth's water suppliers in addressing the potential threat of cyanobacteria in groundwater-under-the-influence wells. Our specific project objectives were as follows:

- Identified surface water bodies for wells classified as under the groundwater-under-the-influence in MA
- Investigated instances of cyanobacteria in groundwater-under-the-influence wells in other states
- Determined Massachusetts water suppliers' level of understanding of cyanobacteria and the best ways to address their informational needs
- Developed informational materials for public drinking water suppliers and the MassDEP

In addition, we provided the MassDEP with recommendations to further develop their drinking water program in regards to the management of cyanobacteria contamination.

CHAPTER 2: BACKGROUND

In this chapter, we will discuss background information relevant to our project. First, we will discuss factors that promote the growth of cyanobacteria. We will also review the dangerous health effects of cyanobacteria toxins, followed by examples of prevention and treatment procedures used to combat cyanobacteria blooms. Lastly, we will present actions taken to regulate cyanobacteria in drinking water around the world and in the United States.

CYANOBACTERIA GROWTH

Access to clean drinking water is a problem worldwide. Water sources can become polluted from storage tanks, septic systems, uncontrolled hazardous waste, landfills, chemical and road salts, and atmospheric contaminants (The Groundwater Foundation, n.d.).

Surface waters are particularly at risk for contamination, and if a ground water well is under the influence of surface water, it can also become contaminated. Figure 1 shows potential sources of surface water contamination. Surface waters are also at risk for contamination by microorganisms. Not all microorganisms pose a threat to humans, however there are certain types that can cause waterborne illnesses. An example of a harmful microorganism is cyanobacteria. When they die, cyanobacteria can release toxins into surface waters, and if these toxins are consumed, they can have serious health effects. Cyanobacteria contamination in public drinking water has become a growing concern worldwide (Paerl and Otten, 2013).

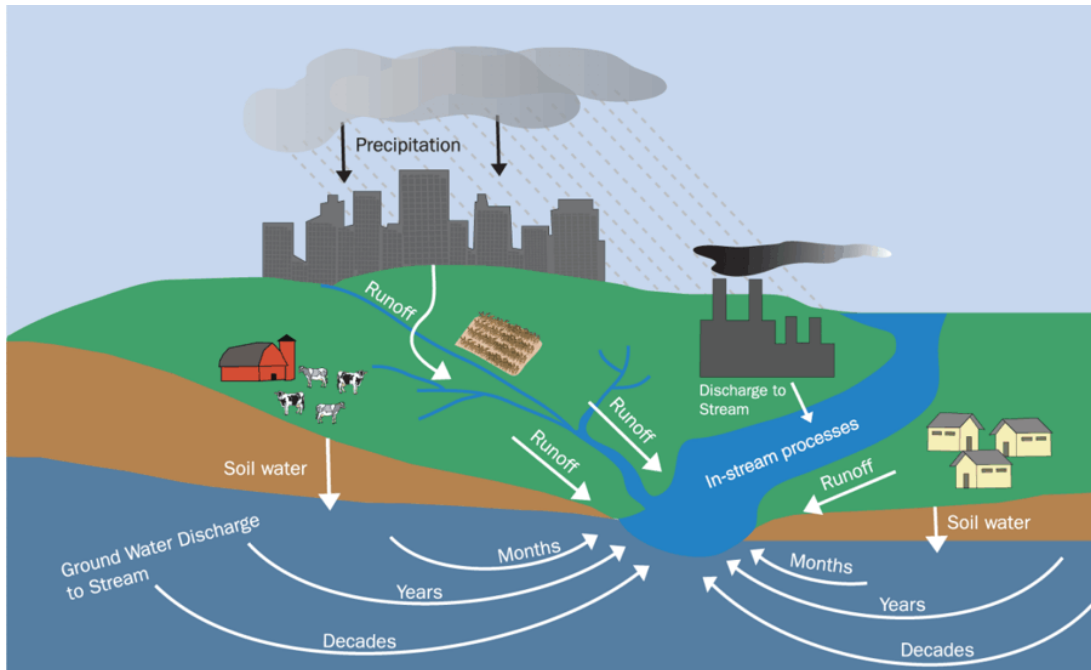


Figure 1. Surface Water Contamination Diagram. Note. From *Toxic Contaminants*, United States Geological Survey.

Cyanobacteria growth is promoted under certain conditions in surface waters. These conditions include a high water temperature (above 77°F), a neutral pH, a lack of water flow, and high concentrations of nitrogen and phosphorus (van Apeldoorn, van Egmond, Speijers, and Bakker, 2007). When a combination of these conditions are present in surface waters, large populations of cyanobacteria can appear and coat the surface water with a layer of green scum. This phenomenon is commonly referred to as a cyanobacteria bloom (van Apeldoorn, van Egmond, Speijers, and Bakker, 2007).

Certain phenomena promote the presence of the cyanobacteria growth triggers listed above. A high concentration of nitrogen and phosphorus in a water body can be attributed to runoff containing fertilizers and detergents (Paerl and Otten, 2013). A stagnant water body can be attributed to a lack of water flow or a drought that lowers the water level. When you combine these conditions with a neutral to slightly basic pH and a

warm water temperature, it creates a situation where cyanobacteria blooms can form easily.

CYANOBACTERIA TOXINS

Cyanobacteria release harmful toxins when cells die. If these toxins are ingested, they can have numerous harmful health effects on their consumers. There are approximately fifty different types of toxins that can be produced by cyanobacteria (Position Statement 8 Toxic Cyanobacterial Blooms, n.d.). The two main types of toxins that are relevant to public drinking water contamination are neurotoxins and hepatotoxins. Both toxins enter the body through the consumption of contaminated drinking water.

Neurotoxins are a category of cyanotoxin that affect the nervous system. They inhibit the neuron's control of essential ion concentrations across the cell membrane and communication between neurons, disrupting the regular function of the nervous system (Aráoz, 2010). If a large amount of this neurotoxin is consumed, it can lead to paralysis, asphyxiation and, in extreme cases, death (Burns, 2008).

Hepatotoxins, another type of cyanotoxin, affect the liver and kidneys (Position Statement 8 Toxic Cyanobacterial Blooms, n.d.). When ingested, hepatotoxins have a direct path through the blood stream to the liver. Hepatotoxins damage the liver by attacking the structural proteins of the liver cells and trigger premature cell death (Romanowska-Duda, Mankiewicz, Tarczynska, Walter, and Zalewski, 2002).

Microcystins, a type of hepatotoxin and common cyanotoxin, can have particularly dangerous health effects. According to Falconer (n.d), the results from a case study performed in southern China showed that people exposed to microcystin-contaminated

drinking water suffered from high rates of liver cancer. In a recent event in Toledo, Ohio during the summer of 2014, over 500,000 residents were without water for close to a week due to a massive cyanobacteria bloom that released microcystins into the water (Zimmer, 2014). More than 100 Toledo residents that drank the contaminated water went to emergency rooms within less than a day of the news release, as some were displaying symptoms such as an upset stomach, dizziness, and vomiting (Dungjen, 2014).

CYANOBACTERIA PREVENTION AND TREATMENT

Although cyanobacteria contamination is a relatively new problem in Massachusetts, other countries and states have researched ways to prevent and treat blooms. Since regulations are in the process of being developed, some of these treatment and prevention techniques could be adopted. It is important to understand techniques to combat cyanobacteria blooms so there is minimal risk of cyanotoxin contamination in drinking water. It is more ideal, however, to prevent a bloom from forming so the risk of cyanotoxin contamination is reduced.

Vertical mixing has shown to be a promising technique for preventing cyanobacteria blooms. A group of scientists in Amsterdam used a vertical mixing device in a lake that commonly developed blooms. The goal of this device was to keep the water moving so it was difficult for the cyanobacteria to proliferate (Johnk, 2008). In order to save on energy costs, the group rotated every week between having the mixer on and off. During one off week, the intense heat caused a massive bloom to form almost immediately. When the mixer was turned back on, the amount of cyanobacteria cells decreased significantly (JOHnk, 2008). However, the energy costs associated with mixing a large body of water are very high. It is difficult to have on and off cycles with

this system because if the conditions are just right when the mixer is off, a bloom can form. Regardless, it still provides a creative way to solve this problem without the use of harmful chemicals.

Ultrasonication can be useful in preventing cyanobacteria blooms and degrading cyanotoxins. According to Ahn (2007), Korean scientists developed a combined water pump and ultrasonication device that was used as an alternative to treating the water with copper sulfate. An experiment was conducted on two similar water supplies that commonly develop cyanobacteria blooms. One water supply had the custom-made apparatus, leaving the other as a control. Ahn discovered that the pond with the device had fewer cyanobacteria cells than the control pond, and the concentration of dissolved microcystins in the pond decreased. However, this technology is relatively new, can be expensive to implement, and is only successful in eliminating cyanobacteria that contain gas vesicles, which not all cyanobacteria have. It also creates the potential to release toxins into the water if the sonication cannot degrade toxins other than microcystins. Ultimately, the problem is the presence of cyanotoxins in the water and not necessarily the cyanobacteria themselves. Nevertheless, it still has potential to be further developed into an effective and eco-friendly solution to the problem.

In addition to prevention techniques, there are also treatment methods that water suppliers have used to rid the water of a cyanobacteria bloom. One common technique is treating the water with copper sulfate. Although treating contaminated waters with copper sulfate is an effective way to rid the water of a bloom, it creates the potential for several dangerous toxins to be released into the public water supply. This treatment technique kills the bloom but releases any toxins the cyanobacteria contained into the water. In one

incident in Sewickley, Pennsylvania, 62% of the people who were connected to water treated with copper sulfate developed gastrointestinal issues within five days (Falconer, 1999). There was another case in Armidale, Australia where a significant portion of a population linked to a copper sulfate-treated water supply had an increase in a particular liver enzyme in their blood. An increase in this liver enzyme is a precursor to toxic liver injury (Falconer, 1999).

