Personal Experience

My parents, both Chinese citizens at the time, came to the United States in the late 80's to attend graduate school. Later on, my mom got a job offer and they moved to the town I was born and raised in, a small town in North Dakota by the name of Grand Forks. We have been here since then. The Red River of the North runs through Grand Forks, and one summer, I was deemed old enough to ride my bike down to the river so that I could explore. It was then that I found the tubes. Big cement tubes. And there was something coming out of them. And whatever that something was, it was draining into *my* river.

When I asked, I was told that those tubes were pipes that drained runoff water from the city to the river. That answered some of my questions, but not all. And later that winter when I found out about Science Fair, I knew what my project was going to be. That was the year of 2005.

For the next four years, I studied river water quality and the river surroundings. A local research center supported my studies by providing the sampling devices and lab facilities that I needed for my project. My first two water quality science projects focused on the long term behavior of common water quality parameters such as pH, turbidity, and the levels of dissolved oxygen and ions. The latter two projects that I conducted focused more on the interaction between the city and the river in terms of how we may be polluting our water sources in ways we don't realize.

If ions that always "live" in the river can be considered a "family", other ions that come and go are like "relatives". To observe the changing presence of the family and its relatives, I went to the river to collect water samples 3-4 times a week from March to November, at times in rain and subzero temperatures. My analysis of these samples contributed over 1700 data points to help fill in gaps in the sporadic analysis of the USGS at the Grand Forks location. The following spring, a big flood hit our area following an early heat wave, causing the river surface to rise 20 feet in a week. Watching the brown river gush by, I anticipated higher levels of family ions. To my surprise, my data showed that the levels of the family ions actually dropped while a relative ion, nitrate, spiked. At first, I thought the unusual weather played a role: when the heat wave hit, the snow melted quickly into a large amount of water that poured into the river all at once, causing the flood and a dilution of all the ions. But why did only nitrate peak in my chromatography? I found my answer in the river's surroundings: the nearby farmland was fertilized each fall using nitrate-based fertilizers, which could be flushed into the river by the flood during the following spring and cause high levels of nitrate.

In addition, since the algae in the river thrived on nitrate along with oxygen, the oxygen level was dramatically reduced by the abnormal algae blooms, making it hard for other marine species to survive. An imbalanced ecosystem was thus triggered! It was the first time through my own scientific discovery I realized that human activities could have a huge impact on the environment. As I used the chemistry knowledge that I learned from school to explain the things I observed, I got more excited and hooked.

As I discussed my data at the science fair and presented to local scientists, I realized that my findings held important implications, but storing the data in spreadsheets had actually limited their utility. Since my project analysis had yielded mountains of information, my head spun when I thought about the myriad ways I could compare the data. Having always loved logic and computers, I thought: *Why not build a database application for my project?* I took a basic programming course at school and explored on my own to learn the knowledge I would need to write my program. After spending many weekends in front of the computer and talking with local programmers, I finished my very first database program. The program had search, graphing, and trend analysis functions, a heavy metal assessment, and a comparison with data from the US Geological Survey. I went on to write programs for all my projects since, using SQL Server to increase availability to local scientists and unlock more advanced applications.

After two years of water quality projects, I had armed myself with programming skills and had established a baseline for river water quality. It was finally time to make my return to the cement tubes. Each tube, called an outfall, collected rainwater from the storm drains in a certain area of the city. Since the rain could wash pollutants off the city streets, I began to ponder the potential link between city land usage and river water quality. After collecting and analyzing over 500 samples from street storm drains, coulees, and outfalls, I discovered that each year the city contributed toxic metals and over 12 tons of nitrate to the river. Most importantly, I found a potential link between an unexpected source and river water pollution. This was the raw material for my most recent study.

