

**December 2016/January 2017 Teacher's Guide for**

***The Flint Water Crisis: What’s Really Going On?***

**Table of Contents**

[About the Guide 2](#_Toc468102606)

[Student Questions 3](#_Toc468102607)

[Answers to Student Questions 5](#_Toc468102608)

[Anticipation Guide 6](#_Toc468102609)

[Reading Strategies 7](#_Toc468102610)

[Connections to Chemistry Concepts 10](#_Toc468102611)

[Possible Student Misconceptions 10](#_Toc468102612)

[Anticipating Student Questions 11](#_Toc468102613)

[Activities 12](#_Toc468102614)

[References 14](#_Toc468102615)

[Web Sites for Additional Information 15](#_Toc468102616)

# 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>.

# Student Questions

**The Flint Water Crisis: What’s Really Going On?**

* 1. Why was the Sewage Department of the Karegnondi Water Authority not ready to deliver water to Flint?
	2. List the two (2) problems that were noticed almost immediately after the Flint River became the water source.
	3. How is a trihalomethane molecule different from a methane molecule?
	4. How do trihalomethanes get into drinking water?
	5. Why did the Romans use lead for water pipes?
	6. List the three metals mentioned in the article that are used to make water pipes.
	7. What happens when lead metal is oxidized?
	8. What is one method used to prevent lead pipes from leaching lead ions into the drinking water?
	9. Explain chemically what happens to the lead(II) carbonate (PbCO3) protective layer when the pH is too low.
	10. What was the reason given for the Flint River water having a high chloride ion (Cl–) concentration?
	11. How can iron (Fe) affect the chlorine (Cl2) concentration, and why is that a problem?
	12. Name four other cities that have recently reported high levels of lead in their drinking water.

# Answers to Student Questions

**(taken from the article)**

**The Flint Water Crisis: What’s Really Going On?**

* + 1. **Why was the Sewage Department of the Karegnondi Water Authority not ready to deliver water to Flint?**

*The Karegnondi Water Authority could not supply water to Flint because they were in the process of building a new pipeline to bring water from Lake Huron.*

* + 1. **List the two (2) problems that were noticed almost immediately after the Flint River became the water source.**

*The two problems noticed almost immediately were:*

1. *foul smell,*
2. *discolored water,*
	* 1. **How is a trihalomethane molecule different from a methane molecule?**

*In a trihalomethane molecule, three of the hydrogen atoms are replaced with halogen atoms (group 17).*

* + 1. **How do trihalomethanes get into drinking water?**

*Trihalomethanes are produced when chlorine, which is used to disinfect drinking water, reacts with organic material such as algae, leaves and weeds.*

* + 1. **Why did the Romans use lead for water pipes?**

*The Romans used lead because it was durable and malleable.*

* + 1. **List the three metals mentioned in the article that are used to make water pipes.**

*The metals that have been used for water pipes are lead, copper, and iron.*

* + 1. **What happens when lead metal is oxidized?**

*When lead metal is oxidized, it loses electrons and forms lead(II) ions (Pb2+), which dissolve in the water. The equation for this reaction is Pb 🡪 Pb2+ + 2e –*

* + 1. **What is one method used to prevent lead pipes from leaching lead ions into the drinking water?**

*One method to prevent lead pipes from leaching ions is to add phosphate (PO43–) ions to the water. They react with the lead, forming solid lead(II) phosphate, Pb3(PO4)2, which forms a crust on the pipes and acts as a protective coating.*

* + 1. **Explain chemically what happens to the lead(II) carbonate (PbCO3) protective layer when the pH is too low.**

*The lead(II) carbonate layer decreases. Lead(II) carbonate dissolves to a very small extent. When the pH is low the excess hydrogen ions react with the carbonate ions and produce carbon dioxide and water. Removing carbonate ions causes more lead(II) carbonate to dissolve and the layer rapidly decreases.*

*PbCO3 (s) ⇌ Pb2+ (aq) + CO32– (aq)*

*CO3 2–(aq) + H+ (aq) 🡪 H2O (l) + CO2 (g)*

* + 1. **What was the reason given for the Flint River water having a high chloride ion (Cl–) concentration?**