In addition to the examples listed above, there are many other prevention and treatment techniques currently being developed to combat cyanobacteria blooms. However, the technology is not at a place where it is feasible to implement. Thus, governments around the world are attempting to resolve this issue with regulations and guidelines. Since cyanobacteria blooms are a relatively new problem however, there is still a lot to be done in regards to regulation of cyanobacteria in drinking water.

REGULATION OF CYANOBACTERIA IN DRINKING WATER

As a result of the increasing occurrence of cyanobacteria blooms worldwide, some nations have begun to regulate cyanobacteria toxins. Many of these nations have looked to the World Health Organization for guidance in the creation of cyanobacteria regulations (WHO, 2008).

The World Health Organization's recommendations have had a significant effect on the creation of regulations for cyanotoxins around the world. In 1998, the WHO established its first suggested maximum cyanotoxin level by stating that microcystin-LR content in drinking water should not exceed 1 microgram per liter (WHO, 2008). Since then, many countries have decided to include this maximum level in their water

regulations. However, Burch (2006) maintains that the WHO only meant this to be a provisional measure until more was understood about the toxicology of the many other less prominent cyanotoxins. Many nations have not expanded their cyanotoxin regulations since adopting the standard recommended by the WHO.

Although most countries have not developed regulations for cyanobacteria, Australia has faced significant issues with cyanobacteria contamination, and thus has adopted more comprehensive sets of recommendations based on their experiences. The southeastern territories of Australia are particularly susceptible to blooms due to the warm, damp environment and large amount of pollution runoff into surface waters (Avolio, 2012). As a result, Australia has developed their water quality regulations beyond the scope of the WHO's recommendations. The WHO's recommendations only mentions microcystins, but Australia's Drinking Water Guidelines also address the dangers of cylindrospermopsins, nodularins, and saxitoxins, some of the secondary toxins produced by cyanobacteria (NHMRC, 2013). Although the guidelines currently state that there is not enough data to set official regulatory levels for these additional toxins, the guidelines do set health advisory levels for each toxin which require notification of the public. The health advisory levels are based on the results of pathological ingestion studies performed on mice and adjusted to the water consumption rates and average body weights of Australians (NHMRC, 2013).

In contrast to Australia, the United States currently does not have any cyanotoxin regulations in place at the federal level. The Safe Drinking Water Act (SDWA), passed in 1974 and amended in 1986 and 1996, allows the EPA to set standards for drinking water contaminants that must be met through the states' own drinking water regulations (EPA,

2014). At this time, the EPA does not regulate cyanobacteria or cyanotoxins in drinking water through this act, because they did not adopt the WHO standard (Palleschi, 2014). However, the EPA is currently in the process of pursuing future regulation of these contaminants.

The SDWA creates a mechanism to implement the regulation of new contaminants via a two-step process. At the recommendation of the scientific community, the EPA may place unregulated contaminants identified to be potentially harmful to drinking water supplies on a list for future consideration (Safe Drinking Water Act, 1996). Although cyanotoxins are not currently federally regulated in drinking or recreational waters, three prominent variants of toxins, microcystin-LR, cylindrospermopsin, and anatoxin-a, have been placed on the Candidate Contaminant List for investigation (EPA, 2012). The WHO has only issued guidelines for microcystin, so this aligns more with the precautions that Australia has taken.

Within twenty-four months of the decision to regulate a contaminant that is under review, the Administrator of the EPA must release a maximum allowable concentration for the contaminant in question (Safe Drinking Water Act Amendments, 1996). Although this is the only action made via the SDWA regarding cyanobacteria so far, recent events with cyanobacteria have spurred the United States government to take further action regarding the regulation of cyanotoxins.

The recent cyanobacteria bloom in Lake Erie has caused a drinking water health advisory level to be set for microcystin by spring 2015. The EPA wants to utilize the SDWA to develop a health advisory level and the Clean Water Act (CWA) to develop “risk based water quality criteria.” Gina McCarthy, the EPA Administrator said, “What

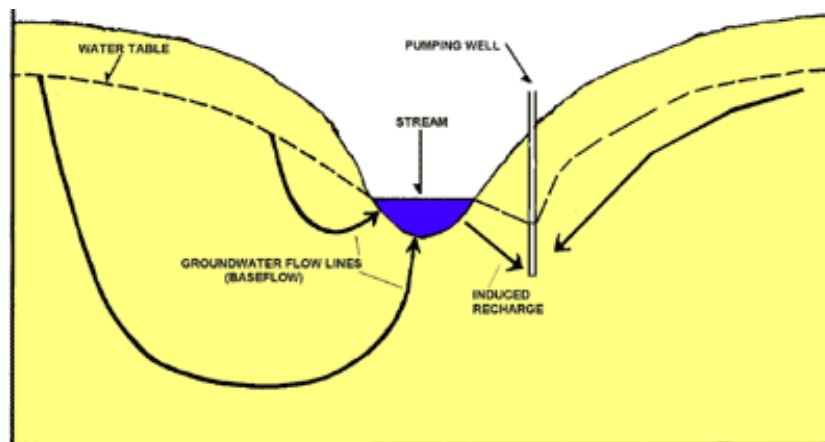
happened in Toledo was just the symptom of two larger problems. Nutrient pollution, and the toxic algae it feeds, is a challenge all over the country” (Palleschi, 2014). The EPA believes the issue of cyanobacteria is not just within the Great Lakes; it is within any community that uses surface water for drinking water, and the problem must be addressed promptly.

Despite this recent push for cyanobacteria regulations at the national level, the states still have regulatory power over drinking water through the SDWA. The SDWA establishes a number of responsibilities for states to uphold regarding drinking water quality management. According to the Act’s 1996 amendments, states are granted “primary enforcement responsibility” provided they meet a number of EPA-established requirements (Safe Drinking Water Act, 1996). These requirements include that states set drinking water contaminant standards at least as strong as those set by the EPA, create procedures to enforce these state regulations, establish programs to conduct sanitary surveys of water systems, and develop plans to provide safe drinking water in the case of natural disaster (Safe Drinking Water Act, 1996). If states fail to meet the requirements for primacy, the enforcement responsibilities fall back to the EPA (Safe Drinking Water Act, 1996). Since the notion of primacy mandates that states adopt regulations at least as stringent as those established by the EPA, states have the right to go above and beyond these regulations as they see fit.

DRINKING WATER REGULATION IN MASSACHUSETTS

Massachusetts has utilized the SDWA to enact regulations with regards to surface water treatment. Surface water sources and ground water sources under the influence of surface water have stricter treatment requirements than regular ground water under the

section 310 CMR 22.20A of the Massachusetts Drinking Water Regulations titled “Surface Water Treatment Rule” of the Massachusetts Drinking Water Regulations (Massachusetts Drinking Water Regulations, 2009). These types of water sources are subject to stricter regulations because they are susceptible to contamination by several, harmful microorganisms, unlike groundwater that is not influenced by surface water. Surface water is capable of traveling through gaps in subsurface material and entering wells that draw from groundwater, as seen in Figure 2. This recharge can put groundwater wells in close proximity to surface water bodies at risk of the same contamination that surface water faces.



*Figure 2. Groundwater-Under-the-Influence Diagram. Note. From *Dispelling Common Ground Water Misconceptions*, New York Rural Water Association.*

Massachusetts currently has tests in place to determine whether a well is categorized as “groundwater-under-the-influence” (GWUI). According to Frank Niles, the GWUI Coordinator for the MassDEP, the department uses certain bioindicators to determine this. The exact process for testing is discussed in Appendix E. Through this

process, Massachusetts sets standards for treatment for five drinking water hazards. However, cyanobacteria are not included on this list.

This process of testing does not link the well to the surface water that is influencing it. In the case of cyanobacteria, this is problematic because the contaminant is in the surface water. Without knowing what surface water influences the well, it is difficult to know if cyanobacteria contamination has occurred.

CONCLUSION

Cyanobacteria and its derivative toxins are a threat to public health. Due to variations in climate and water conditions around the world, there is no single solution to this problem. In Massachusetts, one of the concerns the MassDEP has is that cyanobacteria will enter drinking water through public drinking wells. These toxins can have many harmful effects on its consumers. There are some treatment and prevention techniques that have been tested, but nothing has been deemed a definite solution yet. Massachusetts is on its way to develop regulations on monitoring cyanobacteria in drinking water. Our project is to help provide Massachusetts Water Suppliers with information in order to combat cyanobacteria and to inform them on what preventive measures they can take.

CHAPTER 3: METHODOLOGY

The goal of this project was to help the Massachusetts Department of Environmental Protection further develop their Drinking Water Program to assist the Commonwealth's water suppliers in addressing the potential threat of cyanobacteria in groundwater-under-the-influence wells. The MassDEP was particularly interested in the influence of surface water on public drinking wells due to the fact this case of contamination has not been explored, yet the Department believes that the risks posed by this case could increase over time.