As my study of the Red River moved into its fourth year, I investigated the interaction between street solids and heavy metals and its potential effect on river water. After searching online for published papers with topics similar to mine, I found papers that addressed the sorption behavior of soils, but not any that specifically studied the role of street solids in water quality. My project topic was thus the first study of its kind, and could pave the way for other researchers to conduct similar studies, perhaps on a more comprehensive scale. This could yield a great deal of information that would shape policy concerning the collection and disposal of street solids. For my voice to be heard however, I would first need to conduct the research, and then take action to publish my paper in a research journal.

In this research, I studied the ability of the solids (sand and dust found on the streets) to adsorb and release heavy metals in water based on particle size, pH, and selectivity to certain elements. My results showed that street solids could act as both a sink and source of heavy metals to river water. On my scientific journey, I had discovered more than just water quality issues. I had discovered what I wanted to become: an environmental engineer.

As a future scientist's responsibility, it is certainly important to continue identifying existing problems and to find new technologies to remediate the condition, but a crucial ingredient to solving water quality issues is how the public weighs the issue—public opinion catalyzes change. Since we are living in a geographic location with plenty of water resources, it is even harder to realize how scarce water is globally.

In 2007, I went to Phoenix, Arizona, as a state winner for the national Stockholm Junior Water Prize (SJWP) competition. The SJWP provided many interesting water quality facts to us through various formats, with emphasis on an imminent global crisis. Even after doing a water quality project for two years, I found out there were still many simple facts I did not know. The experience I had in Phoenix inspired me initiate an environmental awareness service project in my hometown, which I named *Give Water a Hand*. I engaged my target audience, elementary school students, with in-class presentations, a hands-on groundwater model demonstration, and student contests. I presented class-by-class on topics such as water resource scarcity, water pollution sources, and pollution prevention. Afterwards, I organized a point-based contest between individual students and also between classes to encourage students to use what they learned from my presentations in their daily lives. I vividly remember my first presentation—I demonstrated that if all the water on earth was represented by a gallon of water, usable freshwater only consisted of around two drops. The students were enraptured and I proceeded to explain to them ways in which they could conserve water.

Although my actions may only be considered small steps relative to the overall scheme of things, I do feel that my service project is representative of the actions that should be taken on the large scale. Such actions may prove to help the water quality dilemma and even offer promise for the future of our water resources.

Research Experience

Introduction

Since the fourth grade, I have had an infatuation with protecting the environment. It all started with a paper recycling project that I recruited my class to participate in, and eventually I decided to combine my scientific pursuits with my love for the environment. I ended up conducting research projects involving environmental science for four years in a row, the last of which I submitted to the Intel Science Talent Search.

My research from prior years indicated that street solids were likely the culprit to pollution of river water. Street solids in my study refer to the sand, dust, and dirt that build up on the streets (i.e. not garbage, sewage, etc.). It's the stuff that the city collects when they send those slow-moving cars down the street with the massive spinning "brooms". In my past studies, the analysis had shown that the water flowing to the river out of the pipes that come from the city was much more polluted than just pure rainwater. So something had to be happening in between! At first I thought perhaps the rainwater had dissolved some pollutants on the street and was carrying it to the river. My third research project dealt with how it was possible that different areas of the city were contributing different pollutants to the river via the rainwater that flowed to the river. I was disappointed, however, when it turned out that the water running on the streets after it rained was not contaminated as much as I thought it would be. Then where did the pollutants come from? I realized that the rain, as it "washed" the streets, would be bringing a lot of dirt and sand with it to the river. I decided that the next year, I would tackle this topic for my research project, focusing on how heavy metal pollutants were getting to the river water.

The next summer, I began going outside with my broom and dustpan and sweeping up sand from various areas throughout the city. I also asked the City Streets Department if they would aid me with my studies by providing me with some of the sand that they swept up when they did their weekly street cleanings. These would be the raw materials for the next few months of my research.

