Project Title: Elevated Groundwater Arsenic Concentrations In Private Wells in Central Maine

School: Waterville Senior High School

Grade Level: 10-12

Teachers: Justin Giroux and Jon Ramgren

Project Partners: Thom Klepach of Colby College was the mentor for this project. Justin Giroux and Jon Ramgren, the chemistry teachers at Waterville Senior High School, collaborated on the implementation of this project.

Teacher Profile:
Justin Giroux has been teaching for 8 years. He has a biochemistry degree from Bates College with a focus on environmental chemistry. His undergraduate research focused on improving the efficiency of CdSe based photovoltaics. Justin is interested in bringing real life problems to his classroom to allow his students the chance to work on something meaningful to their community. To achieve this, his chemistry classes have a focus on energy and water.

Jon Ramgren has been teaching for 29 years. He has a Bachelor of Science in chemistry from North Park College and a Masters in Secondary Science Education from The Ohio State University. Over the last 9 years he has involved students in research opportunities at the Mount Desert Biological Laboratory during April vacations and summers. He coaches the Science Olympiad Team and the National Ocean Science Bowl Team. He enjoys seeing students get involved in new experiences that lead them to engage in further learning about - and exploration of - their world.

Summary: In the fall, Waterville High School students were given a brief water quality unit. They learned about the arsenic problems in groundwater in India and Bangladesh. They also learned about arsenic's effects on the body and the history. Collecting samples done in the late fall with the idea that students could sample water at their camps before they were winterized. Obtaining samples was difficult since many of the students live on public water supplies. Obtaining a sample was worth a grade in each class. Adults in the building were able to help out students who could not find a well to sample. Waterville High School sent 60 samples to Dartmouth College for analysis. It was the student's responsibility to report the results of their sample to the person they obtained the sample from. The students worked on data processing in Tuva Labs. Up until the school shut down due to Covid-19 we had planned on having a forum for the public similar to last year in which students presented talks with slide shows at a community meeting held in Colby College's building in downtown Waterville. Instead, students were given an assignment to write a letter to the Maine legislature about the pending legislation: LD-1943, HP-1387 An Act To Protect Drinking Water for Low-income Maine Residents. Actually sending the letters was optional, but at least 6 letters were sent of the 32 written. We also had planned to have students conduct an experiment involving duckweed and arsenic concentrations ranging from 0 to 100 ppb. We purchased 7 grow light set-ups, one for each class, and duckweed just before the school closure so were unable to implement the experiment. We plan to do this experiment with next year's chemistry classes.

Project Details:
- Jon had a total of 60 students and Justin had a total of 33 students.
- Stipend was used to purchase duckweed and seven grow light seed starter set-ups.
- Materials used:

  - "The Quest for a Clean Drink" https://www.acs.org/content/dam/acsorg/education/resources/highschool/chemmatters/g c-quest-for-a-clean-drink.pdf
  - "The Flint Water Crisis: What's Really Going On?" https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/pastissues/2016-2017/december-2016/flint-water-crisis.html
  - Maine Geological Survey Bedrock Geology Maps https://www.maine.gov/dacf/mgs/pubs/online/bedrock/state.htm
  - "How Much Arsenic is in Rice" https://www.youtube.com/watch?v=9XK66S50oas
  - Tuva Video tutorials https://tuvalabs.com/resources/videos/
  - Tuva pre-made data sets and activities https://tuvalabs.com/content/?show=all&view=block&type=datasets&order_by=- last_modified
  - "Assessment of Arsenic Concentrations in Domestic Well Water, by Town, in Maine, 2005–09" https://pubs.usgs.gov/sir/2010/5199/
  - Questions for "All About Arsenic - Data to Action: A Secondary School-Based..., http://www.allaboutarsenic.org/
- Jon and Justin used Tuva activities to teach students how to use the program. Jon also put the data from the class penny density lab into Tuva and had students make graphs of the data. Justin used Tuva with his periodic table unit. Students also made various graphs of the Arsenic Data Set.
- Data analyses done in Tuva were minimal due to shut down. However, students did work in Tuva for a while to learn the program and to understand what the data was telling them. They used tutorial videos and premade learning modules provide by Tuva.