To meet the project's goal, we planned to complete the following objectives:

- Identified surface water bodies for wells classified as under the groundwater-under-the-influence in MA
- Investigated instances of cyanobacteria in groundwater-under-the influence wells in other states
- Determined Massachusetts water suppliers' level of understanding of cyanobacteria and the best ways to address their informational needs
- Developed informational materials for public drinking water suppliers and the MassDEP

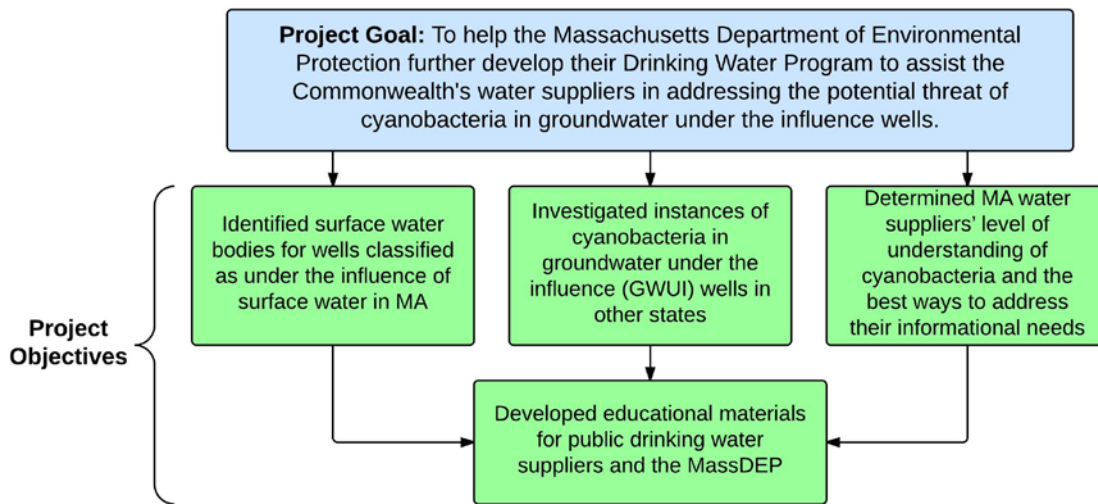


Figure 3. Project Goal and Objectives Chart.

IDENTIFYING SURFACE WATER BODIES

Our first objective was to identify the surface water bodies for wells that are capable of influencing Massachusetts’s GWUI wells. Since cyanobacteria blooms exclusively form in surface water bodies, wells hydrologically linked to surface water are at risk of contamination. The MassDEP provided us with a list of twenty-six wells they have designated as potentially influenced by surface water. This list, located in Appendix C, contains the source ID numbers of the wells. However, the corresponding surface water bodies for each well had not yet been identified. We used the source ID numbers to locate the surface water bodies potentially influencing each well.

To connect each at-risk well with a surface water body, our team consulted with experts affiliated with the MassDEP and used the Massachusetts Geographic Information System (MassGIS) database. The Office of Geographic Information has compiled a spatial information database to aid in emergency response planning, environmental

planning and management, and economic development (Office of Geographic Information, 2014). The MassGIS database can be used to show the locations of surface water bodies capable of influencing ground water wells across Massachusetts. After cross-referencing the locations of affected wells, we identified which surface water bodies are capable of contaminating each well. To determine which wells are connected to which bodies of water, we consulted two water experts, Frank Niles, the Groundwater-Under-the-Influence Coordinator for the MassDEP, and Alice Doyle, GIS Analyst for the MassDEP.

In order to determine which surface water bodies influence each of the twenty-six wells, we used MassGIS software called “Arc Reader 10.1.” We located each of the twenty-six wells by typing the source ID number provided to us by the MassDEP in the finder window. Once the well was located, we drew a circle with a radius of 0.25 miles around it. Although wells more than 150 feet from a surface water body are exempt from tests for the influence of surface water, described in Appendix E, we used this radius because the experts believed that any water body capable of influencing the well would be contained inside this circle. Once we drew the circle, we used the program’s measuring tool to determine how far away the well was from the surface water body. We also used the program to obtain the name of the surface water body. In instances where there were several water bodies within the circle, we recorded of all the distances and names. Table 1 describes the set of data we collected and the justification for collecting it.

Table 1

Well Source Database Content and Justification

Well Attribute	Justification
Source ID Number	This data point will make it easy for the well to be located in the future
Distance From The Water Source	The closer the distance, the more vulnerable the well is to cyanobacteria contamination. By knowing how far away the water body is, we can see which wells are the most vulnerable
Surface Water Body Name	If a bloom occurs in this water source, it will be easy to search by name in the spreadsheet to see which wells will be potentially contaminated

INVESTIGATING INSTANCES OF CYANOBACTERIA IN GWUI WELLS

To learn about instances of cyanobacteria that have occurred in other states, we distributed an email survey to drinking water officials through the Association of State Drinking Water Administrators (ASDWA). This organization consists of fifty high-level drinking water officials in the United States, one from each of the fifty states. Our purpose in distributing these surveys was to determine which states, if any, have had experience with cyanobacteria contamination in public drinking wells. In addition, we wished to learn about which cyanobacteria-related topics these individuals believe water suppliers would like to learn more and the formats they would prefer for informational materials, as part of our project was to develop informational materials for public water suppliers in Massachusetts.

Initially, the MassDEP provided us with an extensive list of potential survey questions to ask the members of ASDWA. Most of these questions asked about the

details of specific instances of when cyanobacteria blooms in surface waters affected water quality in nearby wells and what actions were taken as a result of the bloom. Our team added a question to ask about which cyanobacteria-related topics officials think public water suppliers need to know more. Additionally, we included a question asking officials in what form they think public water suppliers would like to receive informational materials. In designing our survey, we considered that drinking water officials may know the public water suppliers who dealt with blooms directly. As a result, we asked officials to supply the contact information of those water suppliers so that we could reach out to them.

After consulting with ASDWA representative Deirdre Mason and MassDEP liaison Kathleen Romero, we abridged our survey to suit our survey population better. The administrators whom we planned to survey oversee the drinking water programs of entire states. Ms. Mason advised us to remove the questions pertaining to the details of exact instances of cyanobacteria affecting public drinking wells, as those administrators may not be the best audience for such specific inquiries. The public water suppliers to whom the ASDWA members could direct us, according to Mason, would be far more likely to have the details of those cyanobacteria instances and the actions taken to address the instance.

In addition to the survey questions, the team wrote an introduction describing the purpose of the survey to the members of ASDWA. We explained that the MassDEP's Drinking Water Program is investigating public water suppliers' informational needs that need to be addressed with regards to cyanobacteria contamination of public wells. The introduction also described our project team's intent to develop informational materials

on cyanobacteria for water suppliers in Massachusetts. We reassured respondents that results would be kept confidential and that this study was approved by both the MassDEP and WPI's Institutional Review Board.

The survey was distributed to the fifty members of ASDWA via email. According to our sponsor, response rates are often dependent on the staffing levels in each state's environmental department. To encourage responses, we kept the survey to a single page and had a reminder email sent several days after the initial distribution of the surveys to all members of ASDWA. In total, we received fifteen responses.

The first important piece of information we sought to gain from this survey was the contact information of water suppliers who have experience with cyanobacteria contamination of public drinking water. We planned to contact the water suppliers to set up phone interviews. However, based on their responses, we chose a different course of action. We did not obtain any public water supplier contacts because no states reported instances of cyanobacteria contamination in GWUI wells. Thus, we did not pursue interviews with water suppliers in other states.

The second important piece of information from these surveys that affected our methodology was the administrators' responses regarding the content and format of our informational materials for MA public water suppliers. In the survey, we asked administrators to rank the media formats that interested them the most. We wrote a computer program in the Processing language to give each media type a score. On the surveys, public water administrators ranked the list of educational materials on a scale of 1 to 10, 1 being the top choice and 10 being the last. We assigned the first material type

with 10 points, the second with 9 points and so until the tenth one received 1 point. If the material was not ranked, it received 0 points.

We also asked about which cyanobacteria-related topics public water suppliers would want to know more. We provided four topics as choices and a fill-in option. We tallied the number of each response to determine the relative importance of each topic to public water suppliers. The most popular topics are included in our informational materials.

INTERVIEWING MASSACHUSETTS WATER SUPPLIERS

In order to meet our third objective, determining the informational needs of public water suppliers in Massachusetts, we conducted interviews with water suppliers in Massachusetts who oversee wells that are under the influence of surface water. There are twenty-six wells that have been determined through microparticulate analysis for certain bioindicators to fit this criterion. The twenty-six wells fall within seventeen different public water systems. The MassDEP has a master list of every public well in the Commonwealth that contains, among other things, a contact for a supplier at each public water system. We reached out to all seventeen public water suppliers who had a groundwater-under-the influence well in their public water system for interviews by telephone. We conducted thirteen interviews in total.

The intent of the interviews was to learn about the Massachusetts water suppliers' knowledge of cyanobacteria, perception of cyanobacteria as a threat, possible experiences with cyanobacteria, knowledge of their GWUI wells and the surface water bodies nearby, and any processes they have in place for responding to cyanobacteria blooms. The interview questions can be found in Appendix B.

We used our first two questions to determine whether the water supplier had experience with cyanobacteria in their public water system. The first question asked if water suppliers believed algae from nearby surface waters had ever impacted the quality of their GWUI wells to determine if suppliers have had any experience with the type of contamination we are interested in investigating. We then asked if the public water supplier ever received taste or odor complaints from water consumers and if so, what the cause of the taste or odor problem was. We asked this to determine if water suppliers have possibly had experience with cyanobacteria contamination that they were simply unaware of, as taste and odor issues are often associated with cyanobacteria in water. If a public water supplier were to say they had a taste or odor issue in their water that they could not find the cause of, it may be possible that cyanobacteria could have been the cause.

