PREPARED BY THE
SHUTESBURY ELEMENTARY SCHOOL
5/6 GRADE EAST - MR. BERGER'S CLASS

BASED ON THE RESEARCH DONE BY THE 5/6 GRADE EAST

JANUARY 1999

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Introduction and Methods

Fifth and Sixth Grade East at Shutesbury Elementary School is studying the water in our town. We chose to do this study because it is a good community service and teaches fifth and sixth graders important computer skills. Additionally, this type of research project is a good way to introduce elementary students to adult level science. Finally, it provided our class with the opportunity to work with Hampshire College.

For our project we got a Lighthouse grant from the Massachusetts Department of Education. This helped to pay for the use of the Inductively Coupled Plasma Mass Spectrometer (ICP-MS). The ICP-MS tests water for trace levels of elements. The grant also brought computer hardware, software, and technological support to the elementary school.

The well project is one part of our study of water. In our town there is no public water supply, only private wells. There is no law that you have to test your well, so many people have no idea whether their water is safe or not. As a community service we tested chosen families' private wells. We would have liked to have tested every family in town that wished to have their well tested. However, our budget limited us to sixty-five wells. The level of testing that we did on each well if done by a private testing firm would have cost each family over one hundred dollars. Even with our free labor, running the machine was so expensive that we could not cover the costs for every home in town. We were able to test over half of the families from our school. We selected houses from every classroom in the school and geographic region in the town.

Our testing could not be a comprehensive water purity test because the machine we were using could not test for bacteria or organic compounds, including pesticides, some of the most dangerous substances that can get into a well. It could only test for inorganic elements. We couldn't test for all elements, because some, such as Sodium and Calcium, had levels that were too high for the machine to handle. We did, however, test for a lot more inorganic elements than any private water testing firm would.

When our class had finally picked different homes from the town, we put together testing packets. The testing packets contained a survey, about depth of well and the age and material of pipes, and a map to enter house and well location, and a site map. It also contained two sterile bottles to take a Sample A and a Sample B. Sample A was a sample of the first water run from the faucet in the morning. The water had been sitting in pipes all night, so our class suspected that there would be higher levels of elements in Sample A because elements from pipes might leach into the water. Sample B was a sample collected after the water had been running for at least five minutes, so the water in the pipes had been flushed out. Sample B was a true well Sample and Sample A was a pipe sample. We suspected that there would be lower levels of elements in Sample B.

Our next step in our project was locating houses on a big map of Shutesbury that was donated to us by the Metropolitan District Commission, a GPS map especially created for this project. We used different colored pins to show the depth of the wells. There were also different grid sectors to separate parts of town, taken from USGS topographic map grid lines.

The samples came in on a Tuesday morning, and we quickly tested pH using pH paper. Then the samples were taken down to the lab at Hampshire College to be tested for various elements.

The elements and their Government standards for maximum safe levels are:

ELEMENTS	94 EPA STANDARDS
Beryllium	4 ppb
Aluminum	50 ppb
Chromium	100 ppb
Manganese	50 ppb
Iron	300 ppb
Nickel	100 ppb
Copper	1300 ppb
Zinc	5000 ppb
Arsenic	50 ppb
Selenium	50 ppb
Silver	100 ppb
Cadmium	5 ppb
Antimony	6 ppb
Barium	2000 ppb
Mercury	N/A
Thallium	2 ppb
Lead	15 ppb
Uranium	N/A

KEY
ppb - parts per billion
N/A - no government standard

For the next six weeks these samples were tested for levels of elements. We realized about three weeks into the testing that our pH paper had been inaccurate. We got new samples from wells, and students went down to Hampshire College to retest the samples, this time using electronic pH meters, which turned out to be far more accurate than the paper.

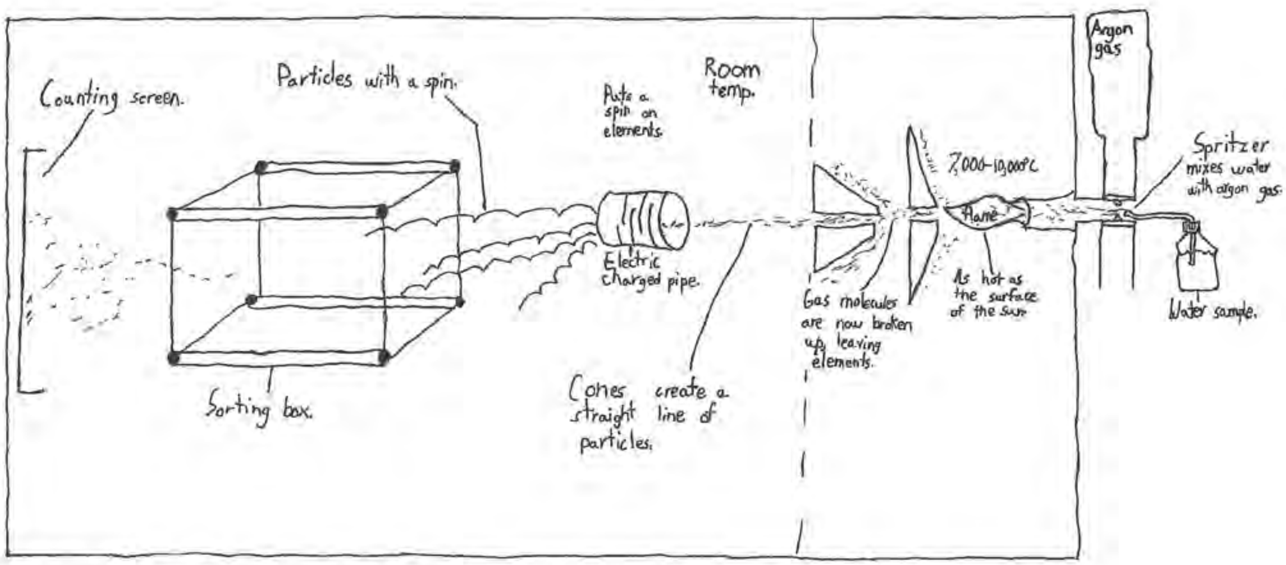
When the results came back from the lab we prepared an individual report for each family. The report included a full table of the elements that were in the water, along with their results and the 1994 EPA standards. We composed letters explaining whether their water was safe or not, and in what way was it unsafe. If our test results showed that the water was unsafe we recommended names of firms to retest the water, just in case we made a mistake.

Our class then looked through the raw data and brainstormed questions to research based on what we thought might be important to the town. This report is the summary of our findings. We hope you find it of interest.

The ICP-MS: How It Works

As you know, the Inductively Coupled Plasma-Mass Spectrometer (ICP-MS) is the machine that we used to test our water samples. When you put the water sample in the machine it is spritzed together with argon gas. This mixture is passed through a chamber with ruby tips. The rubies are used because they are a very hard material and the argon gas water mixture won't wear them down as fast as it would metal. After that it is shot through a flame as hot as the surface of the sun (7,000°C - 10,000°C), which breaks up the water and any compounds in the water leaving just elements. The stream of elements and gas is focused and sent through two sets of cones. Only the elements shooting in a straight line go through the cones. When the minerals come out the other side of the cones, they are sent into an electrically charged spinning pipe. This gives the elements a huge spin. The spinning elements are flung into a box where they are sorted by their weight. The heavier elements settle to the bottom, while the lighter ones stay on top. The elements continue through the box and hit a screen sensor that counts all the elements in the sample. This information is then displayed on a computer screen that is hooked up to the machine.

