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**“Toxic Shorelines: The Science of Algal Blooms”**

*April/May 2018*

**Teacher’s Guide**



**Teacher's Guide for**

***“Toxic Shorelines:
The Science of Algal Blooms”***

**April/May 2018**

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# Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **Solution concentration** | Students may have difficulty interpreting concentration units such as parts per billion (ppb). This article provides students with a real-life application of the importance of measuring extremely small changes in conditions at the ppb level. |
| **Reaction rates** | Temperature plays an important role in the rate of chemical reactions, and this is exemplified by the change in the rate of algal growth and the production of their toxins as the seasons change. |
| **Covalent bonding** | Microcystins bind to protein phosphatase enzymes in the body with covalent bonds and cause destruction of liver cells. This example, showing a biological application of covalent bonding, may interest students as more unusual or memorable than typical carbon-hydrogen bonds.  |
| **Enzymes** | Enzymes, biological catalysts, regulate most biochemical reactions, including the protein phosphatase enzymes described in the article. The article emphasizes the importance of enzymes in maintaining DNA repair and normal cell death. |
| **Solubility** | The low solubility of many phosphorus compounds found in fertilizers had typically required them to be tilled (dug into the ground) to facilitate their absorption by plants. The article emphasizes how current farming techniques allow more of the phosphorus compounds to dissolve, thus increasing algae growth in lakes. |
| **Adsorption** | The article illustrates the role and use of activated charcoal as an *ad*sorbent to purify drinking water by removing toxins and particulates from the water as it flows through the charcoal. (Note: this is *not* absorption.) |

# Teaching Strategies and Tools

**Standards**

* Links to **Common Core Standards for Reading**:
	+ **ELA-Literacy.RST.9-10.1:** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
	+ **ELA-Literacy.RST.9-10.5**: Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., *force, friction, reaction force, energy*).
	+ **ELA-Literacy.RST.11-12.1**:Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
	+ **ELA-Literacy.RST.11-12.4:** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 11-12 texts and topics*.
* Links to **Common Core Standards for Writing**:
	+ **ELA-Literacy.WHST.9-10.2F**: Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).
	+ **ELA-Literacy.WHST.11-12.1E**: Provide a concluding statement or section that follows from or supports the argument presented.

**Vocabulary**

**Vocabulary** and **concepts** that are reinforced in the April/May 2018 issue:

Food Chemistry

Structural Formulas

Chemical Reactions

Reaction Rates

Oxidation & Reduction

Distillation

Environmental chemistry

* Some of the articles in this issue provide information to help students consider their impact on the environment.
* Consider asking students to read “Open for Discussion: Weighing in on calories” to learn about calories in food prior to reading the article “The Protein Myth: Getting the Right Balance.”
* Students may find the infographic on page 19, “As a Matter of Fact: The Aroma of the Seaside” interesting after reading the article “Toxic Shorelines: The Science of Algal Blooms.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles.
* You might also ask them how information in the articles might affect their choices regarding food or water use. Also, ask them if they have questions about some of the issues discussed in the articles.

# Reading Supports for Students

The pages that follow include reading supports in the form of an Anticipation Guide, a Graphic Organizer, and Student Reading Comprehension Questions. These resources are provided to help students as they prepare to read and in locating and analyzing information from the article.

The borders on these pages distinguish them from the rest of the pages in this Teacher’s Guide—they have been formatted for ease of photocopying for student use.

* **Anticipation Guide (p. 8):** The Anticipation Guide helps to engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss students’ responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

***NEW!!!***

Instead of using Anticipation Guides for all articles, consider these ideas to engage your students in reading.

* Before reading, ask them what problems algal blooms in water might cause and how algal blooms might be treated.
* As they read, students should determine if their ideas were confirmed in the article. They can also add to their list of problems caused by algal blooms and possible solutions to the problems.
* **Graphic Organizer (p. 9):** The Graphic Organizer is provided to help students locate and analyze information from the article. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher, if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the article. The use of bullets helps them do this.

If you use the aforementioned organizers to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

* **Student Reading Comprehension Questions (p. 10-11):** The Student Reading Comprehension Questions are designed to encourage students to read the article (and graphics) for comprehension and attention to detail, to provide the teacher with a mechanism for assessing how well students understand the article and/or whether they have read the assignment, and, possibly, to help direct follow-up, in-class discussion, or additional, deeper assignments.

Some of the articles in this issue provide opportunities, references, and suggestions for students to do further research on their own about topics that interest them.

