

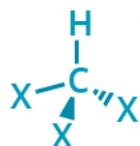
Grand Challenge:

Providing Access to Clean Water

Teacher Instruction Guide for Demonstration
BOM

THE FLINT WATER CRISIS

The American city of Flint, Michigan, has been in the news recently due to the discovery of very high levels of lead in its water supply. But how did this lead get there? Here's a brief explainer.



TRIHALOMETHANES

Disinfectant byproducts; formed by the reaction of chlorine (added to disinfect the water) with organic matter.

X = halogen (commonly Cl or Br)

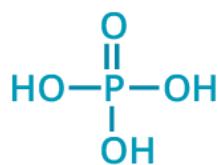
CORROSION: DETROIT VS. FLINT RIVER

0.45 vs 1.60
DETROIT FLINT

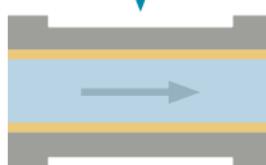
Chloride to sulfate mass ratio (CSMR);
0.45 = low corrosion;
1.60 = very high corrosion.

When high levels of trihalomethanes were detected in Flint's water, ferric chloride (FeCl_3) was added to improve removal of organic matter. However, this increased the water's already high concentration of chloride ions, and as a result made the water more corrosive.

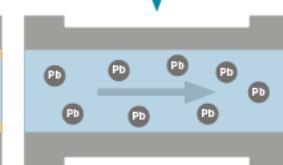
CORROSION CONTROL



WITH PHOSPHATES



WITHOUT PHOSPHATES



Orthophosphates are added to water to reduce the amount of lead leaching into it from pipes. They do this by forming a layer of low-solubility lead-phosphate complexes inside the pipe. This method of corrosion control was not used for the Flint River water supply.



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[1]

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Teacher Instruction Guide

Learning Objectives:

The main learning objective of our demonstration is to encourage students to brainstorm solutions for providing access to clean water based on observations and predictions made during our experiment. Students will also be able to evaluate the results of making their own filter prototypes and then from collaborating with their teammates, decide how to improve upon their original designs to include consideration for unseen germs.

Pre-Demonstration Procedure:

Constructing a Demonstration Worksheet:

Giving each student a worksheet to fill out helps them to remember what they have learned during the experiment. We suggest giving them a space to predict what will happen before the demonstration, to record what they see during the experiment and also a space at the end to reflect on what they have learned and relate it to their own lives. On pages 6-7 we have provided a sample worksheet.

Making Dirty Water:

Here are some things that the teacher should use to make batches of contaminated water that the students will attempt to filter. A good mix of contaminated water will include something that settles at the bottom of the container, something that floats freely around, and something that stays on top of the mix, like oil. This gives students more to look at and emphasizes the difference in contaminants and how they will need more than one filter to catch everything. We suggest 2 gallons of dirty water for an average class size of 30 students or 7-8 groups.

Warning: If the water is made several days beforehand and then stored, depending on the contaminants used there is a high chance the water will start to smell. If the teacher does not mind this then disregard. Also, please be sure to consider how to dispose of your contaminants if they are not safe to dispose of by pouring on the ground or throwing away in the trash or recycle bin.

Recommended Contaminants:

Dirt or mulch

Sand

Oil

Algae

Shredded Candy wrappers

Fish flakes (warning: might cause an unpleasant odor if the water is stored for a few days)

Plant matter

Plastic toy insects

It is also recommended to store the contaminated water in glass mason jars, this will allow the students to more closely observe the water without spilling and then shake before pouring through their filters.

Constructing Filters:

Teachers should provide filter items to have their efficiency tested by the students. The purpose of the individual materials is not to be good on their own. It is best if each filter has strengths and weaknesses. This forces the students to think about how to combine the various filters in order to maximize their strengths and filter as many contaminants from the water as possible. It is recommended that teachers have one unique filter for every five students to ensure that every student has something unique to contribute to their final group.

Recommended filters:

Cotton balls

Charcoal

Coffee filters

Wood chips

Sand

Gravel

It is also recommended to put the filters in a container that can be easily drained into a cup or something to catch the water passing through. For example, in our demonstration we cut water bottles in half and loosened the caps. We poured the water in through the open end and the water filtered through the cap (which also held the filter material inside the water bottle) and into the other half of the water bottle. To increase water flow through the cap, a hole can be punched through it.



[2]

Demonstration Procedure:

Observation Stage:

The first stage of the demonstration begins with the students analyzing the provided dirty water. Students will be divided into groups of up to four members. Each group will receive some contaminated water via glass mason jars so that they can inspect the water more closely and discuss what they see with other group members. On the provided worksheet, students will list all things they observe in the contaminated water. Once every group has made their observations, they will be ready to begin the testing process.

Testing stage:

During the testing stage, each group will have two filter materials to test. No two groups will have the same two materials, so each group has different data to later contribute to the class.

On the worksheet, students will make hypotheses on how well their two assigned filters will remove various things from the dirty water. Then the students will test their assigned filters. They will do this by pouring the contaminated water through each filtration material and collecting the water in a plastic cup. The students will observe the collected filtered water and compare it with their recorded hypotheses.

Brainstorming stage:

Once each group has evaluated their assigned materials, all students will reconvene and share their observations with the class. New groups will be formed by taking one member from each old group and putting them together. Each of the new groups will be able to use their knowledge to create a multi-stage filter using any of the materials that are present. However, each group will only be able to use a maximum of three materials for their filter, and will have to choose materials that will catch as many pollutants as possible.

Each group's filter will be tested in front of the class with the human eye. (Optional) For both a quantitative and qualitative analysis, a TDS (Total Dissolved Solids) indicator may be used on each group's final cup. Make sure that students know that their filters will not be able to perform as well as industrial grade filters and that they should not feel bad because of that.