The next three questions pertained to the supplier's knowledge on their GWUI wells and surface water bodies. First, we asked the supplier if they knew which surface water bodies had the potential to influence their GWUI well or wells. This allowed us to determine if the water supplier was aware of which surface water bodies could affect the water quality of their GWUI well. If the supplier was unable to answer, we provided them with the names of the water bodies our group located within a quarter mile of each of the GWUI wells in that supplier's system. Once the supplier answered correctly or we provided them with the nearby water body names, we asked the supplier what activities could affect the runoff into that water body. We used this to determine possible threats to the surface water that could create a greater risk of cyanobacteria contamination and to determine how aware suppliers are of the threats to their GWUI wells. Then, we asked

the supplier if they knew who owned or controlled the surface water bodies near their wells. We asked this to determine if there was some outside party that is responsible for overseeing this water body that may need to be consulted in the event of cyanobacteria contamination.

Next, we asked the water supplier to walk us through what actions would be taken in the event of a cyanobacteria bloom occurring in one of their surface water bodies capable of influencing their GWUI well. To help guide the suppliers through this question, we sometimes asked follow-up questions about communication that occurs between them and the surface water body owners and controllers or how suppliers would find out about a bloom occurring in the first place. This line of questioning was used to help us determine if suppliers had any processes to respond to cyanobacteria currently established and in part to determine how knowledgeable suppliers were about cyanobacteria.

Our last questions were designed to help us understand the supplier's perception of cyanobacteria and their knowledge of cyanobacteria. Then, we inquired about whether toxic algae blooms were a concern in their public water system. We asked this to determine the supplier's level of concern about cyanobacteria as a threat to their water system, and what factors at play in their water system would lead them to answer the question the way they did. We also asked the water supplier about which topics related to cyanobacteria they would like to learn more. This helped us determine which topics suppliers felt they did not know enough about and which topics they felt it would be useful for them to understand in their role as a water supplier. Our last question asked if there were any questions that we did not ask the supplier during the course of the

interview that it would have been beneficial to ask. If the supplier had a question that they believed we should have asked, we posed it to them.

Following these interviews, we performed content analysis on the summary notes that we took during each interview with a water supplier. We placed each water supplier's response to each of our questions into one or more of our predetermined categories: experiences with cyanobacteria, perception of cyanobacteria, knowledge of cyanobacteria, knowledge of their GWUI wells and surface waters, established procedures, and other responses. Once we categorized all of our responses that we received through these interviews, we drew conclusions about our interview population based on their responses in each category, taking note of outlying responses. We took these conclusions, along with the exceptions and limitations, into consideration as we designed informational material for Massachusetts public water suppliers, as described in the next section.

DESIGNING INFORMATIONAL MATERIALS FOR WATER SUPPLIERS

To complete our fourth objective, we designed informational materials to distribute to Massachusetts public water suppliers. We created these materials based on the results of our ASDWA survey and our interviews with MA public water suppliers. We received fifteen responses to our ASDWA survey and conducted thirteen interviews with MA public water suppliers.

To decide the format of our informational materials, we drew from both our ASDWA survey responses and MA public water supplier interviews responses. Survey respondents were asked about which type of informational material they think would be the best media to distribute to water suppliers. We scored each format option based on the

survey respondents' rankings, as described in the previous section. We also asked public water suppliers what formats they would find useful for informational materials to determine if their opinions were in alignment with those of water officials.

To determine which topics to include in our informational materials, we considered our survey and interview responses. We asked public water officials to indicate cyanobacteria-related topics that they felt public water suppliers would be interested in learning about, as previously described. To verify the answers we received from public water officials, we asked public water suppliers about which topics they would like to learn during our interviews. We used the interest expressed from these answers to help us determine which topics we would cover in the materials. To determine the actual content of our informational materials, we used information we gained from our background research, conversations with experts affiliated with the MassDEP, and materials previously developed by the MassDEP.

CHAPTER 4: FINDINGS

INTRODUCTION

In this chapter, we will discuss the results from our second and third objectives. We will present the findings from our survey administered through ASDWA, as well as findings from our interviews with the Massachusetts water suppliers.

FINDINGS FROM PUBLIC WATER ADMINISTRATORS

Finding 1: There were no reported instances of cyanobacteria in GWUI wells in the states that responded to the ASDWA survey.

When asked the survey question, “Have any public water systems in your state had public wells that were affected by a toxic cyanobacteria bloom in the nearby surface water?” drinking water officials from twelve states said “no” and officials from three states said “don’t know”. The states and their responses are in Table 5 below.

Table 2

States’ Responses to Survey Question 1

State	Response
Georgia	No
Florida	No
Illinois	No
Colorado	No
Kentucky	No
Missouri	No
Montana	No
Alaska	No
Oklahoma	No
Rhode Island	No
Maine	No
West Virginia	No
Arizona	Don’t know
New Hampshire	Don’t know
Minnesota	Don’t know

We found two reasons for why a state said “no” to this question. First, many states may not have had any instances of cyanobacteria in their GWUI wells. When following up with the survey respondents via e-mail, we discovered that three of the respondents explicitly stated that they have not had blooms in their surface waters. Possible reasons that we speculated for lack of blooms include a cooler climate in each state or that they do not test for cyanotoxins.

Second, some of the states have very few GWUI wells. The fewer the GWUI wells in the state, the lesser the chance of a bloom affecting the well. Figure 4 shows the number of GWUI wells in each respondent state.

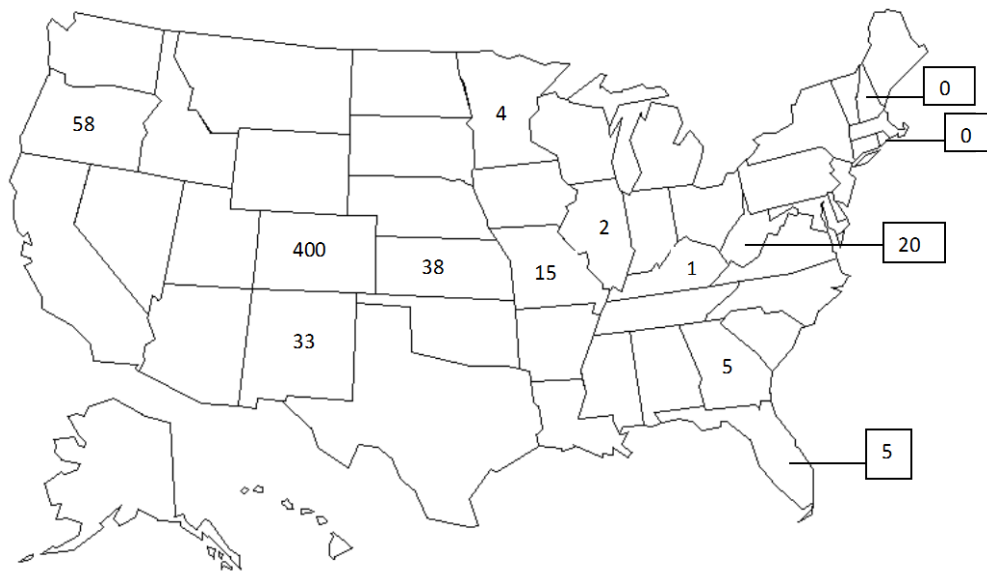


Figure 4. Number of GWUI Wells in Survey Respondents’ States.

Five states reported in the survey follow-up that they do not know whether cyanobacteria has impacted any of their GWUI wells. Originally, two of these states answered “no” on the survey, but in the follow-up, they stated that they did not actually know whether a bloom had affected a GWUI in their state. One reason that states may not

know is because they do not test for cyanotoxins. According to a separate survey administered to the members of ASDWA in April 2014, only six states out of thirty-six respondent states conduct cyanotoxin testing (Association of State Drinking Water Administrators, 2014). Of those six, none conduct routine testing, meaning tests are only performed during incident response. In addition, eight survey respondents reported in the follow-up that they do not test for cyanobacteria or cyanotoxins. This lack of testing could cause a minor incident, such as a small bloom that released insufficient toxins, to go unnoticed.

Finding 2: Public water administrators thought public water suppliers would want to learn more about treatment and prevention plans.

In our second survey question, we asked public water administrators which cyanobacteria topics public water suppliers would like to learn more about. The five choices were treatment plans, prevention plans, biology of cyanobacteria, cyanobacteria toxins and other. Treatment and prevention plans were the most popular topics. Figure 5 below shows the respective scores of the fourteen respondents.

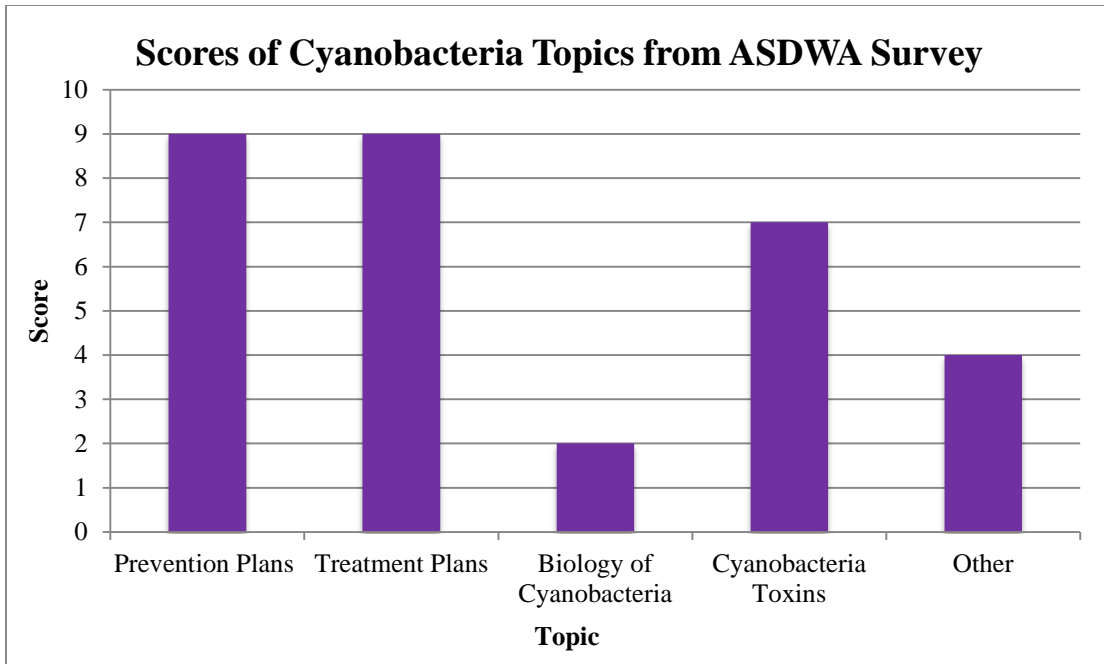


Figure 5. Survey Results for Informational Material Topics.