To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles. The “Web Sites for Additional Information” section of the Teacher’s Guide provides sources for additional information that might help you answer these questions.

“Toxic Shorelines: The Science of Algal Blooms”, *ChemMatters*, April/May 2018

Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

## Anticipation Guide

“A Close-up Look at the Quality of Indoor Air” (*ChemMatters*, April/May 2016 Issue)

**Directions:**  ***Before reading the article*,** in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. Algae can cause health problems through skin contact or breathing.
 |
|  |  | 1. Algae produce less than 10% of the oxygen in the Earth’s atmosphere.
 |
|  |  | 1. Toxins produced by algae can cause liver damage.
 |
|  |  | 1. Toxins become less concentrated at each level of the food chain.
 |
|  |  | 1. Dead algae cause environmental damage.
 |
|  |  | 1. Cleaning up point-source pollution is more difficult than cleaning up nonpoint source pollution.
 |
|  |  | 1. The Clean Water Act of 1972 helped reduce the amount of phosphorus released into lakes in the 1970s and 1980s.
 |
|  |  | 1. Activated carbon can help remove toxins produced by algae.
 |
|  |  | 1. Algae blooms create “dead zone” in the Gulf of Mexico every year.
 |
|  |  | 1. Cover crops can help reduce the amount of phosphorus runoff from fields.
 |

## Graphic Organizer

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

“Toxic Shorelines: The Science of Algal Blooms”, *ChemMatters*, April/May 2018

**Directions**: ***As you read***, complete the graphic organizer below to explain how algal blooms cause problems.

.

|  |  |  |
| --- | --- | --- |
|  | **Describe what it is, or where it comes from** | **What problems does it cause?** |
| ***Microcystins*** |  |  |
| ***Point-source pollution*** |  |  |
| ***Nonpoint source pollution*** |  |  |
| ***Phosphorus***  |  |  |
| ***Domoic acid*** |  |  |
|  |  |  |

**Summary:** On the back of this paper, write a once-sentence summary (15-18 words) describing the chemistry of algal blooms.

## Student Reading Comprehension Questions

“Toxic Shorelines: The Science of Algal Blooms”, *ChemMatters*, April/May 2018

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Name

**Directions**: Use the article to answer the questions below.

* 1. What was the cause of the 2014 Toledo, Ohio, drinking water crisis?
	2. How much of the Earth’s oxygen is produced by algae?
	3. What are microcystins?
	4. Explain the process of biomagnification.
	5. Why did the drinking water problem in Toledo occur during the summer?

**Student Reading Comprehension Questions, cont.**

“Toxic Shorelines: The Science of Algal Blooms”, *ChemMatters*, April/May 2018

* 1. (a) Explain the difference between point-source and nonpoint-source pollution, and (b) give an example of each.
	2. (a) What is the “dead zone” in the Gulf of Mexico, (b) what causes it, and (c) what is its effect?
	3. (a) What is the Environmental Protection Agency’s safe adult drinking water concentration for microcystins, and (b) what was the level in Toledo’s water in 2014?
	4. (a) What is domoic acid, and (b) what are its effects?
	5. How does activated carbon help remove pollutants from water?
	6. List three actions that farmers can take to reduce phosphorus runoff from their agricultural fields.

## Answers to Student Reading Comprehension Questions

1. **What was the cause of the 2014 Toledo, Ohio, drinking water crisis?**

*The 2014 Toledo, Ohio, drinking water crisis was caused by toxins released by algae in Lake Erie, making the water unsafe to drink.*

1. **How much of the Earth’s oxygen is produced by algae?**

*About half of the oxygen in the Earth’s atmosphere is produced by algae.*

1. **What are microcystins?**

*Microcystins are toxins produced by some algae that travel to the liver and bind to and inhibit protein phosphatase enzymes, causing destruction of liver cells.*

1. **Explain the process of biomagnification.**

*Biomagnification is a process in which toxins are passed through food chains, and at each level of the food chain, the toxins become more concentrated.*

1. **Why did the drinking water problem in Toledo occur during the summer?**

*The drinking water problem in Toledo occurred during the summer because the algae,* Microcystis aeruginosa*, depend on warm water temperatures for reproduction, so they grow rapidly in the summer.*

