GRAYSON COUNTY, TEXAS

BLUE-GREEN ALGAE RESPONSE STRATEGY

Summer, 2012

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Grayson County, Texas
Health Department

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Executive Summary

Lake Texoma is an 89,000 acre reservoir that was impounded in 1944. It is managed by the Tulsa District of the US Army Corps of Engineers (TD-USACE). This reservoir is a long-established fishery for many popular game fish, including white and striped bass, largemouth and small mouth bass, and blue and channel catfish. In addition, Lake Texoma is a major tourist destination for activities such as swimming, sailing, power boating, yachting, camping, hiking, and birding. The USACE estimates that the number of annual visitors exceeds 7 million. The Lake Texoma Association or LTA (a non-profit association of Oklahoma and Texas businesses providing goods and services to Lake Texoma consumers) estimates the annual economic value of the lake to be in excess of $600 million.

During 2011, the TD-USACE implemented a program to sample several of the 34 Kansas, Oklahoma, and Texas lakes within its district for the presence of blue-green algae (aka cyanobacteria). The TD-USACE collected lake water samples from Texoma and tested the water for the types (known as genus) and the quantity (referred to as cell counts) of various blue-green algae (BGA) beginning in summer 2011. Prior to initiating the testing, the TD-USACE adopted a modified version of a State of Kansas BGA risk communication tool. The Kansas tool utilizes BGA cell count criteria found in a World Health Organization document written in 2003. During 2011, and as of the print date of this document, no BGA cell count or toxin limits have been adopted by the EPA, the Centers for Disease Control, the State of Texas, or the State of Oklahoma.

The TD-USACE's use of the modified Kansas public relations method resulted in the issuance of a risk level called "Advisory" throughout the summer of 2011 (due to cell counts being higher than 20,000 cells/ml but below 100,000 cells/ml). Two days before Labor Day weekend 2011, and based on Lake Texoma water samples tested in August, the TD-USACE raised its risk communication declaration to "Warning", the Corps' highest level.

After a thorough review of available worldwide cyanobacteria literature by the Environmental Health Division of the Grayson County Health Department (GCHD), the health department determined that the paradigm used to choose and implement the modified Kansas risk communication tool was fundamentally flawed. The TD-USACE's basic assumption that human morbidity (illness) and human and animal mortality (death) are caused by recreating in fresh water lakes containing high cell counts (over 20,000 cells/ml) is not adequately supported by the current body of knowledge of cyanobacteria in US lakes.

The GCHD's official position on the public health hazard posed by BGA blooms is that the potential for serious bodily injury stems almost exclusively with the accidental (or intentional) ingestion of untreated lake water with one or more of the four major BGA toxins (microcystin, cylindrospermopsin, anatoxin-a, or saxitoxin) present at levels capable of poisoning people or animals. It should be noted that the GCHD recognizes the rare potential for contact dermatitis (swimmer's itch) in persons recreating in fresh water with high BGA cell counts.

The purposes of Grayson County's Blue-Green Algae Response Strategy are to:

1. Minimize the probability of human illness or injury from recreational exposure to cyanobacteria cells and cyanotoxins
2. Minimize the probability of pet deaths from consumption of Lake Texoma water

3. Guide the Grayson County Health Department in the management of BGA in both Lake Texoma and, if warranted, in Lake Ray Roberts
4. Create and implement a state-of-the-science risk communication tool to provide accurate, timely, easy-to-understand information to persons recreating in Lake Texoma and to businesses dependent on Lake Texoma

The official GCHD BGA risk communication tool is included in Appendix 1. The first version, entitled "Data-Driven Decision", is expressly intended for use by the Environmental Health Division of the Health Department. There are three situational awareness charts (A-C) used in this "decision tree" or algorithm. After each calendar date on which lake water is collected and tested, health officials will answer whether each of the ten conditions exists. If all of the conditions in Chart A are met, the risk level in Lake Texoma will be a "No Blue-Green Algae Advisory". The color code will be "Condition Green". If water test results and/or public health or environmental conditions result in a "yes" answer to any of the eight conditions in Chart B, the GCHD will declare a risk level of "Blue-Green Algae Watch". The color code will be "Condition Yellow". Should test results or environmental public health data result in a "yes" answer to any of the conditions in Chart C, the Health Department will declare a "Blue-Green Algae Warning". Risk levels of Watch (yellow) or Warning (red) may only be downgraded when two consecutive water tests warrant a risk level downgrade (or when a public health condition, such as a suspected cluster of human illness, proves to be unrelated to exposure to lake water). The second version of the official risk tool (called the Public Information Version) will be provided to electronic and print media in the Texoma region, and placed on the Grayson County website. The most critical single criterion on which the GCHD's risk tool is based is the measured amount and types of cyanotoxins in Lake Texoma water. Because there are no federal government regulations or recommendations on the amount of BGA cell counts or the concentration of the four major toxin groups in recreational or public water source waters, the GCHD researched BGA response plans written and adopted by the states of Ohio, Indiana, Vermont, Oregon, and California. Each of these states' environmental protection, public health, and water resources agencies have done effective jobs of calculating specific, measurable criteria for answering the question "How much cyanobacteria and cyanotoxins is too much?" The state with the most advanced and thorough analysis of the public health implications of cyanobacteria in recreational lakes is Ohio. The GCHD is adopting algal toxin thresholds calculated and adopted by the State of Ohio.

The GCHD, due to its limited assets related to staffing, water sampling, water testing, and disease surveillance will collaborate with multiple agencies and private entities to successfully monitor BGA in Lake Texoma. The health department has created working relationships with the following entities for the effective implementation of this BGA Response Strategy:

- Tulsa District-US Army corps of Engineers
- Lake Texoma Association
- Texas Parks and Wildlife
- Grayson County Sheriff's Office
- Oklahoma University Biological Station
- Oklahoma State Department of Health
- Texas Tech's Institute of Environmental and Human health
- GreenWater Laboratories – Palatka, Florida
- US Fish & Wildlife Services (Hagerman)

In ensuing years, the GCHD will explore opportunities to collaborate with: Austin College; University of North Texas; Southeastern Oklahoma State University; Cooke County, Texas; Bryan and Marshall Counties, Oklahoma; Texas Department of State Health Services; US Centers for Disease Control.

Based on available staffing and funds, the GCHD intends to obtain Lake Texoma water samples twice each month from May through September and once each month from October through April. Water samples will be tested to ascertain the types and amounts of cyanobacteria present, and the concentrations (if any) of the four common cyanotoxins. If situational awareness (e.g. visible blooms and/or scum, reports of human, dog, or wildlife illnesses, suspicious fish kills) requires additional lake sampling, it is the intent of the Health Department to sample as needed.

In conclusion, the GCHD will be the lead governmental agency in monitoring and assessing the public health risks (if any) posed by the seasonal ebb and flow of blue-green algae populations in Lake Texoma (and possibly Lake Ray Roberts). As the worldwide body of scientific and public health knowledge about cyanobacteria and their toxins grows, this official BGA Response Strategy (and possibly the risk communication tool) will be revised and taken before the Grayson County Commissioners' Court for public discussion and action.

The overarching guiding principle for this, and all future BGA Response Strategies is to write, implement, and maintain a public health policy that 1) looks at the "big picture" of recreational water quality and 2) passes the test of common sense.