Discussion:
Students learned that arsenic is a problem when found in drinking water and that many wells in our area have high levels of arsenic. Quotes from students:

- "Our data showed us that about 1⁄4 of the samples brought in from students at our school were above healthy levels."
- "The level of arsenic in Maine's wells is embarrassing. Over half of our state's residents use well water and 1/6th of those wells have dangerously high levels of arsenic. This means that 1/12th or nearly 10 percent of Maine's residents are drinking water contaminated by arsenic."
- "We found that a surprising amount of students had too high of arsenic levels in their homes drinking water."
- "It's important for everyone to be able to get healthy water. Not every family has the ability to figure out and fix the problem if they have Arsenic in their well. It can be very expensive to fix and a lot of families might not fix it because of the cost and be harmed by this dangerous poison."

We learned that most students are interested in finding out if their water is safe. Those that are on city water are not as engaged by the well water study, but still find the Tuva program interesting. I also found that trying to teach from a distance is very difficult when it happens suddenly without preparation. This difficulty is multiplied when the school administration sends mixed messages about what is expected of students and teachers. Additionally, we received a mandate to reduce student workloads substantially, which made it difficult to cover our district standards and see the arsenic project to complete.

Going forward, we want to do more with water in our chemistry course by tying it more to our standards. We see issues for the 2020-2021 school year including possible closures and potential dangers of putting kids together in lab groups. We hope to do more water-based labs outside with a focus on the stream that runs by

our campus to tie in with the arsenic project. Additionally, we plan to learn more about our local public water supply to help engage students who get their water supply from the Kennebec Water District. We are also looking into ways to socially distance labs. Social distancing may also cause water collection issues since many of our students rely on friends and family for their sample collection. We'd like to get more done sooner in the year and implement the duckweed study with the enhanced control of variables such as the amount of light, temperature, and nutrition.

Conclusion:

The arsenic project was well received by students. We did find several families have high levels of arsenic in their well water. We found the percent of wells tested with elevated arsenic was similar this year to last year's results. We were able to teach about what things can be done if there is a high level of arsenic in a given water supply. We did not complete our planned project due to the school shut down. Over the past two years we have gotten better at the logistics of the collection of water samples and Tuva data analysis. We are well positioned for the 2020-2021 school year by enhancing our students' learning by making water quality the central theme of our chemistry classes.

Individual Assignments

1. Google Form: All About Arsenic Reading Questions

1. Long-term exposure to arsenic can lead to a host of health issues, including heart disease; cancer of the_____; diabetes, and more. *2 points

- bladder
- lung
- liver
- prostate
- skin
- all of the above

2. According to the map of the United States of America, which state on the east coast has the largest area of over a 50% chance of having arsenic levels over 10 ug/L in well water? *2 points

- Pennsylvania
- New Jersey
- Maine
- New Hampshire
- Nevada

3. How many people in the United States does a United States Geological Survey (USGS) model published in 2017 predict drink well water containing arsenic above the EPA Maximum Contaminant Level of 10 ug/L? *2 points

- 22 million people
- 2.1 million people
- 1.2 million people
- 120,000 people

4. What is the per capita reliance on private wells for drinking water in the state of Maine? *2 points

56%
28%
77%
46%

5. In Maine, _____ in 10 wells have too much arsenic in them. *2 points

7
5
3
1

6. Can you see, smell, or taste arsenic in water? *2 points

yes
no

7. A contamination level of 10 ug/L (micrograms per liter) is equal to ____ ppb (parts per billion) *2 points

1
10
100
1000

2. Directions for making graphs on Tuva

- Go to http://www.allaboutarsenic.org and scroll down until, on the right side of the screen you see:

TUVA ARSENIC DATA

- If you are unable to find it, your screen may not be wide enough. Expand your screen. You can also scroll down almost to the bottom of the screen and it will show up there.
- Once you have found it, click on the colored Tuva. This will take you to the Arsenic Data Portal on Tuva.
- Click on Explore Arsenic Datasets
- Click on Drinking Water Data (2016 to 2020) *Dataset*
- This will bring you to a graph in the Tuva Labs program that has almost 2000 data points and each point has 28 attributes. It will take a while for the graph to load.
- Once it is loaded, click on the colored bar to the right of the attribute SEPA School…
- Again, it will take awhile for all of the points to change color.
- You will see all of the names of all of the schools that are part of the project show up down the right side of the graph. Before the name of each school there will be a square of a different color.
- Find Waterville. You may have to use the scroll bar on the right side of the box containing the SEPA School names in order to find Waterville. Again, depending on the size of your screen you may only be able to see Wat…

- Place the cursor on the colored box before Waterville and click it.
- Wait patiently until all of the black outlines around the Waterville data points have become bold. You have now selected the Waterville data points.
- Just above the graph is a row of symbols. Find the symbol that looks like a silhouette of a funnel. Place the cursor on the funnel shape, and when choices appear, click on "Keep Only Selected Cases". Wait while all but the Waterville dots leave the graph.
- On the left side of the screen find the words "CASE CARD" and below that the word "Attribute". Scroll down through the Attributes until you see "Arsenic, ug/l". Drag this to the Y axis where it says "(drag and drop Y attribute here)" and drop it there. Wait for the graph to rearrange.
- Now place the cursor over the words "Dot Plot" that are at the top and center of the graph. Click on this and a text box will appear. Delete the words "Dot Plot" and add a title to the graph that describes what the graph shows.
- Bring the cursor to the row of symbols above the graph and find the camera. If the window is not wide enough, you may need to click on the three vertical dots at the right side of this row in order to access additional functions. Once you have found the camera, click on it and a screenshot of your graph will be generated. This screen shot should be uploaded to the Google Form "Lab: First Two Graphs of Waterville Arsenic in Well Water Data" that is part of the Google Classroom assignment.
- Now you can try making different graphs by dragging attributes to just below the X axis and dropping them there. Don't forget to allow time for the graph to rearrange. As you make different graphs, change the name each time to reflect what the graph now shows and then take a screenshot by clicking on the camera icon above the graph like you did for the previous graph to save your work. Once you have a graph you like, double check the name to be sure that it describes what is on the graph you have created, and then take a screenshot by clicking on the camera icon above the graph like you did for the previous graphs. This screen shot should also be uploaded to the Google Form "Lab: First Two Graphs of Waterville Arsenic in Well Water Data" that is part of the Google Classroom assignment.