1. **(a) Explain the difference between point-source and nonpoint-source pollution, and (b) give an example of each.**
	1. *Point-source pollution comes from a single source, while nonpoint-source pollution does not come from a single, identifiable source.*
	2. *An example of point-source pollution is sewage released from a single pipe or source. An example of nonpoint-source pollution is fertilizer run-off from agricultural operations.*
2. **(a) What is the “dead zone” in the Gulf of Mexico, (b) what causes it, and (c) what is its effect?**
	1. *The Gulf of Mexico “dead zone” is the result of numerous huge algae blooms which deplete oxygen in the water when the algae die and decompose, depleting (sucking up) the oxygen.*
	2. *It is caused by agricultural fertilizer runoff carried by the Mississippi River into the Gulf of Mexico.*
	3. *The dead zone’s effect is that it drives away or suffocates fish and other organisms.*
3. **(a) What is the Environmental Protection Agency’s safe drinking water concentration for microcystins, and (b) what was the level in Toledo’s water in 2014?**
	1. *The Environmental Protection Agency’s safe adult drinking water concentration for microcystins is 1.6 parts per billion (ppb).*
	2. *The concentration in Toledo’s water in 2014 was 2.5 ppb.*
4. **(a) What is domoic acid, and (b) what are its effects?**
	1. *Domoic acid is a powerful neurotoxin produced by algae that causes disruptions to the brain and other organs.*
	2. *It can cause short-term memory loss, seizures, and even death.*
5. **How does activated carbon help remove pollutants from water?**

*Activated carbon (charcoal) adsorbs pollutants from water by causing the pollutants to cling to the surfaces of the carbon as the polluted water flows through the carbon.*

1. **List three actions that farmers can take to reduce phosphorus runoff from their agricultural fields.**

*Three actions that farmers can take to reduce phosphorus runoff from agricultural fields include:*

* 1. *better managing the timing and amount of fertilizer they use, to reduce the amount of excess phosphorus;*
	2. *planting cover crops to reduce runoff and erosion; and*
	3. *adding extra strips of vegetation around the edges of fields to hold soil and water in place.*

# Possible Student Misconceptions

1. **“All algae are harmful.”** *Only a small percentage of algae are harmful due to the presence of the toxins they produce. Algae are responsible for producing about 50% of the oxygen in the Earth’s atmosphere. Some algae may be unsightly, or it may change the water’s taste or odor, and impact the recreational and drinking water quality, but they may not be toxic. Some algal blooms are harmful to some forms of ocean life, but may not be harmful to humans. Algae are normal parts of the ecosystem and serve as food for aquatic creatures.*
2. **“Algae blooms only occur in the summer.”** *Algae blooms occur most frequently in the summer when temperatures for rapid growth, ample sunlight, and supplies of nutrients are at their peaks. However, algae blooms can occur anytime and any place that conditions favor rapid growth of the algae. Warmer water due to climate change, or environmental conditions such as water warmed from a power plant or industrial facility, may provide the right conditions for rapid algae growth.*
3. **“All algae blooms are caused by fertilizer runoff from agriculture.”** *Algae are photosynthetic, so they require proper sunlight along with nutrients like nitrogen and phosphorus. The nutrients may come from agricultural runoff, but farmers have been trained in the proper application of fertilizers to minimize wastes, costs, and harmful effects. Homeowners who misapply lawn fertilizers can contribute to nutrient runoff in nearby water sources. In addition, improper handling of human fecal wastes or animal manure can allow these nutrients to accumulate in water sources. Municipal sewage accidents, improperly functioning home septic systems, and large animal feedlots or operations near water can also cause algae blooms.*