<u>**Definitions**</u>

1. Anatoxin-a: a nerve toxin produced by a number of cyanobacteria
2. Beach – area along the shore that is a designated swimming area and that is managed for public use
3. Bioassay – the exposure of sensitive test organisms to water samples to determine the presence of one or more unknown toxic elements or chemicals
4. Blue-green algae – primitive microscopic plants, also called cyanobacteria
5. BMAA – a Blue-Green Algae toxin: chemical name – Beta-N-methylamino-L-alanine
6. Confirmed case – a patient meeting the definition of a probable case AND who's morbidity has been declared consistent with BGA-associated illness by a physician
7. Contact recreation area – area of a lake where swimming, wading, diving, personal watercraft use, water skiing, tubing, wakeboarding, windsurfing, kite boarding, or any other in-water activity may occur that is likely to result in immersion or ingestion of water
8. Cyanobacteria – synonym for blue-green algae
9. Cyanotoxin – a toxin produced by cyanobacteria
10. Cylindrospermopsin – a general cell toxin produced by certain genera of cyanobacteria
11. Cylindrospermopsis- a filamentous cyanobacterium reported to produce saxitoxin, cylindrospermopsin, and BMAA
12. ELISA – Enzyme-Linked Immunosorbent Assay, a rapid assessment method commonly used to detect microcystins, cylindrospermopsin, and saxitoxin
13. EPA – the United States Environmental Protection Agency
14. Finished drinking water – treated water ready for human consumption (tap water)
15. HAB – harmful algal bloom. The rapid growth of one or more species of cyanobacteria in a manner which creates nuisances or potential health risks in recreational and source waters
16. Microcystin – a liver toxin produced by a number of cyanobacteria
17. Microcystis – a unicellular cyanobacterium reported to produce microcystins, anatoxin-a, and BMAA
18. PHAB – potentially-harmful algal bloom. A bloom event of a genus of cyanobacteria which has been known to create cyanotoxin.
19. Photic zone – the uppermost layer in a body of water into which light penetrates in sufficient amounts to influence living organisms, especially by permitting photosynthesis
20. Probable case – a patient meeting the definition of a suspect case AND there is a laboratory documentation of an elevated BGA toxin in lake water
21. PWS – public water supply; a governmental entity which treats source water to create finished drinking water
22. Risk communication tool – a public information document consisting of text and graphics designed to convey to the public the relative risk of a specific activity
23. Saxitoxin – a nerve toxin produced by a number of cyanobacteria (the cause of Paralytic Shellfish Poisoning in humans)
24. Scum – a cyanobacteria bloom that has a dense surface accumulation (e.g. floating mats) of cyanobacterial cells
25. Source water – water used as a source of public drinking water
26. Suspect case – a patient with symptomology consistent with BGA-associated illness AND with exposure to a lake with a confirmed BGA bloom AND without identification of another plausible cause of illness
27. TCEQ – Texas Commission on Environmental Quality
28. TDSHS – Texas Department of State Health Services

29. TPWD – Texas Parks and Wildlife Department
30. Toxicity test – a water analysis method designed to detect the presence, absence, and relative level of toxicity present in water or wastewater

Background

The GCHD became aware of a heightened level of public concern about blue-green algae (cyanobacteria) in Lake Texoma in the period after July 4, 2011. The Department began receiving calls from citizens in Grayson County and surrounding areas after one or more TV station stories aired about BGA's in the lake. Health Department employees researched the news stories and discovered that the Tulsa District of the US Army Corps of Engineers (TD-USACE) had initiated a water testing program in several Kansas, Oklahoma, and Texas reservoirs to determine the amount and types of BGA's present. Officials with TD-USACE described their water sampling efforts in Lake Texoma and informed GCHD that the Corps had chosen a public information advisory system developed by the State of Kansas. This advisory system (aka Risk Communication Tool) was based on a single water test which measures the particular species mix of cyanobacteria in recreational waters and estimates the cell densities (cells per ml of water) of predominant species. Corps officials described a water sampling protocol in which eight standard monitoring sites were sampled once per month. After TD-USACE technical staff members receive cell count data, they use World Health Organization (WHO) criteria adopted in 2003. The Corps declares a Risk Communication level of "Advisory" when BGA cell counts (when any of the 8 sampling sites) equal or exceed 20,000 cells/ml, but are below 100,000 cells per ml (see Appendix II).

During the summer of 2011, the Corps left the risk level at Advisory. When water samples showed cell counts exceeded 100,000 in August (approximately 2 days prior to Labor Day weekend), the TD-USACE raised its risk level to "Warning", the highest risk used by the Corps.

Introduction

Blue-green algae are primitive microscopic plants which exist in almost all aquatic (fresh water) bodies worldwide, as well as in many marine (salt water) environments. As of this writing, there are approximately 2,000 known species of BGA (also known as cyanobacteria), with approximately 90 species known or suspected to be toxigenic. Blue-green algae are an essential and generally beneficial component of complex aquatic and marine ecosystems (Hudnell, 2008) (PBSJ, 2006).

At various times during each season, highly specific (but poorly understood) water chemistry, plankton ecology, and water temperature conditions combine to promote sudden, rapid growth rates of one or more BGA's. These rapid growth events are generally referred to as algal "blooms". During a bloom, cell densities can increase from a few dozen cells/ml to several million cells per ml, at times in under 24 hours. BGA blooms are often highly visible events in lakes and ponds. Blooms beneath the water surface often create discoloration of large surface areas. Colors can be various shades of blue, green, white, or pink. Some types of BGA, during bloom events, create floating mats, typically referred to as scum. Scum formation during severe blooms can cover 100 percent of the surface of a lake's coves and protected areas, and in rare instances, can extend over most of a lake's main water body. Another visible form of floating BGA blooms is surface "foam". These foams are often blown against shorelines, or seen in quiet coves or marinas.

Although cyanobacteria are critically-important components of aquatic and marine food webs, heavy blooms of this group of algae routinely create adverse events affecting the natural and built environments. Large blooms sometimes cause rapid depletion of dissolved oxygen (DO) in specific portions of lakes, resulting in localized fish kills. The high organic load produced during blooms can create difficulties for Public Water Supplies (PWS's). When water treatment plants add chlorine to disinfect drinking water, high organic loading can lead to formation of THM's (trihalomethanes), a potential human carcinogen. Several species of cyanobacteria produce natural molecules which cause taste and odor problems in finished drinking water. These same compounds can create odor nuisances on and near the lake, and can cause taste problems with cooked fish.

A critically-important aspect of BGA's in recreational waters and waters used as public drinking water supplies is their ability to produce bioactive compounds. Some genera of cyanobacteria (e.g. Microcystis, Cylindrospermopsis, Anabaena, and Aphanazominon) are, under certain ecological conditions, capable of synthesizing one or more of the following classes of toxins:

A. Microcystins – liver toxins; more than 60 distinct variants of the same basic molecule
B. Cylindrospermopsis – general cell toxin
C. Anatoxin-a – nerve toxin
D. Saxitoxin – nerve toxin

It is important to note that only certain species of BGA have the capability of producing one or more of these four toxin classes (known as cyanotoxic species). Perhaps more important is the fact that these bioactive molecules are only produced by cyanotoxic species (e.g. Cylindrospermopsis) if the gene or genes that code for the molecules' synthesis is activated ("turned on"). It is common for a cyanotoxic BGA to bloom (with cell densities exceeding 1 million cells/ml), die off, and sink into the sediment without ever producing toxin. Conversely, a BGA species can bloom and release cyanotoxins in concentrations exceeding several hundred micrograms/liter (parts per billion). Currently available scientific literature reveals that there is no apparent correlation between cyanotoxic cell densities and the presence and/or concentration of BGA toxins. Stated another way, the assumption that higher cell counts of a toxigenic BGA genus produce higher amounts of cyanotoxins is not supported by studies to date.

