## STUDENT WORK SECTION

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Students in *Environmental Science* (one of the freshmen level courses included within the Virginia Collaborative for Excellence in Teacher Preparation program) are given the opportunity to socialize the material presented in large lectures by attending smaller guided recitation sections. In recitation, active learning is promoted through the use of role-playing, debates, and writing assignments. The following student paper is an example of such an assignment; it accounted for 2.5% of the course grade. The author is a freshman Pre-Nursing major who clearly demonstrated that she had integrated the concepts associated with acid deposition into the larger ecological picture and into her daily experiences. The work was supervised by Professor Bonnie Brown from the Department of Biology.

# THE EFFECTS OF ACID DEPOSITION

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We are surrounded in a sea of gases. These gases in the atmosphere and certain chemicals mix with water to result in the deposition of a mixture of acidified compounds. Acid deposition is a global environmental threat. From lakes without fish to the ruin of human health, acid deposition has numerous harmful effects. Acid rain, sleet, snow, and other precipitants form when pollutants mix with droplets of water vapor in the atmosphere. The pollutants change the clean, fresh water to droplets of acid. Finally, these acids fall to Earth as various forms of acidic precipitation. However, rain is normally slightly acidic because of the carbon dioxide in air. Normal rain has a pH of 5.6. This is not considered to be a problem because natural systems are slightly buffered. Yet, when other anthropogenic gases are emitted into the atmosphere, then the precipitation becomes even more concentrated with hydrogen ions (acidic). This causes the pH to range from 3.4 to 4.5 [1]. Let's look at the numerous pollutants that cause acid rain and deposition.


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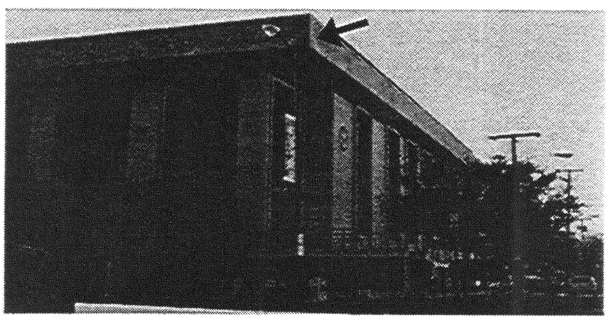
When fossil fuels such as oil, coal, and natural gas are burned, sulfur oxides and nitrogen oxides are emitted into the air. There, they mix with water droplets to make acids. Sulfuric acid accounts for 65% of the excess acidity in acid rain. Nitric acid makes about 30% of the remaining acidity portion in acid rain [1]. These oxides could be derived from factories, power plants, or industrial combustion processes. Ask yourself, "What do these have in common?" The answer is HUMANS! We are the main cause of acid deposition. The acid deposition is most severe in large cities due to the abundance of people and infrastructures that emit these harmful gases. The major cities of the U.S. and Canada have made the rain there ten times more acidic than normal. Also, the acid deposition affects areas that are far from the power plants and major cities because winds can carry pollutants great distances. The pollutants from the midwestern United States are regularly carried to New England and Canada [2]. This is why Canada frequently blames the U.S. for their acid deposition situation. Similar situations occur in Europe, South America, and Asia.

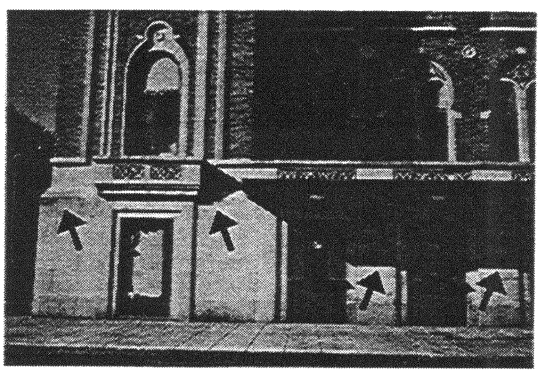
Let's look at the major effects of acid deposition. When acid rain falls to Earth, it soaks into the ground and causes the soil, plants, and rivers to become abnormally acidic. The acid materials deposited directly into the atmosphere alter the acid balance in bodies of water and reduce the pH level. Therefore, acids have a huge impact on plants. Aside from the unsightly spots on leaves and flowers, acids damage the protective wax and cellulose structures. The leaching of minerals from the soil depletes soil of the macronutrients (calcium, magnesium, and phosphate) necessary for plant germination and growth. Acid deposition interferes with photosynthesis. Acidified soil slows down the action of microorganisms needed to recycle nutrients. Acids increase the solubility of metals, eventually causing metal poisoning. Plants play a major role in removing toxins from the air, water, and soil. If the soil has a low pH, then plants will not be as effective in cleaning and stabilizing our environment. As another result of acid deposition, the aluminum and other metals in sediments and soil may dissolve in water and be absorbed by aquatic animals and plants. High levels of metals can kill the eggs of many fish and amphibians. In mature fish, gills can clog with mucous preventing efficient respiration. This disrupts the ecological equilibrium in the aquatic ecosystems. Young and small fish disappear, frogs disappear, mosquitoes flourish, and humans enter a positive feedback cycle of pesticide use and habitat destruction, ultimately resulting in further alterations of plant life. This affects local, native species and could even cause the extinction of a keystone species. Humans can be at risk from the effects of acid deposition. For instance, pollutants from acidic aerosols affect lung and respiratory activity. It also has been suggested that acid deposition can play a role in Alzheimer's disease [3]. To summarize, acid deposition can be harmful to plants, animals, humans, and even buildings.