(Optional) The facilitator can use a manufactured filter straw to clean the dirty water. This water will be tested with the TDS indicator and the results will be compared to the best performing group's filter. This gives the students a point of reference for how a "good" filter can perform.

Reflection:

Finally, a class discussion will be held to talk about what contaminants their filters might have missed, such as bacteria, parasites, or extremely small particles. We will brainstorm and discuss the ways one could remove those from the water, such as boiling or adding chemicals.

Additional Discussion Points Include:

How would your daily life be impacted if you did not have access to clean water? What could you suddenly not be able to do? What did you do to get ready this morning for school or the day that involved using clean water?

How could you obtain water if you didn't have faucets or pipes? If you live near the ocean, what could you do? What are the problems with ocean water and how might you get around them? What if you're landlocked or in a desert?

Buying Materials:

This module allows teachers to be flexible in how they wish to execute the demonstration. They can choose the filter materials, what goes into the dirty water, and the restrictions for the tests that the students will carry out.

A large number of these items can be purchased in large quantities, such as sand or wood chips, where the extra can be used in the classroom for any needed purpose at a later date.

Essentials:

These items are absolutely necessary for carrying out the module. Some of these might be already available in the classroom or easily gathered by asking the students to help out. For example, asking each student to bring in a single empty water bottle is very helpful. Hand sanitizer and paper towels are recommended due to the handling and potential spillage of the “contaminated” water. While the water is not meant to be toxic and should not pose a real danger to students, making sure that they clean their hands is still a must.

Water bottles: housing the filter materials. See diagram [xx]

Plastic or wire mesh: prevent certain filter materials from spilling out of the water bottle.

Coffee filters: prevent certain filter materials from spilling out of the water bottle. Can replace the mesh entirely if needed.

Hand sanitizer

Paper towels

Clear plastic cups: for both collecting and pouring water.

Optional:

These materials might make the process go more smoothly, or add an extra element of interest to the demonstration.

Glass jars: if wanted, the teacher can separate the dirty water into glass jars to give to each group. However, this might be time-consuming and messy as jars are not ideal for pouring. They do allow the students to shake the water up and observe it more closely.

TDS indicator pen: this is an item that tests the conductivity of water and infers the number of particles in the water in parts per million (ppm). If the teacher wishes to give the students a numerical comparison of their filtered water as opposed to purely visual comparisons, they can use the pen.

Life Straw: this is an item that is meant for treating any water to a drinkable level by just drinking through the straw. However if you can filter water through the straw into a clear cup or jar, you can again use the TDS indicator pen to allow students to compare their cleanest water to the clean water from a device guaranteed to get the water clean.

BOM (Bill of Materials):

The cost of materials assuming a class size of approximately 30 students, 7-8 groups, is \$65.99.

Category	Item	Store	Amount	Unit Price	Total
Filter Materials	Sand	Walmart	.5 ft^3	\$ 3.29	\$ 3.29
	Gravel	Walmart	2lb	\$ 2.00	\$ 2.00
	Charcoal	Walmart	11.6lb	\$ 9.43	\$ 9.43
	Wood Chips	Walmart	3lb	\$ 3.99	\$ 3.99
Water Contaminants	Oil	Walmart	1 gallon	\$ 2.28	\$ 2.28
	Sediment	Nature	Any	find outside	\$ -
	Organic Matter	Nature	Any	find outside	\$ -
	Trash	Any	Any	find outside	\$ -
Other	Clear plastic cups	Walmart	80 ct.	\$ 2.58	\$ 2.58
	Filtration Straw	Amazon	1	\$ 11.00	\$ 11.00
	Purity Indicator Pen	Amazon	1	\$ 15.00	\$ 15.00
	Plastic Mesh	Walmart	12"x18"	\$ 5.35	\$ 5.35
	Glass mason jars	Walmart	12 ct.	\$ 9.31	\$ 9.31
	Water	Walmart	2 gallons	\$ 0.88	\$ 1.76
Total	-----	-----	-----	-----	\$ 65.99

Name:

Date:

Part I: Identification of the Problem

Once in your group, inspect the contaminated water. What things do you see? List below as many contaminants as you can identify.

Part II: Hypothesize solutions

Which of the contaminants listed above do you think each filter will remove the best? Try to list the contaminants in order of what will get filtered the most effectively.

Filter	Contaminants speculated to be removed
Sand	
Gravel	
Wood chips	
Charcoal	
Cotton balls	

Part III: Testing!

Your group will be assigned 2-3 filters to test. Write down which filters you are testing. After filtering fresh contaminated water through each filter, record your results in the table below.

Filters tested	Contaminants removed

Name:

Date:

Part IV: Analyzing results

Discuss with your group the differences between how you *thought* the filters would behave, and the actual results that you just obtained. Was there anything that you thought a filter would catch, but it didn't? Were there contaminants that your tested filters caught that you didn't expect?

Part V: Designing your own multi-stage filter!

Teams will be broken up and students will be re-assigned into new groups. Collectively, you should know how every filter behaves. Share your results and listen to other people as they share theirs. As a group, you will design a multi-stage filter that will catch as many of the contaminants as possible. This filter will be tested in front of the class.

- You will only be able to use a MAXIMUM of **3** filter types in your design.
- You have access to all filter materials, which can be found at the front of the room.
- Filters will be tested by pouring the contaminated water through the first part of your filter and collecting the water in a new cup. This new cup will be poured through the second filter and collected again, etc., until your final cup of filtered water has been obtained.
- You will be given a new jar of contaminated water.
- You will only be able to pour water through each of your chosen filters ONCE.

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- [2] Picture taken by us.

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