# Anticipating Student Questions

1. **“Are red tides and algae blooms the same thing?”** *A red tide is a type of algae bloom caused by specific types of algae. Some of these algae or phytoplankton cause the huge algal mass to be red or brown in color. Many people call any algae bloom a red tide, but the preferred term is* harmful algal bloom *(HAB). Some algae blooms discolor the water but are not harmful.*
2. **“Why are children more susceptible to harmful algae toxins?”** *Children often have more sensitive skin, so they react more quickly or more severely than adults when exposed. In addition, children are more likely to accidentally swallow or inhale water when swimming, making them more susceptible to algae toxin poisoning.*
3. **“How can I protect myself from exposure to harmful algal blooms?”** *The main protection is to avoid wading, swimming, or other water-contact activities when algae scums, mats, or cyanobacteria blooms are present. Don’t eat, drink, cook, or wash with untreated surface water from these areas. Common water purification methods such as boiling, filtering, or treating contaminated water do not remove the toxins. Don’t consume shellfish, or bivalves from these areas, and limit or avoid eating fish from contaminated areas. Seek medical attention if you think you or a pet may have been poisoned by these toxins.*
4. **“How can you recognize or detect toxins from harmful algae?”** *It’s not easy to detect or determine if cyanotoxins are present in water. The presence of cyanotoxins or harmful bacteria cannot be detected by observation alone. It is difficult for most people to identify types of algae by sight. Usually, detecting cytotoxins requires collecting and analyzing water samples in a laboratory. However, there are some commercially available test kits to detect the presence of cyanotoxins that do not require extensive training, if that is a necessity or preference.*
5. **“The article mentions large bodies of water like Lake Erie, the West Coast (Pacific Ocean), and the Gulf of Mexico. Do small lakes or bodies of water get algae blooms?”** *Yes! Oftentimes, smaller bodies of water (ponds, lakes, rivers) are more susceptible to algae problems than much larger bodies of water like oceans. Because of their much smaller size and volume of water, these smaller bodies of water heat up more quickly, may have a higher concentration of nutrients, and have less oversight by regulating authorities than larger bodies of water. The article focuses on the larger bodies of water because their effects are more widespread and receive more publicity.*

# Activities

**Labs and demos**

“Effect of Nitrate and Phosphate Levels on the Growth of Algae” lab**:** This five-day lab activity from the American Society for Microbiology provides complete student and teacher handouts and support for students as they study the effects of these nutrients on algal (*Chlorella*) growth. (<https://www.asm.org/images/Education/K-12/mda-algaebwpdf.final.pdf>)

**Lab activity to illustrate parts per million (ppm) and parts per billion (ppb):**  While the Earth System Research Laboratory at the National Oceanic and Atmospheric Administration (NOAA) considers it a math lesson, this lab to produce serial dilutions and understand small concentrations of gases in the atmosphere easily assists students with understanding the ppb concentrations in the algae article. The teacher worksheet provides helpful information and student answers, while the student worksheet includes background, analysis and comprehension questions, and math calculations. (Teacher link: (<https://www.esrl.noaa.gov/gmd/education/info_activities/pdfs/Teacher_MAA_understanding_ppm_and_ppb.pdf>; student link: <https://www.esrl.noaa.gov/gmd/outreach/info_activities/pdfs/MAA_understanding_ppm_and_ppb.pdf>)

**Simulations**

**“Biomagnification” virtual lab simulation:** This simulation from Virtual Biology Lab allows students to manipulate conditions and see how DDT in near-shore waters bioaccumulates through the food chain, culminating in pelicans. Select the tab “Model Info” at the bottom of the page to learn how to use the simulation. (<http://virtualbiologylab.org/NetWebHTML_FilesJan2016/BiomagnificationModel.html>)

**Media**

**“What Makes Blue-Green Algae Dangerous?—Speaking of Chemistry” video (3:53):** *Reactions* from ACS provides this video, with a quick and interesting explanation of the chemistry of an algal bloom and its toxins. The information accompanying the video includes links to related Web sites for algae blooms. (<https://www.youtube.com/watch?v=kNL99XVJjQo>)

**“Overview of Apoptosis” (10:48),** **KhanAcademy video lesson:** The Heisman algae article uses the term *apoptosis*, and this lesson provides a discussion of this normal, programmed death of cells. A written summary of the highlights of apoptosis accompanies the video. (<https://www.khanacademy.org/science/biology/developmental-biology/apoptosis-in-development/a/apoptosis>)

**Lessons and lesson plans**

**Harmful algal blooms (HAB) lesson plan:** “Bad Algae!” is a two-day high school biology lesson provided by the Ocean Service Education division of NOAA that focuses on what are harmful algal blooms and what can be done about them. This NGSS lesson includes background information, learning procedures, a personal student connection, extensions, resources, and links to more information. (<https://oceanservice.noaa.gov/education/lessons/bad_algae.html>)

**Dead zones 5-E lesson:** This lesson from *Teach Ocean Science* leads students through activities (including a lab) to understand dead zones in water and their effects. The lesson includes instructor directions, downloadable student worksheets, and additional resources. (<http://www.teachoceanscience.net/teaching_resources/education_modules/dead_zones/access_classroom_resources/>)

**Lesson unit on harmful algal blooms:** This series of five lessons, “Fitting in the Food Web”; “Building a Bloom”; “Tracing the Toxins”; “Help! It’s a HAB!”; and “A Community in Crisis” all coordinate with Bigelow Laboratory’s *Toxic and Harmful Algal Bloom* Web site, providing numerous resources and links to more resources. In the unit, students learn about HABs and culminate with a town meeting. (<https://archive.bigelow.org/edhab/index.html>)