*The chloride ions in Flint River water come from the road salt used to de-ice the slippery roads. They enter the river as run-off from the roads.*

* + 1. **How can iron (Fe) affect the chlorine (Cl2) concentration, and why is that a problem?**

*Iron can reduce chlorine to chloride ions. This decreases the amount of chlorine dissolved in the water. Chlorine is added to water sources to eliminate pathogens in the water. Without the chlorine, the water-borne pathogens can survive and cause diseases.*

* + 1. **Name four other cities that have recently reported high levels of lead in their drinking water.**

*Cities that have recently had high levels of lead include: Washington D.C.; Durham, N.C.; Greenville, N.C.; and Jacksonville, Miss.*

# Anticipation Guide

Anticipation guides help 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.

**Directions:**  *Before reading*, 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 problem with water in Flint was first noticed by residents in the 1990s.
 |
|  |  | 1. Prior to the public announcement of a problem with the water in Flint, General Motors stopped using the water in its Flint car plant because of fear of corrosion.
 |
|  |  | 1. Trihalomethanes contain carbon and halogens.
 |
|  |  | 1. Lead has been used in plumbing since Roman times because it is durable and malleable.
 |
|  |  | 1. Prior to 2014, lead (II) phosphate formed a protective layer in the pipes in Flint.
 |
|  |  | 1. The lead level in tap water is measured in ppm (parts per million).
 |
|  |  | 1. The Flint water plants try to keep the pH of the water around 7.
 |
|  |  | 1. Phosphate ions added to water combine with lead to form a protective coating inside water pipes.
 |
|  |  | 1. Chloride ions eliminate waterborne pathogens similar to elemental chlorine.
 |
|  |  | 1. More than 30 years ago, the use of lead water pipes in new construction was banned by the U. S Congress.
 |

# Reading Strategies

These graphic organizers are provided to help students locate and analyze information from the articles. 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 articles. The use of bullets helps them do this. If you use these reading and writing strategies 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 |

***Teaching Strategies:***

1. 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.
1. 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.
1. **Vocabulary** and **concepts** that are reinforced in this issue:
* Chemical reactions
* Redox reactions
* Solubility
* Equilibrium
* Le Chatelier’s Principle
* Vitrification
* Hydrogen bonding
* Molecular structures
* Personal and community health
* Rare-earth metals
* Endothermic and exothermic reactions
* Conservation of energy
1. Some of the articles in this issue provide opportunities for students to consider how understanding chemistry can help them make informed choices as citizens and consumers.
2. Engagement suggestions:
* Prior to giving students the article “The Flint Water Crisis: What’s Really Going On?” use a Think-Pair-Share to find out what students already know about the Flint water crisis. During reading, students will reflect on what they thought and how the evidence from the article supports their original ideas (or not).
* Avoid telling students the title of the article, “No Smartphones, No TV, No Computers: Life without Rare-Earth Metals.” Instead, ask them where in their everyday lives they would find rare-earth metals and why they are used. After a short class discussion, give them the article to read.
1. 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 Background Information in the *ChemMatters* Teacher’s Guide has suggestions for further research and activities.

**Directions**: As you read, complete the graphic organizer below to describe the chemistry involved in causing and correcting the Flint water crisis.

|  |
| --- |
| **Causes of the Flint water crisis** |
|  | **How did it get in the water?** | **Why is it a concern?** |
| **Trihalomethanes** |  |  |
| **Lead** |  |  |

|  |
| --- |
| **Correcting the problems** |
|  | **What can (or should) be done?** | **What are some drawbacks to the possible solution(s)?** |
| **Preventing lead contamination** |  |  |
| **High levels of chloride ions** |  |  |
| **Effect of pH** |  |  |
| **Chlorine treatment** |  |  |

**Summary:** On the bottom or back of this paper, write a tweet (140 characters or less) describing how to protect your town from lead contamination in the drinking water.

