



<http://www.asc.org/chemmatters>

**“Making Water Safe
to Drink”**

*(October/November 2017 Issue)*

**Teacher’s Guide**



**Teacher's Guide for**

***“Making Water Safe to Drink”***

**October/November 2017**

**Table of Contents**

[Connections to Chemistry Concepts 3](#_Toc493854501)

[Teaching Strategies and Tools 4](#_Toc493854502)

[Standards 4](#_Toc493854503)

[Vocabulary 4](#_Toc493854504)

[Reading Supports for Students 6](#_Toc493854505)

[Anticipation Guide 8](#_Toc493854506)

[Graphic Organizer 9](#_Toc493854507)

[Student Reading Comprehension Questions 10](#_Toc493854508)

[Answers to Student Reading Comprehension Questions 12](#_Toc493854509)

[Possible Student Misconceptions 14](#_Toc493854510)

[Anticipating Student Questions 15](#_Toc493854511)

[Activities 16](#_Toc493854512)

[References 18](#_Toc493854513)

[Web Sites for Additional Information 19](#_Toc493854514)

[About the Guide 22](#_Toc493854515)

# Connections to Chemistry Concepts

|  |  |
| --- | --- |
| **Chemistry Concept** | **Connection to Chemistry Curriculum** |
| **Types of reactions: double replacement reactions** | Precipitation reactions such as those involving heavy metal ions in water treatment are good examples of these reactions. |
| **Chemical nomenclature** | Trihalomethanes (by-products of water disinfection by chlorine gas) can provide a nomenclature challenge for students (tri=3, halo= halogen). |
| **Heavy metals** | The study of heavy metals can include a brief discussion of their toxic effects, the need to remove them from drinking water, and the processes water treatment plants use to accomplish that task. |
| **Solubility/precipitation** | Precipitation of heavy metal ions by water treatment plants is a great example of compounds that have low solubility. |
| **Solubility and the common ion effect** | While studying solubility, the information in this article provides examples of its pH dependence. Consider the chemical equation in the article showing the formation of Ni(OH)2(s). If additional hydroxide ions (OH–) are added (the solution is kept basic), the reaction will shift to the product, forming more precipitate.  |
| **Acid strength** | During the acid/base unit, you can use the information in this article to discuss hypochlorous acid (HOCl). Although a weak acid (Ka = 3.0 x 10–8), it is strong enough to kill bacteria and viruses once it passes through bacterial cell walls and viral protein coats.  |
| **pH** | Removal of heavy metals by precipitation provides a real world example of the importance of the pH of water. The hydroxide (OH– and bicarbonate (HCO3–) anions are effective bases because they are soluble in acidic solutions. In water treatment the pH of the water must be adjusted to basic (above pH of 7) for precipitation to occur. |

# 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.

* Links to **Next Generation Science Standards**

**HS-PS1-3.** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

**HS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

* + **Disciplinary Core Ideas**:
		- PS1.A: Structure and properties of matter
		- PS1.B: Chemical reactions
		- ETS1.B: Developing possible solutions
	+ **Crosscutting Concepts:**
* Structure and function
* Cause and effect: Mechanism and explanation
* System and system models
	+ **Science and Engineering Practices:**
* Planning and carrying out investigations
* Constructing explanations and designing solutions
	+ **Nature of Science:**
* Science addresses questions about the natural and material world.

## Vocabulary

**Vocabulary** and **concepts** that are reinforced in the October/November 2017 issue:

* + Equilibrium
	+ Solute and solvent
	+ Electrolyte
	+ Ions
	+ Lipids
	+ Osmosis
	+ Metallic and nonmetallic
	+ Igneous, sedimentary, metamorphic rocks
	+ Composting
	+ Aerobic and anaerobic
	+ Carcinogen
	+ Heavy metals
	+ Amalgam
	+ Polymerization
	+ Composites

# Reading Supports for Students

The pages that follow include reading supports in the form of an Anticipation Guide, Reading Strategies, 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.
* **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.
* This issue supports the 2017 National Chemistry Week theme of “Chemistry Rocks!”
* Most of the articles in this issue provide opportunities for students to consider how understanding chemistry can help them in their personal lives.
* The infographic on page 19 provides more information to support the article “Making Water Safe to Drink” on pages 14-16.
* 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 health and/or consumer choices. Also ask them if they have questions about some of the issues discussed in the articles.
* The Background Information in the *ChemMatters* Teachers Guide has suggestions for further research and activities.