An additional concept of great importance to BGA response and public policy is the difference between toxins held inside an algal cell (intracellular) and toxins dissolved in the lake water surrounding algal cells (extracellular). A heavy BGA bloom could occur on a Monday, with cell counts exceeding one million, and total toxin concentration (amount of toxin inside algal cells plus amount dissolved in lake water outside the cells) exceeding 100 ppb. By Tuesday morning, a person could collect a water sample to be analyzed for cell count and toxin concentration, and receive test results a few days later showing very low cell counts (the bloom died off and either sank to the bottom or floated to surface and drifted away) and toxins approaching 100 parts per billion. Private and governmental laboratories generally report toxin concentrations as "total". Lake water samples with BGA cells are treated using a technique to "lyse" or break apart all algal cells, thereby forcing the release of any intracellular toxins. In this manner, lake managers, environmental agency staff, or public health officials possess "worst case" toxin data. Lysing techniques include: Three freeze/thaw cycles; or, use of ultrasonic energy (sonication) to break the cells apart prior to toxin testing. For an agency to differentiate the difference between the amount of toxin (e.g. microcystin) existing as intracellular versus extracellular toxin, the agency would double its lab costs. The lab chemist would filter all solids out of a lake water sample and test the filtered water (reported as extracellular or "free toxin"), then lyse the filtered algae and perform a second test for intracellular toxin. The lab or the submitting agency could then add the intracellular and extracellular concentrations to arrive at a total toxin value.

How Much is Too Much?

One of the major challenges facing state and local government agencies in the US (which are faced with managing BGA blooms in local lakes), is a total absence of federal agency numerical limits on either the allowable maximum cell counts in recreational waters or PWS lakes, or numerical limits on any of the four most common classes of toxins in lake water. With respect to Lake Texoma, as of early May, 2012, the following statements apply:

A. The US EPA has not promulgated any standards related to cyanobacterial cell counts or toxin concentrations
B. The Texas Parks & Wildlife Department does not sample Texas lakes for BGA; however, when investigating fish kills, the department includes the analysis of BGA toxins in water samples to ascertain whether BGA toxins contributed to fish mortality
C. The Texas Department of State Health Services has no standards for the concentration of cyanotoxins in recreational water, drinking water, or edible portions of fish tissue
D. The Texas Commission on Environmental Quality does not test Texas lakes for BGA's; however, it may analyze water for BGA toxins when investigating fish kills
E. No Oklahoma state agencies have promulgated cell count or toxin concentration limits for recreational water, PWS, or edible portions of fish tissue

The TD-USACE, in the summer of 2011, made a policy of using a BGA response plan and risk-communication tool written by the Kansas Department of Health and Environment (KDHE). This policy uses a single water test parameter (BGA cell count) and is derived from a World Health Organization (WHO) document from 2003 entitled "Guidelines for Safe Practice in Managing Recreational Waters".

After extensive review of available scientific and regulatory agency literature on cyanobacteria, the GCHD takes the official position that <u>cyanobacterial cell densities (cell counts), when considered alone and in the absence of toxin levels and recent epidemiologic data, are an ineffective and misleading measure of the relative risk of human and animal morbidity (illness) or mortality (death).</u>

Prior to a discussion of the potential of human (or pet/wildlife) illness, injury, or death after exposure to lakes or ponds experiencing BGA blooms, a brief synopsis of some basic toxicology concepts is needed. The famous quote from Paracelsus "All things are poisons, for there is nothing without poisonous qualities. It is only the dose which makes a poison", is worth noting. With respect to any known toxin, the toxin must have a method or "route" of entering the body of a person or animal before creating an adverse health effect. The three routes of exposure for any poison are: Inhalation (breathed into lungs); Ingestion (swallowed into stomach); or Absorption (penetrating the skin and being absorbed into the blood).

Inhalation of lake water (containing algal toxins) occurs when swimming or boating. Microscopic droplets of lake water, suspended in the air above the lake (called microaerosols and needing to be in the "respirable range" of 1-10 microns in diameter), are breathed deep into the lung. In theory, tiny droplets released into the air by wind, waves, and boating activities could contain BGA cells and/or BGA toxins. As microscopic water droplets are absorbed into a person's air sacs (alveoli), in theory BGA toxins could enter the blood stream. Preliminary field studies by the CDC (studies performed in California) indicate that inhalation of microaerosols while recreating in a lake with elevated BGA toxins <u>may not be</u> a viable health risk for exposure to BGA toxins (Backer, et.al. 2010)

Skin absorption is another theoretical exposure route for algal toxins. At the present time, there is insufficient evidence to indicate whether people or pets have experienced systemic poisoning by absorbing algal toxins through skin or mucous membranes. A more common health risk involving BGA's and skin relates to documented cases of skin rash (similar to "Swimmer's Itch"), burning and itching skin, and burning sensations of the eyes and lips when swimming in lakes, (or walking along shorelines) experiencing BGA blooms.

Persons swimming in public reservoirs in Nebraska, Ohio, and northeastern Oklahoma during algal blooms have reported skin and even gastrointestinal (GI) symptoms (nausea, vomiting). During one bloom in Grand Lake (OK) in the summer of 2011, over 40 persons self-reported one or more of these symptoms to the state health department (Grand Lake officials, during a peak bloom event, found the toxin microcystin at 358 ppb).

Ingestion is probably the most significant potential route of exposure to algal toxins. Persons or pets (e.g. dogs accompanying owners to lake shore) who swallow significant amounts of lake water containing elevated levels of one or more BGA toxins could be injured if the dose of toxin is sufficient to harm nerves or internal organs (e.g. liver or kidney damage). Although there is not a single case of a person being killed in the US after intentional or accidental ingestion of BGA-infested lake or pond water, there are several reports of dog and livestock deaths attributed to BGA toxins. Several dog deaths have been reported (and later confirmed to be caused by ingestion of algal toxin) in Nebraska, Ohio, and California. During BGA blooms that float to the water's surface, thick algal scums can form. It is not uncommon for scum to contain cyanotoxins. If dogs are allowed to swim in scum-covered lake coves or other shoreline areas (and if the BGA species has produced cyanotoxins), the dog may drink large quantities of water and may exit the water with algal scum on its fur. Several dog deaths have been reported to occur within less than an hour after dog was observed self-grooming (licking) the scum from its fur. Post-mortems (called autopsies in people and necropsies in animals) for some of the dogs after drinking scum-covered pond or lake water revealed acute liver damage (usually linked to elevated concentrations of either microcystin or anatoxin-a).

In order for a person (adult or child) to ingest a dose of one of the four classes of BGA toxins sufficient to cause acute (short term or immediate) poisoning, relatively large amounts of lake water would have to be swallowed. Table I and II below show the quantity of lake water which would have to be swallowed for a 150-pound adult or a 40-pound child to receive a lethal or near-lethal dose. The tables also show the quantity of lake water that would have to be ingested by 80-pound dog or a 10-pound dog to receive a lethal or near-lethal dose.