**Projects and extension activities**

**Understanding and describing the ecological implications of harmful algal blooms:** *Project Oceanography* publishes the 2001 unit “Unit III Red Tide and Harmful Algal Blooms”, providing students with information and general guidelines to observe algal growth in response to varying nutrient levels, explain water quality changes caused by algal growth, and assess the potential effects of water quality on an ecosystem. Student procedures, extensions, and limited teacher support are included. (<http://www.marine.usf.edu/pjocean/packets/sp01/sp01u3p2.pdf>)

**Research and study of contamination of local bodies of water:** Students could use the Thirteen Online project “Contaminated Water”, shifting the original lesson’s broad approach on water pollution, to a focus on algae as the primary contaminant, for an extended project. The Web site provides possibilities for procedures, objectives, assessment, computer resources, additional Web sites, and a guide to help students use “the” scientific method of investigation. (<http://www.thirteen.org/edonline/wue/water1_overview.html>)

# References

**The references below can be found on the *ChemMatters* 30-year DVD, which includes all articles
published from the magazine’s inception in October 1983 through April 2013; all available Teacher’s Guides, beginning February 1990; and 12 *ChemMatters* videos. The DVD is available from the American Chemical Society for $42 (or $135 for a site/school license) at this site:** [**http://ww.acs.org/chemmatters**](http://www.acs.org/chemmatters)**. Click on the “Teacher’s Guide” tab to the left, directly under the “*ChemMatters Online"* logo and, on the new page, click on “Get the past 30 Years of *ChemMatters* on DVD!” (the icon on the right of the screen)**

**Selected articles and the complete set of
Teacher’s Guides for all issues from the past three
years are available free online at the same Web site, above. Click on the “Issues” tab just below the logo, *“ChemMatters Online”*.**

***30* Years of *ChemMatters !***

Available Now!

 The 2008 article “Those Blooming Algae!” addresses topics similar to the Heisman article. This article discusses a red tide in the Gulf of Mexico in 2004, possible causes for algal blooms, and a potentially beneficial compound extracted from a species of algae. (Baxter, R. Those Blooming Algae! *ChemMatters*, 2008, *26* (4), pp 10–12)

 The December 2008 Teacher’s Guide for “those Blooming Algae!” (See above) provides background information on algae and phytoplankton, ocean chemistry, algae and nutrient stimulation, reducing atmospheric carbon dioxide by photosynthesis, and using algae as a biofuel.

 “Nitrogen from Fertilizers: Too Much of a Good Thing” provides additional information on the other primary nutrient involved in algal blooms, nitrogen. The article addresses the nitrogen cycle, excess fertilizers causing environmental damage (including to oceans), and a sidebar on the Haber-Bosch synthesis of ammonia. (Nolte, B. Nitrogen from Fertilizers: Too Much of a Good Thing. *ChemMatters*, 2010, *28* (4), pp 5–7)

Read about using algae as a renewable source for extracting hydrocarbons to produce fuel for powering vehicles in “From Fish Tank to Fuel Tank”. The article provides a chemical reaction for forming an algal precursor to biodiesel and a chart comparing the attributes of using algae, soybeans, corn kernels, and corn stalks as sources of plant-derived fuels. (Hill, M. From Fish Tank to Fuel Tank. *ChemMatters*, 2012, *30* (4), pp 12–14)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

 “Investigating Aquatic Dead Zones” is a high school activity published by *The Science Teacher* to investigate the concept of a dead zone, and it includes the procedure, materials list, teaching hints, and student questions. Another activity in the article looks at dead zones from the concept of density as it relates to stratification of the water. (Testa, J; et al. Aquatic Dead Zones. *The Science Teacher*, 2010, *77* (2), pp 29–34; <http://static.nsta.org/files/tst1002_29.pdf> Note that this link may take you to a brief abstract only; the full article is only available to National Science Teachers Association members or subscribers to one of its journals.)

 “Reducing Phosphorus to Curb Lake Eutrophication Is a Success” details the success of decreasing lake eutrophication by controlling phosphorus in nine countries. Controlling nitrogen inputs were less successful than controlling phosphorus inputs to the lakes. (Schindler, D.; et al. Reducing Phosphorus to Curb Lake Eutrophication Is a Success. *Enviro. Sci. Technol.*, 2016, *50* (17), pp 8923–8929; <http://pubs.acs.org/doi/10.1021/acs.est.6b02204>. Note that this link takes you to a brief abstract only, the full article is only available to American Chemical Society members or subscribers to the journal.)

