Project Title: Arsenic Project

School: Gorham High School

Grade Level: 9

Teacher: Ms. Sarah Clemmitt

Project Partners:

Dr. Kate Buckman, Dartmouth Toxic Metals Superfund Research Program, Dartmouth College

Teacher Profile:

I have been teaching science for 23 years, and have taught at five different high schools including a broad mix of small, large, urban, suburban, rural, private and public. I currently teach 9th grade Integrated Science, Chemistry, Physics and AP Chemistry at a small, rural school in New Hampshire. I completed my undergraduate work at Colgate University with a BS in Geology and my graduate work at George Washington University with a MEd in Secondary Science Education. Throughout my career, I have committed to bringing citizen science to my curriculum and have actively pursued opportunities for students to get out in the field, to work with real data, to be placed in internships with local scientific organizations, and to present their findings in venues beyond the classroom.

Summary:

At Gorham Middle High School we teach Integrated Science to all 9th graders. This course is a blend of introductory physics and chemistry intertwined with relevant earth science topics all in alignment with Next Generation Science Standards (NGSS). We are in the process of blending a curriculum thread focused on water quality, heavy metals and the chemistry involved. In addition to the core ideas, we are committed to the NGSS Science & Engineering Practices. This Data to Action project involving arsenic in well water fits in perfectly. In the 2019-2020 school year, our 9th grade classes were composed of 35 students in two sections, leveled by ability. To my surprise most of the students live in homes with access to the town water supply so we were only able to collect ten samples for analysis. These samples were tested at Dartmouth College for fourteen metals. This year we focused only on the arsenic content in wells in Maine and New Hampshire. Due to remote learning resulting from the COVID19 pandemic, students analyzed the data using Google Sheets rather than TUVA. They focused on the percentage of wells above the state standards, where they are located, and the relationship to the type of well. Each student presented their information in a "mock outreach" project simulating one way to share scientific information with their communities.

Project Details:

June 2019 – I attended the Data Lit workshop at MDI to familiarize myself with the general aspects of arsenic in well water in Maine and New Hampshire, the role that schools are playing in public health outreach, and the details of data analysis, including but not limited to the use of TUVA.

December 2019 – I introduced the arsenic project to my students, found out which families had wells, and reviewed sample collection procedures. Given how rural Coos County is I was surprised at how few of my students live in homes with well water. Most live within the boundaries of the town water supply. Six students and four faculty supplied samples from four towns – Gorham, Randolph, Berlin and Milan. One student's family chose not to participate.

January 2020 – Samples mailed to MDI on January 15, 2020.

March 2020 – Kate Buckman and I met on March 6, 2020 to discuss my progress and questions.

March 2020 – Gorham's data was posted on Anecdata

April 2020 – Gorham Middle High School switched to remote learning on March 18, 2020. Most of the month of April was spent helping my students adjust to new technology and new social circumstances, as well as reworking my curriculum to accommodate this new format. As a result, I did not move ahead with the arsenic project until May.

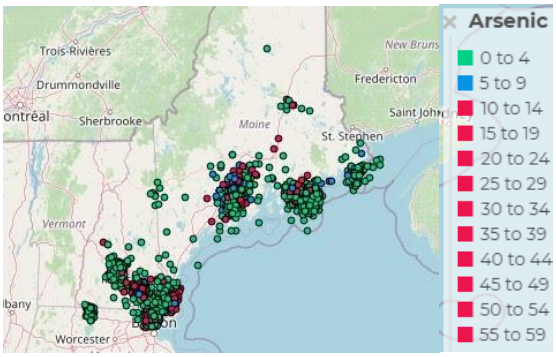
April 2020 – I met with Jane Disney and Anna Farrell via Zoom on April 9, 2020 to evaluate where I was with the project and how they could support me given the changes schools were encountering. One of the main points of discussion involved TUVA. Up to this point my students were working with Google Sheets. I planned to show them the power of TUVA and compare it to Sheets, but the switch to remote learning interfered. In light of this, I did not plan on using TUVA this year. To introduce a new platform onto top of the transition to remote learning was simply not practical.