Table I

Quantity of Lake Water Ingested to Receive a Potentially Lethal Dose of Microcystin, Assuming that Mouse and Human Toxic Responses are Equivalent

20 ppb Microcystin in Lake Water

	Gallons of Water	*Pounds of Water*
40 pound human	10.79	90.04
150 pound human	40.45	337.56

Quantity of Lake Water Ingested to Receive a Potentially Lethal Dose of Microcystin, Assuming that Mouse and Human Toxic Responses are Equivalent

(at actual concentrations found in Grand Lake, Oklahoma in June, 2011)

Highest measured concentration of Microcystin was 358 ppb

	Gallons of Water	*Pounds of Water*
40 pound human	.60	5.03
150 pound human	2.26	18.86

Quantity of Lake Water Ingested to Receive a Potentially Lethal Dose of Microcystin, Assuming that Mouse and Dog Toxic Responses are Equivalent
20 ppb Microcystin in Lake Water

	Gallons of Water	*Pounds of Water*
10 pound dog	2.70	22.50
80 pound dog	21.57	180.00

Quantity of Lake Water Ingested to Receive a Potentially Lethal Dose of Microcystin, Assuming that Mouse and Dog Toxic Responses are Equivalent
(at actual concentrations found in Grand Lake, Oklahoma in June, 2011)
Highest measured concentration of Microcystin was 358 ppb

	Gallons of Water	*Pounds of Water*
10 pound dog	.15 (19.3 ounces)	1.26
80 pound dog	1.21	10.06

*** This is not including additional dose amounts that could be ingested from a dog self grooming algae scum off its fur.**
**** LD50 for Microcystin- mouse used in Calculations = 45 mcg/kg**
***** 20 ppb Microcystin is algal toxin threshold for BGA Warning (condition red)**

Table II

Quantity of Lake Water Ingested to Receive a Potentially Lethal Dose of Cylindrospermopsin, Assuming that Mouse and Human Toxic Responses are Equivalent
20 ppb Cylindrospermopsin in Lake Water

	Gallons of Water	*Pounds of Water*
40 pound human	1054	8800
150 pound human	3955	33002

Quantity of Lake Water Ingested to Receive a Potentially Lethal Dose of Cylindrospermopsin, Assuming that Mouse and Dog Toxic Responses are Equivalent
20 ppb Cylindrospermopsin in Lake Water

	Gallons of Water	*Pounds of Water*
10 pound dog	263	2200
80 pound dog	2109	17601

*** This is not including additional dose amounts that could be ingested from a dog self grooming algae scum off its fur.**
**** LD50 for Cylindrospermopsin- mouse used in Calculations = 4400 mcg/kg**
***** 20 ppb Cylindrospermopsin is algal toxin threshold for BGA Warning (condition red)**

Public health officials, environmental agency officials, and lake managers have a responsibility to warn lake users of not only conditions which could cause acute hazards, but of water conditions in which accidental swallowing could result in chronic, subtle, long-term organ or tissue injury. For that reason (protection from both chronic or acute health hazards), the GCHD has chosen algal toxin thresholds calculated and adopted by the State of Ohio (see Table III). The algal toxin thresholds adopted by the

State of Ohio are established at concentrations thought to be at least 100 times more protective than necessary (a built-in safety and uncertainty factor).

The GCHD recognizes the relatively high animal and human toxicity posed by the four common types of BGA toxins. Appendix III summarizes documented instances of algal toxins, during extremely rare and unusual BGA blooms, in which people and/or livestock or pets were injured or killed. The Health Department also wishes to emphasize that the rare, highly-unusual water conditions or human mistakes which led to these sometimes spectacular incidents may seldom, if ever occur in Lake Texoma or surrounding lakes.

Use of BGA Risk Communication Tools

Basis of Tool

The GCHD has studied the topic of BGA in US recreational waters from August, 2011 through May, 2012. Based on the most current scientific and regulatory agency data and recommendations available, the Health Department has created a three-level risk communication tool, and has developed two versions of the same tool. The two versions (attached as Appendix I), are labeled as: 1) the Data-Driven Decision version; or, 2) the Public Information version.

This new risk communication tool is holistic in its concept. Rather than being based on a single water test result (like BGA cell count or BGA toxin results), it requires the Health Department to look at the "Big Picture". Approximately twice each month (more often if water quality or epidemiologic conditions change) the Environmental Health Division of the GCHD will use the Data-Driven Decision version of the Tool, and answer questions or describe conditions described in charts A, B, and C. The three BGA "situational awareness" charts guide Environmental Health scientists to assess available data and information concerning:

- Recent water tests for BGA cell counts and algal types
- Recent water tests for BGA toxins
- Reports of fish kills
- Reports of dog or livestock deaths
- Reports of wildlife deaths near Texoma shoreline
- Human illness linked to lake water exposure
- Recent toxicity tests (Microtox instrument or bioassays)
- Recent reports of BGA scum or other visible evidence of blooms

The Data-Driven Decision version of the BGA communication tool serves as an algorithm, or decision-tree to guide Health Department staff to one of the three advisory levels including:

No BGA Advisory
BGA Watch
BGA Warning

The concept of the GCHD's new public information and education technique is borrowed from the National Weather Service's severe thunderstorm and tornado advisory system. Most Americans instantly recognize that the term "Tornado Watch" means that weather conditions exist which are favorable for the formation of a tornado. Likewise, citizens know that when weather reports on radio or TV state that their community is under a “Tornado Warning”, that a tornado has been spotted, and confirmed by official storm spotters.

Under this BGA tool, when conditions meet “Chart A”, an official communication will be posted showing a “No Blue-Green Algae Advisory”. The signage will be colored green and will be described as “condition green”. Verbiage on the No Advisory signage will communicate that all forms of lake recreation are encouraged.

When any conditions listed in Chart B exist, the risk level will be increased to condition yellow, a Blue-Green Algae Watch. Public information contained on signage and websites will emphasize that boating, fishing, and swimming are allowed, and that fish are safe to consume. Lake patrons will be advised to be observant for surface scum or discolored water, and encouraged to provide safe drinking water for dogs.

If any condition listed on Chart C is documented, the risk level will move to Grayson County’s highest level (a BGA Warning or Condition Red). Public information contained on signage and websites will emphasize that boating and fishing are allowed and fish are safe to eat; however, warning language will state that swimming and wading are prohibited, that dogs must be prevented from swimming in or drinking lake water, and that “in-water” use of personal watercraft, kayaks, canoes, and wind surfing equipment is strongly discouraged.

When either a BGA Watch or Warning risk level is declared, the risk level will not be downgraded one level (e.g. Warning to Watch or Watch to No Advisory) until two consecutive lake sampling events (on different calendar dates) reveal toxin concentrations which warrant the downgrade.

The GCHD reserves the right to revise and upgrade the Risk Communication Tool as the body of knowledge regarding the public health implications of cyanobacteria expands.

Algal Toxin Thresholds (from State of Ohio)

The GCHD has carefully reviewed the cyanotoxin thresholds and guidelines adopted by states such as California, Oregon, Indiana, Vermont, and Ohio. The state which appears to have devoted the largest amount of assets and time to create a state-of-the-science BGA Response Plan is Ohio; therefore, the algal toxin thresholds or “trigger points” developed by Ohio’s public health and environmental protection subject matter experts are hereby adopted by the GCHD. Each of the four most common BGA toxins is discussed below:

Toxicity Review

Toxicity values for microcystin, anatoxin-a, cylindrospermopsin, and saxitoxin were selected for the establishment of recreational and drinking water thresholds. The toxicity values are referred to as either “reference doses (RfDs)” or “tolerable daily intakes (TDIs)”. Either one is intended to represent a “safe” dose for humans, below which no toxic effect is to be expected. The values are expressed in milligrams per kilogram body weight per day (mg/kg-day). Both RfDs and TDIs include safety factors of between 3 and 3000, depending on the number, variety, and quality of the available studies. The values are derived to account for varying lengths of exposure to the toxins, including an acute exposure, which can be as short as one day, a short-term exposure, a subchronic exposure, and a chronic (or lifetime) exposure. Not all toxins have all four exposure lengths assessed, depending on the toxin-specific data available specific to the toxin.