# Connections to Chemistry Concepts

**(for correlation to course curriculum)**

1. **Organic Chemistry**—Structures of THMs provided in the Dingle article would serve as an excellent extension to the discussion of organic molecules and the reactions they undergo. Students could be asked to compare the structure of methane to a trihalomethane.
2. **Concentration**—When teaching concentration units, this article could be used to introduce the concept of parts per million and explain it is a common concentration unit used when measuring trace quantities. It could be compared to percent by mass concentrations.
3. **Oxidation-reduction reaction**—When teaching oxidation-reduction reactions, this would serve as a prime example of how the process is a part of our everyday life. Students could be asked to describe the oxidation of the iron pipes using chemical equations.
4. **Solubility rules and precipitation**—Students should be able to predict that lead carbonate and lead phosphate would be insoluble and form a precipitate by using their solubility rules.
5. **pH**—As a lesson in an acid-base unit, teachers could use the article to emphasize that a low pH means that it is an acid and contains more hydrogen ions, which affects the corrosion of the pipes.
6. **Le Châtelier’s Principle**—This is an excellent article to help students grasp the importance of Le Châtelier’s principle as a real world example as they study equilibrium. Students could be asked to describe the shift in the lead carbonate equilibrium as the pH changes. They could also be asked to suggest factors that would shift the equilibrium so the lead carbonate coating is preserved.

# Possible Student Misconceptions

**(to aid teacher in addressing misconceptions)**

1. **“Bottled water is pure water.”** *Bottled water is not pure water. Pure water would only contain molecules of H2O. Pure water can be produced, but it is expensive to make and to keep pure. As soon as the pure water comes in contact with air, it will dissolve oxygen and nitrogen. Dissolved gases give a water a pleasing taste. Trace minerals found in water are important for chemical reactions in our body. Other compounds are added to our water to make is safer and healthier (e.g., chlorine is added to disinfect it and fluoride is added to prevent tooth decay).*
2. **“Adding chlorine to drinking water is dangerous because it forms trihalomethanes.”** *OK, this one isn’t really a misconception, because chlorine* ***can*** *react with organic material in water to form trihalomethanes and it does pose some potential health hazards. However, the greatest threat of danger in drinking water is the presences of harmful water-borne pathogens. One of the best methods for destroying these bacteria is chlorination. Chlorination not only destroys these disease causing agents, it travels with the water through the pipes to our taps, killing bacteria all the way. Other disinfection methods, such as the use of ozone or ultraviolet light, tend to work for only a short period of time while in the water treatment plant.*
3. **“Bottled water is better than tap water.”** *Bottled water can be more convenient, and some prefer its taste to tap water, but there is no reason to think that it is better for you. Tap water is regulated by the Environmental Protection Agency (EPA) and is routinely tested. Municipalities are required to report the results of these tests. Bottled water is regulated by the Food and Drug Administration (FDA), but manufacturers are not required to report to the consumers where the water comes from or how it is treated or what it might contain. Many brands of bottled water use municipal water (tap water). Some producers of bottled water use springs as their water source which may contain impurities you may not want to consume. Such an example is:*

… Fiji Water, a popular and overpriced brand, even among already overpriced bottled water. In 2007, they ran a series of magazine ads claiming, “The Label Says Fiji Because It’s Not Bottled in Cleveland.” The city government of Cleveland was not amused and hired specialists to run tests on the city’s water versus Fiji’s. The results showed that Fiji water contains 6.3 micrograms of arsenic — which is poisonous to humans — per liter. Cleveland’s city water supply is arsenic-free and infinitely cheaper.

(<http://www.kstatecollegian.com/2012/09/20/3-myths-and-misconceptions-about-water-debunked/>)

# Anticipating Student Questions

**(answers to questions students might ask in class)**

1. **“How do I know if my tap water has lead in it?”** *According to the Center for Disease Control and Prevention:*

The only way to know whether your tap water contains lead is to have it tested. You cannot see, taste, or smell lead in drinking water. Therefore, you must ask your water provider whether your water has lead in it. For homes served by public water systems, data on lead in tap water may be available on the Internet from your local water authority. If your water provider does not post this information, you should call and find out.