May 2020 – Sarah Dunbar, the teacher at Mount Desert Elementary School, allowed me to sit in on her 7th grade presentations. This was helpful in two ways. (1) It is always helpful to gain ideas from colleague on how they approach the topic of arsenic and the data. (2) I was able to see how smoothly the class handled online presentations and the questions that followed.

May 2020 – I rolled out a set of three, remote learning modified, assignments for my classes.

1) As we had not discussed this project since December, I began with a reintroduction to arsenic and the project. They watched In Small Doses: Arsenic (10 min) and completed the following worksheet, All About Arsenic Introduction, Level 1 (adapted version for Level 2 & 3 students)
2) Next they looked at the data, Arsenic Data, Level 1 (adapted version for Level 2 & 3). As stated earlier, rather than introducing TUVA, they analyzed the data using Google Sheets. I downloaded the data and sanitized it for two levels of students, Drinking Water Data (2016-2020), Level 1 and Drinking Water Data (2016-2020), Level 2 & 3.

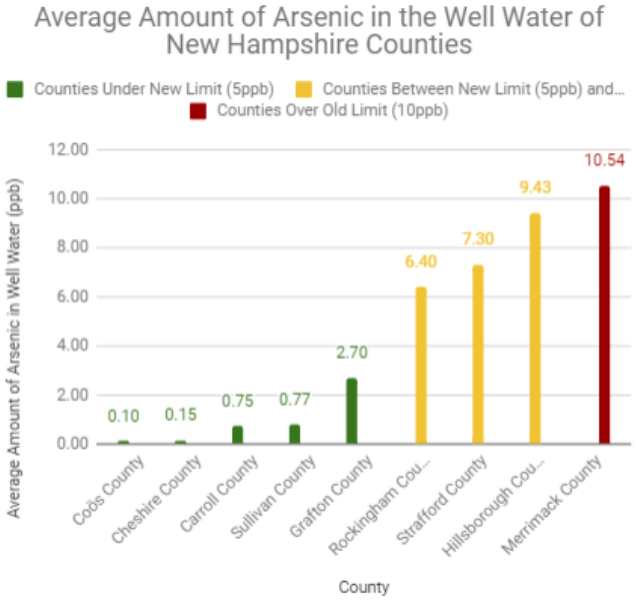
   As they were not using TUVA and geography plays a significant role, I created on TUVA so they could see the geographic distribution of the data.