Anatoxin-a

U.S. EPA's draft toxicological review of anatoxin-a from 2006 was used as the basis for the toxin thresholds presented here. Although the document was draft at the time of the threshold development, it contained the most recent, relevant, and well-reviewed studies available for anatoxin-a. Short-term and subchronic reference doses (RfDs) are given in the review. U.S. EPA determined that data were inadequate to develop acute or chronic RfDs. After considering both the short-term and subchronic RfDs, the committee decided to use the subchronic RfD to develop toxin thresholds. The committee's rationale for this decision was that the thresholds developed using the subchronic RfD were closest to the thresholds for anatoxin-a in use by other states and organizations (e.g., California, Washington). The subchronic RfD is from a 7 week rat drinking water study, and is 0.0005 mg/kg-day based on systemic toxicity, which includes an uncertainty factor of 1000. The uncertainty factor includes a factor of 10 for rat to human variability, 10 for variability among humans, and 10 for database deficiencies, including limitations within the study used as the basis for the RfD, lack of reproductive studies, and lack of toxicity testing in a second species.

Cylindrospermopsin

U.S. EPA's draft toxicological review of cylindrospermopsin from 2006 was used as the basis for the toxin thresholds presented here. Although the document was draft at the time of the threshold development, it contained the most recent, relevant, and well-reviewed studies available for cylindrospermopsin. The only RfD developed for cylindrospermopsin is for subchronic exposures, based on an 11 week mouse study. The RfD is 0.00003 mg/kg-day based on increased kidney weight, which includes an uncertainty factor of 1000. The uncertainty factor includes a factor of 10 for mouse to human variability, 10 for variability among humans, and 10 for database deficiencies, including a lack of a chronic study, lack of a study in second species, and the lack of reproductive or developmental studies.

Microcystins

The committee reviewed both U.S. EPA's 2006 draft toxicological review of microcystin LR, RR, YR, and LA, as well as the World Health Organization's (WHO) 2003 microcystin-LR in drinking water background document. The committee generally found the U.S. EPA toxicological review to be more recent and inclusive of available studies evaluating microcystin toxicity. However, the committee decided to use the WHO tolerable daily intake (TDI, similar to an RfD) instead of U.S. EPA's RfD for microcystin, owing to the widespread use and acceptance of the TDI by a variety of other governments and organizations evaluating algal toxin risks. The committee agreed that should U.S. EPA finalize its microcystin toxicological review, revisiting the microcystin threshold values would be appropriate.

The WHO TDI is 0.00004 mg/kg-day, derived from a 13-week mouse study. The basis for the TDI is liver pathology, and includes an uncertainty factor of 1000. The uncertainty factor includes a factor of 10 for mouse to human variability, 10 for variability among humans, and 10 for database deficiencies, including the lack of chronic data and carcinogenic studies.

Saxitoxin

Neither U.S. EPA nor WHO have, at the time of this report, issued an RfD or TDI for saxitoxin. To develop a saxitoxin guideline, the committee reviewed information in the Report of the Joint FAO/IOC/WHO ad hoc Expert Consultation on Biotoxins in Bivalve Molluscs from 2004, as well as a peer-reviewed paper by Galváo et al. 2009 in the journal Toxicon, Saxitoxins Accumulation in

Freshwater Tilapia (Oreochromis niloticus) for Human Consumption. The joint FAO/IOC/WHO report recommends an acute reference dose for saxitoxins of 0.0007 mg/kg-day, but does not establish a TDI. The report does not describe the toxicological basis for the recommended value.

The Galváo et al. paper states that "From available reports on exposure in humans, a lowest-observed-adverse-effect-level (LOAEL) in the region of 1.5 ug STXs/kg b.w. could be set, and an estimated no-observed-adverse-effect-level (NOAEL) of 0.5 ug STXs/kg b.w. was established. Thus the CONTAM panel has defined an acute reference dose (ARfD) of 0.5 ug STXs/kg b.w." The citation given in the Galváo paper is the European Food Safety Authority, 2009, Marine Biotoxins in Shellfish – Saxitoxin Group Scientific Opinion of the Panel on Contaminants in the Food Chain.

Using the WHO and U.S. EPA method of applying an uncertainty factor to the NOAEL to derive an RfD or TDI, the committee agreed to apply an uncertainty factor of 100 to the NOAEL-based ARfD, 10 for human variability and 10 for a lack of chronic, developmental, and reproductive studies. The resulting value for use in calculating a saxitoxin threshold is 0.000005 mg/kg-day.

Exposure Assumptions
Children were assumed to have a body weight of 15 kg, and adults were assumed to have a body weight of 60 kg, based on exposure assumptions from WHO Guidelines for Safe Recreations Water Environments, Volume 1, 2003. Recreational ingestion of water was assumed to be 0.1 liters per event for both children and adults. Children were assumed to drink 1 liter of water per day, and adults were assumed to drink 2 liters of water per day. Ingestion rates were taken from U.S. EPA's Exposure Factors Handbook, except for the 1 liter per day for children, which was taken from U.S. EPA's 2009 Edition of the Drinking Water Standards and Health Advisories.

Calculations
The basic calculation used in developing all thresholds is:

$$\text{Threshold} = \frac{\text{BW x TDI or RfD}}{\text{IR}} * \text{CF}$$

Where:
BW = Body weight in kg
TDI = Tolerable Daily Intake in mg/kg-day
RfD = Reference Dose in mg/kg-day
IR = Ingestion Rate in L/day
CF = Conversion Faction, 1000 µg/mg
Threshold given in µg/L

Numeric Thresholds

Table III

Threshold (µg/L)	Microcystin**	Anatoxin-a	Cylindrospermopsin	Saxitoxin**
Recreation – Public Health Advisory	6	80	5	0.8
Recreation* – No Contact Advisory	20	300	20	3

Drinking – Do Not Drink	1	20	1	0.2

*Recreation No Contact Advisory thresholds are also used as Drinking Do Not Use thresholds
** Microcystin and saxitoxin thresholds are intended to be applied to total concentrations of all reported congeners of those toxins.

Water Quality Monitoring

The topic of water quality monitoring in Lake Texoma is deceptively complex. Multiple federal, state, and local government agencies have, as a part of their mission, the responsibility to periodically collect lake water samples, then test said samples for specific properties (called parameters) that are of specific short and long-term interest to the agency collecting the samples. The TD-USACE regularly collects water samples to monitor the overall "health" of the lake. Some of this routine sampling is performed by biologists and technicians officed in the TD-USACE headquarters in Tulsa. At times, TD-USACE biologists and technicians officed at the Denison Dam Office collect lake water samples. The TD-USACE monitors for basic water chemistry and dissolved oxygen. In addition, the Corps tests water samples from eight official, standard sampling locations (shown in Table IV below) for the presence of BGA. These BGA samples are observed by a microscopist, who identifies specific cyanobacteria to genus (sometimes to species) and then estimates cell densities (aka cell counts) of each identified cyanobacterium.