Although “treatment plans” and “prevention plans” received the highest scores, after speaking with our liaison, Ms. Kathy Romero, as well through completing our background research, we discovered that there are not any fully developed and ready-to-be-implemented cyanobacteria treatment and prevention methods available.

Finding 3: Public water officials believe that suppliers wish to receive online content about cyanobacteria.

A website was the most popular format for informational materials on cyanobacteria among the fifteen respondents, followed closely by email. The computer program we wrote scored each category based on where each survey respondent ranked it. The process is described in the Methodology section “Investigating Instances of Cyanobacteria in GWUI Wells.” Figure 6 below shows the final scores each category received.

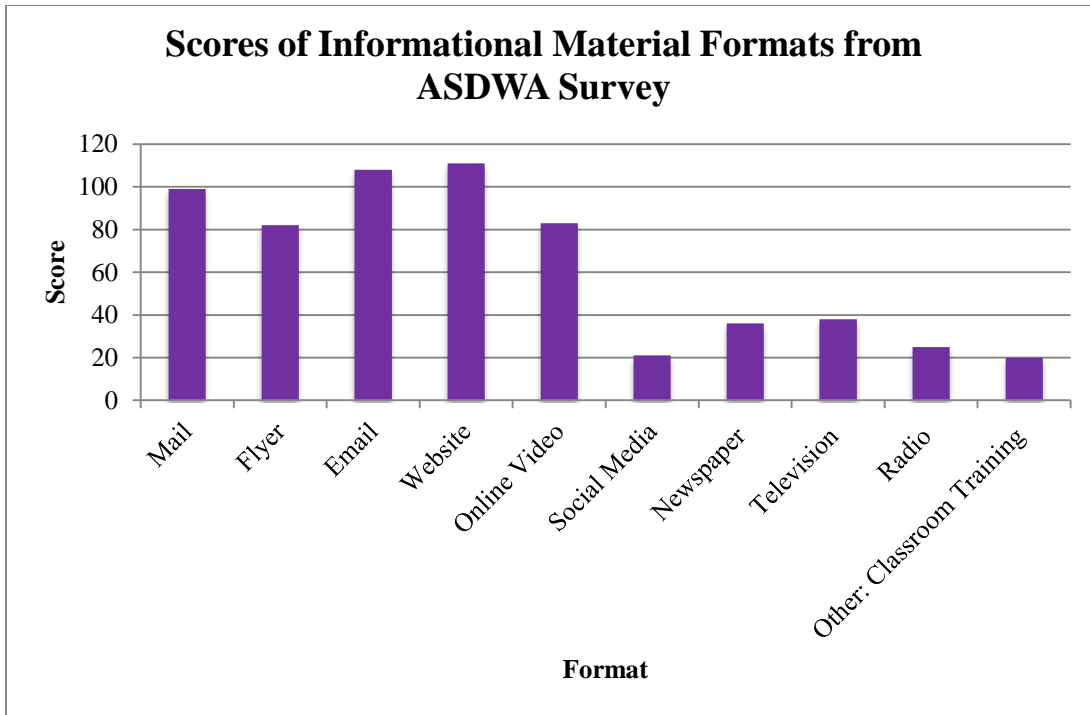


Figure 6. Survey Results for Informational Material Formats

Since the two highest scores were “email” and “website”, it appears that there is a desire from the public water administrators for online resources on cyanobacteria. However, “mail” and “flyer” received the third and fourth highest scores, so there is still a demand for hard copies of these materials as well. In addition, there was only a 9-point difference between the second and third score, and only a 16-point difference between the second and the fourth score. This differential is rather small in the scheme of our scoring system, as one additional first ranking by a state could give the format 10 more points. However, since the drop-off from the fifth highest score to the sixth highest score was 45 points, we feel it is reasonably safe to assume that there is not a significant desire for informational materials in the format of “social media”, “newspaper”, “television”, or “radio”.

Although there is an abundance of social media sites, “social media” ended up ranking second to last. This could be explained by the fact that social media is not a typical platform for professional advice to be distributed. Another reason we speculated why social media ranked low is because many of the water suppliers are older and do not use the sites as frequently as younger generations do. A study found that 89% of internet users 18 to 29 years old use social media sites while 65% of internet users 50 to 64 years old use them. This shows there is generally less use of social media among the older group (Pew Research, 2014). Table 3 below shows the age percentages of public water suppliers in Massachusetts. Since 89.3% of the suppliers are over 35 years old, it is reasonable that social media was not a popular format for informational materials.

Table 3

Age Distributions of the New England Water Works Association

Age Range	Percentage
65+	17.2
55-64	35.9
45-54	23.8
35-44	12.4
25-34	7.8
18-24	3.7

“Classroom training” also ranked low as a format for informational materials. Since we did not initially consider this format on our survey question, it is not surprising that it received a low score. However, two survey respondents ranked it as first in the “other” section. It is notable that it ranked first twice, since it was not listed in the options. In addition, in our follow-up interviews with the water suppliers, one supplier said they would prefer “classroom training” for education on cyanobacteria.

FINDINGS FROM PUBLIC WATER SUPPLIERS

Finding 4: Most of the MA water suppliers we interviewed were aware of what cyanobacteria are.

Although some suppliers were not familiar with the term cyanobacteria, ten of eleven respondents had heard of cyanobacteria before we interviewed them. Suppliers were more familiar with the term “blue green algae” which was the common name used before the biology of cyanobacteria was fully understood. This may be explained by the high average age of MA public water suppliers. As previously shown, Table 6 displays the age ranges of the membership of the New England Water Works Association, of which many MA public water suppliers are a part. Once the water suppliers understood what we meant by cyanobacteria, they were generally able to answer our questions on the topic.

The events in Toledo, Ohio this summer could have also informed the public water suppliers of what cyanobacteria are. As described in our introduction and background section, a massive bloom in Lake Erie left 500,000 residents without water this summer (Zimmer, 2014). Since this directly relates to the profession of the public water suppliers, this may be another reason why the suppliers were familiar with cyanobacteria.

Finding 5: MA water suppliers do not believe they have had any instances of cyanobacteria contamination in their water systems.

None of the eleven water suppliers reported having any experience with cyanobacteria. When we asked suppliers if they believed that cyanobacteria in their surface waters had ever affected the quality of their well water, all responded either “no”

or “not to their knowledge”. It is reasonable to assume they have not had any experience with cyanobacteria based on their responses to some of our other questions. When asked if their system had ever suffered from taste or odor issues, a telltale sign of the presence of cyanobacteria in drinking water, suppliers stated that either they did not suffer from taste or odor issues in their water, or traced their taste and odor issues to other causes like chlorination, internal plumbing issues, iron, or salinity.

This discovery is consistent with Finding 1. It appears that parties that deal with public water supplies have either not had experience or do not know if a bloom has affected the public water they oversee. This emphasizes the idea that there is little awareness for cyanobacteria contamination in general.

Finding 6: Public water suppliers are not particularly concerned about cyanobacteria contamination in their public water system.

Although the water suppliers we interviewed knew what cyanobacteria were, there was little concern expressed about cyanobacteria affecting their public water supplies. Since public water suppliers do not have experience with cyanobacteria contamination in their GWUI wells (Finding 5), it is reasonable that they are not concerned about it. When asked whether or not toxic algae blooms were a concern in their water system, the eleven respondents said they were not worried about cyanobacteria in their own systems. Notably, three different suppliers stated that since the closest water bodies to their GWUI wells were rivers, the formation of cyanobacteria was improbable. Their justification is biologically sound because cyanobacteria blooms require stagnant water to form; however, high summer temperatures and extended periods

of low precipitation could cause sections of their rivers to become stagnant, and therefore prone to bloom formation (van Apeldoorn, van Egmond, Speijers, and Bakker, 2007).

Finding 7: Most public water suppliers expressed an interest in learning about potential threats to their drinking water.

Despite the fact that water suppliers are not currently concerned about cyanobacteria in their own public water systems, eight out of eleven expressed interest in learning about anything that threatens drinking water quality. Three suppliers outright said that they did not wish to know anything more about cyanobacteria, but the other eight respondents had at least one area in which they were interested in learning more. Most of these eight asked for basic knowledge on the bacteria, but some of the more specific responses included the effectiveness of traditional water treatments against cyanobacteria, government action being taken to regulate cyanobacteria, and seasonal biases that can promote blooms.

As stated in Finding 4, this interest could have been spurred by the cyanobacteria incident in Ohio. Two suppliers we talked to asked if our questions were developed in response to the incident in Toledo. One of these two spoke to the importance of being proactive as a water supplier, and how water suppliers in Toledo chose to wait until the blooms in Lake Erie proved to be problematic instead of treating the blooms before they were a serious issue. This sort of sentiment could explain why the MA suppliers we interviewed wished to learn about cyanobacteria, despite not seeing it as a threat to their water systems.

