Acid Rain: It's Effect on Marble Tombstones

A Science Fair Project by Nicky Lenzen – February 2011

Question: How does acid rain affect our historical monuments?

Hypothesis: Acid rain does have an effect on materials such as the ones used in tombstones.

Background information:

Acid rain was one of the subjects on a list of science-fair projects, and my grandma suggested I look at the effects of acid rain on tombstones. I enjoy different types of projects, and this sounded interesting.

The scientific community has been discussing acid rain for a number of years. Rain naturally has a slightly acid pH. The acid in a liquid is determined by its hydrogen ions, and these are measured on a pH scale. The scale ranges from 0 (highly acid) to 14 (basic). A solution with a pH of 7 is considered neutral. In Oregon, the rain ranges from a pH of 5.2 to 5.4. These numbers are both are in the acid range. In the northeastern part of the United States, the rain is more acid because there are more cities, more people, and more industrial plants. Industrial plants spew out sulphur, and that raises the acid level. Cars create nitrous oxide, and that raises the acid level. The biggest pollutant has been coal-fired plants. The polluting emissions either fall to the ground in what is called "dry deposition," or they get into the water cycle and fall to the ground in a "wet deposition."

This project is one that other scientists have done, but I didn't realize until I got into the research.

The project helps prove that burning fossil fuels has more than one bad effect. Pollution is a serious thing. This project raised my awareness about the effect of acid rain on historical artifacts – with tombstones being my sample.

Before I started this project, I wasn't interested in tombstones. Now that I've seen the effect of acid rain, it makes me want to help find a way to protect our environment and our historical artifacts. Everyone seems to think that pollution affects your health, but it also affects the environment around you.

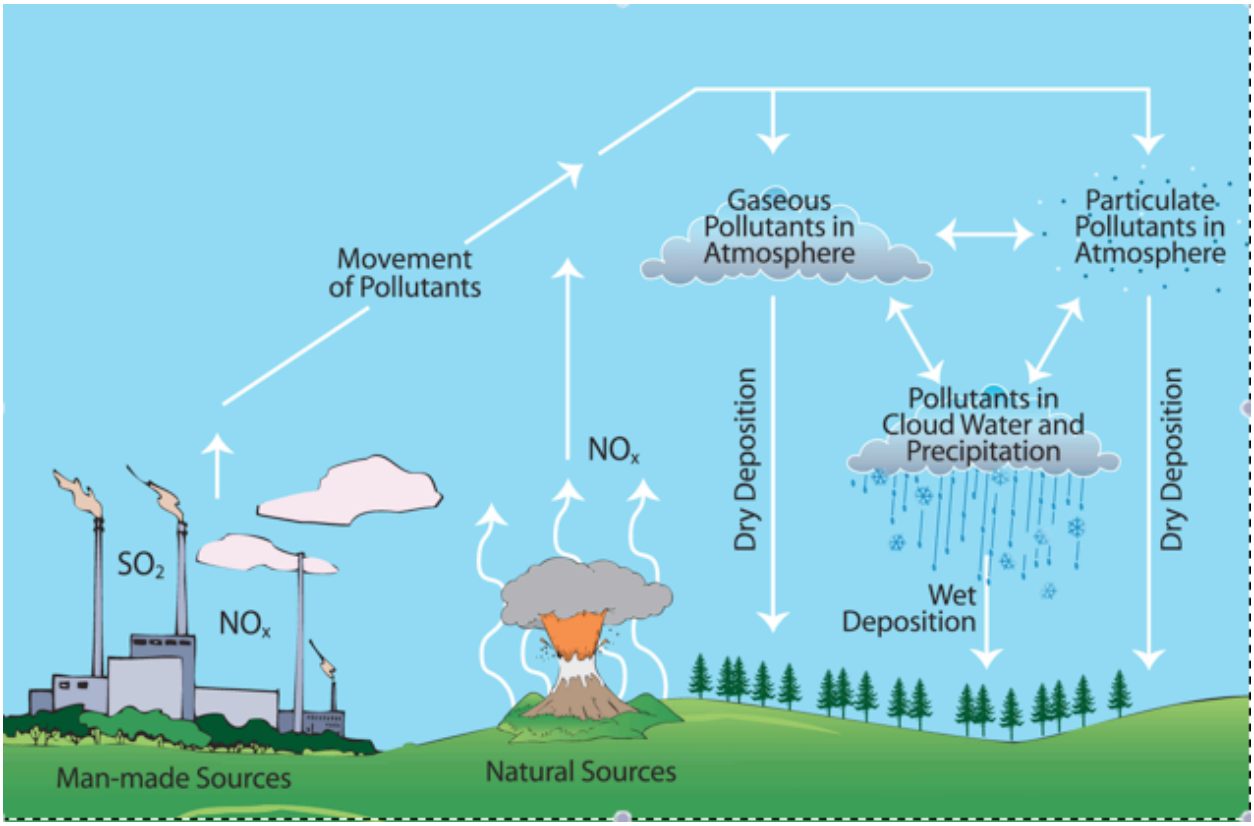
Variables

Independent variable (the thing that changes): The pH of the rain in the cemetery.