“Making Water Safe to Drink”, *ChemMatters*, October/November 2017 Issue

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. The most common waterborne disease is due to strains of *E. coli.*
 |
|  |  | 1. Chlorination and ozone are used to kill bacteria and viruses in water.
 |
|  |  | 1. Drinking water comes only from underground aquifers.
 |
|  |  | 1. At water treatment plants, the pH of water is adjusted to be acidic so that pipes do not corrode.
 |
|  |  | 1. Heavy metals can be precipitated out of water by adding compounds such as NaOH or CaO.
 |
|  |  | 1. The use of chlorine for disinfecting water can produce harmful by-products.
 |
|  |  | 1. The EPA regulates only about 10 contaminants in drinking water.
 |
|  |  | 1. EPA regulations are based on scientific data.
 |
|  |  | 1. One part per billion is the same as 1 mg/L.
 |
|  |  | 1. Many contaminants are introduced into drinking water through human actions.
 |

“Making Water Safe to Drink”, *ChemMatters*, October/November 2017 Issue

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

## Graphic Organizer

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

“Making Water Safe to Drink”, *ChemMatters*, October/November 2017 Issue

**Directions**: ***As you read***, complete the graphic organizer below to describe the chemical reactions involved in treating the contaminants found in drinking water.

|  |  |  |  |
| --- | --- | --- | --- |
| **Contaminant** | **Why is this a problem?** | **Chemicals used for treatment** | **Possible problems posed by treatment** |
| **Viruses and Bacteria** |  |  |  |
| **Heavy Metals** |  |  |  |
| **Pesticides, carcinogens, and endocrine disruptors** |  |  |  |

**Summary:** On the back of this paper, summarize the important issues related to water treatment in a sentence (20 words or less).

## Student Reading Comprehension Questions

“Making Water Safe to Drink”, *ChemMatters*, October/November 2017 Issue

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

Name

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

* + 1. Which water contaminants should concern us?
		2. Which diseases associated with untreated water come (a) from bacteria and (b) from viruses?
		3. Give two reasons why it is difficult to track viral infections to contaminated water.
		4. How does chlorine gas kill bacteria and viruses?
		5. List two ways that ozone kills bacteria and viruses.
		6. Name two major advantages of using ozone over chlorine as a disinfection technique.

**Student Reading Comprehension Questions, cont.**

“Making Water Safe to Drink”, *ChemMatters*, October/November 2017 Issue

* + 1. In the water-treatment process, explain (a) how and (b) why the pH is adjusted near the end of the purification process.
		2. How can heavy metals present at the source of the drinking water be removed?
		3. In the precipitation reaction given in the article, what is the formula of the precipitate?
		4. What is an unintended hazard of using chlorine as a disinfection agent?
		5. Describe two ways that heavy metals get into the water supply.
		6. How can water purification plants reduce heavy metals that leach from the linings of pipes?

## Answers to Student Reading Comprehension Questions

1. **Which water contaminants should concern us?**

*Water contaminants that should concern us include bacteria, viruses, parasites, heavy metals, pesticides and carcinogens.*

1. **Which diseases associated with untreated water come from (a) bacteria and (b) viruses?**
2. *Bacterial diseases associated with untreated water include dysentery, typhoid, cholera, botulism and legionella.*
3. *Viral diseases associated with untreated water include hepatitis A and SARS.*
4. **Give two reasons why it is difficult to track viral infections to contaminated water.**

*It is difficult to track viral infections to contaminated water because*

* + - * 1. *people may not associate their illness with drinking water.*
				2. *SARS mimics flu symptoms, and some viral infection symptoms may take several days to appear.*
1. **How does chlorine gas kill bacteria and viruses?**

*Chlorine gas forms a weak acid called hypochlorous acid (HOCl) when added to water. Bacterial cell walls are negatively charged; the weak acid is electrically neutral, so it passes through cell membranes, chemically attacks lipids in cells walls, and destroys the enzymes and structures in bacterial and viral cells.*

1. **List two ways that ozone kills bacteria and viruses.**

Ozone kills germs by

*breaking through the cell membranes (and interfering with the work of their enzymes) to destroy bacteria.*

*diffusing through the protein coats of viruses, damaging their ribonucleic acid.*