ICP-MS Diagram



Summary of Findings

The first and most important thing that we would like to share with the town is that there were no toxic elements above EPA standards in B Samples, the samples that represented well water. We did, however, find levels of some elements which exceeded EPA secondary standards. Secondary standards are elements that make the water smell bad, taste bad, cause plumbing problems, or discolor your laundry. The elements which we found that exceeded secondary EPA standards were Iron, Manganese and Aluminum.

We have contacted a number of experts regarding the health concerns of these elements and everyone seems to agree that Iron and Manganese are not a concern. Most people feel also that Aluminum is not a concern, although there are some people who are still worried about Aluminum levels. A few years ago, there were articles which linked Aluminum to Alzheimer's disease, but most scientists feel that the research behind those articles was inaccurate and that the connection was false. The two families with high Aluminum levels remain concerned.

In all, we had four wells which exceeded EPA levels in Iron, four in Manganese, and two in Aluminum.

Sample A values were very different. A Samples were the ones that had been sitting in the pipes overnight. We had many A Sample values which were above EPA standards. The elements which were high in Sample A's were Copper, Lead, and to a lesser extent, Zinc and Nickel. This suggests that these minerals are leaching into people's water from their pipes.

The EPA standard for Copper is 1,300 ppb's. In A Samples we found certain houses that had Copper levels in the twenty thousands. In fact we had one Sample A Copper that had 42,000 ppb's but only 191 ppb's in Sample B.

Because some homes had such high levels of Copper in Sample A we wanted to look into more details of why there are such high levels of Copper in Sample A. We researched a number of questions relating to Copper levels. We looked into the pH of the water to see if Copper was leaching from pipes more in houses where the pH was lower, meaning the water was more acidic. There was a slight positive relationship, but not as much as we had expected. We think this may be because none of our water samples were very acidic – low in pH.

We also looked at Copper levels and the age of the pipes. We wondered if newer houses had more Copper leaching in. We did find a clear relationship. It only applied to houses which had very high levels of Copper (above about 5,000 ppb), but in those houses, the newer homes had higher levels, and older homes lower levels. We also had a very interesting story with an outlier. The house that had 42,075 ppb's of Copper, much higher than anyone in town, turned out to be a special case. The family told us that they took the sample from a laundry faucet that hadn't been used for about four days. This suggested to us that the longer the water sits in your pipes, the more the elements may build up. The lesson to us is that if your water has been sitting in pipes for a long time, such as coming back from vacation, you may want to run your water first to flush your pipes before drinking it.

The EPA standard for Lead is 15 ppb. The A Samples in our town were consistently higher than our towns B Samples. We had A Samples as high as 56 ppb's, but B Samples didn't go higher than 9 ppb's, and most were near 0 ppb's.

It is important to say that Lead is a very dangerous element that can cause brain damage. We were very happy that we did not find any Sample B's that were over EPA standards. However, we found 11 A Samples that were above the EPA limit of 15 ppb's. This means that 18 percent of the homes we tested in Shutesbury had over EPA standards of Lead in Sample A. It is possible that about 1 in every 5 homes in town have over EPA Lead standards in water that has been sitting in their pipes. People may want to consider running their water or filtering their water who have high Lead levels.

We were interested in where this Lead was coming from. We assumed that the older homes with Lead solder would have Lead coming from the pipes and newer homes would have none. We were surprised to find not only that newer homes had Lead, but the many homes with higher Lead were the newer homes. There was even a slight relationship that linked higher Lead to newer homes. This was one of our most surprising findings in the whole study. We don't understand where the Lead is coming from if it is not from the solder.

The EPA standard for Zinc is 5000 ppb's. Most of the samples we tested had experimental errors, so we did not include Zinc in our report. But we found a couple of A Samples that had high levels. A few samples were two times the limit.

We investigated a number of research questions, including sectors of town verses elements, to see if certain elements clustered in certain sectors of town. The group who researched that question found no strong relationships.

Another group looked for relationships between different elements, to see if high levels of one element would tend to mean that there would be high levels of another elements in the well water. This group found no strong relationships.

One group researched depth of well verses levels of different elements. They found no relationships.

In conclusion, we were very pleased to find no unacceptable levels of toxic elements in any wells we tested in town. Although we were not able to test every well in Shutesbury, we were able to test wells in every sector in which there were homes. Our research did raise some questions and concerns regarding water that has been sitting in pipes in people's homes.

A more full description of our results can be found in this report.

Research Group 1: Town sectors and Elemental Patterns

1) What correlation did we research?

Our research group investigated the different sectors in the town to see if some sectors had higher levels of certain elements in the well water. We used a grid on a topographic map to divide a large map of Shutesbury into sectors.

2) Why did we choose this correlation to look at?

We wanted to know if certain sectors of town have higher levels of certain minerals than others.

3) What did we expect to find?

At the time we didn't know what to expect.

4) What did we find?

We used two topographical maps that were large sized maps (about 4 feet by 5 feet) prepared especially for our class by Philip A. Lamothe at the MDC. These were GIS maps with exactly the information on them that we requested. We used standard USGS topographic map grid lines for our sector lines. We divided the town into seventeen sectors.


Matt, Cori, and Cory placing pins on the map.

On one of the maps we used pins to indicate all sixty-two wells that we picked in Shutesbury. And then on the second map we put colored pins to represent the twenty wells with the highest concentration of each mineral. Then we made a key for what colored pins represented what minerals.

Students in the class looked at the map to try to find visual patterns. We didn't find any clear patterns in any one of the sectors. We then realized there might be a pattern that we didn't see on the map. So we wrote down how many wells were in a sector and then wrote down how many certain colored pins were in that same sector. For example, sector "C6" had six wells and 21 different colored pins in that sector.

We did that to all the sectors on the map that had wells in them and we copied it onto Microsoft Excel. Once the data was in a table, some slight patterns emerged. Three sectors had higher total minerals than other sectors, and it turned out that all three sectors were in one area of town. We highlighted this area on the town map, which follows.

We then started over with a different approach. We only used pins for the top five wells in each mineral category. We thought we might see patterns that didn't appear in the top twenty. One new pattern did emerge. The southern sectors of town had all the Barium.

Research Group 1: Lead in A Samples vs. Lead in B Samples.

1) **What correlation did we research?**

   We researched Lead in A Samples vs. Lead in B Samples.

