Guidance for Local Public Health Agencies: Approaches to Addressing Lake Water Safety for Recreation after Flooding

This document summarizes information that local public health agencies should consider when deciding on an approach to assess or address water quality concerns at lakes or other water bodies affected by heavy rainfall or flooding. The information is separated into two sections: the factors influencing microbial risks in water bodies, and potential approaches for public health actions for water bodies affected by flooding.

Factors Influencing Microbial Risks in Water Bodies

Why are some lakes more susceptible to microbial hazards than others?

Microbial hazards are more of a problem in some lakes, and some parts of lakes, than in others.[1] Even under normal conditions, microbial hazard levels within different areas of the same lake will vary. For example, a shallow bay with aquatic vegetation or the area around a stream inlet is different from open deep water. The level of microbial hazard in a particular area (lake or location on a lake) is influenced by proximity of the location to known damaged sewage treatment plants, failed septic systems, and land use in the immediate surrounding areas (agricultural land and runoff vs. forested land).[2,3] The level of microbial hazard is also influenced by the density of potential sewage/septic influx in relation to size of water body (dilution effect).

Why might microbes get into lake water?

All lakes have some level of microbes at all times. Rainfall and flooding events can wash microbes from various sources into surface waters (Figure 1)[4]. This results in elevated counts of bacterial indicator species (or *indicators*) after a rainfall and increases one's chance of illness.

[1] P Jacob, A Henry, G Meheut et al. Health Risk Assessment Related To Waterborne Pathogens From The River To The Tap. *Int. J. Environ. Res. Public Health*. 2015. 12;2967-2983.
[2] Y. A. Pachepsky and D. R. Shelton. *Escherichia Coli* And Fecal Coliforms In Freshwater And Estuarine Sediments. *Critical Reviews In Environmental Science And Technology*, 41:1067–1110, 2011. p.1077
[3] P Jacob, A Henry, G Meheut et al. Health Risk Assessment Related To Waterborne Pathogens From The River To The Tap. *Int. J. Environ. Res. Public Health*. 2015. 12;2967-2983.
[4] M.N. Byappanahalli, M.B. Nevers, A. Korajkic et al. Enterococci in the Environment. *Microbiology and Molecular Biology Review*. Vol. 76; No. 4, 2011. p. 685–706.

Wildlife. Microbes from wildlife and bird feces can get washed into surface waters during rainfall and flood events. In addition, wildlife and birds visit lakes and introduce microbial contamination through feces all the time.

Runoff. Runoff can wash microbes from manure spread on agricultural fields and other sources into surface waters.

Point and Non-point Sources Due to Human Activity. Microbes can be introduced to a lake through point-source (one large source) and non-point source (several small sources) contamination. Contamination may affect only one part of the lake, the whole lake, or an entire lake chain depending on the pattern of water flow in the lake.

An example of point-source contamination is discharge of untreated wastewater into a lake from a damaged sewage treatment plant or damaged sewer line. Point-source contamination typically involves larger volumes of waste entering the environment from an industrial setting.