Finding 8: The state lacks a clear process for water suppliers to respond to cyanobacteria blooms.

Water suppliers identified a variety of actions they would take if they encountered a cyanobacteria bloom in their water system, indicating that there was no uniform agreement about what should be done. Below is a list of the actions MA water suppliers said they would take in the event of a cyanobacteria bloom:

- Call MassDEP For further assistance
- Collect samples of contaminated water
- Treat water with copper sulfate
- Treat water with chlorine and UV light

The situation was similar in the event of a cyanobacteria bloom in surface water nearby a well. Respondents stated three common responses to the question, “Walk through what would occur if a cyanobacteria bloom formed in one of the water bodies that influences your well.” Contacting the MassDEP for further instruction was the most common answer to this question. The next most common response was to take samples of the contaminated water for testing. Those who mentioned testing often also mentioned contacting the MassDEP, as water suppliers are not capable of testing these samples for cyanobacteria in their own facilities. Suppliers also brought up three actual treatment measures they may use in the case of a cyanobacteria bloom. The three techniques are treating the water with copper sulfate, chlorine, or UV light. Regardless of the response given, it is clear that there is not currently one uniform plan of response among public water suppliers.

Finding 9: Most suppliers were aware of the surface water bodies located near their GWUI wells.

We discovered through our interviews that eight out of eleven suppliers were aware of the nearby surface water bodies. Eight of the suppliers were able to name at least one nearby water body that was capable of influencing their well. If there was a water body on our list that the supplier did not know of, several times it was a water body that was outside of the 150-foot radius that is used to determine GWUI wells. As described in our methods chapter, all water bodies within the 150-foot radius have stricter requirements for treatment and testing. We used a 0.25-mile radius to locate all of the water bodies because the experts we spoke to believe this is a maximum distance a water body can be away from a well and still potentially influence it. Water suppliers may not know of the maximum distance, hence why they are not aware of water bodies outside of the 150-foot radius.

Water suppliers also provided us with the names of some surface water bodies that were not on the list that we developed from MassGIS. This is because some of these water bodies are too small to show up on the software. This deficiency by MassGIS to locate smaller water bodies could have implications in the future if a bloom were to form and the water supplier did not know about it. Although MassGIS is a powerful tool, it still has limitations.

Finding 10: Water suppliers that we interviewed that did not own the surface water(s) influencing their wells do not communicate with those who oversee the surface water

We found that water suppliers that we interviewed that do not own the surface water body in question do not communicate with those who oversee the surface water bodies that influence their wells. This contrasts with Finding 9 because a majority of the suppliers knew the surface water bodies that impacted their GWUI wells. However, this conforms to Finding 5 because this lack of communication could lead the suppliers to be unaware if a bloom formed in the water body.

Finding 11: Some water suppliers were aware of the activities that occurred around the nearby surface water bodies.

There were eight out of eleven water suppliers who were aware of the activities occurring around the nearby surface water bodies. Some of these activities included golf courses, industrial and residential areas, and roads near the surface water bodies. These activities are notable as they all produce pollutants that could runoff into water bodies and cause a cyanobacteria bloom to form.

There are a few reasons why three out of eleven water suppliers did not know about the activities occurring near their wells. One reason could be that the activities surrounding the water system are not potentially hazardous to the water quality. Another reason may be a general lack of communication with the surface water owners, as stated in Finding 10, as well as the residences and businesses that surround the water system.

CHAPTER 5: RECOMMENDATIONS

In this chapter, we present recommendations to public water suppliers in Massachusetts and to the MassDEP to assist both in preventing the contamination of public drinking water by cyanobacteria entering their GWUI wells. The following recommendations are based on the information presented in our Background chapter, our findings chapter, and other information obtained from our sponsor.

MASSACHUSETTS PUBLIC WATER SUPPLIERS

Recommendation 1: Public water suppliers with GWUI wells in their system should identify which surface water bodies are capable of influencing their wells.

Currently, public water suppliers are not required to determine which surface water bodies are capable of influencing their GWUI wells. When testing is done to determine groundwater's influence on wells, microparticulate analysis is performed to determine the presence of bioindicators that can occur in surface waters, as stated in the "Cyanobacteria Regulation" section of the Background. Nevertheless, establishing the connection between the actual surface water body and the GWUI is not part of testing.

Although the team created a list of surface water bodies that are near each GWUI well in the state of MA, we discovered through our interviews that this list did not always match the water bodies suppliers provided, as stated in Finding 9. Some potentially influential water bodies are too small to show up in the MassGIS database or were simply left out due to human error. These other water bodies should not be disregarded as they can still form blooms and contaminate a GWUI well.

To properly identify all potentially influential surface water bodies, public water suppliers should locate all surface water bodies within 150 feet of their GWUI well, the

same that is required by the state of MA when testing GWUI wells. Public water suppliers could use our list of all water bodies within a quarter mile developed through GIS, shown in Appendix C, as a reference; however, public water suppliers could complete this task more accurately, as our group was restricted to the use of MassGIS, which as stated in our discussion of Finding 9, has its limitations. Additionally, public water suppliers are more familiar with the physical area of their public water system than we were. Once these bodies are all identified, water suppliers should use this list to start identifying potential sources of contamination, as described in Recommendation 2.

Recommendation 2: Public water suppliers with GWUI wells should identify potential hazards to the surface water bodies that can influence their GWUI wells.

We found through interviews that eight of our eleven water suppliers were aware of the hazards that occurred within the domain of their systems, but the suppliers have not necessarily formally identified the hazards and developed ways to minimize the risks. Furthermore, there may be other water suppliers among the three in the state who are also unaware. By identifying the hazards, water suppliers would be in a better position to control inputs that cause blooms. For example, as described in Finding 11, two surface water bodies within these public water systems are adjacent to golf courses. Golf courses can use large amounts of fertilizer to maintain their grounds, which creates the potential to raise concentrations of nitrogen and phosphorus in the nearby surface water bodies through storm-water runoff. Nitrogen and phosphorus from fertilizer can trigger the formation of cyanobacteria blooms, as stated in the “Cyanobacteria Growth” section.

By making a comprehensive list of the potential risks to their water systems and then developing action plans to address these risks, public water suppliers could

minimize the potential for cyanobacteria blooms to form in the surface waters near GWUI wells, and by extent, reduce the chance of cyanobacteria contamination. Water suppliers could consult the MassDEP's Office of Research and Standards for assistance, which is responsible, in part, for ecological risk evaluation for the MassDEP (Rowan West & Smith, 2014).

Recommendation 3: Public water suppliers with GWUI wells should communicate regularly with those whose activities are determined to be a potential hazard to their surface water bodies.

Our third recommendation works in conjunction with Recommendation 2. By identifying the hazards surrounding their GWUI wells, water suppliers can start a conversation about improving protection of the wells. The MassDEP already provides a wealth of information to the public via the MassDEP website on how residents and businesses can adopt practices to prevent source water contamination. We recommend that the suppliers provide educational materials created by the MassDEP and encourage surrounding residences and businesses to report any problems they experience that may impact nearby surface water bodies. These actions can minimize risks in the area and raise awareness of cyanobacteria in public water systems.

However, facilitating sort of communication may prove to be more difficult in certain circumstances. For instance, one public water supplier stated that the stream that they believed to influence their GWUI well was close to a busy road. Runoff from paved road surfaces can prove harmful to surface water bodies. Since there is not a single party responsible for this risk source, public water suppliers would have to consider different approaches for managing it.

MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION

Recommendation 4: The MassDEP should continue to raise awareness of cyanobacteria among public water suppliers.

The eleven water suppliers we interviewed in this state appear to not be particularly concerned about cyanobacteria, as shown in Finding 6. Also concerning is the fact that two of the suppliers we interviewed believed that the treatments they already use, like copper sulfate, chlorine, or UV light, are effective in treating cyanobacteria. These treatments are sometimes worthwhile, but are not always reliable due to their limitations. For instance, copper sulfate, at certain quantities can prove harmful to human health, as described in our “Cyanobacteria Treatment and Prevention” section.

By raising awareness of the threat of cyanobacteria, the MassDEP can encourage its water suppliers to be properly prepared for the possibility of a cyanobacteria outbreak, which can help mitigate this issue before it becomes widespread. As stated in Finding 7, public water suppliers we interviewed appear to be receptive to learning about and addressing any potential threats to their public water supplies. We believe that the MassDEP is taking initiative by starting this project, as Massachusetts has had no recorded instances of cyanobacteria that affected their public drinking water (See Finding 5).

The MassDEP can raise awareness of cyanobacteria among water suppliers with GWUI wells through the distribution of informational materials. As part of our project we designed a fact sheet (Appendix D). The fact sheet describes what cyanobacteria are, how it may contaminate GWUI wells, and what actions suppliers may take to prevent contamination. Based on Finding 2, the topics we included on our informational materials

are mainly focused around specific actions the suppliers can take now to prevent cyanobacteria contamination in their drinking water, because we feel this will be the most useful to them. We did not feel it would be useful to the water suppliers to include explanations of techniques like sonication and vertical water mixers, as discussed in our background chapter, because public water suppliers cannot actually implement them yet. The fact sheet is currently under review by the director of the MassDEP's Drinking Water Program.

Informational materials, such as the fact sheet, should be distributed via email to water suppliers, as Finding 3 suggests and as our follow-up interviews with public water suppliers confirmed. The content of our informational materials is in alignment with the recommendations we made to public water suppliers in Recommendations 1-3.