# Web Sites for Additional Information

**Blue-green algae (cyanobacteria)**

The Environmental Protection Agency (EPA) provides information on cyanobacteria and cyanotoxins, including a description of cyanobacteria and cyanotoxins, what species of cyanobacteria produce toxins, the most common U.S. cyanotoxins, and additional information. The information can be found at <https://www.epa.gov/nutrient-policy-data/cyanobacteriacyanotoxins>.

Purdue University and Wichita State University host a Web site, *Cyanosite,* devoted to cyanobacteria*.* This site has links to “Cyanobacteria Image Gallery”, “Culture Media Recipes”, “Toxic Cyanobacteria”, “Experimental Protocols”, “Cyanobacteria Taxonomy”, “CyBib Bibliographical Archive”, and “Annotated Links”, with rich information in each link. (<http://www-cyanosite.bio.purdue.edu/>)

 “Cyanobacteria and Cyanotoxins: From Impacts on Aquatic Ecosystems and Human Health to Anticarcinogenic Effects” is a 2013 review of the negative and beneficial effects of cyanobacteria and their toxins. This review includes 95 references and contains some in-depth information. (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3813918/>)

**Harmful algal blooms (HAB)**

 “Human Health Effects from Harmful Algal Blooms: a Synthesis” is a 2013 report by Canadian and U.S scientists focused on the Great Lakes. Contents of the HAB report include background information, occurrence and distribution, human health effects, risks from exposure, economic effects, and more. (<http://www.ijc.org/files/publications/Attachment%202%20Human%20Health%20Effects%20from%20Harmful%20Algal%20Blooms.pdf>)

***Microcystis* algae**

 “Effect of Light Exposure and Nutrients on Buoyancy of *Microcystis* Colonies”, a poster presentation from the University of Michigan’s School of Natural Resources and Environment, presents data and conclusions on a study of the vertical distribution of *Microcystis* harmful algal blooms in Lake Erie. (<https://www.glerl.noaa.gov/pubs/posters/Ming_IAGLR_2017.pdf>)

**Microcystins**

 “*Microcystis aeruginosa* and the Effects of Microcystin-LR on Ecosystems and Human Health” looks at the organism and the toxin described in the Heisman article that were responsible for the Toledo, Ohio, water crisis in 2014. Dangers to humans, ecosystems, and a chemical structure of microcystin-LR are provided. (<https://microbewiki.kenyon.edu/index.php/Microcystis_aeruginosa_and_the_Effects_of_Microcystin-LR_on_Ecosystems_and_Human_Health>)

An information sheet from the Iowa Department of Public Health provides answers to frequently asked questions about cyanobacteria and microcystin toxins. (<https://www.idph.iowa.gov/Portals/1/Files/EHS/algae_faq.pdf>)

**Apoptosis**

Biology textbook author John Kimball provides online information about cell death. His explanation of the two types of cell death, from injurious agents or suicide, provides information on the mechanisms of apoptosis—with diagrams, connections to cancer and immune systems, and links to additional information. (<http://www.biology-pages.info/A/Apoptosis.html>)

**Biomagnification**

 *Earth Eclipse* supplies “What Is Biomagnification?”—an easy to understand explanation. Causes, effects, and the process of biomagnification are parts of the information supplied. (<https://www.eartheclipse.com/ecosystem/causes-effects-process-of-biomagnification.html>)

 PolarTREC hosts the activity “Bioaccumulation of Toxins”, which allows students to use marshmallows to simulate environmental toxins to model bioaccumulation in a food chain. The activity provides the student worksheet, photocopy handouts, procedures, and sample student answers. (<https://www.polartrec.com/files/resources/lesson/10856/docs/bioaccumulation_toxins_final_1.pdf>)

**Climate change and algal growth**

 The EPA published a 2013 document, “Impacts of Climate Change on the Occurrence of Harmful Algal Blooms”, that describes how changes in temperature, salinity, carbon dioxide, rainfall, and other factors may impact HABs. (<https://www.epa.gov/sites/production/files/documents/climatehabs.pdf>)

“Algae, Cyanobacteria Blooms, and Climate Change” examines the causes and results of algal blooms and changing climate conditions. The 2017 article from the Climate Institute provides diagrams, some data, charts, and references. (<http://climate.org/wp-content/uploads/2017/05/bennett_algalblooms-1.pdf>)