2) **Why did we choose this correlation to look at?**

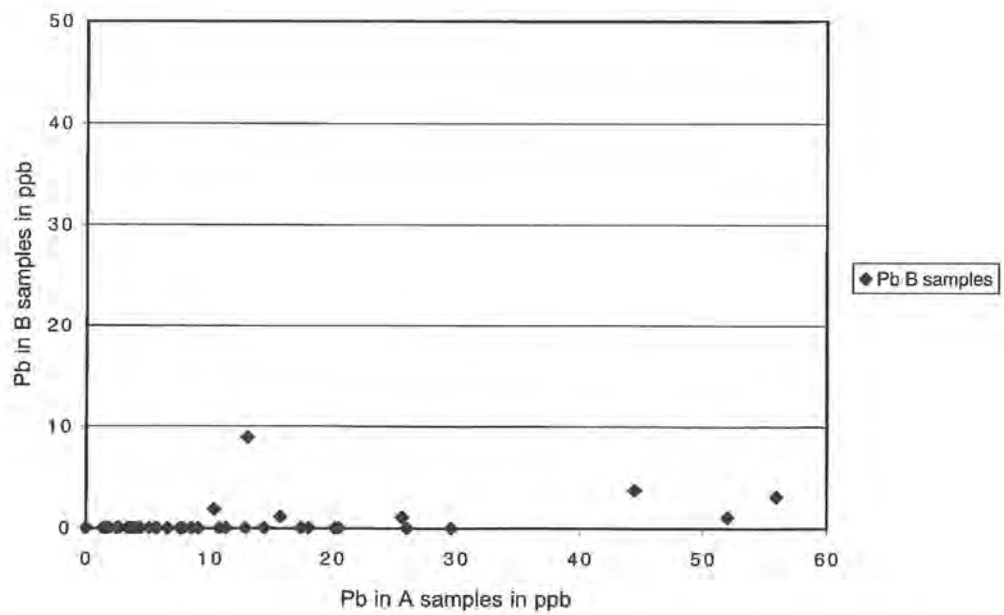
   We were interested to see if either A Samples or B Samples had more Lead than the other. Above 15 ppb, Lead is considered a toxic substance in water. Though none of our B Samples were above this standard, some A Samples were. We wanted to see how much of the Lead we found was coming from the pipes, rather than coming from the ground.

3) **What did we expect to find?**

   We thought that there would be more Lead in A Samples than in B Samples, because the A Samples were sitting in the pipes all night long and they might collect Lead from the pipes.

4) **What did we find?**

   We found that there was more Lead in A Samples than in B Samples, in 61 out of the 62 samples tested. As you can see in the graph, all the A Samples are below the 45 degree line which means that there is more Lead in A Samples than in B Samples. In fact most of the A Samples were on the x axis line which means that there was no Lead at all in the B Samples. You can see this in the following graph.



We are not sure where the Lead is coming from in people's pipes. Lead solder was used in pipes, but it hasn't been used for more than ten years. Most houses had higher Lead in Sample A, even if they were new houses. Where is this Lead coming from?

Could it be coming from faucets? Pumps? Entry pipes? We don't know. We have talked to some plumbers, but we still don't understand this.

Research Group 2: pH vs. the Difference in Lead and Copper in A & B

1) **What correlation did we research?**

We researched pH vs. the difference in levels of Lead and Copper in Samples A and B.

2) **Why did we choose this correlation to look at?**

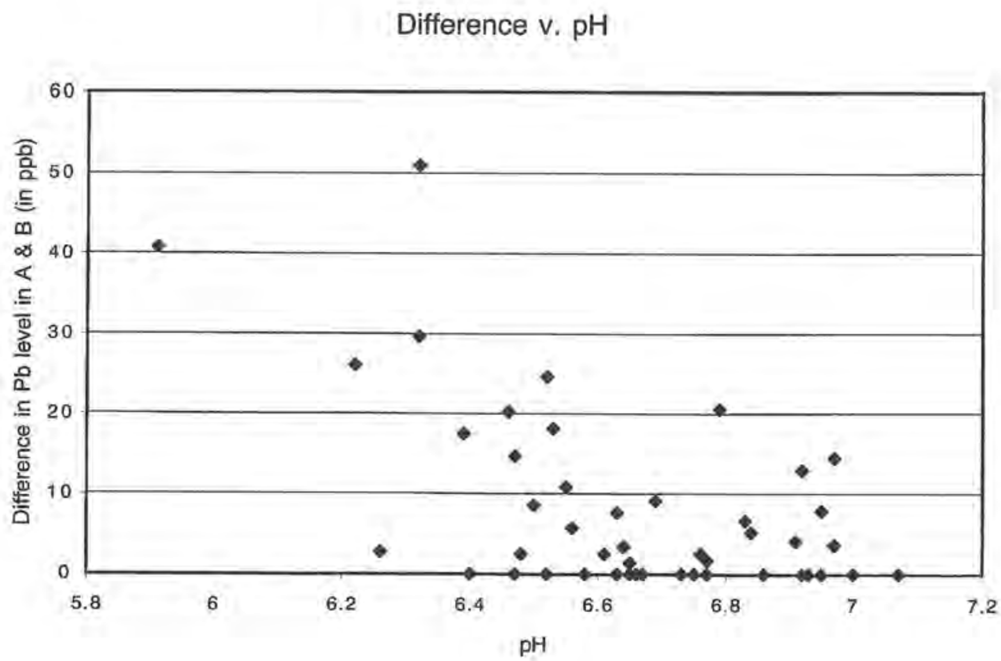
We chose this correlation because we wanted to see if the more acidic water would eat away at the pipes a little bit and affect the levels of minerals in the water in Sample A.

3) **What did we expect to find?**

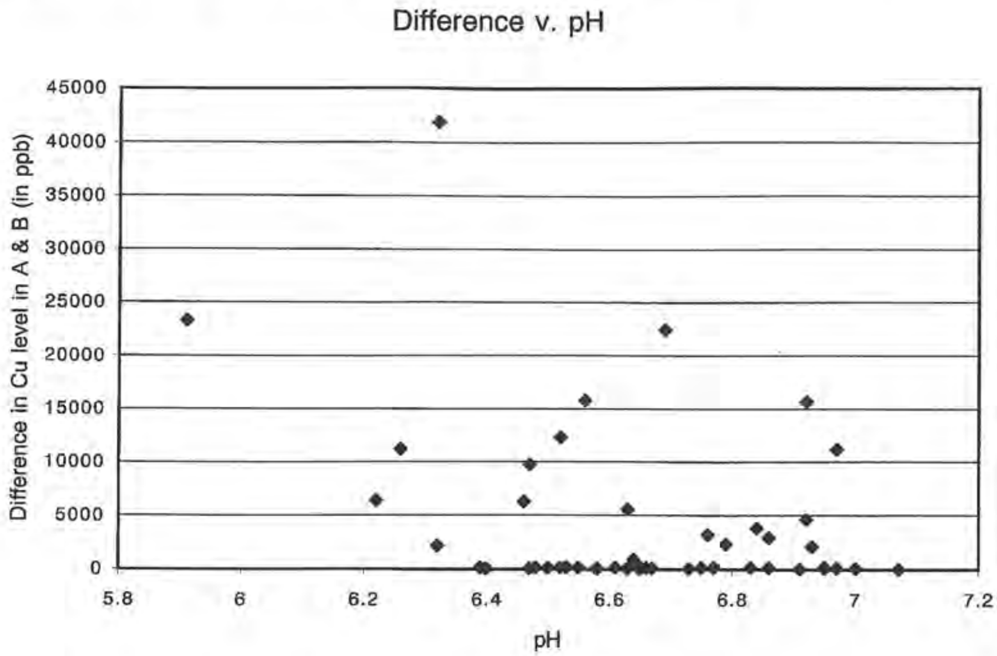
We expected to find that the lower pH levels would raise the amount of Copper and Lead in Sample A because the acid in the water might dissolve some of the Copper and Lead from the pipes or solder. We decided to take the difference between the levels of minerals in Sample A and in Sample B, and graph this against pH levels.