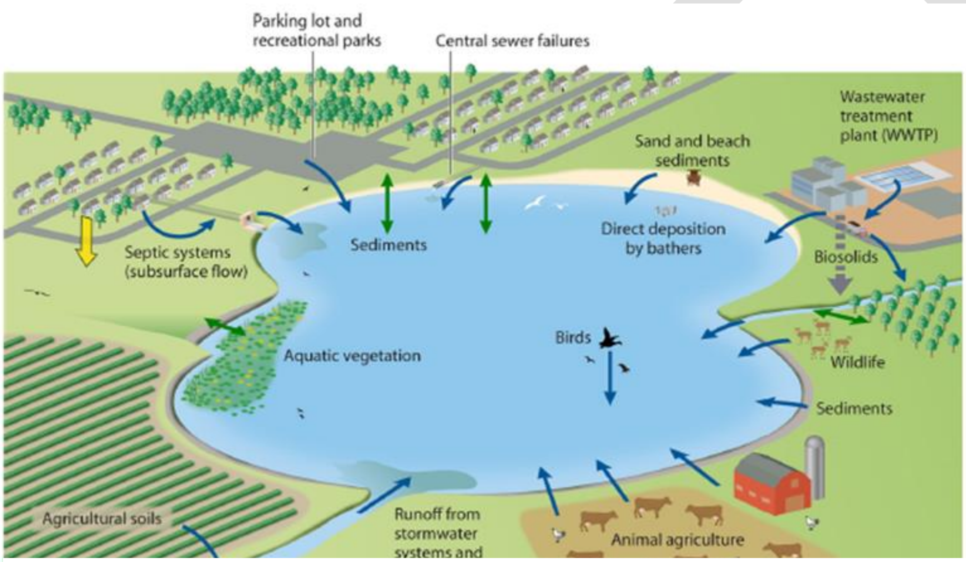

FIGURE 1: SOURCES OF ENTEROCOCCI IN WATER BODIES (BLUE ARROWS) AND AREAS OF FLUX BETWEEN A RESERVOIR AND THE WATER COLUMN (GREEN ARROWS)

An example of non-point source contamination is multiple poorly maintained or damaged private on-site wastewater systems (e.g., septic systems) around a lake, each leaking a small amount of wastewater into the lake.

Floods affect septic systems by interrupting the normal movement and filtration of wastewater as it travels from the septic tank through the leach field/drain field (figure 2) and down into the ground. A flooded drain field or leach field can cause sewage to back up into the house since the waste water is not able to filter downward through the soil like it normally does. This may cause pathogens to seep into surrounding floodwaters and surface waters. For recommendations on what homeowners can do to lessen the impact of a flooded septic system visit: https://www.ag.ndsu.edu/flood/media-resources/news-releases/during-the-flood/flooding-can-affect-septic-systems.

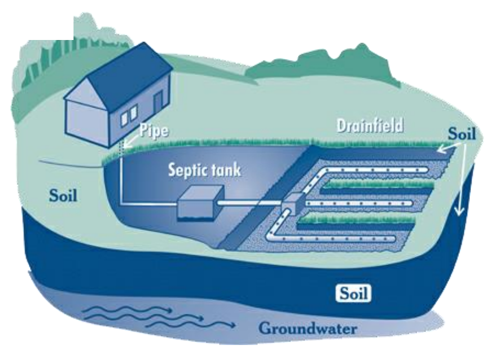

FIGURE 2: RESIDENTIAL SEPTIC SYSTEM AND DRAINFIELD

What factors affect how long microbes will survive in the water?

It is difficult to predict how long pathogens will be present in a body of water, as there are many factors that influence their survival.[5,6] In general, parasites survive the longest, followed by viruses, then bacteria.[7] Factors that influence their survival include:

Exposure to ultraviolet (UV) light. UV light from the sun inactivates pathogens over time, with parasites surviving the longest and bacteria surviving the shortest amount of time. The rate at which UV light inactivates pathogens depends on how far the light is able to penetrate the water column. Pathogens would be expected to be inactivated the fastest in clear, clean, shallow water because light can penetrate deeper into the lake. In cloudy water or deep waters, pathogens survive longer as they are out of the reach of sunlight.[8,9]

Runoff contains soil and debris that will increase the turbidity (reduced clarity) of lakes, which in turn reduces the ability of UV light to penetrate into the water column and inactivate pathogens. As a result, pathogen survival can be prolonged, particularly for pathogens deposited in deeper portions of a lake or in lake sediments.

Temperature. Pathogens survive longer in colder temperatures while warmer water temperatures can promote their inactivation.[10] For example, *E. coli* die-off is 1.7 to 3 times faster at 60°F than at 41°F.[11]

Deposition in Sediment. Pathogens can also be deposited in lake bottom sediment, which protects them from UV light and provides for colder temperatures, prolonging survival. These pathogens can be resuspended into the water column when the sediment is resuspended by the propeller action of boats in shallow water, foot action by bathers, or rough wave/wind action.[12] While this makes the pathogens available to cause infections again, it also reintroduces them to inactivation by UV light.

Inactivation by other Pathogens and Predators. Bacteria counts have been observed to drop faster over time when other pathogens are present in the water. This is thought to be due to competition for nutrients, predation, and other chemical/biological activity in the ecosystem.[13]

While some studies have looked at the survival of various pathogens in various water settings, there are no specific data for flood events. *E. coli* can survive in water for days to several weeks, depending on environmental

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[5] Y. A. Pachepsky and D. R. Shelton. *Escherichia Coli* And Fecal Coliforms In Freshwater And Estuarine Sediments. *Critical Reviews In Environmental Science And Technology*, 41:1067–1110, 2011. P. 1081

[6] M.N. Byappanahalli, M.B. Nevers, A. Korajkic et al. Enterococci in the Environment. *Microbiology and Molecular Biology Review*. Dec. 2012; Vol. 76; No. 4. p. 685–706.