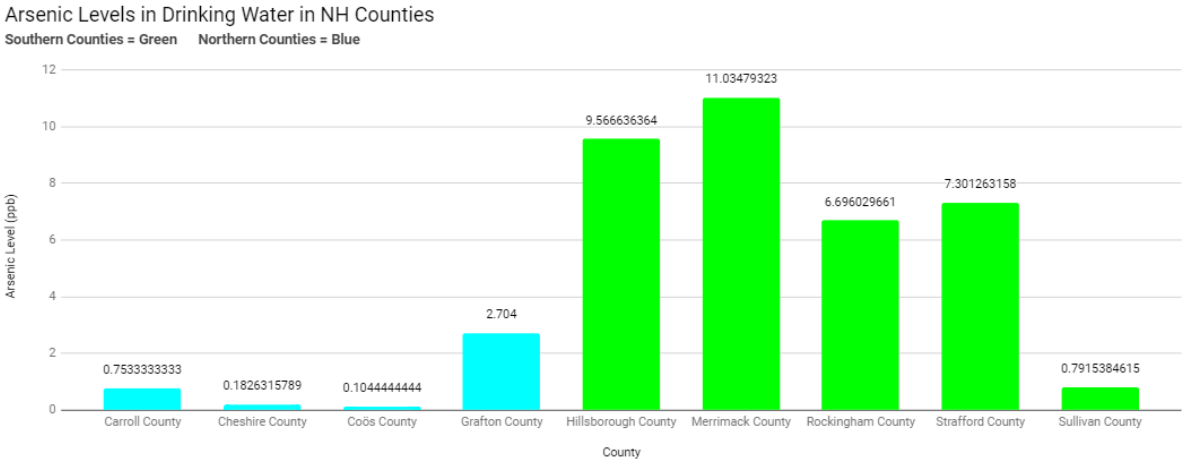


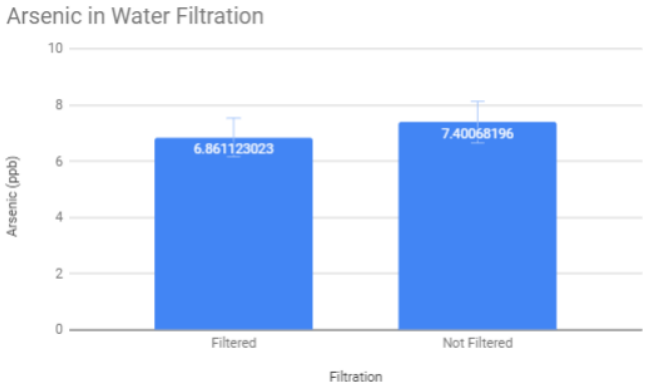
   Since the school system requested that all learning be asynchronous, rather than holding a brainstorming session I asked them to select one of the following four questions to analyze.

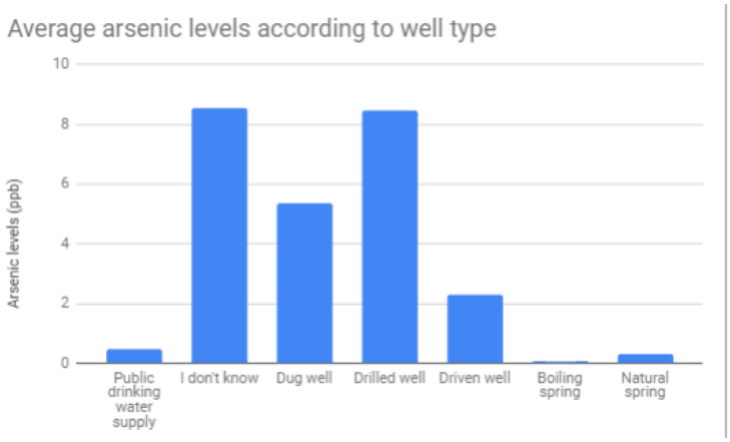
   - What percentage of the wells tested are above the state maximum?
   - Which counties in New Hampshire have the highest levels of arsenic in private wells?
   - Are arsenic levels related to whether or not the water is filtered?
   - Does the amount of arsenic depend on whether the well was dug or drilled?

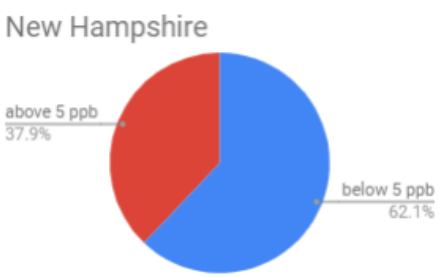
Below are samples of the graphs students produced.

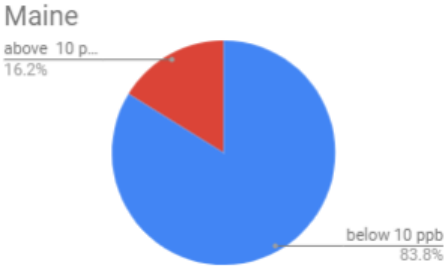


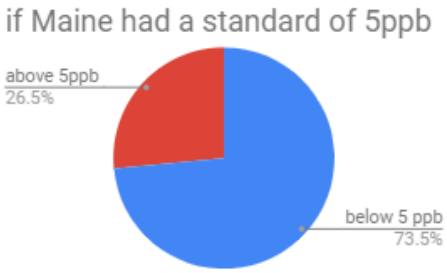












As they processed the data, they were asked to consider

- How to select data to isolate what they were examining and not include interference from other variables?
- How to show more than one relationship by color coding or breaking the data into subgroups?
- How different do values have to be in order to be considered statistically different?
- The limitations of the data set?

They followed up with an individual "meet" with me to discuss these aspects of their graph and a paragraph synthesizing their understanding of the following (1) What relationships or non-relationships were revealed? (2) What else should be considered? (3) To better define the relationship, what do you wish you had more information about? Below are three examples of student responses.