4) **What did we find?**

In graphing Lead, we believe we found a relationship as we guessed there would be. In the graph of Lead which follows, you will see that the data suggest that as the pH levels go down (more acidic water), the Lead levels in most cases go up.



We did not find any clear relationship between the difference of Copper in A and B vs. pH. The graph below suggests that there may be a slight trend.



Research Team 3: pH vs. Cu and Pb in Sample A

1) **What correlation did we research?**

   Our research team did research on pH verses Copper and Lead in Sample A.

2) **Why did we choose this?**

   We chose to do research on pH verses Copper and Lead in Sample A because we thought that the more acidic the water, the more it may eat away at the pipes during the night. If your pipes are made of Copper, or if you have any Lead in your solder or faucet, we thought that it may leach into your water as a result of the acidic water.

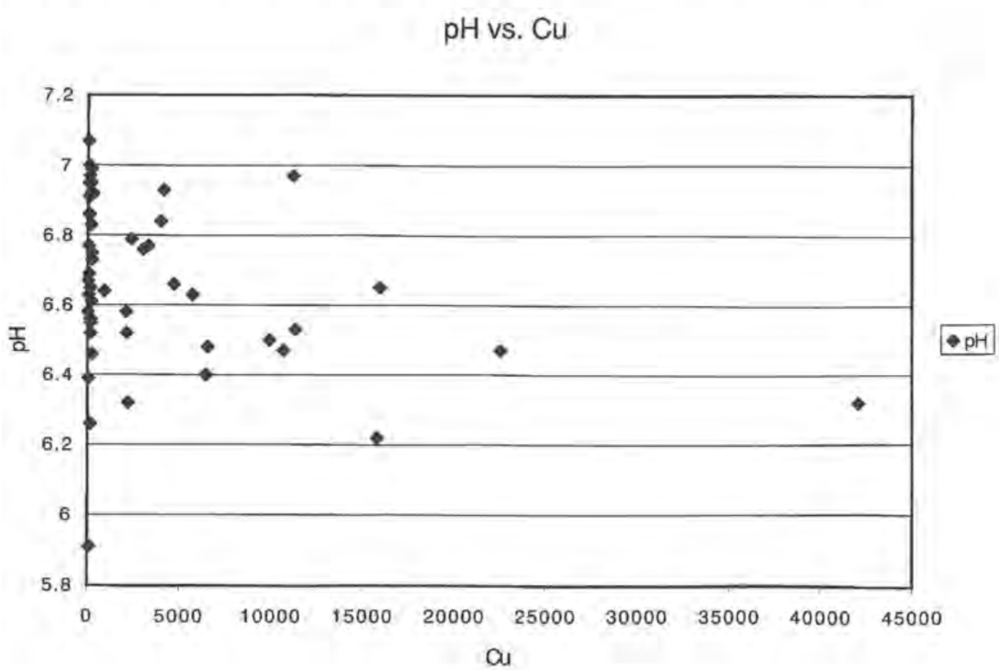
3) **What did we expect we might find?**

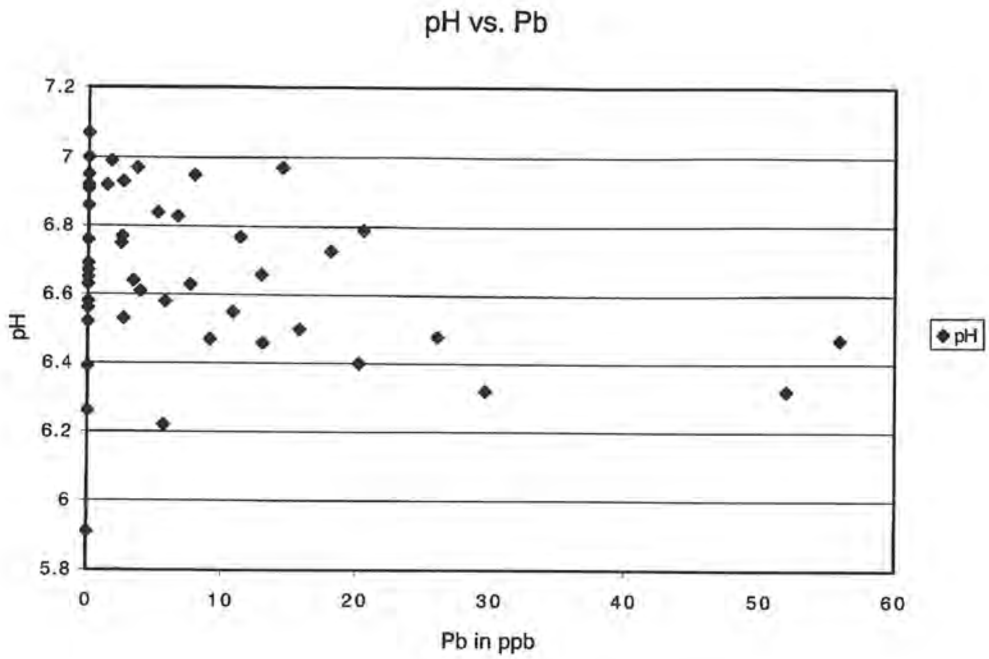
   We expected to find that when the pH was lower, for example, 6.5 and below, the Copper or Lead would be higher.

4) **What did we find?**

   We created scatter graphs of pH levels verses Copper and Lead levels using Microsoft Excel. We expected that there would be a stronger relationship than we found between pH and these two elements. There may be a slight relationship, as we noticed that in Copper verses pH, eight out of ten of the highest samples in Copper were in the lower half of pH, where the water is more acidic. In Lead verses pH, seven out of ten were in the lower half of the graph.

   In these data, it doesn't seem that pH is a big factor in how much Copper or Lead was leached into the water, contrary to what we guessed. We think this may be because none of the well samples were very acidic. Our most acidic sample was 5.9. If we had gotten samples that were closer to 5, our theory may have held up. It's important to remember that a pH of 5 is ten times as acidic as a pH of 6.




pH vs. Pb
7.2
7
6.8
6.6
6.4
6.2
6
5.8
pH
0
10
20
30
40
50
60
Pb in ppb
pH

Research Group 4: Cu in A vs. Cu in B

1) What correlation did we research?

We looked at Copper in Sample A versus Copper in Sample B.

2) Why did we choose this correlation to look at?

We chose Copper in Sample A vs. Sample B because Copper was one of the minerals we found in high levels in Sample A. It also seemed to us that Copper levels in Sample A tended be higher than levels in Sample B. And we thought that higher levels of Copper in Sample A would mean that pipes were leaching Copper into the water. But we couldn't assume this was true without looking at all the data on a table and graph and seeing if there really was a relationship.