[7] *G. J. Medema*, *M. Bahar*, *F. M. Schets*. Survival Of *Cryptosporidium Parvum*, *Escherichia Coli*, Faecal Enterococci And *Clostridium Perfringens* In River Water: Influence Of Temperature And Autochthonous Microorganisms. Water Science and Technology. Jun 1997. 35;11-12; 249-252.

[8] M.N. Byappanahalli, M.B. Nevers, A. Korajkic et al. Enterococci in the Environment. *Microbiology and Molecular Biology Review*. Dec. 2012; Vol. 76; No. 4. p. 685–706.

[9] F. Garcia-Pichel And B.M. Bebout. Penetration Of Ultraviolet Radiation Into Shallow Water Sediments: High Exposure For Photosynthetic Communities. Marine Ecology Progress Series. Vol. 131: 257-262, 1996.

[10] *G. J. Medema*, *M. Bahar*, *F. M. Schets*. Survival Of *Cryptosporidium Parvum*, *Escherichia Coli*, Faecal Enterococci And *Clostridium Perfringens* In River Water: Influence Of Temperature And Autochthonous Microorganisms. Water Science and Technology. Jun 1997. 35;11-12; 249-252.

[11] *G. J. Medema*, *M. Bahar*, *F. M. Schets*. Survival Of *Cryptosporidium Parvum*, *Escherichia Coli*, Faecal Enterococci And *Clostridium Perfringens* In River Water: Influence Of Temperature And Autochthonous Microorganisms. Water Science and Technology. Jun 1997. 35;11-12; 249-252.

[12] Y. A. Pachepsky and D. R. Shelton. *Escherichia Coli* And Fecal Coliforms In Freshwater And Estuarine Sediments. *Critical Reviews In Environmental Science And Technology*, 41:1067–1110, 2011. P. 1087

[13] *G. J. Medema*, *M. Bahar*, *F. M. Schets*. Survival Of *Cryptosporidium Parvum*, *Escherichia Coli*, Faecal Enterococci And *Clostridium Perfringens* In River Water: Influence Of Temperature And Autochthonous Microorganisms. Water Science and Technology. Jun 1997. 35;11-12; 249-252.

conditions.[14] Some beach monitoring programs have observed *E. coli* levels at a beach drop to safe levels within two to three days of a rainfall event.[15] Die-off rates for *Cryptosporidium* oocysts are approximately 10-fold lower than those of *E. coli* and Enterococci.[16] In vitro studies have demonstrated survival of *Cryptosporidium* oocysts in river water samples for almost six months.[17]

A key point to remember is that microbes were present in the lakes prior to the flooding and will always be present at some level.

Are microbe levels the same throughout a lake?

No. As microbes enter a water body with runoff, they don't stop moving. The movement of the water can continue to redistribute microbes as they remain suspended in the water column. Microbes are expected to settle out faster in calmer, more slow-moving shallow water bodies. Conversely, in areas where there is more velocity, a current, or increased wave or wind action, microbes are likely to stay suspended for a longer period of time and travel longer distances.

Once in a lake, there are a variety of factors that affect how microbes move through the lake, including:

- Wind/water action (prevents settling out and promotes resuspension).
- Water depth.
- Patterns of lake flow.
- Presence and velocity of a current.
- Rainfall and storms.
- The volume of water entering during flooding event.

Because of these factors, microbial hazards will not be spread uniformly throughout the lake, nor will the levels of microbes remain the same in any one place over time.[18]

Are there other concerns about biological hazards in flood-affected lakes?

Some species of blue-green algae can produce toxins which cause health effects in humans and animals. Although blue-green algae are naturally present in lakes, the likelihood of a harmful algal bloom occurring increases in flood-impacted waters.

Flooding and heavy rainfall events may wash additional nutrients into the lake and help resuspend nutrients deposited in the lake sediment. These nutrients act as fertilizer for the algae and blooms may form as water and

[14] *G. J. Medema*, *M. Bahar*, *F. M. Schets*. Survival Of *Cryptosporidium Parvum*, *Escherichia Coli*, Faecal Enterococci And *Clostridium Perfringens* In River Water: Influence Of Temperature And Autochthonous Microorganisms. Water Science and Technology. Jun 1997. 35;11-12; 249-252.

