View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by DigitalCommons@CalPoly

Acid Rain: The Effects

By

Torrey Mortimer

Advised by

Professor William Preston

SocS 461, 462

Senior Project

Social Sciences Department

College of Liberal Arts

CALIFORNIA POLYTECHNIC STATE UNIVERSITY

Fall, 2009

Table of Contents

Proposal

In a world experiencing increasing population, urbanization, and developing nations looking to compete on a global market with post-industrial nations, the effects of acid precipitation require greater consideration. As the world's energy demand rises, and with the cheapest and most abundant source of energy being coal, the occurrence of acid precipitation is on the rise.

The goal of my project is to research and report on the effects of acid deposition on humans, animals and the environment that surrounds them. When I have completed my project, I hope to be able to explain the impacts that acid deposition has on the world, and the importance of switching to clean, renewable sources of energy to those who are either less educated than I or who have been educated in a different field.

I plan to accomplish my project by doing extensive research no acid deposition. I plan on using journals and books to find out how much acid deposition is created, when, where and why it falls, and its effects on humans, animals, and other environmental variables.

I feel that acid deposition is one of many energy/ pollution-related problems. For example, the emissions of CO_2 and other greenhouse gases into the atmosphere are equally as detrimental, if not more. All of these problems need to be addressed, especially by industrialized nations, if we want generations that follow to live in a healthy world. The developed countries need to set an example for developing nations. For they are the ones with enough money and educated people to develop and put-into-use clean, affordable, renewable sources of energy.

Annotated Bibliography

Backhouse, Frances. "No Silver Lining." American Forests 111.3 (Autumn 2005): 22(1). Expanded Academic ASAP. Gale. California Polytechnic State University. 9 May 2009 <http://find.galegroup.com.ezproxy.lib.calpoly.edu:2048/itx/start.do?prodId=EAIM>.

This article reports on the state of soils in Europe and the evidence of acid deposition-caused damage to trees. The report explains that trees require calcium for healthy growth. Acid rain robs trees of this vital nutrient by leaching it from the soil and by mobilizing aluminum, which interferes with calcium uptake by roots. The reason I will be using this article, and the importance of this article is that a unique, recently found repository of soil in Europe has allowed a U.S. Geological Survey scientist to examine samples that date back nearly a century. Their analysis revealed a trend of decreasing concentrations of calcium in a "root-available" form and increasing concentrations of "root-available" aluminum. These soils were from 1929 to 1964. The evidence of these damaged soils was seen in decreased diameter growth of spruce trees in the area.

Bulger Jr., Arthur J. “Blood, Poison and Death: Effects of Acid Deposition on Fish.” Proc. of the Conference “Acid Rain: Are the Problems Solved” from the Center for Environmental Information. 2-3 May 2001, Washington D.C. Ed. James C. White. 26 Apr. 2009 <http://www.ceinfo.org/resources/Acidrain/32_Bulger.pdf>.

Bulger Jr. details the effects of acid deposition on lakes and streams focusing on the detrimental effects to fish. I will be using this article because it covers where acid deposition is coming from, how the buffering capacity of landscapes and geology can determine the acidity of a nearby lake or stream, the leaching of aluminum from soils, how the gills of fish are affected, and why acid waters kill fish. The author also presents a model showing what would happen if humans were to continue to burn fossil fuels at today’s rate, a reduction of 40%, and a reduction of 70% and how these possible outcomes would affect the acidity of lakes. Much of his data was collected in the north-east United States and he uses the Adirondacks and the Appalachian Mountains as examples in his studies.

"Effects of Acid Rain- Human Health." 8 June 2007. U.S. Environmental Protection Agency. 5 May 2009 < http://www.epa.gov/acidrain/effects/health.html>.

Acid deposition in any form is not harmful to humans, but the pollutants that cause acid deposition, sulfur dioxide (SO_2) and nitrogen oxides (NO_x), do damage human health. These gases interact in the atmosphere to form fine sulfate and nitrate particles that can be transported long distances by winds and inhaled deep into people's lungs. This article reports that elevated levels of fine particles can lead to increased illness and premature death from heart and lung disorders, such as asthma and bronchitis. I will be using this article to show that human health is effected by acid deposition-forming particles.

Gordon, John, Mark Nilles, and LeRoy Schroder. "USGS Tracks Acid Rain." April 2003. United States Geologic Survey. 25 April 2009. <http://bqs.usgs.gov/precip/reports/arfs.htm>.