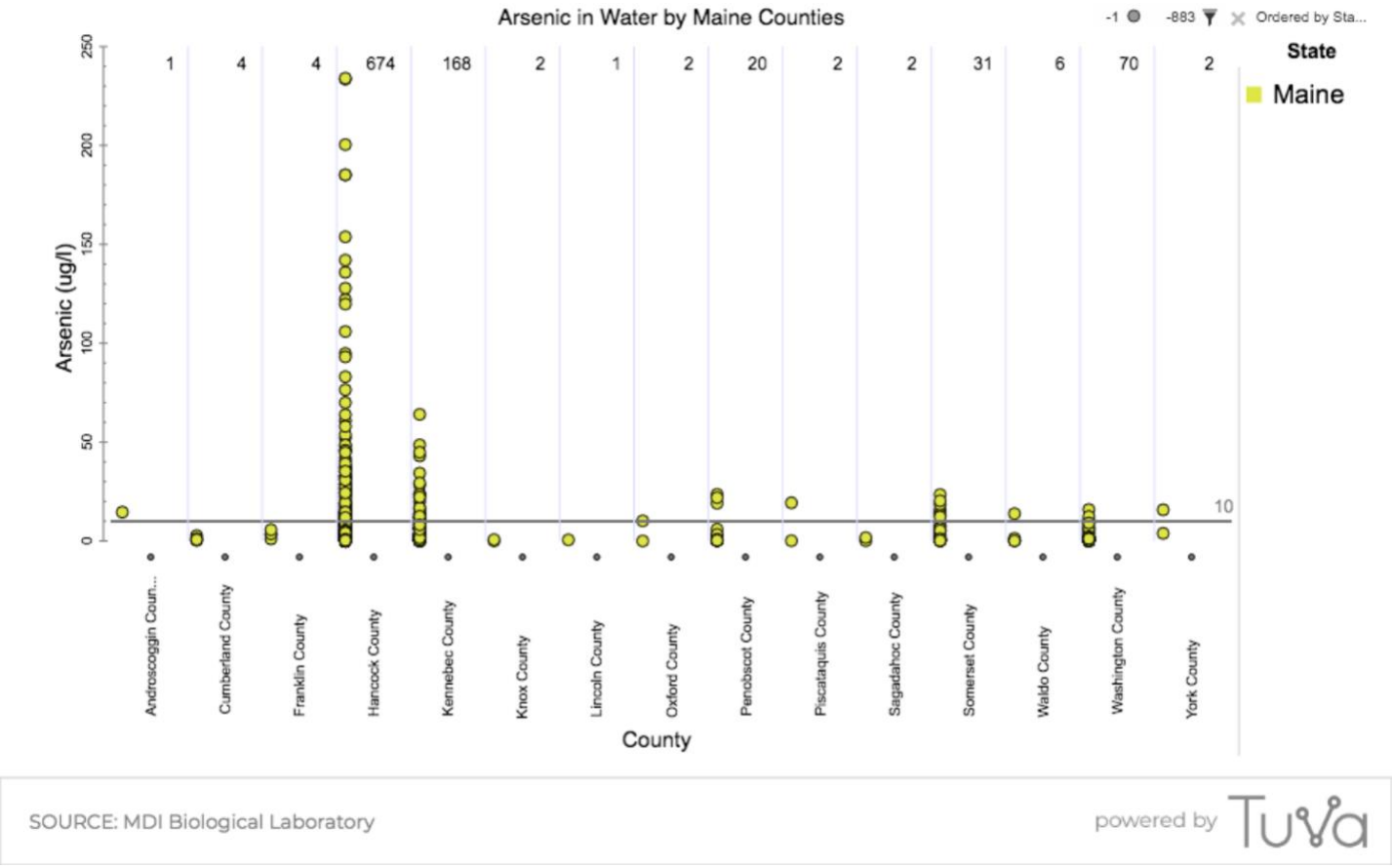
3. Lab: First Two Graphs of Waterville Arsenic in Well Water Data

1. Upload your first graph. (15 points) *
2. What is the highest concentration of arsenic found in the Waterville part of the Arsenic in Well Water (2016-2020) data set? (2 pts) *
   - 0.616 ug/L
   - 5.85 ug/L
   - 48.62 ug/L
   - 233.96 ug/L
3. Upload your second graph. (15 Points) *
4. Why did you choose this graph? (3 points) *
5. What, if any, significant relationship is shown by this graph? (2 points) *
6. Describe the evidence on your graph that shows the relationship you described in question 5 is significant. If your graph did not show a significant relationship, explain what evidence from the graph led to that conclusion. (3 points) *

4. Two Articles on Arsenic.

Read the attached articles. Complete the Google Form "Arsenic: How do we compare? How should we respond" based on the data in our study and these readings. You may want to make your own graph or graphs

of the arsenic data. Look at the earlier assignment "Lab: Create Your First Graphs of Arsenic in Well Water Data" for instructions on how to get to the data and make graphs.
The two articles are found on the discussion group.
https://labcentral.mdibl.org/workspaces/view/5ad60685-2768-4c77-bdc1-17c4d1dec312/forums/5aeb2e4b-a8d4-411f-97fa-40d7d1dec312/5ec83d16-ff3c-40a1-8c29-0727d1dec312



Google Form: Arsenic: How do we compare? How should we respond?