Controlled variable (the thing that stays the same): The material of the tombstone (white marble).

Responding variable: The difference between the thickness of the base of the stone and the top of the stone. (When the stone was new, the two thicknesses were identical.)

Water Cycle showing how pollutants get on to tombstones



Procedures

1. Find a puddle of water and use a pH strip to find out what the pH of the rain is.
2. Measure (with a ruler) the side of a tombstone at the base and at the top. I used stones with a 2-inch width at the bottom.
3. Compare the measurements from the top and the bottom.
4. Record all your findings.

Data Table: Amount of weathering on white marble tombstones

Cemetery: Crescent Grove Cemetery

pH: 4.5

This cemetery is next to Washington Square, an area where there is a lot of auto pollution.

Name	Died	Base	Top	Difference
Baby Walworth	1891	2	1 12/16	4/16
Milton P. Smith	1901	2	1 12/16	4/16
Morton Anderson	1907	2	1 13/16	3/16
Margaret Brown	1898	2	1 12/16	4/16
Salena Coats	1895	2	1 12/16	4/16
Malissa Coats	Unknown	2	1 12/16	4/16
Margaret Bryant	1898	2	1 12/16	4/16
Sarah Ann Davies	1888	2	1 11/16	5/16

Cemetery: St. Paul Cemetery

pH: 6.0

This cemetery is in St. Paul, Oregon, a rural area. The only industry is an agricultural plant called Marion Ag. The farmers use fertilizer on the ground to change the pH of the soil. Most farmers want their soil to have a pH of 6.0 to 7.0.

Name	Died	Base	Top	Difference
Lars Olson	1920	2	1 14/16	2/16
Thomas Coakley	1887	2	1 15/16	1/16
Ester Fields	1884	2	1 13/16	2/16
Paul Ernst	1883	2	1 13/16	3/16
James Cosgrove	1862	2	1 12/16	4/16