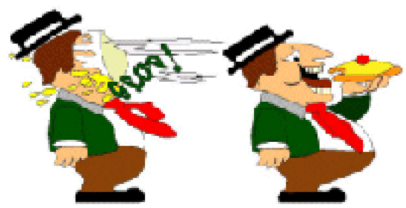
Preliminary Analysis

After collecting all of the solids that I would be using for my study, I first tried to “get to know them a little better” before running any tests. I used sieves to separate the solids into parts, or fractions, based on the size of the sand particles. Then I dried them and measured their weight and density. Using a microscope, I took some pictures of the solids. Finally, I used an acid to dissolve the solids in a solution and measured the level of heavy metals (poisonous metals such as lead, arsenic, and cadmium) in the solids.

Adsorption Study

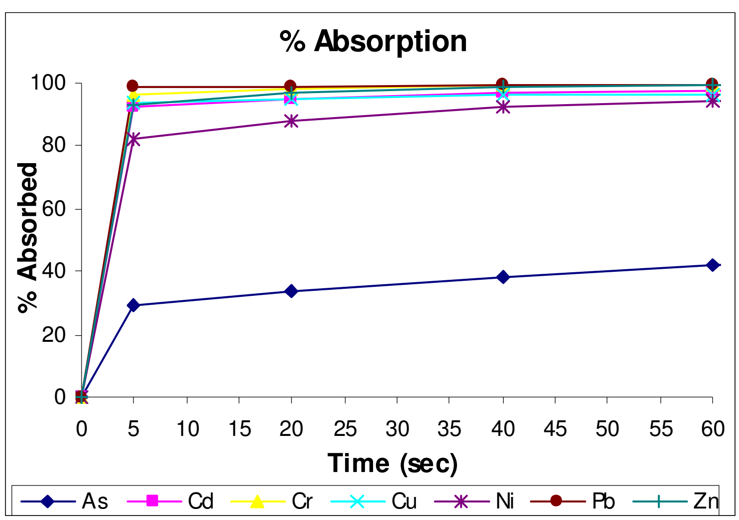
After characterizing some of the physical traits of the solids, I decided to proceed to the chemical experiments I planned on doing. I started off with the assumption that the solids were the key to polluting the river water. “Well then,” I said to myself, “the heavy metals would have to get on the solids somehow.” The premise is that the sand particles on the microscopic level are not smooth and round as they appear to the naked eye. They might have small holes or dents that make them act like a sponge for heavy metals, and suck them onto their surface. This is called adsorption.

Adsorption versus Absorption



http://www.chemvironcarbon.com/doc/uploaded/Image/en/adsorption-vs-absorption.gif

The first thing I wanted to find out about the solids was just how fast they could adsorb pollutants. I made a solution of heavy metals, and mixed in a certain amount of the solids. By varying the amount of time I kept the solids in contact with the heavy metal solution, and by testing the amount of heavy metals left in the solution after I filtered out the solids, I was able to make a graph of the level of pollutants adsorbed versus time. And boy was I surprised! The data showed that after only five seconds, almost all of the heavy metals had been adsorbed! I was flabbergasted; I never expected the solids to adsorb pollutants that quickly.



Immediately after seeing the uncanny speed with which the pollutants were adsorbed, my question was, “How much can the solids adsorb?” I was able to test this by putting the solids in higher and higher concentrations of heavy metal solutions. What I found was just as astonishing. The solids could adsorb heavy metals up through the concentration of 300-500 m[M], which is in many cases hundreds of times higher than even the highest pollution concentrations in nature. Just with those first two tests, I had come upon a revelation: when presented with pollutants dissolved in a solution, street solids could adsorb all of the pollutants, and they could do it in an instant.

Next, I began to think about the other factors that could affect the adsorption process. One of the first things that came to mind was the particle size. I used the different particle size fractions that I had sieved out to conduct another series of adsorption tests, using the fractions one at a time. At lower concentrations, I found that all the fractions seemed to behave similarly. However, at the highest concentrations of heavy metals, the larger particle fractions seemed to have trouble adsorbing all the metals, whereas the smaller fractions took no performance hit. This indicated that the smaller particles might be having an easier time picking up pollutants because they had more surface area.