1. **Name two major advantages of using ozone over chlorine as a disinfection technique.**

The two advantages ozone has over chlorine are that

1. *ozone must be made on site because it is highly reactive and does not last long. Chlorine cannot be produced on site and has to be shipped or stored as a gas or as bleach, and*
2. *fewer unintended reactions occur in the water being cleaned with ozone.*
3. **In the water-treatment process, explain (a) how and (b) why the pH is adjusted near the end of the purification process.**

a. *The acidity is adjusted by adding lime (calcium oxide, CaO) near the end of the purification process.*

b. *The pH is adjusted to ensure that the pH of the water remains basic as it leaves the municipal plant to prevent acidity from corroding metallic water-distribution pipes.*

1. **How can heavy metals present at the source of the drinking water be removed?**

*Heavy metals present at the source of the drinking water can be removed in the water treatment facility by precipitation reactions.*

1. **In the precipitation reaction given in the article, what is the formula of the precipitate?**

*In the chemical reaction given in the article, the precipitate’s formula is Ni(OH)2(s).*

1. **What is an unintended hazard of using chlorine as a disinfection agent?**

*An unintended hazard of using chlorine as a disinfection agent is the formation of trihalomethanes, especially chloroform (CHCl3); all are suspected carcinogens.*

1. **Describe two ways that heavy metals get into the water supply.**
	1. *When groundwater comes into contact with soil or rocks that contain high concentrations of arsenic, the water dissolves some of the metal.*
	2. *Heavy metals enter the drinking system by leaching from the linings of pipes in the distribution system.*
2. **How can water purification plants reduce heavy metals that leach from the linings of pipes?**

*Water purification plants can reduce heavy metals that leach from the linings of pipes by adding corrosion inhibitor compounds to the water.*

# Possible Student Misconceptions

1. **“My uncle says that when water runs swiftly over rocks it is cleaned for drinking.”** *When water runs swiftly over rocks it may be cleaned of visible debris, but this does not remove microscopic parasites such as giardia, commonly found in backcountry streams or lakes. Giardia causes mild to severe intestinal problems that can last for weeks.*
2. **“To avoid all contaminants, I’ll just drink distilled water!”** *Yes, distilled water is pure water (only molecules of H2O), so you will not be drinking any contaminants. Yet, this is not a healthy choice. Tap water contains minerals that catalyze reactions in your body and ions that are essential in the transmission of the nerve impulses, keep your heart beating, and maintain the balance of water in your cells and blood plasma.*
3. **“I read that one billion people in the world don’t have enough water, so I am worried that the world must be running out of water.”** *Running out of water globally is a major misconception because all of the water present when the world was formed is still here. Unfortunately, water is not evenly distributed; there are droughts in some areas and floods in others. Much of the earth’s water is located where it is not easily accessible—in deep lakes, jungle rivers, polar ice caps—and some of our water is polluted.*
4. **“I always drink bottled water because it is purer than tap water.”** *This depends upon the source of the bottled water. It may come from municipal sources that are the same as tap water, or spring water sources containing impurities such as heavy metal contaminants from rocks and the ground.*
5. **“My Mom says that drinking six to eight glasses of water every day will keep me healthy.”** *Yes drinking water is important, but the amount depends upon the weather and how much you sweat, your height, weight, muscle mass and the food that you eat. Your diet can supply much of your water needs. Actually drinking too much water can lead to water intoxication, hyponatremia. If you perspire excessively and drink so much water that your body’s sodium level drops, your brain cells may swell, leading to death. (Read the Larter article, “A Toxic Dose of Water”, in this* ChemMatters *issue.)*