**Point-source and nonpoint-source pollution**

The EPA supplies a Web site, *Polluted Runoff: Nonpoint Source Pollution,* which includes the tabs “Restore & Protect” and “Learn”. The “Learn” tab has links to “What is Nonpoint Source”, “Types of Nonpoint Source”, and “Education Materials for Students”. (<https://www.epa.gov/nps>)

NOAA provides information on pollution, including both point source and nonpoint source. Information and pictures provided in numerous links present understandable content on these pollution types. (<https://oceanservice.noaa.gov/education/kits/pollution/03pointsource.html>)

**Domoic acid**

For a one-page description of domoic acid: its chemical structure, distribution, mode of action, effects on human health, and effects on other organisms, see <http://www.nmfs.noaa.gov/pr/pdfs/health/domoic_acid.pdf>.

Domoic acid may have been the cause of bizarre bird behavior and deaths in 1961 in the Santa Cruz, CA, region, and the inspiration for Alfred Hitchcock’s horror movie “The Birds”. (<https://www.livescience.com/17713-hitchcock-birds-movie-algae-toxin.html>)

**Dead zones**

 An NOAA media release from August 2017 provides information on the New Jersey-sized dead zone in the Gulf of Mexico that year. The release includes a diagram showing the size and oxygen concentrations in the water, with embedded links in the news release. (<http://www.noaa.gov/media-release/gulf-of-mexico-dead-zone-is-largest-ever-measured>)

*National Geographic* supplies the article “Dead Zone”, teaching readers about natural dead zones, as well as those caused by pollution. An explanation of eutrophication, environmental factors, photographs, and additional links enhance the article. (<https://www.nationalgeographic.org/encyclopedia/dead-zone/>)

**Eutrophication**

“Eutrophication: Causes, Consequences, and Controls in Aquatic Ecosystems”, furnished by *Nature,* provides a complete overview of eutrophication with photos and explanations. The Web site also includes an extensive reference list and recommendations for further reading. (<https://www.nature.com/scitable/knowledge/library/eutrophication-causes-consequences-and-controls-in-aquatic-102364466>)

**Phosphorus pollution**

The*Lake Erie Algae* Web site from Heidelberg University (Toledo, Ohio) covers 45 years of Lake Erie algae and pollution, including: “The History of Lake Erie’s Troubles”, “How Do We Know Phosphorus Is the Culprit?”, “Point Source vs Non-Point Source Pollution”, “Why Is dissolved phosphorus such a problem for Lake Erie?”, and “The Way Forward”. The video “A Tale of Two Rivers: Lake Erie Algae” (6:31) examines how phosphorus from the Maumee and Cuyahoga Rivers watersheds impact the algal growth. (<http://lakeeriealgae.com/>)

This comprehensive 2018 article in the *Water Resources Research* journal describes the worldwide effects of human activities on phosphorus pollution and the results in freshwater systems. The article, “Global Anthropogenic Phosphorus Loads to Freshwater and Associated Grey Water Footprints and Water Pollution Levels: A High-Resolution Global Study”, looks at phosphorus pollution from mineral-based and manure-based fertilizers and from wastewater, and it provides explanations, tables, and useful charts, breaking down information by countries, pollution sources, and 20 major river basins. (<http://onlinelibrary.wiley.com/doi/10.1002/2017WR020448/full>)

**Toledo’s water crisis**

 A Toledo newspaper, *The Blade*, publishes the Web site *Toledo’s Water Crisis*, with articles, photos, and videos of the August 2014 drinking water crisis, arranged daily or weekly from August 2–23, 2014. Abundant information arranged by headline and type of resource is linked to the site. (<http://www.toledoblade.com/watercrisis>)

 The City of Toledo hosts a Web site, *Toledo Water Quality*, with a color-coded gauge indicating the current quality of the drinking water supply. Links on the page include “Frequently Asked Questions”, “Toledo Water Test Results”, and “Water Treatment (with sub links)”. (<http://toledo.oh.gov/services/public-utilities/water-treatment/water-quality/>)