[15] Email from K. Sorsa, Public Health Madison & Dane County, Environmental Health, 7/26/2016.

[16] *G. J. Medema*, *M. Bahar*, *F. M. Schets*. Survival Of *Cryptosporidium Parvum*, *Escherichia Coli*, Faecal Enterococci And *Clostridium Perfringens* In River Water: Influence Of Temperature And Autochthonous Microorganisms. Water Science and Technology. Jun 1997. 35;11-12; 249-252.

[17] L. J. Robertson, A. T. Campbell, And H. V. Smith. Survival Of Cryptosporidium Parvum Oocysts Under Various Environmental Pressures. *Applied And Environmental Microbiology*, Nov. 1992, P. 3494-3500.

[18] Y. A. Pachepsky and D. R. Shelton. *Escherichia Coli* And Fecal Coliforms In Freshwater And Estuarine Sediments. *Critical Reviews In Environmental Science And Technology*, 41:1067–1110, 2011. P. 1093.

air temperatures rise and suspended sediment settles, particularly in shallow, slow-moving lakes. Because of this, blooms may occur weeks or months after a flooding event.

High densities of blue-green algae increase the likelihood of adverse health effects occurring after exposure. In areas where harmful algal blooms are uncommon, education should be provided to the public on the recognition of blooms and potential health effects of blue-green algae exposure. For more specific information on the health effects, bloom recognition, and how to report harmful algal bloom-related illness to the DPH Harmful Algal Blooms Program, visit https://www.dhs.wisconsin.gov/water/bg-algae/index.htm.

Approaches to Addressing Lake Water Safety for Recreation After Flooding

There are two main approaches a public health department can take when assessing risk and providing recommendations to the public:

1) testing recreational water to assess and/or demonstrate safety.
2) recognizing that after a flood, microbial risks will decrease over time, and offering recommendations based on what is known about the general behavior of microbial hazards over time.

The choice of which approach is most appropriate depends on the resources available and considerations such as the known size, depth, and health of the individual lake, and how much the lake is used for “wet” activities such as swimming and water sports. The tables on the following pages list pros and cons for each approach.

Approach #1: Testing Recreational Water to Assess Safety

Philosophy: By testing a sample of the water from a water body and measuring the amount of bacteria present, we can compare the result against established criteria to determine if it's safe to swim.

Pros

- Water testing is established practice and trusted by public
- Evidence-based (EPA)
- Indicators used (E. coli and Enterococci) reliably reflect pathogens present in human sewage

Cons

- There are limitations to the testing indicators:
  - Just because an indicator is absent or at safe levels, it does not necessarily mean other pathogens are also absent or at safe levels.
  - Although a positive indicator test suggests fecal contamination, it doesn't tell us what other fecal pathogens (e.g., *Cryptosporidium*, *Giardia*, viruses and various bacteria) may be present.
  - Testing for indicator bacteria will not tell you the source of pathogens (human vs. animal vs. environmental). More expensive, intensive testing is needed to determine this.
  - Parasites can survive for many days after the *E. coli* counts suggest the beach is safe again.
  - In a water body that is not routinely monitored, indicator bacteria test results will still not tell you if that contamination came from the flood or is the normal everyday state of the lake.
- It is impossible to test and declare an entire lake "safe."
  - Where routine monitoring is absent, a single sample is insufficient to evaluate risk. Multiple samples collected at regular intervals over a period of time from the same location are necessary to assess risk.
  - Results are specific to the beach/immediate area sampled and should not be generalized to an entire water body.
  - "Safe" test results can create a false sense of security and lead to poor swim hygiene.

Approach #2: Allowing Time for Hazard to Dissipate and Emphasizing Safe Swimming Habits
Philosophy: Pathogen levels are highest immediately after a flooding event and tend to decrease over time. Avoiding contact for a period of time allows the natural forces that inactivate pathogens to work. Combining this with qualitative evaluation of water conditions by the swimmer before swimming reduces their risk of illness.
Pros
• Allows for public health recommendations where testing is not logistically or economically feasible. • Encourages the public to evaluate lake water quality prior to using the water. • Can be applied more easily to water bodies because there is less work and cost.
Cons
• No analytical (quantitative) data are collected to help inform specific recommendations/advisories. • It is difficult to prescribe how long swimming should be avoided. • Recommendations may change based on additional rain events or floods. • Public may be uncomfortable with the lack of test results for the water body. • Public acceptance of this approach is highly dependent on effective risk communication, education, and outreach. • Risk is considered lower, but may not yet be "safe" according to EPA criteria. There are no guarantees.