# Anticipating Student Questions

1. **“Does boiling water eliminate all contaminants?”** *Boiling water kills bacteria, viruses and parasites because the heat destroys the structure and denatures the proteins of living organisms. However it does not remove toxic chemicals and heavy metals from water.*
2. **“I live in Southern California where we don’t have enough water. There is plenty of water in the ocean so why doesn’t the government just build plants to remove the salt from ocean water?** *Desalination is used to remove salt from ocean water, producing drinking water, but this process is very expensive because much electrical energy is required to evaporate the water. Desalination may negatively affect coastal water quality if effluent containing a high concentration of salt, sediment and marine organism debris is not cleaned and adjusted to the salinity, pH and temperature of the area where it is discharged.*
3. **“Why was the water in Columbia, S.C., Flint, MI, and Baltimore, MD unsafe to drink?”** *Updated infrastructure in all three of these cities was lacking. In Columbia, lead was leached from corroded pipes that serve homes, and floods destroyed two canals, releasing bacteria into the water system. In Baltimore, drinking fountain pipes leached lead. To save money, Flint changed its water supply to the Flint River, but corrosion controls were not implemented, so lead and E. coli were released from corroded supply lines.*
4. **“How is ozone produced at water treatment facilities?”** *Most water treatment facilities use the Corona Discharge method to produce ozone. A spark of high voltage electricity is sent through a flow of oxygen, the electricity splits the diatomic O2 into singlet oxygen atoms that combine with other O2 molecules to form O3. This is similar to the way ozone is produced by lightning or ultraviolet radiation in the upper atmosphere.*
5. **“Since the symptoms are similar, how can I tell if I have SARS or the flu?”** *Both SARS and the flu begin with high fevers and may include symptoms of pneumonia, such as a cough, difficulty breathing, or shortness of breath. SARS is very rare, but there are laboratory tests that can help with identification. However these are not reliable in the early stages of infection.*
6. **“I’ve read about how much of our water stays in underground compartments called aquifers. Why don’t we just inject them with disinfection materials to kill bacteria and viruses?*”*** *You are correct when you say that much of our water is stored underground, but aquifers are underground areas of porous rock that absorb and transmit water. The underground water is always naturally flowing and picking up new bacteria and viruses as it moves underground and eventually reaches the surface, where it will mix with possibly contaminated surface water. So, water in aquifers would still require disinfection when it reaches the surface.*

# Activities

**Labs and Demos**

**Lab activity, “Solar Still Challenge”:** The challenge to build a solar still was developed for the International Year of Chemistry (IYC 2011). The activity uses household materials and provides complete instructions for the teacher. Since this was a global challenge, students were invited to contribute water quality data from their experiment to an on-line international map. Links on this site also take you to salinity and acidity experiments. (<http://water.chemistry2011.org/web/iyc/experiments>)

**“Precipitation and Solubility Chemistry Laboratory” (1 class period):** This micro-lab experiment was designed for high school honors students. The material includes pre- and post-lab questions, laboratory procedures (using well-plates) plus safety and waste management instructions. (<http://nshs-science.org/chemistry/make_handout.php?course=820&%20path=common&%20handout=CLH-precipitation_reactions>)

**Simulation**

**“Precipitate Reactions”:** These simulations use animations of ionic reactions at the particle level to show the formation of precipitates (requires *Flash* *Player* app). (<http://preparatorychemistry.com/precipitation_flash.htm>)

**Media**

**“The Water Treatment Process” video (3:20):** This video takes the viewer through a municipal water treatment plant illustrating the removal of metals, flocculation, filtration, pH adjustment, activated carbon filtration and disinfection by ozone and chlorination. (<https://www.youtube.com/watch?v=9z14l51ISwg>)

**Two YouTube videos on the Flint water crisis, from CNN:**

1. “Here’s How Flint’s Water Crisis Happened” (4:29): This video shows how political decisions led to changing the city’s water supply to the Flint River and the subsequent rulings that precipitated the dangerous pollution crisis. (<https://www.youtube.com/watch?v=nTpsMyNezPQ>)
2. “Flint Water Crisis 2017” (8:51): this video shows some of the cognitive and behavioral problems displayed by children affected by drinking water containing high levels of lead. Teachers and health care personnel are shown working with young children to diagnose signs of lead poisoning and find ways to teach children with subsequent brain disorders. (<https://www.youtube.com/watch?v=3-hVMjgzEiI>)

**Lessons and Lesson Plans**

**“Water Quality” (six 50-min. class periods) and “Water Quality Testing” lab activity (1-2 hours):** This very thorough 5E (Engage, Explore, Explain, Extend, Evaluate) lesson plan is designed for students to study their local water quality and the effects of water pollutants. Complete information is given, including handouts for students and grading rubrics for teachers. (<http://www.learnnc.org/lp/editions/criticalthinking/6650>)

**“Precipitates”:** Complete instructions, material list, questions and guidance for the teacher for each of the 5 E parts of the lesson are given. Although “Reacting Two Compounds to Form a Precipitate”, University of California, Irvine (UCI), was designed for 8th grade, it can be easily adapted for high school chemistry students. (<http://www.cfep.uci.edu/cspi/docs/lessons_secondary/precipitate%20Lab.pdf>)