Concerning the 1st bar graph (see above) of As levels by county:

There were two main ideas that were discussed with Mrs. Clemmitt. The first of these ideas was related to the graph. The graph represented the average amount of arsenic in wells in each New Hampshire county. The bars on the graph were color coded to represent the range of the average amount of arsenic in each county. It was recommended that a legend be added that explained the ranges of the color coding. The graph showed that counties in the southeast corner of the state had higher levels of arsenic. In the discussion, it was explained that the correlation between the county location and amount of arsenic was most likely due to a belt of rocks, high in arsenic that went through the area. The arsenic in these rocks would then be absorbed by the water, contaminating it with arsenic.

It should be remembered that other factors, such as a low amount of wells in northern New Hampshire, could be the reason for the apparent relationship. To make sure of the rocks causing the arsenic levels, I wish that I had more information on the types of rocks in each county of New Hampshire. A detailed study of this information in addition to the arsenic levels would be likely to provide definite results.

Concerning the 2nd bar graph (see above) of As levels by county:

The data showed that the counties with the most arsenic in their private wells were Merrimack County and Hillsborough County, with an average of 11.0 ppb and 9.6 ppb respectively. Strafford and Rockingham Counties follow close behind with arsenic averages of 7.3 ppb in Strafford County and 6.7 ppb in Rockingham County. Coos County and Cheshire County had the least amount of arsenic in their private wells with an average of 0.12 ppb and 0.18, respectively. We discussed that the levels of arsenic in the southern counties of New Hampshire are most likely higher than the ones in the Northern counties because of the rock in the Earth under those counties. The arsenic that is found in water from the ground and water that you get from wells originates from two places, water with high pH and low dissolved oxygen levels, and rocks with arsenic in them. I wish I had more information on exactly what types of rocks contain the arsenic in NH. I would also like to know more about where those rocks are present in the ground around New Hampshire geographically to see if those levels of arsenic are caused more by the rocks or the water.

The map shows arsenic data in New Hampshire and in Maine. The largest clusters were in the most populated areas. The most common place to find arsenic is in drilled wells compared to dug wells. Gorham was tested to show if there was any arsenic was in the northern part of the state. The average ppb for drilled wells was 8 and the average for ppb dug wells was 5.5. Another thing to be considered is the type of soil surrounding the wells. More information on the numbers and types of wells tested in the upper half of both states could be helpful.

Concerning the bar graph of filtered vs. unfiltered wells (see above):

Ms. Clemmitt and I talked about how there is no relationship shown, how there are high levels of arsenic in the same line, and if people are using the right filter. There is no relationship revealed because the difference in the average levels of arsenic between if people are using a filter or not doesn't show much of difference the average level for the people that say they use a

filter is 6.9 and the average for people that don't use a filter is 7.4 which isn't much of a difference. I think what type of filter that people are using should be considered because there's different types of filters and some do not filter out the arsenic in the water which the people that are using the filters that do not filter out arsenic might be the reason why the yes column is so high on the graph. I wish there was more information about what type of filter people are using. The areas that have no signs of arsenic should be taken out so you can see more of a relationship on the map.

Concerning the pie charts (see above):

When looking at the charts, there is no true relationship between the two charts. It is more of a comparison between the two charts. New Hampshire and Maine have different requirements for the level of arsenic they can have in the water. New Hampshire has a requirement of 5ppb or below but Maine has a requirement of 10 ppb or lowers which is the same as the federal requirement. The New Hampshire chart says that 62.1% is below the state requirement and In Maine, 83.8% is below their state requirement. When the Maine chart was changed to 5ppb or lower, the percent of it being lower than 5 ppb is higher than New Hampshire. Something that could be considered is more testing needs to be done.

3) In lieu of a community outreach, I had the students create a "mock outreach" product, Arsenic Project Wrap Up, explaining to them the following: This Arsenic project and the Mercury project we worked on with Dartmouth are called "Citizen Science" projects. The idea behind these projects is that anyone, anywhere can participate in meaningful scientific research. It is hoped that you will become more knowledgeable about the scientific process and play a role in influencing larger decisions about science policy in your community.