**Inhibitors**

 The *LibreText* “Chemistry” Web page presents "Drugs as Enzyme Inhibitors," which complements the Heisman article. Penicillin is used as an example of an inhibitor interfering with the action of an enzyme, similar to the microcystins blocking protein phosphatase enzymes. ([https://chem.libretexts.org/Textbook\_Maps/Organic\_Chemistry\_Textbook\_Maps/Map%3A\_Organic\_Chemistry\_(Bruice)/31%3A\_The\_Organic\_Chemistry\_of\_Drugs%3A\_Discovery\_and\_Design/31.07%3A\_Drugs\_as\_Enzyme\_Inhibitors](https://chem.libretexts.org/Textbook_Maps/Organic_Chemistry_Textbook_Maps/Map%3A_Organic_Chemistry_%28Bruice%29/31%3A_The_Organic_Chemistry_of_Drugs%3A_Discovery_and_Design/31.07%3A_Drugs_as_Enzyme_Inhibitors); note: readers may need to register for free to access some information.)

 *KhanAcademy* supplies a great lesson, "Enzyme Regulation." The content explains cofactors and coenzymes; reversible, irreversible, competitive, and noncompetitive inhibitors; allosteric enzymes; and feedback inhibition, with diagrams and text. (<https://www.khanacademy.org/science/biology/energy-and-enzymes/enzyme-regulation/a/enzyme-regulation>

**Concentrations (parts per million or billion)**

The lab activity “Using Serial Dilution to Understand ppm/ppb” is adapted from a SEPUP lesson, and its objectives include defining ppm and ppb, and understanding that a contaminant may be present even when it’s not visible. (<https://sph.unc.edu/files/2013/07/serial_dilution_activity_2012.pdf>)

This link is a straight-forward explanation of small concentrations (e.g., ppm, ppb), using comparisons, conversions, and example quantities for solids and liquids. The example toxin is PCB, but the information is applicable to any substance. (<http://pmep.cce.cornell.edu/profiles/extoxnet/TIB/ppm.html>)

**Reaction rates and temperature**

 “The Effect of Temperature on Reaction rates” explains collision frequency and activation energy, due to temperature changes on reaction rate. The site includes appropriate high school-level information with diagrams and examples. (<https://www.chemguide.co.uk/physical/basicrates/temperature.html>)

 The *LibreText* “Chemistry” Web page provides “Changing Reaction Rates with Temperature” for another explanation of the effect of temperature on reaction rates. It, too, has a diagram to support the text, as well as links to two videos and three questions to check reader comprehension. (<https://chem.libretexts.org/Core/Physical_and_Theoretical_Chemistry/Kinetics/Modeling_Reaction_Kinetics/Temperature_Dependence_of_Reaction_Rates/Changing_Reaction_Rates_with_Temperature>)

**Covalent bonding**

 The PBS Web site *Covalent Bonding* includes a 35-screen student interactive, “Covalent Bonding Tutorial”, support materials explaining covalent bonds, and discussion questions for student use. Educational standards for the materials are provided for teachers. (<https://aetn.pbslearningmedia.org/resource/lsps07.sci.phys.matter.covalentbond/covalent-bonding/#.Wm-FhKinFhE>)

 *ChemGuide* has the Web page, “Covalent Bonding – Single Bonds”, with a clear explanation of this phenomenon. The page includes “A Simple View of Covalent Bonding”, with text and dot-diagrams, as well as “A More Sophisticated View of Covalent Bonding”, and “Hybridisation”. (<https://www.chemguide.co.uk/atoms/bonding/covalent.html>)

**Adsorption**

 The Web site *Diffen* publishes a comparison chart of absorption and adsorption, along with explanations, diagrams, and the video “Absorption and Adsorption” (4:53). The site also provides examples of uses of these two processes. (<https://www.diffen.com/difference/Absorption_vs_Adsorption>)

A more scientific explanation of adsorption comes from *Chemistry Learning*. Information on adsorption in liquids and solids, free energy, adsorption factors with mathematical formulas, and useful diagrams are provided. (<http://www.chemistrylearning.com/adsorption/>)

# About the Guide

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Articles from past issues of *ChemMatters* and related Teacher’s Guides can be accessed from a DVD that is available from the American Chemical Society for $42. The DVD contains the entire 30-year publication of *ChemMatters* issues, from February 1983 to April 2013, along with all the related Teacher’s Guides since they were first created with the February 1990 issue of *ChemMatters*.

The DVD also includes “Article”, “Title”, and “Keyword” indexes that cover all issues from February 1983 to April 2013. A search function (similar to a Google search of keywords) is also available on the DVD.

The *ChemMatters* DVD can be purchased by calling 1-800-227-5558. Purchase information can also be found online at <http://tinyurl.com/o37s9x2>.