(<https://www.cdc.gov/nceh/lead/tips/water.htm>)

1. **“Why is fluoride added to drinking water?”** *Fluoride is known to help prevent tooth decay by strengthening the enamel. Since, in most areas of the country, fluoride is not a common mineral in diets, it is added to water.*
2. **“What is hard water?”** *Hard water is defined as water containing large quantities of calcium and magnesium ions. It is generally formed when water runs through limestone, chalk or other mineral deposits containing calcium or magnesium. The water dissolves some of these ions. Hard water interferes with the cleansing action of soap. It also tends to form limescale (calcium or magnesium carbonates) in hot water heaters. Hard water is inconvenient and can reduce the lifetime of equipment such as boilers and water heaters. It does have some health benefits. Humans need calcium and magnesium in their diet, and drinking hard water does contribute small amounts of these minerals to our dietary needs.*
3. **“How much water do humans need on a daily basis?”** *It is important to remember that everybody’s needs are going to be a little different. Our daily water needs are obtained predominantly by drinking but to a lesser extent by eating water containing food. It is recommended that we consume between 1.5 and 2.0 liters of water per day. It is important to note that anything containing water, such as tea and coffee, counts towards our daily requirement. Our total daily need for water is 2.5 liters. Between drinking water containing fluids and the water containing food this amount will be adequate for most people.*

# Activities

**Labs and Demos**

1. **Wet lab to simulate the water purification process:** This lab, “Water Filtration”, uses “swamp” water (water with dirt or mud added) and goes through the basic process of purification used in many municipal water treatment plants. It includes aeration, coagulation, sedimentation and filtration in the purification process. This is a very simple lab to execute. (<https://www3.epa.gov/safewater/kids/pdfs/activity_grades_4-8_waterfiltration.pdf>)
2. **Wet lab, which is a little more involved, simulates the purification of waste water:** The “Foul Water Lab” is adapted from the textbook *Chemistry in the Community*. Three different processes are used: oil/water separation, sand and gravel filtration and charcoal adsorption and filtration. This procedure includes a nice follow-up that includes questions, calculations, and data analysis. (<http://ralston-web.jeffco.k12.co.us/ralston/html/science/chemistry/Labs/Foul%20Water%20Lab.pdf>)
The original version of this lab can be found in the *Chemistry in the Community* textbook, published by the American Chemical Society. *Chemistry in the Community 6th edition*, W. H. Freeman and Company/BFW: New York, 2011; pp 479–482.
3. **Water contamination demonstration:** This demonstration takes about 10 minutes. In a simple manner, it simulates how easily water becomes contaminated and relates it to drinking water standards. It includes suggestions for a follow-up discussion. (<http://serc.carleton.edu/introgeo/demonstrations/examples/watercontamination.html>)
4. **Series of demonstrations and wet labs that explores equilibrium and Le Châtelier’s Principle:** “All Things Being Equal” provides objectives, and detailed instructions for the teacher, as well as student procedure, preparation time, expected results, and questions with suggested answers.

(<https://www.nsta.org/highschool/connections/201210AllThingsBeingEqualTeachersGuide.pdf>)

**Simulations**

1. **Water sources and its purification:** This simulation explains where most municipalities get drinking water. It then goes through the typical process of water purification. It does provide an interactive quiz at the end and a comparison of bottled water to tap water. (<http://techalive.mtu.edu/meec/module03/index.htm>)
2. **Lead entering drinking water:** “Flint’s Water Crisis Explained in 3 GIFs”, produced by *Time*, illustrates graphically the difference between the Detroit water and the Flint River water. (<http://time.com/4191864/flint-water-crisis-lead-contaminated-michigan/>)
3. **The actual chemistry of lead entering the water system:** “Corrosive Chemistry: How Lead Ended Up in Flint's Drinking Water” is a one minute simulation produced by *Scientific American*. (<https://www.scientificamerican.com/video/corrosive-chemistry-how-lead-ended-up-in-flint-s-drinking-water1/>)
4. **pH:** This PHET simulation, “pH Scale”, tests the pH of various common materials. It provides molecular views of the relative numbers of hydroxide ions and hydronium ions in solution. It also looks at the effect of dilution on pH. (<https://phet.colorado.edu/en/simulation/ph-scale>)