**Projects and Extension Activities**

**“Neo- Malthusian vs Anti-Malthusian”, a debate:** Students will prepare for and then debate these two opposing views of the relationship between population size and resource consumption with the focus on water. Following a short written explanation, a video (8:26) located on this Web site describes the two viewpoints, shows pertinent graphs, provides data to support each view and gives clear instructions as focus for this debate. (<http://share.nanjing-school.com/dpgeography/patterns-and-change-core-unit/sl-patterns-and-change-4-resource-consumption/1-patterns-of-resource-consumption/neo-malthusian-vs-anti-malthusian/>)

**“Water Filtration Challenge”, laboratory activity (1–2 hours):** This is aNational Aeronautics and Space Administration/Jet Propulsion Laboratory (NASA/JPL) engineering challenge for students, grades 5–12. Students are presented with the challenge to clean waste water and given materials to build, test, and measure the performance of their filtration device; analyze the data collected; and use this information to work toward an improved filtration design. Complete teacher instructions are included on this site: <https://www.jpl.nasa.gov/edu/teach/activity/water-filtration-challenge/>.

# 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!

Chemical reactions for the formation of hypochlorous acid (HOCl) from chlorine gas and water are given showing that as the pH changes, the size of the chemical symbols in the HOCl equilibrium increases or decreases to illustrate the amount of hydrogen ion (H+) present. You may find this an effective way to present acidity changes to students. (Tanis, D.; Dombrink, K. Swimming Pool Chemistry. *ChemMatters*, 1983, *1* (2), pp 4–5)

This article presents a chemical engineering problem and describes the chemistry involved in developing a practical process for removing arsenic from personal drinking water in a non-industrialized region of India. (Brownlee, C. The Quest for a Clean Drink. *ChemMatters*, 2008, *26* (2), pp 4–6)

This article describes how bioremediation was used to remove toxic perchloroethylene (PCE), discarded by dry cleaning facilities, from the drinking water. The author shows and explains the chemical redox reactions that occur when bacteria decompose PCE to ethylene gas. (Argentine, C. Microbes and Molasses: A Successful Partnership. *ChemMatters*, 2012, *30* (2), pp 9–11)

Author Dingle provides details on both the chemistry and the political problems that led to high levels of lead in the drinking water of Flint, Michigan. Pictures of corroded pipes, accompanied by chemical equations, provide a good oxidation/corrosion lesson. (Dingle, A. The Flint Water Crisis. *ChemMatters*, 2016, *34* (4), pp 5–8)

# Web Sites for Additional Information

**Safe Drinking Water Act (SDWA)**

 The “Clean Water Enforcement Act” (1972) set wastewater standards for industry and, since then, the U.S. Environmental Protection Agency (EPA) has monitored the quality of water from livestock and poultry feeding operations, storm drains, oil spills and waste water treatment plants. Links on this Web site provide additional information. (<https://www.epa.gov/laws-regulations/summary-clean-water-act>)

 In 1974 the U.S. EPA enacted SDWA to protect public health by setting limits for natural and manmade contaminants in public drinking water and, in 1996, the law was expanded to include protection of drinking water at its source (e.g., rivers, lakes, reservoirs, springs and groundwater wells). History and details of the SDWA can be found here: <https://www.epa.gov/sites/production/files/2015-04/documents/epa816f04030.pdf>.

**Waterborne pathogens**

This site contains details about *Escherichia coli* (*E. coli*) bacteria, including its importance to living systems and the harmful effects of the *E. coli* O157:H7 strain. This O157:H7 strain can serve as an indicator of human and animal waste contamination in drinking water supplies. (<http://www.freedrinkingwater.com/water-contamination/ecoli-bacteria-removal-water.htm>)

 Two Centers for Disease Control and Prevention (CDC) sites provide information on waterborne pathogens. One provides detailed information about the viral infection Severe Acute Respiratory Syndrome (SARS), its transmission and symptoms. (<https://www.cdc.gov/sars/about/faq.html>), and the second lists waterborne pathogens (bacterial and viral), their route of transmission, preventative measures, and death rates from major outbreaks. (<https://www.cdc.gov/nceh/vsp/training/videos/transcripts/water.pdf>)