   They were asked to choose from the following list:

   - **Slide Show** presentation that could be given to another class or at a town meeting.
   - **Letter to the Editor of the Berlin Daily Sun** explaining arsenic contamination of wells in the North County and greater New Hampshire (think southern NH), the July 2019 changes made in New Hampshire, and offers solutions for people with private wells.
   - **Map of NH Counties** including some basic statistics on well water contamination in that area from our data set - number of wells, percent exceeding the Maximum Contaminant Level (MCL), types of wells.
   - **Historical Essay** on our understanding of the toxicity of arsenic and how we have learned to manage this toxin.
   - **Timeline** of our understanding of the toxicity of arsenic and how we have learned to manage this toxin.
   - **Testimony** about the bill that was passed last July (2019) lowering the Maximum Contaminant Level (MCL) in New Hampshire from 10 ppb to 5 ppb. Describe the bill and why it was proposed. Share your thoughts on the change and relate it to the data set.
   - **Brochure or Infographic** discussing the health risks of arsenic, how arsenic gets into drinking water, ways to remove arsenic from well water, etc.
   - **Short Film** about arsenic and well water contamination.

   Most students chose the first option. Below are samples from student products of the other options.

Sample Letter to the Editor

The arsenic levels in our state are getting to the point where it's almost out of control. Northern New Hampshire is expected to have higher levels of arsenic since we are surrounded by bedrock. We need to inform the residents, especially those who have private wells. The water from private wells have more chance of higher levels than those using town wells. If arsenic is in the town water the Water Department takes care of it but if you have your own well it's the owner's responsibility. This problem is more serious in the southern parts of the state but we all should be aware that arsenic in our water and may cause health problems.

New Hampshire gets its drinking water from groundwater which contains high levels of arsenic due to the amount of bedrock in our state. "Past research from Dartmouth College suggests this is one reason the state has some of the nation's highest rates of certain cancers, such as bladder cancer." (Annie Ropeik) This is a problem that cannot be solved through heating or boiling the

water. You should consider using reverse osmosis, ultra-filtration, distillation, or ion exchange. This project will take a lot of commitment but if continue working on it the health of NH residents will be better off.

As of July 12, 2019 New Hampshire reduced allowable levels of arsenic to 5ppb in public drinking water. NH is the first state in New England to make the arsenic levels below the federal limit of 10 ppb. With this recent change hopefully we can inspire other states to the same thing.

Sample Map of NH Counties

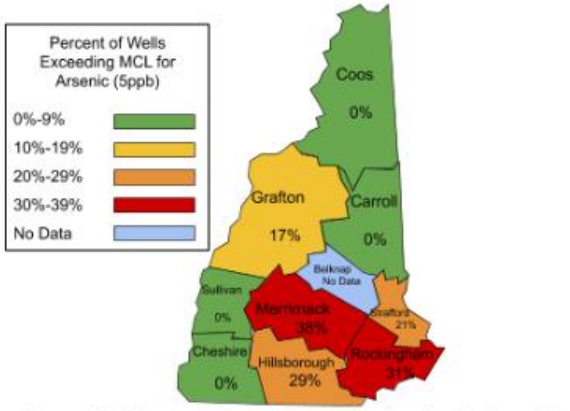


Figure 1. The Percent of Wells in New Hampshire Counties that Exceed the Maximum Contaminant Limit for Arsenic

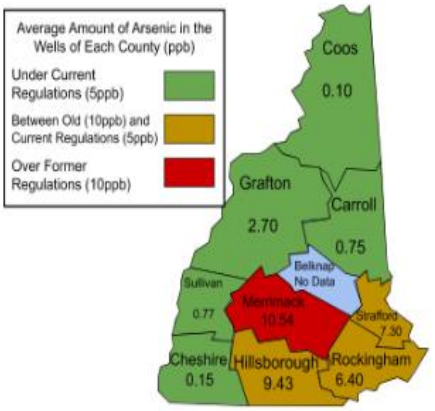


Figure 2. The Average Amount of Arsenic in each County's Wells in Parts per billion