**Media**

1. **The water purification process:** “Water and You: The Water Treatment Process” (4:19) is a clever video showing and explaining the water treatment process. (<https://www.youtube.com/watch?v=KMP9-49I1U4>)
2. **Flint water crisis:** The CNN news report “Here’s How Flint’s River Crisis Happened” (4:28) explains the events that lead to the crisis in Flint. (<http://www.cnn.com/videos/us/2016/01/21/flint-michigan-water-crisis-ganim-dnt-ac.cnn>)
3. **The explanation of flocculation:** This Massachusetts Institute of Technology video, “Flocculation” (5:34), provides an excellent explanation of flocculation. It includes both demonstrations of flocculation of actual water samples as well as explaining the process with molecular view drawings. (<https://www.youtube.com/watch?v=5uuQ77vAV_U>)
4. **Chemical and physical properties of lead:** This video (8:08) from *Periodic Videos* by the University of Nottingham not only gives the properties of lead but also provides a wide range of interesting facts about lead. It includes information about lead used by the Romans as well as being used as lead pipes. (<http://www.periodicvideos.com/videos/082.htm>)
5. **Lead poisoning:** The *How Stuff Works* video “Lead—A Sweet Tasting Poison” (1:32) provides a short but informative description of the effects of lead poisoning. (<https://www.youtube.com/watch?v=EGac6S0NLXk>)
6. **Oxidation-reduction reactions:** There are two videos on redox reactions; one is useful for an introductory lesson while the other is very detailed and better for advanced students.
7. “Redox Reactions: Crash Course Chemistry #10” (11:12) is a video that would be good as an introductory lesson. It is fast moving and involves humor, while providing accurate information. (<https://www.youtube.com/watch?v=lQ6FBA1HM3s>)
8. “Oxidation and Reduction” (11:03) is the first in a series on redox reactions produced by the Kahn Academy. This video provides a sophisticated explanation of the oxidation/reduction process. It is done using symbols and drawings to explain the exchange of electrons. This video and the rest in the series can be found at <https://www.khanacademy.org/science/chemistry/oxidation-reduction/redox-oxidation-reduction/v/introduction-to-oxidation-and-reduction>.
9. **Le Châtelier’s Principle:** Both videos below explain equilibrium and Le Châtelier”s Principle. One is short and is good as an introduction to the concepts. The other video is detailed and the first in a series on equilibrium.
10. “Le Châtelier’s Principle” (7:00) is a video good as an introduction. It provides an excellent explanation using pictures of equilibrium systems, symbols and molecular models. At the end of the video, a real life application of the principle is provided. (<https://www.youtube.com/watch?v=PciV_Wuh9V8>)
11. “Le Châtelier’s Principle” (14:42) by the Kahn Academy is a detailed video that gives an in-depth explanation of the principle. It presents the explanation in terms of symbols and molecular models. It is the first in a series on factors that affect equilibrium. (<https://www.khanacademy.org/science/chemistry/chemical-equilibrium/factors-that-affect-chemical-equilibrium/v/le-chatelier-s-principle>)

**Lessons and Lesson Plans**

1. **A series of lessons on drinking water:** This site, created by the EPA, includes activities on water pollution, building models of aquifers, and the availability of ground water. It also has suggestions for games dealing with drinking water. (<https://www3.epa.gov/safewater/kids/teachers_9-12.html>)
2. **Water—at elementary, middle and high school levels:** These lesson are aligned with national standards and produced by Open Square Foundation. They include individual lesson plans, as well as a unit plan that includes cross-curriculum suggestions for the study of water and the global water crisis. (<http://water.org/news/lesson-plans/> )
3. **Oxidation-reduction reactions:** At this site, a lesson plan for the teaching of redox reactions is provided. It includes a PowerPoint and activity sheets that can be downloaded. It states the objectives, prior knowledge necessary, and guiding questions. It also provides suggestions for methods for teaching this lesson. (<http://www.cpalms.org/Public/PreviewResourceLesson/Preview/156068>)

**Projects and Extension Activities**

1. **A debate or town meeting dealing with a water crisis:** The EPA has a design for a town meeting that looks at an industry coming to town that could potentially threaten the water supply. The description for this debate can be found at <https://www3.epa.gov/safewater/kids/pdfs/activity_grades_9-12_proposedtankfarm.pdf>.
2. **Student research project on waterborne diseases:** Students could research various waterborne diseases such as cholera, typhoid, dysentery, amoebiasis, shigellosis, giardia, and legionnaire’s disease. They could research the cause, how it affects the body, the seriousness, how it is transmitted, and the cure.
3. **Students write a position paper:** Students could research the pros and cons of bottled water vs tap water. From their research they would write a positon paper explaining why one is better than the other, citing facts to support their position.
4. **Students could debate chlorination:** Students could research the pros and cons of using chlorine or chlorine-containing products for disinfecting drinking water. A class debate or risk-benefit analysis could then be held to argue each point.