On the national level, the MassDEP has raised awareness of the possibility of cyanobacteria contamination in GWUI wells through the surveys our group distributed through ASDWA. The MassDEP also appears to be taking initiative on this issue, as none of the respondents to our survey reported any instances of GWUI contamination by cyanobacteria, as shown in Finding 1. This could be because there were no instances or because of a lack of awareness of those instances. By continuing to raise awareness within its own state and within ASDWA, the MassDEP may encourage other states and water suppliers throughout the US to take steps to prevent cyanobacteria contamination in public water supplies.

Recommendation 5: The MassDEP should continue to investigate monitoring and treatment techniques for cyanobacteria through their Office of Research and Standards.

Through our background research and our discussions with our sponsor, Kathy Romero of the DEP, we determined that there are not currently any fully developed procedures to treat cyanobacteria or its derivative toxins. We believe it would be beneficial for the DEP's Office of Research and Standards, which is responsible for assessing risk to ecological and human health, to continue their development of these methods so that they may be implemented by water suppliers. Alternatively, this research and development could be conducted by a future project team from WPI as a part of an Interactive Qualifying Project or a Major Qualifying Project.

One challenge future researchers may face in developing these techniques is making them feasible for MA water suppliers to implement into their systems. Researchers should work to make these systems as cost-effective as possible, as the current perceived risk of cyanobacteria in MA among water suppliers is low, as stated in Finding 6. Thus, acquiring sufficient funding to implement measures to protect water from something that is not perceived as a relevant threat may be challenging.

Once researchers develop implementable treatment and monitoring techniques, we believe that the MassDEP should inform public water suppliers of them through email, as mentioned by 4 of our follow-up interviews with water suppliers, or through in-person trainings, as mentioned by one of our follow-up interviews. This step is important, as some suppliers believe that the treatments they already use are effective in treating cyanobacteria, as stated in Recommendation 4.

Recommendation 6: The MassDEP should work with water suppliers to conduct a study on cyanobacteria vulnerability in at-risk water systems.

Our third recommendation for the DEP is to conduct a study on cyanobacteria vulnerability in surface water bodies that influence GWUI wells. This study could involve the creation of a quantitative assessment of cyanobacteria contamination risk in water bodies. It would be useful to create a comprehensive list of the factors that make a water body more at risk and develop a scoring system that weights these factors and assigns a relative risk rating. For example, a water body that is generally stagnant and has several sources of runoff into it would be at high risk for contamination, and within this system, it would receive an appropriate numerical value to express this level of vulnerability. The DEP could contact the directors of other state drinking water programs through ASDWA and consult them on how to design this risk rating system, as they may have experience with designing such risk rating systems for other water quality issues.

Once this system is developed, the MassDEP can use the system to assess the risk of cyanobacteria contamination at surface water bodies that influence groundwater wells in the state. The MassDEP could conduct this study more easily if water suppliers have already identified the hazards to their surface water bodies, as suggested in Recommendation 2. This study could help the DEP determine which GWUI wells are most at risk for contamination and may require more attention when it comes to prevention efforts, and eventually the treatment techniques which are developed in Recommendation 5.

Recommendation 7: The MassDEP should create and distribute information on a uniform process for responding to cyanobacteria blooms.

As discussed in Finding 8, many water suppliers do not have a uniform procedure to address a cyanobacteria bloom in their water system. Although many of the suppliers knew to report a cyanobacteria bloom to the DEP, it would be ideal to provide actions for suppliers to take before contacting the DEP. These sorts of actions could include collecting samples of water for future testing or advising the water consumers to inform them if they have been having taste or odor issues with their drinking water. Despite the fact that eight of the states we surveyed reported that they do not test for cyanotoxins in their GWUI wells regularly, as shown in Finding 1, other states may already have uniform response processes in place and could help the MassDEP develop their own processes.

Some water suppliers may not see developing such a process as worthwhile due to the characteristics of the surface water bodies in their system. As stated in Finding 6, three of the suppliers we interviewed had rivers that could influence their water bodies and dismissed concerns of cyanobacteria forming in those rivers. These suppliers may not see the need to have a process like this in place, as they believed cyanobacteria was not a relevant threat to their public water system.

However, since most public water suppliers we interviewed expressed interest in being proactive on the issue of cyanobacteria, we believe public water suppliers would be appreciative of the MassDEP's guidance on this issue. Eight of the eleven public water suppliers we interviewed expressed interest in learning more about cyanobacteria, as shown in Finding 7. We also believe that public water suppliers whose water bodies are

deemed to be vulnerable to cyanobacteria contamination, as determined by the study described in Recommendation 6, would be receptive to guidance from the Department.

Once the DEP develops a uniform procedure for responding to a cyanobacteria bloom, they should consider utilizing email, paper mailings, and publishing information on their website, as these proved to be some of the most popular formats shown by our survey responses in Finding 3.

CONCLUSION

By completing our background research, distributing surveys to public water administrators via ASDWA, and conducting interviews with Massachusetts public water suppliers, we were able to develop informational materials in the format of a fact sheet for Massachusetts public water suppliers and the MassDEP. Educating public water suppliers, who are the first line of defense in the protection of public drinking water, is crucial as cyanobacteria blooms may one day pose a threat to Massachusetts. Informing this particular set of water suppliers who oversee GWUI wells is important because no states that responded to our survey have experience with this situation. An important initial action that these public water suppliers can take is to understand the contamination hazards that their public water system faces and to develop plans to mitigate these hazards, with which the MassDEP may be able to assist them. The purpose of our two deliverables, the well data spreadsheet and the fact sheet, is to educate the suppliers and provide them with the knowledge they need to prevent cyanobacteria contamination in their public water system.

We also provided the MassDEP and public water suppliers with a set of recommendations based on our findings from our surveys with public water administrators and our interviews with public water suppliers in Massachusetts. These recommendations may help the Department and the suppliers determine their course of action in combating the potential issue of cyanobacteria contamination. The majority of our recommendations suggest continued preventative action on the part of both suppliers and the MassDEP. Although few large scale cases of cyanobacteria contamination of drinking water have occurred in Massachusetts, or elsewhere in the United States, the

effects of climate change and increased pollution could lead to more frequent or severe toxic blooms. Given the public health consequences of cyanobacteria and its derivative toxins, it is important that the MassDEP persist in promoting readiness and prevention among water suppliers and water officials in other states. We believe that our informational materials, our findings, and our recommendations may help the MassDEP continue to take the initiative in preventing dangerous cyanobacteria blooms in public drinking water.

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APPENDIX A: ASDWA SURVEY QUESTIONS

Dear State Drinking Water Administrators:

Massachusetts Department of Environmental Protection (MassDEP) Drinking Water Program is working to identify and address informational needs regarding cyanobacteria contamination of drinking water drawn from wells under the influence of surface water. MassDEP is partnering with a group of students from Worcester Polytechnic Institute (WPI) to begin this project and would like to request the participation of State Drinking Water Administrators in the following survey.

The purpose of this survey is to gather more information on cyanobacteria through any relevant experiences other states have had with cyanobacteria outbreaks. This study is quite timely given the growing frequency and severity of cyanobacteria outbreaks and their impact on public health, especially in light of the recent events in Toledo, OH this past summer.

We plan to develop informational materials for public water suppliers in MA who oversee wells that are under the influence of surface water based on these responses. This study has been approved by MassDEP and the WPI's Internal Review Board and data collected will be kept confidential. At the conclusion of this survey, we will distribute the results to members of ASDWA by email. If you have any questions on this survey or information please contact Kathy Romero, MassDEP Drinking Water Program at 617-292-5727.

Thank you for your responses,

Kathleen Romero
Drinking Water Program MassDEP

&

Cara Berner
Deanna Clark
Samuel Flibbert
Kate Piotrowicz

The WPI Cyanobacteria Project Team

Attachment: Survey

**Massachusetts Department of Environmental Protection (MassDEP) Drinking
Water Program Cyanobacteria Contamination of Drinking Water Drawn From
Wells Under The Influence Of Surface Water Survey.**

Thank you for your participation in this survey. Please return the completed Form to:
Deanna.Clark@state.ma.us.

SURVEY QUESTIONS

1.
 - a Have any public water systems in your state had public wells that were affected by a toxic cyanobacteria bloom in the nearby surface water?
Yes No Don't know
 - b If yes, can you refer us to the public water suppliers that have been affected?
Please list multiple contacts if applicable.
Contact name:
Phone number:
Email address:
Public Water System:
 - c Please provide your contact information.
Respondent name:
Name of state:
Phone number:
Email address:
 - d May we contact you for more information if necessary?
Yes No
2. The MassDEP is planning to develop informational materials for public water suppliers with wells under the influence of surface water and for the owners of the surface water bodies.
 - a Which of the following topics pertaining to cyanobacteria would public water suppliers like to know more about?
 - i Prevention plans
 - ii Treatment plans
 - iii Biology of cyanobacteria
 - iv Cyanobacteria toxins
 - v Other:
 - b Through which of these formats would public water suppliers be interested in receiving educational materials on cyanobacteria? Please rank all that you believe they would be interested in from most interested (starting with the number 1) to least interested.
Newspaper:

Website:
Social Media:
Online Video:
Radio:
Television:
Mail:
Flyer:
Email:
Other:

Thank you for your participation in this survey. Please return the completed Form to:
Deanna.Clark@state.ma.us.