- Based on the data in our study and these readings, how do Waterville and Maine compare to the rest of the world when it comes to arsenic in water supplies. *
- What do you think our response should be locally and globally to arsenic contaminated water supplies? *
- You may upload up to 5 graphs that you would like to support your answers. You do not have to upload any graphs.

5. Google Form Letter to the Legislature: Arsenic
Write a letter to the Maine legislature about the pending legislation: LD-1943, HP-1387 An Act To Protect Drinking Water for Low-income Maine Residents, and upload it to the Google Form Letter: Arsenic provided below. If you would like me to submit your letter, please let me know.

- Read the information provided below:
  - The text of the bill.
  - The cost analysis if the bill is enacted.

  - Talking points from the Environmental Health Strategy Center.
  - You may also want to talk about what our data says about arsenic in our area. If you would like to look at that data again you should be able to see the graph that you made previously for the "Lab: First Two Graphs..." assignment. If you can't find your graph or you would like to make a new graph the instructions are attached to "Lab: First Two Graphs..." assignment. The instructions were called "How to Select Data in Tuva Lab".
  - The text and fiscal impact statements found at this url: http://legislature.maine.gov/legis/bills/display_ps.asp?paper=HP1387&PID=undefined&snum=129&sec0:
- Letter writers guide found here: https://www.maine.gov/sos/kids/government/path/exploring/write
- Talking points:
  - Protect Drinking Water for Low-income Maine Residents LD 1943 will protect people by requiring the state to provide free arsenic testing to low income residents and to set a health-protective maximum contaminant level (MCL) for arsenic in drinking water based on updated science.
  - Arsenic harms health for a lifetime.
  - Beginning with prenatal exposure, arsenic can harm health for a lifetime. Many pregnant women drinking well water have no idea of the health threats they and their children may face.
  - Arsenic in drinking water causes bladder, skin, and lung cancer. In Maine and other northern New England states, bladder cancer rates are 20 percent higher than in the rest of the nation.
  - A 2014 study of Maine school children with elevated levels of arsenic in their water showed a decline of average IQ scores five to six points lower than their peers with clean water.
  - In a state where over half the population drinks and cooks with well water, one in six wells is estimated to be unsafe, leaving more than 100,000 children and adults at risk.
  - When USEPA last revised its standard for Arsenic in drinking water in 2001, it had originally proposed 5 ppb and suggested that 3 ppb was feasible. However, the agency increased the level to 10 ppb to reduce costs to water utilities. Maine follows the USEPA level.
  - Since 2001, more evidence has accumulated as to the impact of lower levels of arsenic exposure. Based on epidemiological studies, California health officials have set a goal of .004 ppb in order to avoid lung and bladder cancers (a level 2,500 times lower than the EPA level).
  - Maine should follow the lead of two other states that have lowered their arsenic standard to further protect their citizens: New Jersey (2006) and New Hampshire (2019).
  - While the standard set by this bill will only be enforceable in the case of public water supplies, the standards are referenced by the state, laboratories, water treatment consultants and others helping residential well owners. It is extremely difficult to muster resources to help residential well owners reduce the level of a contaminant in their water lower than required of public systems.
  - Testing and remediation can be cost-prohibitive, especially for families that live paycheck to paycheck.

1. Would you like me to forward your letter to the Maine Legislature? *
   - Yes. Please forward my letter to the Maine Legislature.
   - No. Please do not forward my letter to the Maine Legislature.
2. Class
   - Applied Chemistry Block 1
   - Applied Chemistry Block 3
   - Applied Chemistry Block 4

- Honors Chemistry Block 2

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