Table IV
Lake Texoma Blue-Green Algae Sample Sites

1. Highway 377/Highway 99 Bridge
2. Eisenhower State Park - UNT-17
3. Johnson Creek
4. Lakeside PUA
5. Little Glasses Creek
6. Little Mineral Arm
7. Sheppard Annex
8. Treasure Island

The University of Oklahoma has, for many decades, managed and operated the Oklahoma University Biological Station (OUBS) on the northwestern shore of Lake Texoma. The OUBS is a state-of-the-science university aquatic research facility with an international reputation for scientific excellence. Under the leadership of Dr. Dave Hambright, the OUBS conducts year-round studies of Lake Texoma's fisheries, aquatic biology and ecology, and water chemistry. The OUBS has the capability to provide BGA cell counts, identification down to genus (and sometimes species), and BGA toxin analyses (using ELISA Kits for microcystin, cylindrospermopsin, and saxitoxin). The Oklahoma Division of Wildlife and Fisheries

(ODWF) performs some lake sampling activities, primarily aimed at monitoring the valuable gamefish populations in the lake. During the first half of 2012, the GCHD began shipping water samples to two laboratories in an effort to obtain BGA identifications and cell counts, and to obtain data on the presence of the four major groups of BGA toxins. A summary of the results of GCHD's sampling efforts in 2012 is shown in Tables V and VI. Analytical results in February, March, and April show BGA cell counts dropping from the 20,000-40,000 cells/ml range to counts below 5,000 cells/ml. Cyanotoxin concentrations, analyzed by two separate laboratories (Texas Tech's Institute for Environmental and Human Health and GreenWater Laboratories in Florida), have failed to detect anatoxin-a, microcystin, or saxitoxin in February, March, and April. The toxin cylindrospermopsin has been found at ultra-trace levels (just above the method's detection limit of 0.1 parts per billion). Cylindrospermopsin concentrations have ranged from 0.1 ppb to 0.6 ppb. <u>This level of toxin has no public health significance in recreational waters.</u>

Table V
Texas Tech's Institute for Environmental and Human Health (IEHH)
Blue-Green Algae Test Results

Sample Date	Sample Site (Lake Texoma)	Toxin	Result
2/22/12	UNT	CYN	0.10 ppb
		MC	ND
	Little Mineral Arm	CYN	0.05ppb
		MC	ND
	Sheppard Annex	CYN	ND
		MC	ND
	Treasure Island	CYN	0.13 ppb
		MC	ND
03/28/12	377/99 Bridge	CYN	ND
		MC	ND
	Johnson Creek PUA	CYN	0.15 ppb
		MC	ND
	Lakeside PUA	CYN	0.19 ppb
		MC	ND
	Little Glasses	CYN	0.27 ppb
		MC	ND
	UNT 17	ANTX-A	ND
		CYN	0.25 ppb
		MC	ND
		STX	ND BRL
	Eisenhower Swim Beach	ANTX-A	ND
		CYN	0.19 ppb
		MC	ND
		STX	ND BRL

04/16/12*	Little Mineral Arm	ANTX-A	ND
		CYN	0.19 ppb
		MC	ND
		STX	ND BRL
	Treasure Island	ANTX-A	ND
		CYN	0.20 ppb
		MC	ND
		STX	ND BRL

ANTX-A = Anatoxin-A (Detection Limit = 0.25 ppb)
CYN = Cylindrospermopsin (Reporting Limits = 0.05-0.1 ppb)
MC = Microcystin (Detection Limit = 0.1 ppb)
ND = Not detected
STX = Saxitoxin (Reporting Limit = 0.05 ppb)
BRL = Below reporting limit

* As of April 16, 2012, the IEHH laboratory began analyzing samples for ANTX-A and STX.

WHO recommended maximum concentration of MC in finished drinking water (tap water) is 1.0 ppb.

Table VI
GreenWater Laboratories (GWL)
Blue-Green Algae Test Results

Sample Date	Sample Site (Lake Texoma)	Cell Count	Toxin	Result
02/22/12	UNT 17	11,330 cells/mL	ANTX-A	ND
			CYN	0.2 ppb
			MC	ND
			STX	ND
	Little Mineral Arm	17,477 cells/mL	ANTX-A	ND
			CYN	0.1 ppb
			MC	ND
			STX	ND
	Sheppard Annex	26,644 cells/mL	ANTX-A	ND
			CYN	0.05-0.1 ppb
			MC	ND
			STX	ND
	Treasure Island	33,502 cells/mL	ANTX-A	ND
			CYN	0.1 ppb
			MC	ND
			STX	ND
	377/99 Bridge	48,971 cells/mL	ANTX-A	ND
			CYN	0.05-0.1 ppb
			MC	ND
			STX	ND

03/28/12	Johnson Creek PUA	11,375 cells/mL	ANTX-A	ND
			CYN	0.3 ppb
			MC	ND
			STX	ND
	Lakeside PUA	25,657 cells/mL	ANTX-A	ND
			CYN	0.6 ppb
			MC	ND
			STX	ND
	Little Glasses Creek	23,147 cells/mL	ANTX-A	ND
			CYN	0.3 ppb
			MC	ND
			STX	ND
Sample Date	**Sample Site (Lake Texoma)**	**Cell Count**	**Toxin**	**Result**
04/16/12	UNT 17	1,314 cells/mL	ANTX-A	ND
			CYN	0.1 ppb
			MC	ND
			STX	ND
	Eisenhower Swim Beach	1,103 cells/mL	ANTX-A	ND
			CYN	0.2 ppb
			MC	ND
			STX	ND
	Little Mineral Arm	3,821 cells/mL	ANTX-A	ND
			CYN	0.1 ppb
			MC	ND
			STX	ND
	Treasure Island	1,314 cells/mL	ANTX-A	ND
			CYN	0.1 ppb
			MC	ND
			STX	ND

ANTX-A = Anatoxin-A
CYN = Cylindrospermopsin
LOD = Limit of Detection
LOD = 0.05 ppb (ANTX-A & CYN), 0.15ppb (MC), 0.05 ppb (STX)
LOQ = Limit of Quantitation
LOQ = 0.1 ppb (ANTX-A & CYN), 0.15 ppb (MC), 0.05 ppb (STX)
MC = Microcystin
ND = Not detected above the LOD
STX = Saxitoxin

WHO recommended maximum concentration of MC in finished drinking water (tap water) is 1.0 ppb.

It is the intent of the GCHD, operating within the limitations of annual Environmental Health Program budgets, to regularly collect and obtain analyses on Lake Texoma water samples. The Health Department will collaborate with all state and federal entities which operate water monitoring programs to ensure that Lake Texoma is monitored for BGA bloom events and for the presence (or absence) of cyanotoxins. The GCHD intends to create a comprehensive body of knowledge regarding BGA life cycles throughout the yearly seasons. To accomplish this task, the GCHD intends to either collect itself (using Environmental Health employees and the Grayson County Sheriff's patrol boat and pilot or obtain water samples collected by other governmental or university partners, representative water samples from both Texas and Oklahoma waters. If feasible, the GCHD plans to obtain three to four samples, one day each month during the months of October through April, and analyze the samples for BGA cell counts and the four common toxins. During the heavier lake use months (May-September), the GCHD prefers to obtain two sets of water samples per month. The results of each set of samples will be used to determine which of the three BGA risk levels to declare and describe to the lake-using public (see Appendix I). As the body of knowledge regarding cyanobacteria in Lake Texoma expands, the GCHD will continually examine advances in water testing technology, in search of sensitive, rapid, relatively inexpensive toxicity testing methods. It is conceivable that the trademarked "Microtox" test method may be deployed in the future. Also, the use of sophisticated "bioassays" may be deployed. Bioassays involve placing highly sensitive test organisms (fathead minnows or tiny fresh water crustaceans) in Lake Texoma water (in aquaria) for 24-72 hours to observe for unusual mortality.