**Municipal disinfection—chlorine**

 In addition to the gaseous form, this Web site lists the types of dry and liquid chlorine used in municipal plants and the environmental factors that determine chlorine’s effectiveness. The site shows how to calculate contact (retention) time, the time required from chlorine’s introduction to the production of safe drinking water. (<http://www.water-research.net/index.php/water-treatment/tools/chlorination-of-water>)

 This Web site provides information about harmful by-products of chlorine disinfection. A graph displays trihalomethane (THM) formation as a function of chlorine contact time; another graph shows how organic carbon concentration influences the formation of THMs; and a table lists by-products from various disinfection techniques. (<http://www.lenntech.com/processes/disinfection/byproducts/disinfection-byproducts.htm>)

**Municipal disinfection—ozone**

 This site discusses, explains, and provides a list of the advantages and disadvantages of municipal use of ozone to disinfect drinking water. A schematic, “Automatic Ozone Injection, Filtration, and Recirculation of Iron, Manganese”, illustrates the method used to filter (remove) metal oxide precipitates formed during ozonation. (<http://www.water-research.net/index.php/ozonation>)

 Although ozone is an unstable molecule with a half-life of only 30 seconds, it is a strong oxidizing agent that forms the free radical OH\*. A description of how OH\* leads to harmful by-products and ways to control their formation are provided at: (<https://www.wwdmag.com/microfiltration/strategies-minimizing-ozonation-products-drinking-water>)

**Municipal water treatment process**

This site describes primary, secondary and tertiary municipal water treatment. In the Wood-Black article diagram, the first four steps are designed to reduce THM formation by removing organic material before chlorine is added (step 5). (<http://www.filtronics.com/blog/tertiary-treatment/stages-in-typical-municipal-water-treatment/>)

 Students can use the map on this U.S. EPA site and click on their state and water district to retrieve a local Customer Confidence Report (CCR) that shows the level of contaminants in their water. The CCR lists the source of their water, and the Web site contains links to frequently asked questions (FAQs). (<https://ofmpub.epa.gov/apex/safewater/f?p=136:102>)

**Heavy metals**

This manuscript describes the sources, toxicity and carcinogenicity of heavy metals in our environment. Detailed focus is on arsenic, cadmium, chromium, lead and mercury, and the potential for exposure in water, air and soil. (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4144270/>)

 Research describes a novel approach to removal of heavy metal ions from waste and ground water using a reusable metal chelator that forms metal complexes removable by filtration. A graph on this site shows how pH is a critical factor in successful removal. (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4355739/>)

**Pesticides**

The National pesticide Information Center (NPIC) site has prepared this fact sheet on pesticides in drinking water. Sections include: how pesticides enter drinking water, health effects from pesticides and what is being done to remove them from drinking water. (<http://npic.orst.edu/factsheets/drinkingwater.pdf>)

 In municipal water treatment, activated carbon and filtration are usually used to remove pesticides, because chemical treatments may degrade synthetic molecules forming harmful by-products. Fenton’s oxidation reaction is one of the most effective treatments, the chemistry of which is shown here: <http://www.pjoes.com/pdf/10.4/207-212.pdf>)

**Endocrine disruptors and carcinogens**

 This site reports data collected during a study of water released from wastewater treatment plants and the monitoring of Minnesota’s rivers and lakes for endocrine-active compounds. Sampling methods and analysis of the effects on fish are described. (<https://www.pca.state.mn.us/sites/default/files/lrp-ei-1sy11.pdf>)

 Recognizing the possible carcinogenicity of pesticides and endocrine disruptors, the European Union (E.U.) proposed a list of criteria to define endocrine disruptors. This article discusses the politics involved when environmental groups, the pesticide industry, and E.U. member countries work toward an agreement on the regulation of these compounds. (<https://www.euractiv.com/section/energy-environment/news/eu-experts-agreeoncriteria-for-endocrine-disrupting-chemicals-in-pesticides/>)

# About the Guide

Teacher’s Guide team leader William Bleam and editors Pamela Diaz, Steve Long and Barbara Sitzman created the Teacher’s Guide article material.

E-mail: bbleam@verizon.net

Susan Cooper prepared the anticipation and reading guides.

Terri Taylor, *ChemMatters* Teacher’s Guide interim editor, coordinated production and prepared the Microsoft Word and PDF versions of the Teacher’s Guide.

E-mail: chemmatters@acs.org

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>.