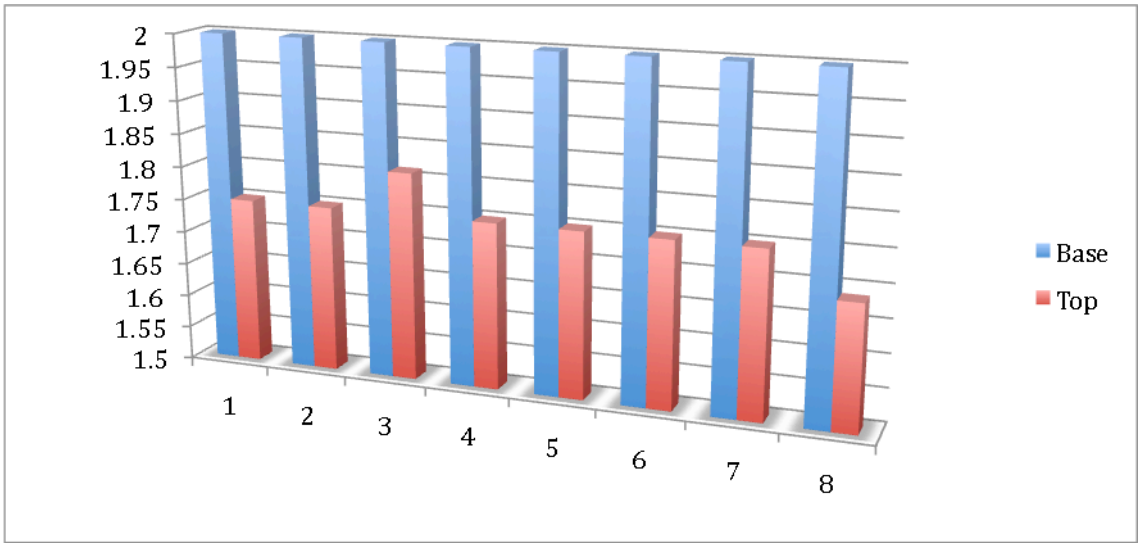
Cemetery: Champoeg

pH: 6.0

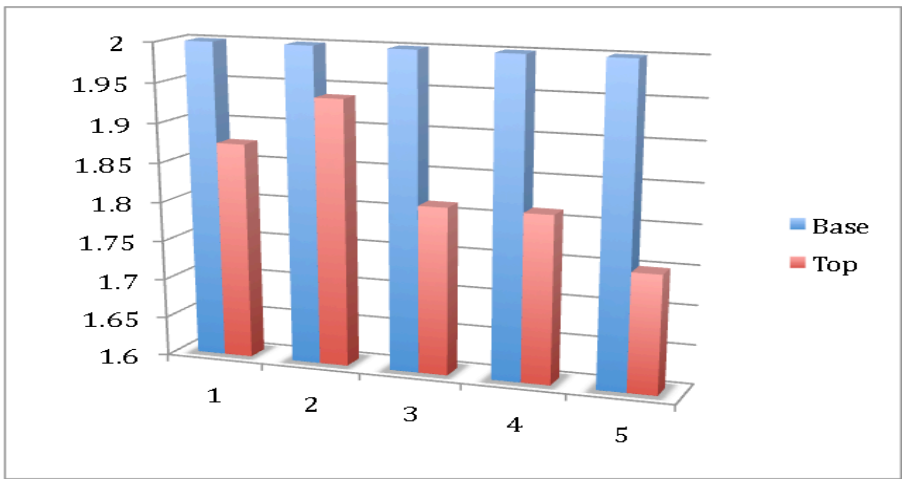
This cemetery is a couple of miles away from St. Paul. It is in a very rural area with no towns around it.

	Died	Base	Top	Difference
Eberhard	1876	2	1 13/16	3/16
Juliza Jones	1883	2	1 15/16	1/16
Frannie Jones	1890	2	1 14/16	2/16
Bauer	1869	2	1 12/16	4/16

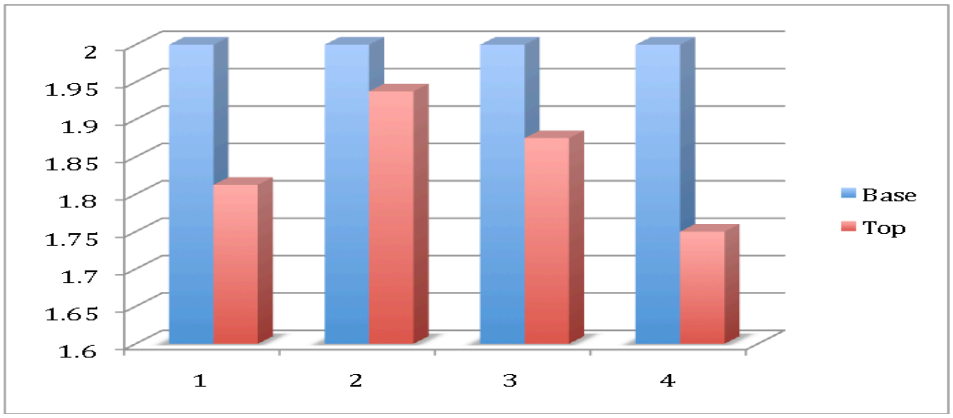
Crescent Grove



St. Paul



Champoeg



Data Analysis

When I looked at the tombstones, you could tell that there was more than dirt on the stone. You could see that it was very weathered, and the color of the stone had changed. If you look at just a dirty tombstone, you should be able to wipe off the dirt and see the original stone. However, there was no way that I could wipe off the black marks on the weathered stones, and those stones were, also, rough and pitted. If you accidentally bumped into a stone, you would get a bad scrape. For many of the stones that were cracked, some had actually fallen over. This cracking may or may not have been associated with acid rain.

I measured the base and the top of each two-inch slab tombstone. There is a dramatic difference between the base and the top. The base is always thicker than the top of the stone. The top is thinner because the acid rain hits the top before it hits the bottom. Even though the acid rain is not highly acidic (like orange juice), it is still acid enough to dissolve marble over time.

What surprised me was that it didn't seem to make much difference about how old the stones were. They all showed about the same amount of weathering. We could tell which side the weather comes from by the weathering and the color on each tombstone. If you look at one stone, you might see that one side was blacker and rougher than the other side. By that you could tell that the blacker and rougher side was where the rain first landed on the stone. You could also see the real color of the stone at the base where it was away from the weather.

Another factor that seemed to affect the marble was the amount of acid in the rain. After taking the pH at the cemeteries, I noticed that it was more acidic at Crescent Grove, a cemetery near a populated area and a main road. The pH at St. Paul was less acidic because there are fewer people to add pollution to the air and the water cycle, and the farmers add fertilizer to their soil. The fertilizer has a high pH, and that seeps into the ground and then comes back up into the water cycle.

pH of common substances and my test results

Gastric juices	1.0
Lemon juice	**2.2**
Vinegar	**2.4**
Tomato juice	**4.1**
Crescent Grove Cemetery	**4.5**
Oregon water	**5.2-5.4**
St. Paul hops require	**5.7 plus**
Champoeg Cemetery	**6.0**
St. Paul Cemetery	**6.0**
St. Paul fruit trees require	**6.6-7.0**
St. Paul ornamental trees require	**6.0-7.0**
Blood	**7.4**
Baking soda and water	**8.4**
Toothpaste	**9.9**

Conclusion

By the looks of it, the only explanation for the weathering of these headstones is acid rain. There are not many other things that would cause the destruction of the marble. The only other things that would affect these stones would be wind, storms, and the environment around them. These can add to the effect, but the one constant factor is acid rain.