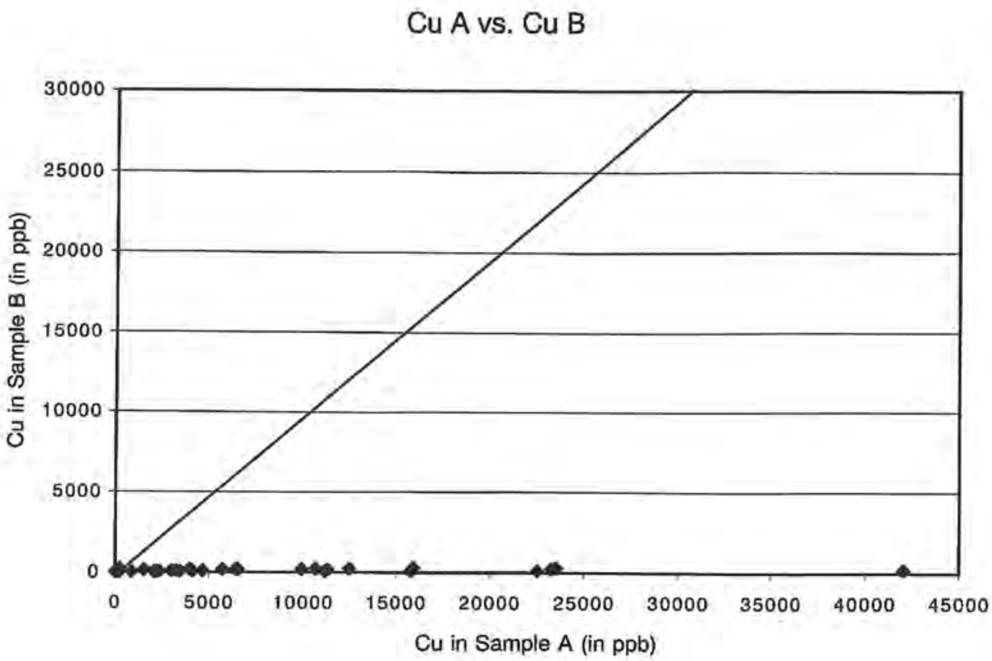
3) What did we expect to find?

We thought generally that Sample A would have higher levels of Copper than Sample B because lots of the homes we tested had Copper pipes. We knew there were some homes in which Sample A was much higher, and we expected that this would be true for most other houses.

4) What did we find?

As we thought, A Samples were much higher in levels of Copper than B Samples. The EPA standard for Copper is 1300 ppb (parts per billion). None of the B Samples were higher than that, but some A Samples were much higher. For example, house number 102 had 42000 ppb. Copper in Sample A, but in Sample B it was only 191, well under the standard. We looked at other houses that were in the twenty thousands and also had B Samples under the limit. These data indicate that most of the Copper in water from wells we tested leached in from the pipes.

Here is a scatter graph of A Samples vs. B Samples. We drew a 45-degree diagonal line from the origin. If all of the dots were on this line or near it, that would mean that each well's Sample A and Sample B had approximately equal levels of Copper in them. If this were true, then the Copper would all be coming from the ground, and not the pipes. This was true for Iron. But as you can see, all of the dots are below this diagonal in the A direction, and in fact, are almost all on the x-axis, showing that almost all of the Copper came from the pipes.


Cu A vs. Cu B
30000
25000
20000
15000
10000
5000
0
Cu in Sample B (in ppb)
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
Cu in Sample A (in ppb)

Research Team 5: Cu vs. Pb in Samples A & B

1) **What correlation did we research?**

   We, Julian and Noah K, researched Cu (Copper) versus Pb (Lead) in Sample A and B.

2) **Why did we research this?**

   We chose to research this subject because both Copper and Lead can be dangerous in high amounts. They can both be found in old Copper pipes around the world.

3) **What did we expect to find?**

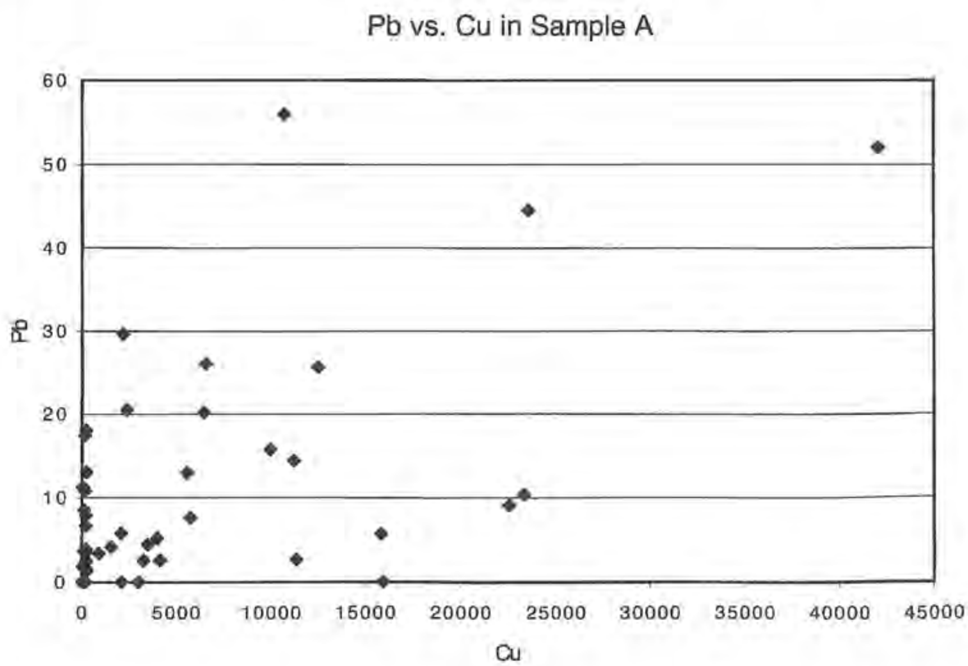
   We expected to find a relationship in Sample A that higher levels of Copper would mean higher levels of Lead. We thought that homes that had higher Copper in Sample A might have water that leached a lot of Copper from the pipes, and we thought that the same water might tend to leach more Lead from the solder of the pipes (if Lead solder was used).

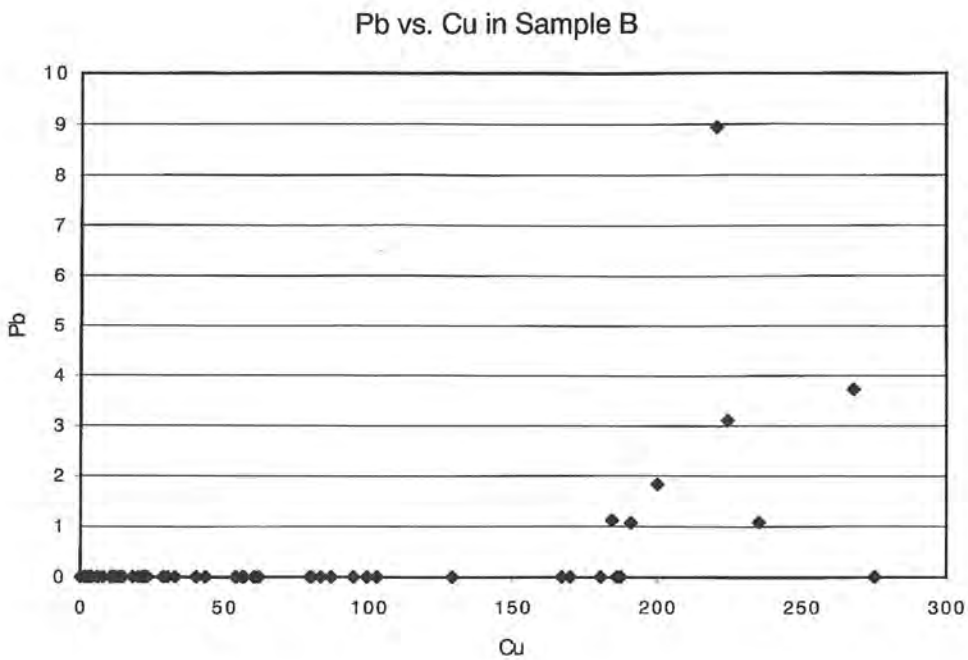
   We didn't expect to find a relationship in Sample B.