Recommendations for Implementing Approaches 1 and 2

Approach #1: Testing Recreational Water to Assess Safety

Testing at public bathing beaches and boat launches, where the public is most likely to have contact with water and greater numbers of people can be exposed, should be prioritized. In public messaging, be sure to emphasize that even with testing, it is impossible to declare an entire lake "safe."

In areas where testing will be pursued, multiple repeated sampling events are required in order to interpret results for public health purposes. A single sampling event is not sufficient. This means that testing should happen in the same fashion for multiple consecutive days (at least three days, or weekly for multiple weeks) in the same area, and have safe results. For example:

- Test on three consecutive days (Monday, Tuesday, Wednesday). If all three results are safe, it's okay to swim. If one or more of the results is unsafe, keep testing on sequential days until three safe results are obtained. If the trend in results shows levels are wildly fluctuating, this suggests the lake is still being impacted. Waiting a week and testing the water again will help identify if there has been a significant decline in indicator levels. If results are much higher than the EPA criteria, this suggests you should wait a week or so before retesting the water. Testing on consecutive days when levels are extremely elevated will not be worth the effort.
- Test weekly for at least three weeks: in remote areas, it may be easier to test a water body once a week on the same day for at least three weeks to get a picture of the baseline water conditions and be able to see trends in microbe levels.

Samplers should be trained or experienced. The same sampling protocol should be followed for each sample. A video demonstrating proper beach water collection for *E. coli* testing can be found on the WSLH website at http://www.slh.wisc.edu/environmental/microbiology/.

Use the EPA Recreational Water criteria for *E. coli* (and/or Enterococci) to determine "safe" conditions. Additional information on the recreational water criteria can be found at:

- Wisconsin Beach Health Frequently Asked Questions - http://www.wibeaches.us/apex/f?p=181:5#standards
- Wisconsin DNR's document on Beach Monitoring Program Requirements. This document also includes information about starting a beach monitoring program, and when and how to test.
- Wisconsin State Laboratory of Hygiene's page on Water Microbiology Tests http://www.slh.wisc.edu/environmental/microbiology/.

Approach #2: Allowing Time for Hazard to Dissipate and Emphasizing Safe Swimming Habits

In public messaging, consider explaining this choice in the context of the limitations (cons) that go along with testing.

- **Use broad messaging**: Risk (and pathogen levels) is highest immediately after a flooding event and tends to decrease over time. Over time, sunlight and other natural forces kill germs in the water. Avoiding contact for a period of time allows the natural forces that inactivate pathogens to work, and combined with the qualitative evaluation of water conditions (see information provided below and on safe swimming pages for recommendations to include in messaging) by the swimmer before swimming, reduces one's risk of illness.
- **Consider how microbial hazards diminish after flooding:** Hazard dissipation can take different amounts of time for each lake. There is no universal "all clear" date, but the amount of time we expect it would take for levels to return to baseline may be estimated based on historical events, consideration of the factors that affect microbial survival, or testing of surrogate lakes or beaches.
- **Emphasize good swim hygiene:** This should be a priority. Educate the public on how to qualitatively evaluate water conditions (see Messaging, below) and offer tips to reduce risk. Mention alternatives to swimming that are lower risk.
    - *Evaluate water conditions before letting yourself, your family, or your pets enter.*
    - *Don't swallow lake water- don't even get it in your mouth. Avoid splashing/getting splashed. Don't submerge your head under water.*
    - *Supervise small children to make sure they don't drink lake water.*
    - *Don't swim with open wounds or shortly after surgery.*
    - *Don't swim while you have diarrhea.*
    - *Shower after swimming in any water body.*
    - *People with weakened immune systems, infants, and pregnant women should avoid swimming in untreated waters.*
    - *Should anyone develop signs of gastrointestinal illness (diarrhea, vomiting), wound infections, or skin rashes after swimming, they should contact their medical provider.*