APPENDIX B: MASSACHUSETTS PUBLIC WATER SUPPLIERS' INTERVIEW

QUESTIONS

1. Do you believe that algae from nearby surface waters are impacting the water quality in your well(s)?
2.
 - a. Have you ever received complaints about taste or odor in your water?
 - b. If yes, did you discover what caused this?
3.
 - a. Do you know which surface waters have the potential to impact your well(s)?
 - b. If no, give them the bodies of water that are within $\frac{1}{4}$ miles of their well.
4. Do you know who owns or controls the surface water?
5. Do the surface water owners communicate if they have any water quality problems?
6. Do you communicate with that person or group about the issues at your well(s)?
7. How would you find out if there was a toxin algae bloom in the surface water that may impact your well(s)?
8. Are toxic algae blooms something you are concerned about in your Public Water System?
9. We are developing informational materials for public water suppliers? Which of the three of these types would you find most useful? (Mail, Flyer, Website)

APPENDIX C: WELL DATA SPREADSHEET

PWS NAME	SOURCE ID	WATER SOURCE 1	DISTANCE 1 (ft)	WATER SOURCE 2	DISTANCE 2 (ft)	WATER SOURCE 3	DISTANCE 3 (ft)	CONTACT INFORMATION: Phone
GUILDER HILLS WATER SYSTEM	1090008-01G	Fenton Brook	1,055.41					Richard Edwards, (917) 612-2858
PONDEROSA CAMPGROUND	1148018-01G	Daniels Brook	326.060145					Elaine Thomson, (413) 443-4200
CONNIES SILVERBROOK CAFE LLC	1260003-01G	Calm River	262.856381	Silver Brook	286.497427	Buck River	391.457366	Constance D Andreea, (413) 258-4597
1896 HOUSE POND/SIDE	1341011-01G	Hemlock Brook	422.821896					Suzanne Morelle, (413) 458-8125
1896 HOUSE BROOKSIDE	1341012-01G	Hemlock Brook	17.109127					Suzanne Morelle, (413) 458-8125
1896 HOUSE RESTAURANT	1341024-01G	Hemlock Brook	71.520133					Suzanne Morelle, (413) 458-8125
ACTON WATER SUPPLY DISTRICT	2002000-04G	Fort Pond Brook	312.731987					Christopher Allen, (978) 263-9107
ACTON WATER SUPPLY DISTRICT	2002000-09G	Butter Brook	92.742659					Christopher Allen, (978) 263-9107
ACTON WATER SUPPLY DISTRICT	2002000-10G	Butter Brook	592.461785					Christopher Allen, (978) 263-9107
ACTON WATER SUPPLY DISTRICT	2002000-11G	Butter Brook	653.673914					Christopher Allen, (978) 263-9107
ACTON WATER SUPPLY DISTRICT	2002000-12G	Butter Brook	624.822592					Christopher Allen, (978) 263-9107
ACTON WATER SUPPLY DISTRICT	2002000-13G	Butter Brook	536.144645					Christopher Allen, (978) 263-9107
SOUTH GRAFTON WATER DISTRICT	2110001-01G	Blackstone River	1,090.12					Steven Lemoine, (508) 839-0512
AQUARION WATER COMPANY MILLBURY	2186000-01G	Howe Pond	294.476491	Howe Reservoirs [E.B.]	1,103.05	Unnamed (Pond)	1,239.51	Michelle Desorcy, (508) 865-3998
WHITINSVILLE WATER COMPANY	2216000-02G	Cook Allen Brook	198.7797973	Reservoir No. 4	523.142215	Purgatory Brook	989.835183	Randy Swigor, (508) 234-7358
STURBRIDGE WATER DEPARTMENT	2287000-01G	Old Sturbridge Pond	541.015478	Quinebaug River	701.711208	Unnamed	77.089955	Shane Moody, (508) 347-2513
HOPEDALE WATER DEPARTMENT	2138000-04G PW	Mill River	237.277843					Timothy Watson, (508) 478-2080
HOPEDALE WATER DEPARTMENT	2138000-08G PW	Mill River	270.560045					Timothy Watson, (508) 478-2080
LECESTER WATER SUPPLY DISTRICT	2151000-07G	Not in Data						Roger Hammond, (508) 892-8484
WESTFORD WATER DEPARTMENT	3330000-07G	Stony Brook	758.152298					Stephen Cronin, (978) 692-5529
WESTFORD WATER DEPARTMENT	3330000-08G	Beaver Brook	454.833863					Stephen Cronin, (978) 692-5529
WILLINGTON WATER DEPT	3342000-05G	Lubbers Brook	271.137597	<null>	320.193959			Michael Woods, (978) 658-4711
DIGHTON WATER DISTRICT	4076000-04G	Segreganset River	102.560801					Charles Cestodio, (508) 824-9390
PLAINVILLE WATER DEPARTMENT	4238000-02G	Turnpike Lake	48.674606	Old Mill Brook	1,201.96			James Marshall, (508) 685-6871
SWANSEA WATER DISTRICT	4292000-08G	Cole River	71.694629					Robert Marquis, (508) 676-9097
WESTPORT HARBOR AQUEDUCT CO.	4334001-02G	Coddeast Pond	264.828405					Rick Blackall, (401) 829-8716

APPENDIX D: INFORMATIONAL MATERIAL



DRAFT

Cyanobacteria Contamination in GWUI Wells

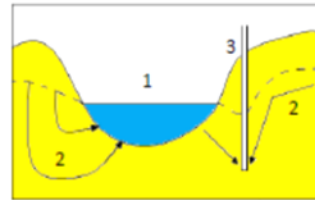
What is cyanobacteria and why is it harmful?

Cyanobacteria, or commonly known as blue-green algae, are naturally occurring organisms in most water bodies. When cyanobacteria cells proliferate, a bloom may form. Cyanobacteria are also capable of producing toxins that are released into water bodies when the cells die. If these toxins are consumed, they can have very serious health consequences.



How can cyanobacteria affect my GWUI well?

Ground water under the influence (GWUI) wells can be impacted by nearby surface water bodies. If a fissure develops in the underground sediment, it creates a hydraulic pathway that can allow cyanotoxin contaminated water to quickly flow into the well.



KEY: 1: surface water 2: groundwater flow 3: well

What can I do now to prevent contamination in my water supply?

Recommendations for treatment of cyanobacteria blooms are still being developed. However, there is a lot you can do as a public water supplier to prevent cyanobacteria contamination in your public wells. Below are tips on communication and prevention techniques you can use to help keep your water supply safe.

Communication	Prevention
<ul style="list-style-type: none">• Locate surface water bodies that may impact your wells• Actively communicate with those who oversee the surface water bodies that impact your wells	<ul style="list-style-type: none">• Identify conditions in these surface waters that promote cyanobacteria growth (Example: nitrogen and phosphorus runoff, lack of water flow)• Encourage nearby residents and businesses to use fertilizers and detergents less frequently or find low nitrogen and phosphorus alternatives• Monitor fertilizer and detergent runoff into surface water bodies that may impact your wells

For more information please visit <http://www.mass.gov/eea/agencies/massdep/water/drinking/source-water-protection-for-drinking-water-supplies.html#1>

APPENDIX E: PROCESS OF MICROPARTICULATE ANALYSIS IN MASSACHUSETTS

Microparticulate analysis tests are used to categorize wells as “groundwater-under-the-influence.” According to Frank Niles, the Groundwater-Under-the-Influence (GWUI) Coordinator for the MassDEP, the Department uses the certain bioindicators to test 100-gallon samples of untreated water. The number of particles for all of the bioindicators listed in Table 4 are counted in the 100 gallon samples, and depending on this number, the risk factor falls within the following ranges: not significant (NS), rare (R), moderate (M), heavy (H), and extremely heavy (EH). The MassDEP has assigned a relative risk rating, all of which may be seen in Table 2, to each of these ranges for each of these bioindicators. The sum of these ratings creates a relative risk value for a water body. A relative risk value below 9 indicates low risk of surface water contamination, a value between 10 and 19 indicates moderate risk, and a value greater than 20 indicates high risk. For example, if 8 particles of Giardia were found in a 100-gallon sample, this would fall within 6-15 in the M category. The risk factor value M for giardia is 25, which puts the surface water at high risk for contamination. This test is only required for wells within 150 feet of a surface water body.

Table 4

Numerical range of each primary bio-indicator (Particulate)

Indicators of surface water ¹	EH ³	H	M	R	NS
Giardia ²	>30	16-30	6-15	1-5	<1
Coccidia ²	>30	16-30	6-15	1-5	<1
Diatoms ⁴	>150	41-149	11-40	1-10	<1
Other Algae ⁴	>300	96-299	21-95	1-20	<1
Insects/Larvae	>100	31-99	16-30	1-15	<1
Rotifers	>150	61-149	21-60	1-20	<1
Plant Debris ⁴	>200	71-200	26-70	1-25	<1

Table 5

Relative Surface Water Risk Factors

Indicators of surface water ¹	Relative Risk Factor ³				
	EH ²	H	M	R	NS
Giardia	40	30	25	20	0
Coccidia	35	30	25	20	0
Diatoms	16	13	11	6	0
Other Algae	14	12	9	4	0
Insects/Larvae	9	7	5	3	0
Rotifers	4	3	2	1	0
Plant Debris	3	2	1	0	0

Refer to Table 1 for range of indicators counted per 100 gallons.

Key= EH – extremely heavy M – moderate NS – not significant
 H – heavy R – rare

Risk of surface water contamination

≥20 – high risk

10-19 – moderate risk

≤9 – low risk

Untreated well water samples go through two sets of microscopic particulate analysis (MPA) to be properly categorized, once in the fall and once in the spring

(MassDEP, 2009). If a sample receives a moderate or high risk rating in these first two samples, future testing must be conducted. If these future samples also register as moderate or high risk, the well is categorized as “GWUI” and is subject to the same treatment requirements as surface water.