4) **What did we find?**

   In Sample A, we did not find the clear relationship that we thought we would. As you can see from the scatter graph, which follows, there is not a clear shape to these data that would make us believe that as Copper levels rose, Lead levels also rose.

   In Sample B, we were surprised to see a possible relationship between Lead and Copper. This only exists when the Copper levels in the ground are high. As you can see from the graph following, when the Copper reaches above 170 ppb (parts per billion) the Lead starts to rise. All samples under 170 ppb Copper have no Lead. As the Copper levels rise above 170 ppb, Lead levels rise in most cases in what appears to be a relationship.




Pb vs. Cu in Sample B
Pb
10
9
8
7
6
5
4
3
2
1
0
0
50
100
150
200
250
300
Cu

Research Group 6: Elements vs. Well Depth in B Samples

1) What correlation did we research?

We researched depth of well vs. the amount of elements present in the sample.

2) Why did we choose this correlation to look at?

We wanted to see if there was any relationship between the depth of people's wells and the levels of elements like Manganese, Iron, Copper, and Lead.

3) What did we expect to find?

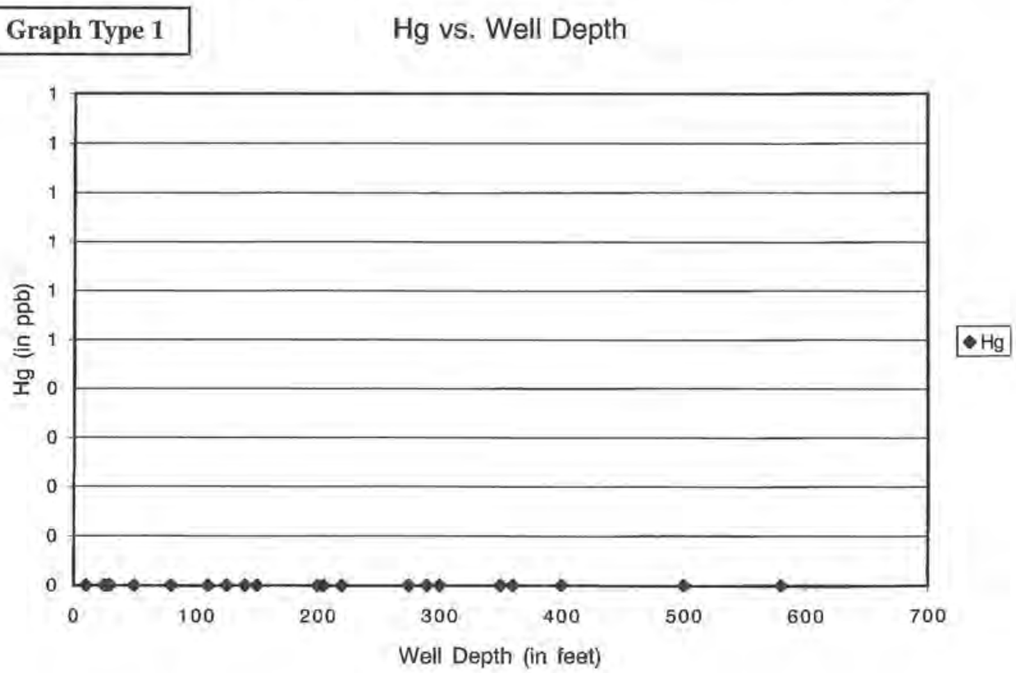
We expected to find some relationships between the depth of the well and the amount of the element in the sample. We thought the deeper wells might have more of the heavier elements.

4) What did we find?

When we graphed the amount of the element in the sample vs. the well depth, we came up with three types of scatter graphs. However none of them showed a clear relationship between the depth of the well and the amount of element in the sample.

The graph of Mercury vs. well depth is an example of the graphs where all the data points were on the x-axis. This tells us there is not a measurable amount of Mercury in our samples. Cadmium, Thallium, Gold, and Beryllium are elements with a similar graph. There was no relationship found between the element and the well depth.

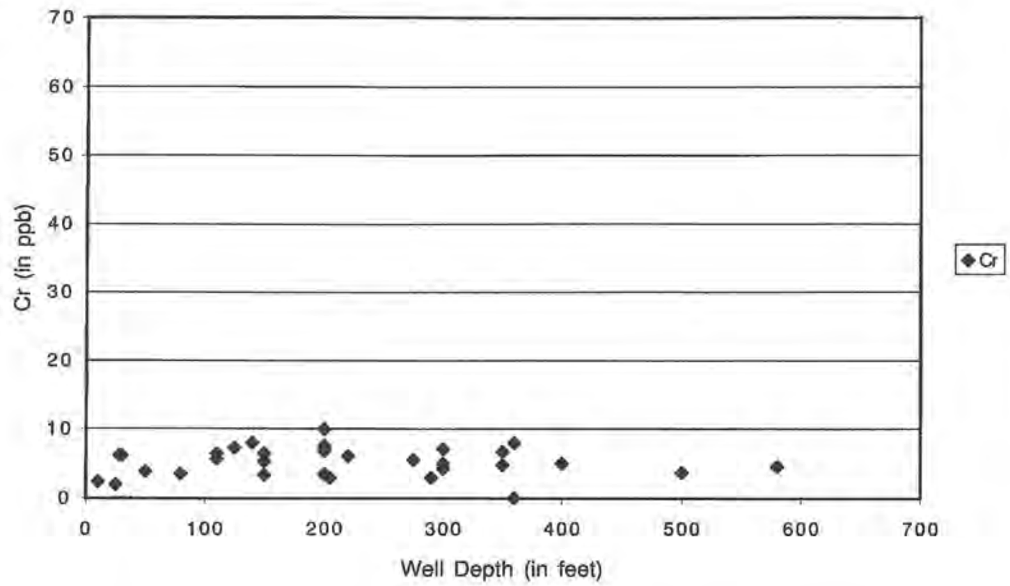
Graph Type 1



Graph type two has most of the data points on the x-axis with a few outliers showing that very little of this element is present except for the outliers. In this report, we are including Chromium, but the other elements with type two graphs are Lead, Nickel, Arsenic, and Aluminum. There are no relationships in these graphs between well depth and amount of element.