Additional Healthy Swimming materials, including posters, pamphlets, tweets, and more can be found on DHS' website at https://www.dhs.wisconsin.gov/beaches/swimming.htm and the CDC's website at http://www.cdc.gov/healthywater/swimming/materials/index.html

- If homeowners or associations want more information about testing their lakes privately: explain the limitations of testing (and single sample testing) described above and provide contact information for nearby public health labs, if available, that run appropriate tests and explain which tests should be chosen. Offer interested parties the link to the WSLH sample collection demonstration video.[19]

Additional Alternative Strategies

In addition to the two strategies mentioned above, there are other alternative approaches that could be considered:

1. Test a few representative lakes (in size, depth, date and degree of impaction) in the affected area for multiple consecutive days or weeks and measure how long it takes to become "safe". Extrapolate the same likely schedule of sedimentation and inactivation to other similar lakes. As an example, during the flooding in 2008, beaches were closed in Dane County as the sewer district was forced to discharge raw sewage into Madison area lakes. *E. coli* levels returned to safe levels after three weeks.[20]
2. Test a few private drinking water wells around a lake and use the well testing results as a surrogate for testing the lake water. If a well is contaminated by flooding, lake water would also be contaminated, and the types and concentration of pathogens would be similar. Note that well depth and condition of the well (e.g., casing integrity) may affect results; a deep well with a completely intact casing would not be under the influence of surface water. A well that tests positive, which indicates surface water contamination and likely has a cracked or shallow casing, is a better surrogate for lake water testing.

Considerations for Public Messaging

People may be More Comfortable Assessing Hazards They Can See

Messaging regarding physical hazards (e.g., submerged vehicles, rocks, trees, debris), especially while boating, often relies on the individual to assess the risk. The public is often more comfortable assessing risk from hazards they can see. Asking people to assess microbial risk (which they can't see) requires the provision of additional information on what conditions/observations correspond to high microbial levels. While you can't tell exactly how safe a lake is just by looking at it, there are signs that suggest the water may not be safe for recreational activity:

- Recent rainfall or flooding event (increases runoff and/or septic leaching)
- Reduced water clarity (indicates suspended particles, dirt, debris, runoff recently introduced)
- Color changes (corresponds to runoff and/or presence of blue-green algal bloom)
- Higher than normal water level (indicates recent rainfall or flooding event)
- Abnormal odors

[19] Beach Water Collection for E. coli Testing (video). Available at http://www.slh.wisc.edu/environmental/microbiology/

[20] Email from Kirsti Sorsa, Public Health Madison & Dane County, Environmental Health 7/26/2016

Keep in mind that assessing departures from "normal" water conditions and/or return to "normal" conditions is going to be difficult or impossible for non-residents, vacationers, visitors, etc. Providing guidance on dangerous color, clarity, signs of harmful algal blooms, etc. will be essential for this population. Posting advisory signage with helpful pictures and educational messaging can help people evaluate water conditions themselves and can be posted long-term. DHS can assist with developing advisory language. For an example of a blue-green algae related advisory sign, visit https://www.dhs.wisconsin.gov/publications/p01082.pdf.

People Forget What It Was Like Before the Flood

Sometimes people forget that beaches and lakes may not have been routinely monitored in their county in the past, and expect monitoring to take place after a flood event. Suddenly, the level of water safety that was assumed by the public even without testing disappears after a flood. The inherent risk that comes with swimming in an untreated unmonitored natural water body is something people often overlook. It can be helpful to remind them that swimming in a lake is not like swimming in a chlorinated swimming pool (and even that's not always safe!) Lakes are open biological systems that interact with wildlife, weather, land, and humans, and it is always the responsibility of the swimmer to evaluate water conditions and use his/her best judgment when deciding to swim. By deciding to swim, he/she is always accepting a certain level of risk.

For More Information

Additional information on these topics can be found at:

- Beach Health: http://www.wibeaches.us/apex/f?p=BEACH:HOME
- Healthy Swimming Practices: http://www.cdc.gov/healthywater/swimming/materials/index.html
- Blue-Green Algae and Harmful Algal Blooms: https://www.dhs.wisconsin.gov/water/bg-algae/index.htm

If local public health agencies have additional questions about the information in this document, please contact the Bureau of Environmental and Occupational Health at 608-266-1120.