The USGS does a great job of answering this question: what is acid deposition? The article describes how acid rain is formed, what the difference is between acid rain and acid deposition, and the effects of acid rain on nature and humans. The article also provides access to a nationwide network of acid rain monitoring stations which are updated weekly. The article gives a good overview of the basics of acid deposition. I will be using this article to explain the basics of acid deposition.

Howarth, Robert. "Coastal Ecosystems." Proc. of the Conference "Acid Rain: Are the Problems Solved" from the Center for Environmental Information. 2-3 May 2001, Washington D.C. Ed. James C. White. 26 Apr. 2009 <http://www.ceinfo.org/resources/Acidrain/33_Howarth.pdf>.

Howarth explains how nitrogen, after is has fallen from the sky, moved through soils, streams, and lakes and made its way to the ocean, effects the coastal oceans. Nitrogen is a nutrient to plants, and in small amounts can lead to more algal and plant growth which can lead to greater fish harvests. But, too much nitrogen is very harmful to coastal regions. Howarth explains that too much nitrogen leads to a decrease in dissolved oxygen, an increase in the incidence and duration of harmful algal blooms, and the loss of biodiversity. He also relates the locations of these “dead zones” to the location, and proximity of pollution sources. The report details the altering of the nitrogen cycle through human introduction of nitrogen to the atmosphere. I will be using this article to explain the detrimental effects of excess nitrogen on coastal waters.

Kaiser, Jocelyn. "Acid Rain's Dirty Business: Stealing Minerals From Soil." Science 272.n5259 (April 12, 1996): 198(1). Expanded Academic ASAP. Gale. California Polytechnic State University. 8 May 2009 <http://find.galegroup.com.ezproxy.lib.calpoly.edu:2048/itx/start.do?prodId=EAIM>.

This article investigates the slow recovery rates of forests and lakes in countries where measures have been taken to reduce acid deposition. After looking at a New Hampshire forest for 30 years, researchers have learned that the soils were greatly affected by acid deposition. The researchers found that acid rain has been leaching the soil in their study area of large amounts of the base mineral ions that buffer, or neutralize, acids and are essential to plant growth. The chemistry of soils takes hundreds to thousands of years to develop, since acid deposition has dramatically changed the chemistry of the soil, it will take a very long time for the forests to return to a pristine, healthy state. Although countries have taken action to reduce the burning of fossil fuels, scientists don’t believe that this we be a sufficient fix. If we were to completely stop burning fossil fuels today, the soils may, with an unknown but great amount of time, return to their original state, which in turn would lead to healthier streams, lakes and coastal oceans. I will be using this article as a case study to show the harmful effects of acid deposition on soils and trees.

Lawrence, Greg. "Forest and Terrestrial Systems." Proc. of the Conference "Acid Rain: Are the Problems Solved" from the Center for Environmental Information. 2-3 May 2001, Washington D.C. Ed. James C. White. 26 Apr. 2009 <http://www.ceinfo.org/resources/Acidrain/34_Lawrence.pdf>.

Lawrence discusses the effects of acid deposition on forests, soils and trees. The article goes into great detail to explain how calcium buffers acid. According to his studies there has been a depletion of calcium, a mobilization of inorganic aluminum, and an accumulation of sulfur and nitrogen in soils effected by acid deposition. The ratio of aluminum to calcium in the soil is a great determinant of how well a tree can deal with stressors such as extremely cold winters. If the ratio is greater than one, then there is a greater amount of stress put on the tree, the tree is less healthy, and is also susceptible to other stressors. I will be using this article to explain the effects of acid deposition on forests, soils and trees.

Pearce, Fred. "Diversity Hotspots Face Fatal Dousing with Acid." New Scientist 109.2546 (April 2006): 9. Expanded Academic ASAP. Gale. California Polytechnic State University. 15 Aug. 2009 <http://find.galegroup.com.ezproxy.lib.calpoly.edu:2048/gtx/start.do?prodID=EAIM>.

This article reports on biodiversity hotspots across the globe. The author reminds the reader of Europe's industrialization and how their ignorant actions greatly harmed the forests and wildlife nearby. He uses this history and relates it to the type of industrialization going on in many places around the world. I will be looking at the findings of model predictions which indicate that a number of diversity hotspots, in or near newly industrializing nations, will be inundated with a large quantity of acid deposition if things don't change. These diversity hotspots could potentially be irreversibly damaged.