If there is only a limited amount of surface area available on each little sand particle, are the different pollutants going to end up competing for a place to “dock”? This was the question I asked myself as I conducted my next experiment. To conduct this experiment, I used a solution containing many different heavy metal pollutants, and several solutions containing only one pollutant at a time. As I increased the concentration of the pollutants, I saw that when all of the heavy metals were present, the solids seemed to stop adsorbing after a certain concentration. When only one heavy metal was present, though, that plateau concentration was much higher. I hypothesized that when a heavy metal had no competition from the others, it had all of the particle’s sites to itself and thus more could be adsorbed.

Desorption/Leaching Study

After finishing my work with finding out how the street solids could adsorb heavy metals and some factors that affected that process, I began to think: “Isn’t that a good thing? All the heavy metals are sucked up by the solids, and now the water will be less polluted, right?” With further brainstorming, I realized that the answer was no; not if the heavy metals were released again. This was the basis of the desorption study of my project.

When I was little, I used to love Frosted Flakes®. They were so much better than regular corn flakes because of the delicious sugar coating! You can imagine my dismay when I decided to try Frosted Flakes® with milk, only to discover that the sugar was all gone. It had all come off into the milk. This is the idea behind desorption. When the street solids that have sucked up heavy metals are washed into the river, this could make their “sugar come off”. Relative to the cereal example I just used, this is of course much less sweet, and much more harmful for the environment. In short, desorption is the opposite of adsorption (discussed in the previous sections).

For my desorption study, I wanted to get a more quantitative number for how much was really being released from the solids, so I used a set of “spiked solids” that I made. To prepare those solids, I exploited the fact that during the adsorption study, the solids were adsorbing almost all the heavy metals. By first putting the solids through a similar process, I now knew the level of heavy metals already on the solids! Now I could measure how much was given off.

When conducting the experiments I varied a few different parameters, including the duration of the leaching process, the number of times the leaching process was repeated, the pH of the solution, and the type of water used for leaching (river water, storm drain water, rainwater). Overall I found that the longer the leaching took place for, the more heavy metals leached out. Repeating the process yielded less and less metals each time, but leaching occurred nonetheless. Lower pH levels caused more pollutants to desorb. Finally, the type of water used surprisingly had little or no effect on the amount leached out.

As for particle size effects on the leaching process, it was interesting to find that the largest particles seemed to release the most toxins, even though the middle sized fractions had the most heavy metals. I had expected the leaching to occur kind of like how people are taxed. In general, the more money you have, the more you have to pay in taxes, and I thought that the particles with the most heavy metals would also desorb the most. However, I posited that because of the size of the larger particles, they were not able to “hold on” to the metals as easily.

Looking at the data from my leaching results, I discovered that a relatively small portion of the adsorbed metals were leached out, usually less than 5%. Again, although these values seem to support the notion that the street solids play a beneficial role in pollutant interactions along the rainwater’s paths from the clouds to the streets to the storm drains and eventually to the river, we should take the outcome of the experiments with a grain of salt. The solids are still going to acting as a sink for pollutants, in other words a sort of magnet that ends up concentrating perhaps normally benevolent levels of heavy metals into pollution powerhouses. Since the smallest particles end up adsorbing the most metals (mentioned earlier), and they tend to be lighter dust particles which would be stirred up by the river, it is possible that fish could inhale the dust and become poisoned. Even if these particles remain on the streets, if they are blown up by the wind, humans and other animals could inhale them as well. Lastly, assuming none of these are true, if the particles just remain on the streets, repeated leaching by rainwater could result in a larger total amount of heavy metals leached out.

Conclusion

From this project, I learned much more than some information about how street solids function in the process of river water contamination. Of course I discovered that street solids can act as both a sink and a source of heavy metals to river water, but there's much more to my journey than my scientific results. I solidified my passion for science and math over the course of four years, and realized there was so much more to science, especially chemistry, than just books, equations, and laws. There is an entire world out there waiting to be discovered that cannot be found in any textbook. And all it takes is a little curiosity.