Graph Type 2

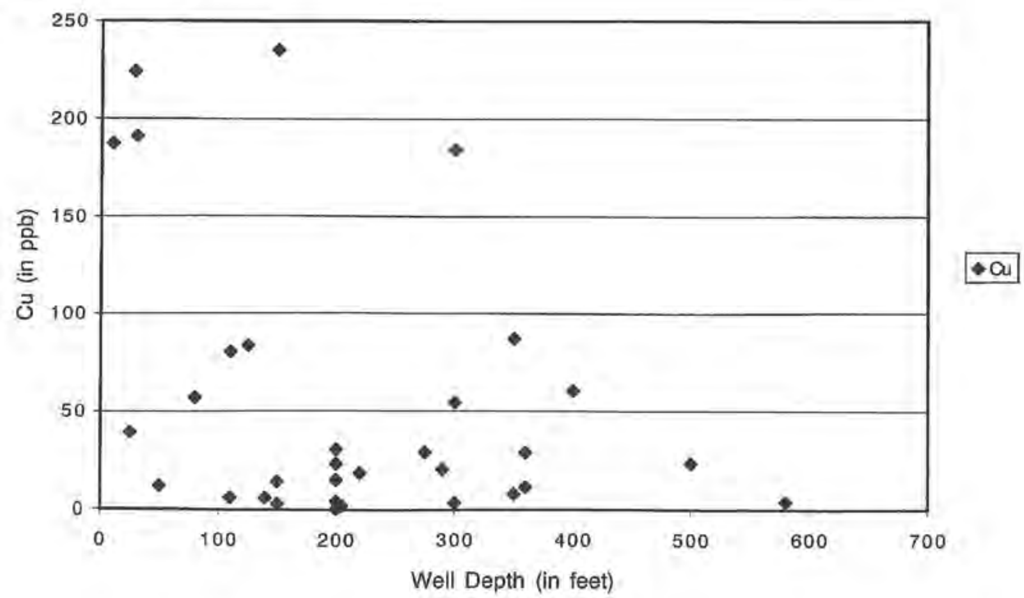
Cr vs. Well Depth



As an example of the third type of graph we are showing you Copper vs. well depth. This graph is more scattered than the 2 graphs you just saw, but we still didn't find a clear relationship between the element and the depth of the well. The other elements that are in graph type 3 are Iron, Manganese, Selenium, and Barium.

Graph Type 3

Cu vs. Well Depth



Research Group 7: Age of Pipes vs. Copper and Lead in Sample A

1) What correlation did we research?

We researched the amount of Lead and Copper in Sample A (the water sitting in pipes all night) vs. the age of the pipes.

2) Why did we choose this correlation to look at?

We found high levels of Copper, up to 42,000 ppb (parts per billion) in some Sample A's and we wondered why. We wanted to find out if the material of the pipes or age of pipes had an affect on the amount of Copper in Sample A.

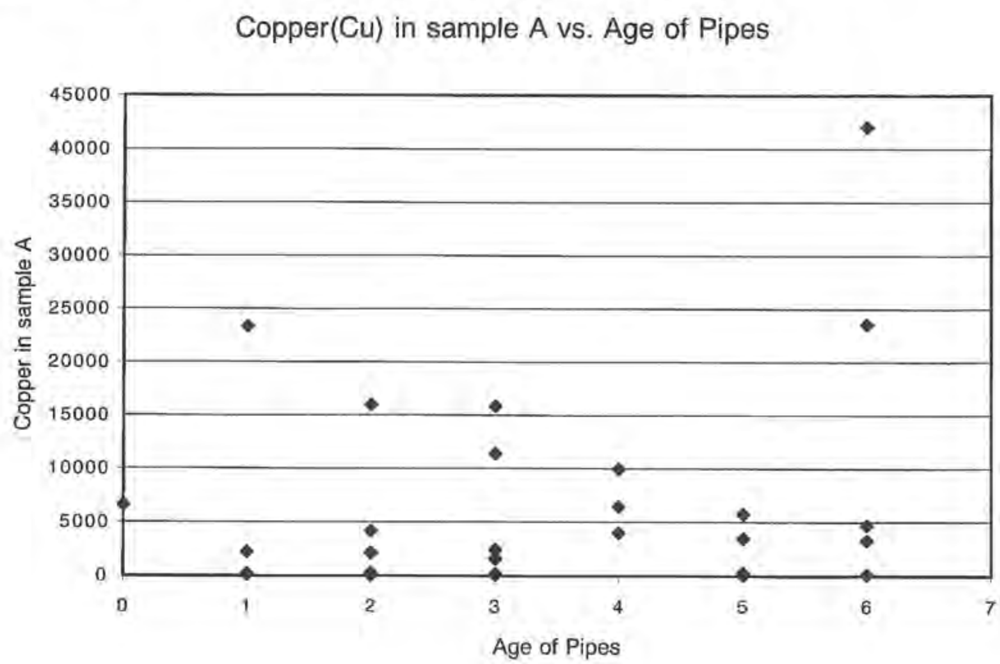
3) What did we expect to find?

We thought we would find that the newer the pipes the more Copper, because it would be shedding, for example, when you wear a new pair of socks and at night you take them off, there is usually little pieces of yarn fluff on your feet. We thought it might be the same with the pipes.

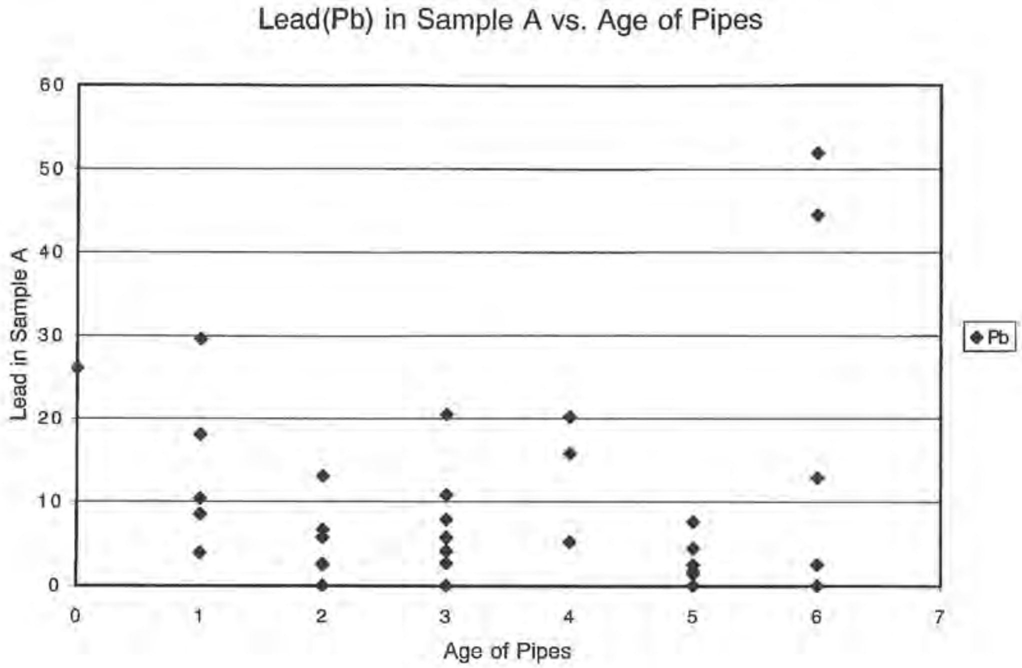
With Lead we thought the opposite. We thought the older the pipes the more Lead there would be, because the older pipes have Lead solder.

4) What did we find?

With Copper we did find a slight relationship in our data which agreed with our guess. It was only true on samples with very high Copper, over 5,000 ppb. In those samples, as you can see in the graph below, the newer pipes tend to have higher levels of Copper than the older pipes in most cases. Our highest Copper level, 42,000 was in older pipes, but it was an invalid sample because it sat in the pipes for four days and nights.



In Lead we also found a slight tendency in those samples with higher Lead (over 10 ppbs) for the newer pipes to have more Lead. This is the opposite of what we thought we'd find! These new pipes don't have Lead solder. So where is the Lead coming from? We don't know where it is coming from. We are interested in finding out.



Research Group 8: Mn vs. Fe in B

1) What correlation did we research?