"Plant Calcium and Acid Rain." Environment 49.4 (May 2007): 7. Expanded Academic ASAP. Gale. California Polytechnic State University. 15 Aug. 2009 <http://find.galegroup.com.ezproxy.lib.calpoly.edu:2048/gtx/start.do?prodID=EAIM>.

This article explains how plants have sensors that detect how much calcium is available and regulate growth and development. If there is not enough calcium, then the plant will slow or halt growth until more calcium becomes available. I will be using this article to help explain what happens to plants when acid deposition falls on the soil out of which they grow. I will also be using this article to relate the stunted growth of trees in places where acid deposition is common.

Striegel, Mary F. “Materials and Cultural Resources.” Proc. of the Conference “Acid Rain: Are the Problems Solved” from the Center for Environmental Information. 2-3 May 2001, Washington D.C. Ed. James C. White. 26 Apr. 2009 <http://www.ceinfo.org/resources/Acidrain/36_Striegel.pdf>.

In this discussion, Striegel details the affects of pollution on stone buildings, statues, and structures. She doesn’t claim that all of the affects are from acid deposition; instead she tells us the deterioration is mostly from sulfur dioxide. Once a pollutant has landed on the stone, it forms an alteration crust. The alteration crust is made up of calcium sulfate, which is more water soluble than the stone the pollutant landed on, and with rains, the alteration crust is removed. She explains her studies on surface morphology and porosity of stone structures. The rougher the surface and the more porous a rock, the better the rock is at holding the pollutant and the easier it is for the rock to deteriorate. I will be using this article to explain the effects of acid deposition on human structures.

Outline

I. Introduction

A. How is acid deposition formed?

B. Location of acid deposition-forming pollutants

C. Map of rain water pH across the U.S.

D. Types of acid deposition

E. History of acid deposition-forming pollutants

F. Reduction in emissions

G. Acid deposition affects soils, forests, lakes, streams, coastal waters, animals, human structures and human health.

II. Soils

A. Why are healthy soils so important?

B. Importance of calcium in soils

C. Acid deposition leaches calcium from the soil

D. At different depths, soils are affected differently

E. When there is a greater number of acid anions than there are base cations, inorganic aluminum begins to mobilize and stunt tree growth

F. Soils samples from the past show a decrease in calcium throughout time

G. Case studies

III. Forests

A. Importance of trees and forests

1. Carbon sink

2. Habitat to plants and animals

3. Biodiversity

a. Possible miracle medicines

b. Food chain

B. Degraded soils leave forests and trees susceptible to harmful elements

C. Case Studies

    1. Red spruce
    2. Sugar maple

  D. Plant’s molecular sensors interaction with calcium in the soil

    1. Sense not enough calcium
    2. Sensors tell plant to halt growth

IV. Lakes and Streams

  A. Eastern United States

  B. The buffering capacity of the bedrock geology is a big determinate of a lake or stream will be effected by acid deposition.

    1. Soft bedrock provides substantial buffering of acidity
    2. Hard bedrock provides little buffering of acidity

  C. High elevation streams and lakes are more affected due to lower buffering capacity of their catchments

  D. Acidification episodes

    1. Sulfur works its way out of soils and after a rain, washes to streams and lakes
    2. Excess nitrogen in soils gets washed to streams and lakes after a rain

  E. Aluminum in acidic conditions is deadly to fish

    1. Metabolic poisoning
    2. Electrolyte imbalance
    3. Circulatory collapse

  F. Other aquatic species are affected by the acidic water

  G. Case studies

V. Coastal Ecosystems

  A. Excessive nitrogen on the east coast of the U.S. reaches coastal waterways

  B. In moderation, nitrogen helps growth of plants

  C. Excessive Nitrogen results in:

    1. Decrease in dissolved oxygen
    2. Increase incidence and duration of harmful algal blooms

3. Decrease in biodiversity

4. Decrease in nursery grounds

D. Case Studies

VI. Human Structures

A. Process

1. Wet or dry sulfur dioxide deposited on a stone

2. Interacts with the stone and creates a weakened alteration crust of calcium sulfate

3. Further rains wash the alteration crust away

B. Types of stone react differently to acid deposition

C. Porosity and surface morphology help determine how a stone will react to acid deposition

D. Case studies

VII. Humans

A. Acid deposition doesn't affect humans directly

B. Fine particles of sulfur dioxide and nitrogen oxides, the chemicals that make up acid deposition, do affect human health