Epidemiology Efforts

The term epidemiology [derived from "epidemic" and "ology" (the study of)] involves the study of disease patterns. As a key component of the GCHD's holistic approach to BGA management, the department will be observant for human or animal diseases or incidents which are potentially linked to water in Lake Texoma. Staff members will provide cyanobacteria fact sheets to all hospitals in Cooke and Grayson counties (Texas) and to Bryan and Marshall counties (Oklahoma). These CDC-produced fact sheets describe symptoms which can be associated with exposure to cyanobacterial cells and/or toxins. Each of the hospital emergency departments will be encouraged to report patients presenting at an ER (who have had recent lake water exposure) with morbidity consistent with cyanotoxin exposure.

A second method of communicating with physicians in the region will involve presentations to county medical societies. GCHD officials will seek permission to present BGA information to members of county medical societies in Cooke, Grayson, Bryan, and Marshall. In order to take advantage of "sentinel events" (e.g. dog deaths, suspicious clusters of wildlife deaths near the lakeshore, fish kills, etc.), the GCHD will take the following actions:

1. Mail BGA fact sheets (from CDC) to all veterinarians in the four-county region
2. Seek assistance from the federal agency which manages the Hagerman Wildlife Refuge (US Fish & Wildlife Service) to rapidly report unusual deaths of mammals and birds near the lakeshore
3. Seek assistance from the state agency which manages Eisenhower State Park (Texas Parks & Wildlife) to rapidly report unusual deaths of mammals and birds near the lakeshore
4. Seek assistance from the Oklahoma University Biological Station (OUBS), from Texas Parks & Wildlife fisheries biologists, and from the Army Corps of Engineers to report fish kills, surface scum, or lake discoloration

The GCHD intends to aggressively pursue epidemiologic investigations related to human illnesses, dog deaths, wildlife mortality, and fish kills to determine whether they are sentinel events for harmful algal blooms with toxin formation.

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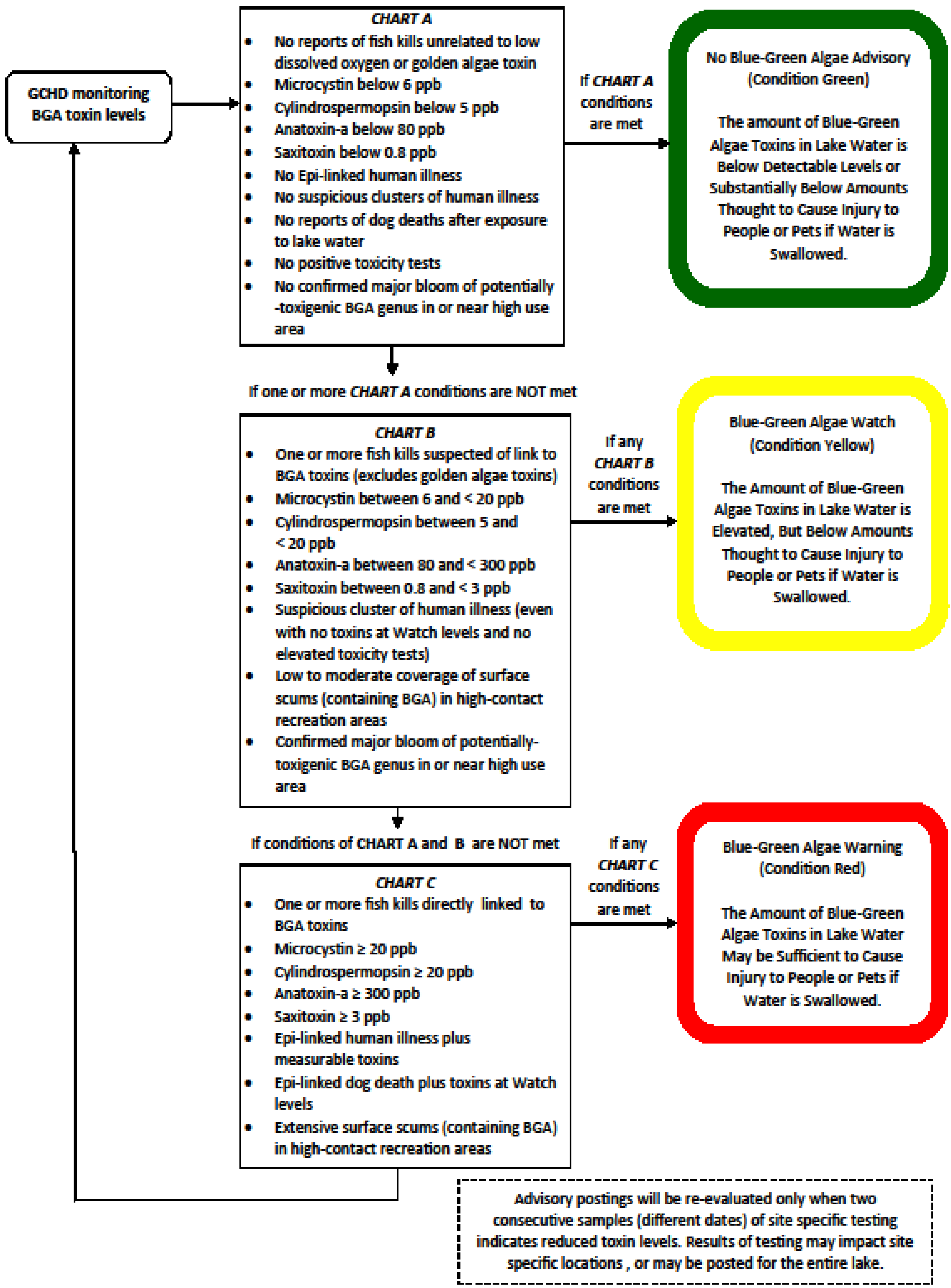
Appendix I

Grayson County Health Department Blue-Green Algae Risk Communication Tool

Data-Driven Decision Version

Revision Date: 05/08/12

These Risk Tools apply only to recreational waters —Not to Public (Finished) Drinking Water Supplies (Tap Water)



Grayson County Health Department Blue-Green Algae Risk Communication Tool

Public Information Version

Revision Date: 05/08/12

These Risk Tools apply only to recreational waters —Not to Public (Finished) Drinking Water Supplies (Tap Water)

No Blue-Green Algae Advisory (Condition Green)

The amount of Blue-Green Algae Toxins in Lake Water is Below Detectable Levels or Substantially Below Amounts Thought to Cause Injury to People or Pets if Water is Swallowed.

- Based on the most recent water tests and available human or pet health data, no health risks associated with blue-green algae are evident
- All forms of lake recreation are encouraged

Blue-Green Algae Watch (Condition Yellow)

The Amount of Blue-Green Algae Toxins in Lake Water is Elevated, But Below Amounts Thought to Cause Injury to People or Pets if Water is Swallowed.

- Boating, fishing, and swimming are allowed
- Fish are safe to eat (throw away internal organs)
- Be observant for scum or discolored water
- Provide bottled water or other safe drinking water for pets
- Report suspected illnesses to the Grayson County Health Department

Blue-Green Algae Warning (Condition Red)

The Amount of Blue-Green Algae Toxins in Lake Water May be Sufficient to Cause Injury to People or Pets if Water is Swallowed.