# References

**(non-Web-based information sources)**

**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”*.**

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This article discusses lead poisoning, as well as some of the uses of lead. (Gough, M. Lead Poisoning. *ChemMatters*, 1983, *1* (4), pp 4–7)

 An excellent explanation of Le Châtelier’s Principle can be found in this classic article: Davenport, D. When Push Comes to Shove: Disturbing the Equilibrium. *ChemMatters*, 1985, *3* (1), pp 14–15.

Michael McClure writes an article about the mysterious death of several cows, which were poisoned by lead. In the article he explains the process for analyzing lead. (McClure, M. Mystery Matters: The Cattle Killer. *ChemMatters*, 1986, *4* (3), pp. 13–15)

An older article on wastewater treatment can be found in the issue given below. It
does have some interesting graphics. (Garber, C. Wastewater. *ChemMatters*, 1992, *10* (2),
pp 12–15)

 The lead poisoning of Beethoven is described in this article: Withgott, J. Mystery Matters: Lead—Beethoven’s Heavy Metal Ailment. *ChemMatters,* 2001, *19* (3), pp14–15.

 Information about lead, its history, uses, and health effects are described here: Brownlee, C. Bling Zinger: The Lead Content of Jewelry. *ChemMatters*, 2006, *24* (2), pp 11–14.

 The Teacher’s Guide for April 2006 article above provides additional information on lead poisoning and its symptoms.

This article describe the process used to treat waste water. (Haines, G. Is this Water Recycled Waste? *ChemMatters*, 2011, *29* (1), pp 8–10)

The Teacher’s Guide for the February 2011 article above contains additional information on water purification, filtration and EPA water standards.

# Web Sites for Additional Information

**(Web-based information sources)**

The Center for Disease Control and Prevention provides basic information about municipal water treatment. It includes a clear graphic of the process. In addition, it does describe what types of treatments that can be done in the house. (<http://www.cdc.gov/healthywater/drinking/public/water_treatment.html>)

 This site provides a more detailed description of municipal water treatment. (<http://www.lenntech.com/applications/drinking/purification/drinking-water-preparation.htm>)

 The USGS describes the various processes that are used in wastewater treatment in a short, concise manner. (<http://water.usgs.gov/edu/wwvisit.html>)

 A more detailed discussion of wastewater treatment can be found at <http://www.science.uwaterloo.ca/~cchieh/cact/applychem/watertreatment.html>.

 At this EPA educational site the history of water treatment is described in a one-page fact sheet. (<https://nepis.epa.gov/Exe/tiff2png.cgi/P1002SMN.PNG?-r+105+-g+15+D%3A%5CZYFILES%5CINDEX%20DATA%5C00THRU05%5CTIFF%5C00001267%5CP1002SMN.TIF>)

**Flint River and the water crisis**

 This article by the Flint Water Study explains some of the problems with the Flint River water: <http://flintwaterstudy.org/tag/drinking-water/>.

 This *C&EN* article, “How Lead Ended up in Flint’s Tap Water”, describes the Flint River crisis. This is the article that was cited in the *ChemMatters* article. (<http://cen.acs.org/articles/94/i7/Lead-Ended-Flints-Tap-Water.html>)

 This *New York* Times article describes the investigation by Marc Edwards to determine the problems with the Flint water. (<http://www.nytimes.com/2016/08/21/magazine/flints-water-crisis-and-the-troublemaker-scientist.html?_r=1>)

 A timeline of the events that occurred in the Flint water crisis can be found here: <http://www.msnbc.com/msnbc/flint-water-crisis-timeline>.

 Another article that is well written discusses the pollution in the Flint River. It can be found at this site: <http://www.theverge.com/2016/2/26/11117022/flint-michigan-water-crisis-lead-pollution-history>.