Sample Testimony

New Hampshire House Bill 261 is a bill that required the Maximum Contaminant Level of arsenic in drinking water from wells and other sources of groundwater to be lowered from 10 ppb to 5ppb. This bill was passed on July 12, 2019, and was placed in effect on October 10th, 2019. The bill requires the commissioner of the NHDES to change the rules about arsenic contamination in drinking water. The bill also requires the commissioner to initiate the rules that enforce lowering the amount of arsenic in groundwater for public water systems. Before the bill was officially approved, the commissioner was required to review the groundwater standard and decide whether or not to lower the amount of arsenic allowed in the drinking water. This was decided by "taking into consideration the extent to which the contaminant is found in New Hampshire, the ability to detect the contaminant in public water systems, the ability to remove the contaminant from drinking water, the impact on public health, and the costs and benefits to affected entities that will result from establishing the standard." It also states that if the water is very contaminated, the Department of Environmental Services will "assist with the capital costs of compliance with new or revised maximum contaminant levels or ambient groundwater quality standards." This means that if money is needed to remove the arsenic from water then the DES will help with the cost.

This bill was proposed because the Dartmouth College Superfund Research Project found that people with more than 5 ppb of arsenic in their drinking water had increased risk for diabetes, heart and lung disease, and bladder, lung, and skin cancer. This bill was proposed to try and stop these negative health effects and make sure people are healthy. According to Adeline Lopez of Environmental Factor, "The law applies to public water systems, yet nearly half of all New Hampshire residents rely on private wells." I think that this change to the law is very necessary since there have been adverse effects on people's health, but I also think that this bill is only helping half of the residents in NH because it is not taking into account the people with private wells. There are high amounts of arsenic in water from private wells, and the government needs to also include something that helps those people. According to the data from the Dartmouth Toxic Metals Superfund Research Program, four counties in New Hampshire have an arsenic content average that is above 5ppb. Wells in Merrimack county had an average of 11 ppb of arsenic, which is even higher than the previous limit for arsenic. High arsenic levels can cause major health risks to the people in New Hampshire who rely on their wells for drinking water. It is the state government's duty to keep ALL the people in their state safe, and I don't think that they are doing it with this law.

Discussion:

Students are leaving this school year with a broader awareness of toxic metals and water quality. This year they participated in two citizen science water quality projects, both of which have demonstrated that there are protocols for sample collection and the role that citizens can play in the acquisition of data. In

addition, the science was not something that came out of a textbook, rather the science was intimately linked to their community and the broader communities of the state and New England, its geology and history.

As 9th graders, they began to appreciate how to handle larger volumes of data (approximately 1800 data points) and the tools available to make that easier as well as the subtleties of how to display data to demonstrate a relationship, or multiple relationships, all in the same graph. As the end of the school year was radically altered and the community outreach portion was disrupted, the outreach piece was less developed than intended.

As this was my first year working on this SEPA project, my primary learning revolved around arsenic and water quality. In order to not only present the data set in a comprehensible way to younger high school students and to blend the information into our already existing science curriculum, I read a lot and asked a lot of questions. I am quite pleased with the results and excited to continue to develop this project.

Early in this process I came to the understanding that the community outreach piece of this project would need to be slightly different for our school. Living in Coos County, it is unlikely that we will sample any wells with elevated levels of arsenic. However, many of students have family members that live in the southern region of the state and many students leave us for college and jobs in southern New Hampshire or coastal Maine. Jane Disney and I are mulling over ideas of how to have the data analysis my students do be part of a broader public health initiative by coordinating next year with a southern "partner" school.

In addition, I intend to begin data collection much earlier next year. The school is changing my classes to be semester long with one section meeting each semester. In order to have both sets of students involved, I will collect samples twice, in early September and again in late January. Essentially the whole process will happen twice, once each semester.

Conclusion:

I have a strong commitment to citizen science and throughout my career have actively sought out data driven projects to foster a deeper connect between my students and their community. The All About Arsenic project is a beautiful fit. For us, up in Coos County, this project allows students to not only look at the water quality in their own homes and gain awareness of where their water is coming from, but the project also expands the definition of "community" to what is going on in other portions of the New Hampshire and New England that affect legislation. I cannot think of a better way to begin having them explore the interconnectedness of people and regions.

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Acknowledgement: The work reported in this publication was supported by the National Institute of General Medical Sciences of the National Institutes of Health under Award Number R25GM129796. The content is

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