- Swimming and wading are prohibited
- Do not let pets drink lake water or wade/swim in lake
- Do not touch scum
- Boating and fishing are allowed
- Fish are safe to eat (throw away internal organs)
- Report suspected illnesses to the Grayson County Health Department
- In-water activities, such as use of personal water craft, kayaks, canoes, wind surfing equipment, and similar water recreation equipment are strongly discouraged

Appendix II

US Army Corps of Engineers - Tulsa Division
http://www.swt.usace.army.mil/TDR/eNewsStory.cfm?Number=1516

SIGN	POSTING	REMARKS
CLOSED	**Closed**	**Contact with water prohibited.**
	**Harmful algae present** **Unsafe for People and pets**	**Considered to have adverse health effects. Due to test result levels, contact with water prohibited.** **Link for printable signs:** **http://www.swt.usace.army.mil/WWWattachments/TX%20CDC_WHO%20Moderate%20Level%20Posting.pdf**
	**Harmful algae present** **May be unsafe for people and pets**	**Swimming, water skiing and water contact is discouraged. If bloom is observed, avoid and report sightings.** **Link for printable signs:** **http://www.swt.usace.army.mil/WWWattachments/TX%20HAB-BGA%20Advisory%20Sign.pdf**

Appendix III

Reported Incidents (Humans)

Cyanobacteria are commonly found in freshwater lakes and reservoirs throughout the world. At times, when conditions are favorable, certain cyanobacteria can dominate the phytoplankton in those lakes and reservoirs and form a nuisance bloom. Since 1949, case reports and anecdotal references can be found concerning individuals having had recreational exposure to cyanobacteria. The reported illnesses include hay fever-like symptoms, skin rashes, severe headaches, pneumonia, fever, myalgia, vertigo and blistering in the mouth, with gastro-intestinal symptoms being the most frequently reported illness (Stewart, Webb, Schluter, & Shaw, 2006). Several reports describe allergic reactions while other report more serious illnesses. In one reported case, a six-year old girl had skin eruptions appear after she was exposed to a lake containing cyanobacteria. Other children, who were exposed to the same recreational water as the six-year old girl, appeared unaffected. This particular case was diagnosed as a hypersensitivity case. In a separately reported case, three hours after one adult male accidentally swallowed lake water containing Microcystis sp. and Anabaena circinalis, he reported cramping, abdominal pain, and nausea; followed by painful diarrhea, fever, severe headache, lassitude, myalgia, and arthralgia. In another case, one of just a few reports of mass effects, involved about 25% of the (20 - 30) children participating, who experienced conjunctival and upper respiratory symptoms after attending a school aquatic event (Stewart, et al., 2006).

In a case concerning occupational exposure, workers obligated to collect water samples were exposed to water visibly affected by cyanobacteria scum. Two of the occupational exposure cases involved British soldiers and sea cadets performing canoe exercising at the request of their superiors. The waters were reported to contain a “heavy bloom of Microcystis sp. and scum of Oscillatoria.” Reports included cold and flu-like symptoms, sore throat, cough, diarrhea and vomiting.

Only six studies have been conducted since 1990, therefore human epidemiological data for recreational exposure to freshwater cyanobacteria is limited. Based upon two Australian cohort studies, significant increases in symptoms were reported in individuals exposed to freshwater containing cyanobacteria in comparison to their unexposed counterparts. There were no significant symptoms reported in the other four studies conducted in the United Kingdom and Australia. Regardless, the potential for serious injury or death remains a possibility if a cyanobacteria bloom produces toxins that are capable of causing severe dysfunction to the hepatic or central nervous system. Oral ingestion or possibly inhalation can serve as an exposure route for toxins found in recreational waters, which are formed by cyanobacterium (Stewart, et al., 2006).

In a case report from 1979, concerning an algal bloom on a tropical island off the coast of Queensland, Australia, at least 140 children and 10 adults experienced moderate to severe symptoms from a “Palm Island Mystery Disease,” brought about after consuming untreated drinking water, which was later known to have contained cyano-bacterium. The patients presented with signs of malaise, anorexia, vomiting, headache, painful liver enlargement, initial constipation followed by bloody diarrhea and varying levels of severity of dehydration. Based upon blood test, some of the children suffered from liver damage. The most life-threatening symptom from the exposure was the extensive kidney damage noted in some individuals. Almost 70% of the patients required intravenous therapy and in the most severe cases the individuals went into shock. All of the patients received treatment and none of the patients died. All of the individuals who were a part of this major hepato-enteritis outbreak received their drinking water from one source. Further studies of the water source, using mice, revealed that after

being exposed over several days to the organism cultured from the dam, the mice slowly developed tissue damage in the gastrointestinal tract, kidney and liver. Future monitoring revealed cyano-bacterium (Cylindrospermopsis raciborskii) caused the bloom, with sample concentrations detected at up to 300,000 cells per ml (Stewart, et al., 2006).
In 1996, several human fatalities were reported when a dialysis center in Caruaru, Brazil used unfinished water (water was treated with alum, but was not filtered or chlorinated) for several days to treat patients undergoing dialysis. The untreated water had been obtained from a local reservoir containing cyanobacteria that had produced the toxin microcystin. Of the 130 patients treated over the course of four days, 116 experienced visual disturbances, nausea, and vomiting. Almost one month later, 26 of the patients died from acute liver failure. The concentration of microcystin found in liver tissue from 17 case patients who died, ranged from 0.03 to 0.60 mg per kg of liver tissue (Jochimsen, Carmichael, Cardo, Cookson, et al., 1998).

Reported Incidents (Animals)

Cyanobacteria can produce a range of potent toxins. Reports from over 120 years ago can be found, detailing incidences where sheep, horses, dogs and pigs died within hours of consuming water from an affected lake. Since then numerous reports have been made detailing the gruesome deaths of several other animals within just a matter of minutes after drinking from an affected body of water (Stewart, et al., 2006).

Hudnell (2008) indicated that in 1994 in Australia, thirteen sheep died shortly after consuming water from a dam found to contain Anabaena circinalis (problematic cyanobacterium in Australia). Elevated levels of saxitoxin were found in the bloom material and within the intestinal lining of one of the sheep. Afterward, mice were exposed to the same material found in the bloom and died in less than twelve minutes after being exposed to the toxin. Prior to their death, the mice began to stagger, gasp, leap, and experience respiratory failure. Just a few years prior to this incident, during the spring and summer of 1991 in Australia, 1,100 sheep were lost by one farmer, due to a six-week long bloom.

In Omaha, Nebraska on May 4, 2004, public health officials responded to their first cyanobacterial case when two dogs died within hours of drinking water from a small private lake. Later, the cause of death was concluded to be caused by the ingestion of the toxin Microcystin. Within that same year, additional dogs, numerous wildlife, livestock, and over 50 accounts of human skin rashes, lesions, or gastrointestinal illnesses were reported at other Nebraska lakes. The dominate genera identified in those lakes were Anabaena, Aphanizomenon, and Microcystis (Hudnell, 2010). Pets exposed to Anatoxin-a can suffer from difficulty breathing, muscle tremors, convulsions, paralysis and death due to asphyxiation. Such health effects can occur within 30 minutes after exposure (California, 2010).

At this time, there are no federal or state regulations for algal toxins in drinking water or recreational water. The World Health Organization (WHO) set guidelines for Microcystin toxin at 1 part per billion (ppb) in drinking water and 20 ppb for recreational waters. No similar guidance has been issued for toxins produced by Aphanizomenon (Ohio EPA, 2010). In 2009, in Ohio's Grand Lake St. Marys Microcystin levels reached 82 ppb. In 2010, the levels were detected above 2,000 ppb. Toxin levels can vary significantly at different times and locations (Ohio EPA, 2010).