We were searching for any relationship between levels of Manganese and Iron in Sample B (the flushed well water).

2) Why did we choose this correlation to look at?

We chose to look at Manganese and Iron because those were two minerals which seemed to be high in Sample B. We wanted to see if there was any tendency for wells that were high in Iron to be high in Manganese.

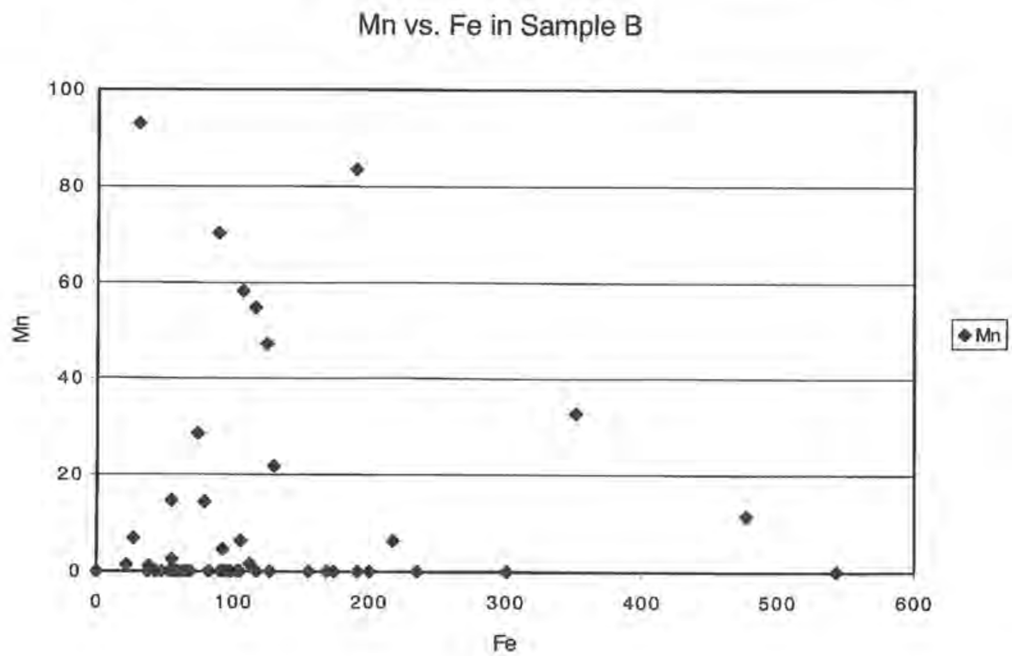
3) What did we expect to find?

We thought when one was high, the other might be too, because there were some wells with high levels in both.

4) What did we find?

We prepared a scatter graph of Manganese and Iron. The graph follows. There was one well which was an outlier because its Manganese was above 1,000 ppb, which is not seen on this graph. There is also one house which was an outlier, high in Iron, which is not seen on this graph. All the other homes are included. The outlier that was high in Iron wasn't high in Manganese; the outlier that was high in Manganese was not high in Iron.

Looking at this graph, there doesn't seem to be a relationship between Manganese and Iron. We did notice that the three highest Iron samples were low in Manganese, but three examples were not enough to show a relationship.



Research Group 9: Fe vs. any Factor in B Samples

1) **What correlation did we research?**

We researched Iron vs. any factor in B Samples.

2) **Why did we choose this correlation to look at?**

We noticed that most of the B Samples had some amount of Iron in them. Although only four were over the 1994 E.P.A. standards (300 ppb), we were curious to see if the high levels of Iron in the samples related to high levels in any other elements.

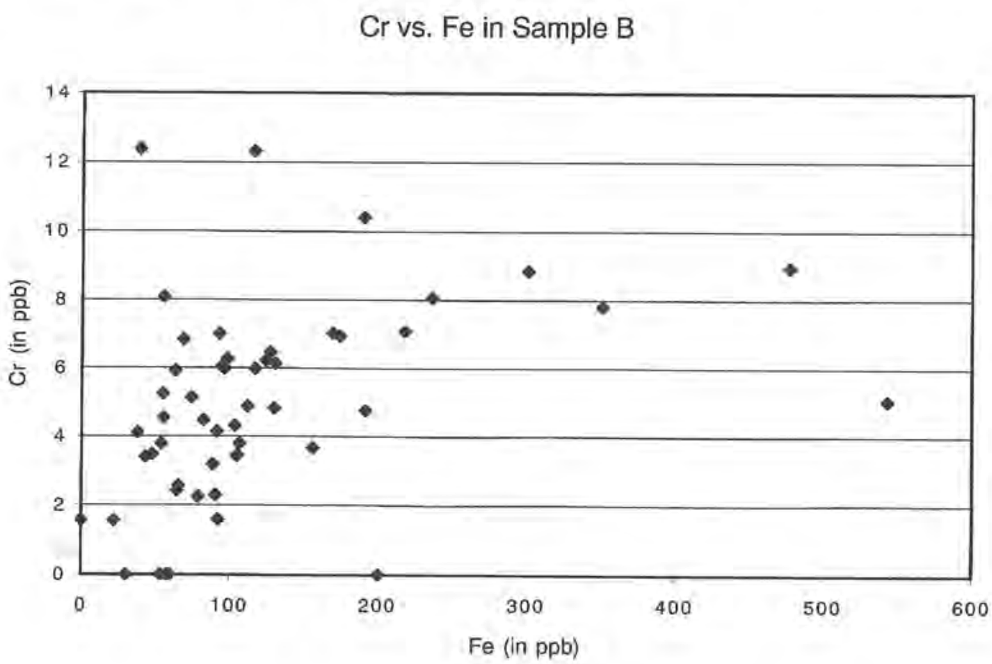
Although we can't tell you all of our findings we (Rebecca and Elena) would like to share with you one graph that we found interesting.

3) **What did we expect to find?**

We thought that perhaps high levels of Iron would be related to high levels of other elements.

4) **What did we find?**

Our five graphs plotted Iron against Copper, Manganese, Aluminum, Barium and Chromium. We found that only one had a clear relationship. Our Chromium vs. Iron in B Samples graph had a slight arch. The graph showed that as the amount of Iron in the water increases, so does the amount of Chromium. However, when the amount of Iron reaches 500 ppb the amount of Chromium starts to decrease.



Research Group 10: Mn in Sample B vs. All Factors
Al in Sample B vs. All Factors

1) **What correlation did we research?**

   We were looking for general correlations between Manganese in Sample B and any other factor. We also looked for relationships between Aluminum and any other factor.

2) **Why did we choose this correlation to look at?**

   We chose this topic because we wanted to find if there were relationships between our Manganese and Aluminum results and any other factor in our study. These two elements were chosen to be included in this study because we had a few results that were above EPA standards. Although Manganese and Aluminum are not considered a health issue by most people, they can discolor the water and give it a metallic taste when above EPA standards.

3) **What did we expect to find?**

   We really did not know what to expect to find in this case.

4) **What did we find?**

   We did not find any relationships when we graphed our data. We graphed only Manganese in B vs. Iron in B, Aluminum in B vs. Iron in B, Manganese in B vs. Copper in B, Aluminum in B vs. Copper in B, and Manganese in B vs. Aluminum in B. The data on our graphs was always scattered around in many tiny clusters, but as far as we could see there were not any relationships.