Acid deposition affects the surfaces of buildings, bridges, automobiles, historical statues, and monuments. Limestone, marble, stone, concrete, and metals have been used throughout history for the construction of human infrastructures. Surface rock is destroyed when limestone or marble react with acid rain. Limestone reacts with nitric acid and sulfuric acid to form calcium nitrate and sulfate. Metal structures literally dissolve in acid. These chemicals, after a while, begin to erode and alter the surface and color of the anthropogenic structures, demolishing the structural components of buildings and ruining the aesthetic view of historical monuments. The damaging effects of acid deposition on structures can be seen near campus and around Richmond, Virginia (Figure 1). I was astounded at how much deterioration was occurring!

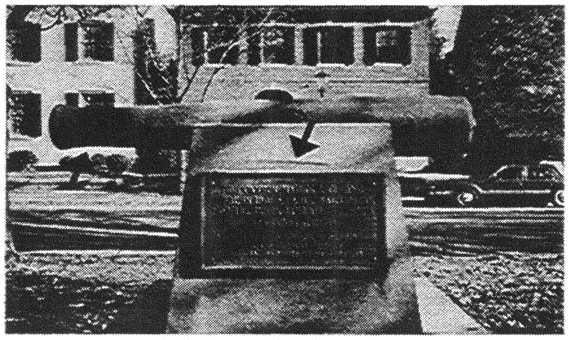
**Figure 1.** Well-known sites in Richmond, Virginia that show evidence of degradation (indicated by arrows) due to acid deposition.



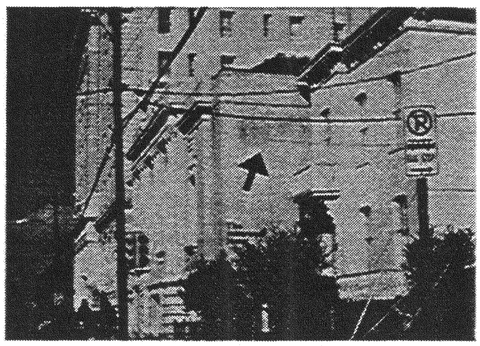
**The Richmond (VA) Public Library shows evidence of erosion along the roof, (denoted by arrow) and discoloration of marble walls.**



**Extensive damage has occurred to Richmond (VA) Landmark Theater calcareous structural materials, particularly around doors and windows.**



**Typical monument in Richmond, VA showing erosion (pitting) and discoloration of concrete stand as well as accelerated rusting of the iron canon.**



**Acid deposition has marred the walls of the prestigious Jefferson Hotel in Richmond, VA.**

How are we trying to prevent acid deposition? Some acid deposition cannot be prevented—volcanoes (sulfur oxides a.k.a., $SO_x$) and forest fires (nitrogen oxide, a.k.a. $NO_x$) for example. However, once deposited, some of the effects of acid can be remedied and much production of acid precursors is preventable. In the freshwaters of England and the U.S., acid precipitation is buffered by carbonates, so ecological destruction is slower to appear [3]. Once detected, reduced pH in a lake or pond can be increased by a technique called liming. Liming involves adding large quantities of hydrated lime to the waters to increase the pH. In 1990, the U.S. passed the Clean Air Act, which resulted in significant reduction of four of six major air pollutants by the year 2000. We have recently created electric vehicles that approximate zero emissions. Some sulfur compounds can be taken out of fossil fuel before it is burned. Yet, the best overall solution is to limit the emission of pollutants at their source. If each individual reduced their share of pollution by conserving energy and carpooling, then the acid deposition problem would decrease precipitously. ■

## References

[1] M. Bright, *Acid Rain*, Gloucester Press, 1991.

[2] G. Howells, *Acid Rain and Acid Waters*, E. Horwood, New York, 1995.

[3] http://royal.okanagan.bc.ca/mpidwirn/atmosphereandclimate/acidprecip.html