 An infographic about the Flint River crisis was created by Compound Interest and can be found at <http://www.compoundchem.com/2016/01/25/flint-water/>.

**Lead**

Interesting facts about lead and its uses can be found at this site: <http://www.livescience.com/39304-facts-about-lead.html>.

 Some basic physical and chemical properties of lead can be found at <http://www.chemicool.com/elements/lead.html>.

 Information about lead can be found in this article. It includes information about its history, properties, occurrences, extraction, and health effects. (<http://www.chemistryexplained.com/elements/L-P/Lead.html>)

 The occurrence and the effects of lead in drinking water are described in this article: <http://www.water-research.net/index.php/lead>.

**Trihalomethanes**

A short basic article that explains what trihalomethanes are, how they are formed, and their health effects can be found at <http://www.nesc.wvu.edu/ndwc/articles/qanda/otsp99_q_a.pdf>.

 This article gives more details about the health effects of trihalomethanes: <http://des.nh.gov/organization/commissioner/pip/factsheets/ard/documents/ard-ehp-13.pdf>.

 At this site trihalomethanes are described and discussed in relationship to the Flint water crisis: <http://www.waterandhealth.org/tthm-drinking-water-flint-michigan-story-lesson/>.

 This blog describes disinfection byproducts found in drinking water. It includes information on their history, toxicity, and how they are regulated. (<https://www.hydroviv.com/blogs/water-smarts/disinfection-byproducts-in-drinking-water-toxicity-history-and-policy>)

**Oxidation, reduction and corrosion**

 Concise definitions of oxidation, reduction, oxidation numbers and redox reactions are given at this site. (<http://www.chemteam.info/Redox/Meaning-of-Redox.html>)

 This site describes redox reactions. It provides instructions and examples for balancing redox reactions. It also has a quiz the students could use to test themselves. (<http://chp090.chemistry.wustl.edu/~coursedev/Online%20tutorials/Redox.htm>)

 This site gives rules for assigning oxidation numbers and provides examples for assigning oxidation numbers to compounds. It also gives examples for recognizing redox reactions. (<http://chem.libretexts.org/Core/Analytical_Chemistry/Electrochemistry/Redox_Chemistry/Oxidation-Reduction_Reactions>)

 At this site, the corrosion of drinking water pipes is described. It includes information on the health effects of the corrosion and the factors that contribute to the corrosion. (<http://soiltesting.tamu.edu/publications/E-616.pdf>)

 This Center for Disease Control and Prevention article describes the causes of water pipe corrosion. (<http://www.cdc.gov/fluoridation/factsheets/engineering/corrosion.htm>)

 This article provides information about the causes for corrosion of the pipes in Flint, Michigan. It describes the mistakes made in Flint, the science of the corrosion and the economics of the situation. (<http://theconversation.com/the-science-behind-the-flint-water-crisis-corrosion-of-pipes-erosion-of-trust-53776>)

**pH**

A concise explanation of pH, and acids and bases can be found at <http://www.sciencebuddies.org/science-fair-projects/project_ideas/Chem_AcidsBasespHScale.shtml>**.**

A more detailed discussion of pH can be found at this site. It also describes the values of pH and provides examples of the pH of common materials. (<http://hyperphysics.phy-astr.gsu.edu/hbase/chemical/ph.html>)

 At this USGS site, pH is described in terms of water properties. It describes the measurement of pH and the effect of pH on water quality. Included in the article is a map of the pH of natural waters in the United States. (<http://water.usgs.gov/edu/ph.html>)

**Le Châtelier’s Principle**

This article gives a clear definition of the Le Châtelier’s Principle and provides an explanation of how concentration, pressure and temperature affect equilibrium. There is a short quiz at the end to test understanding. (<http://www.chemguide.co.uk/physical/equilibria/lechatelier.html>)

 At this site, the effects of Le Châtelier’s Principle are described by using calculations. There is an example problem for students to try at the end of the article. (<http://chemed.chem.purdue.edu/genchem/topicreview/bp/ch16/lechat.html#top>)

 A detailed explanation of equilibrium and Le Châtelier’s Principle can be found at this site. It includes clear examples and links to videos, additional information, and quizzes. (<http://www.chem1.com/acad/webtext/chemeq/Eq-02.html>)