C. The fine particles of these pollutants, when inhaled are related to:

1. Increased illness

2. Premature death from heart and lung disorders, such as asthma and bronchitis

D. Indirect effects of acid deposition

VIII. Conclusion

A. Review of topics covered

B. Implications for newly industrializing nations

C. Reasons for post-industrial and newly industrializing nations to stop creating these pollutants

D. A grim look to the future

Introduction

In a world experiencing increasing population, urbanization, and developing nations looking to compete on a global market with post-industrial nations, the effects of acid deposition require greater consideration. As the world's energy demand rises, and with the cheapest and most abundant source of energy being coal, the occurrence of acid deposition is on the rise. Acid deposition is caused by the "emission of the gases Sulfur dioxide (SO2) and Nitrogen oxides (NOx)" (Gordon). A small percentage, around 5%, of these gases are released naturally from the earth through volcanoes, forest fires and bacterial action in decaying vegetation, but the majority, around 95% of these gasses are anthropogenic and come from humans producing energy by burning fossil fuels such as petroleum, coal, and natural gas (Gordon). As the map below (figure 1) shows, the great majority of power plants in the U.S. are either natural gas or coal, and are located in the Eastern U.S.

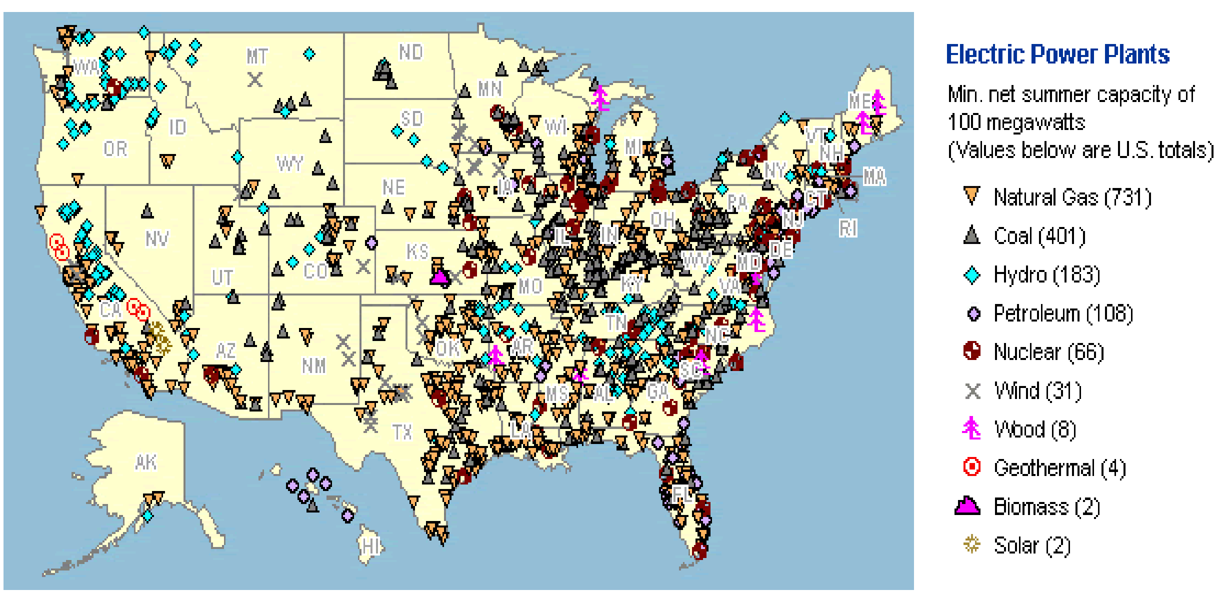

Figure 1. Location and type of U.S. power plants (Gordon).

When sulfur dioxide and nitrogen oxides are released into a moist atmosphere, they get "converted to nitric acid (HNO3) and sulfuric acid (H2SO4) through oxidation, the chemical attachment of free oxygen to other elements and compounds, and dissolution, the process of a substance dissolving and dispersing into a liquid" (Pidwirny). In simpler terms, the gases get incorporated into clouds and eventually fall to the ground as rain, snow, fog, or mist; this is called "wet deposition." Wet deposition can also form when "ammonia gas (NH3) from natural sources is converted into ammonium (NH4)" (Pidwirny). When talking about wet acid deposition, scientists determine what is acid by measuring the pH of the precipitation. Usually, any precipitation that has a pH under 5 is considered acid. However, if the pH is lower than what is natural or the norm for a given area, it too can be called acid (Gordon).

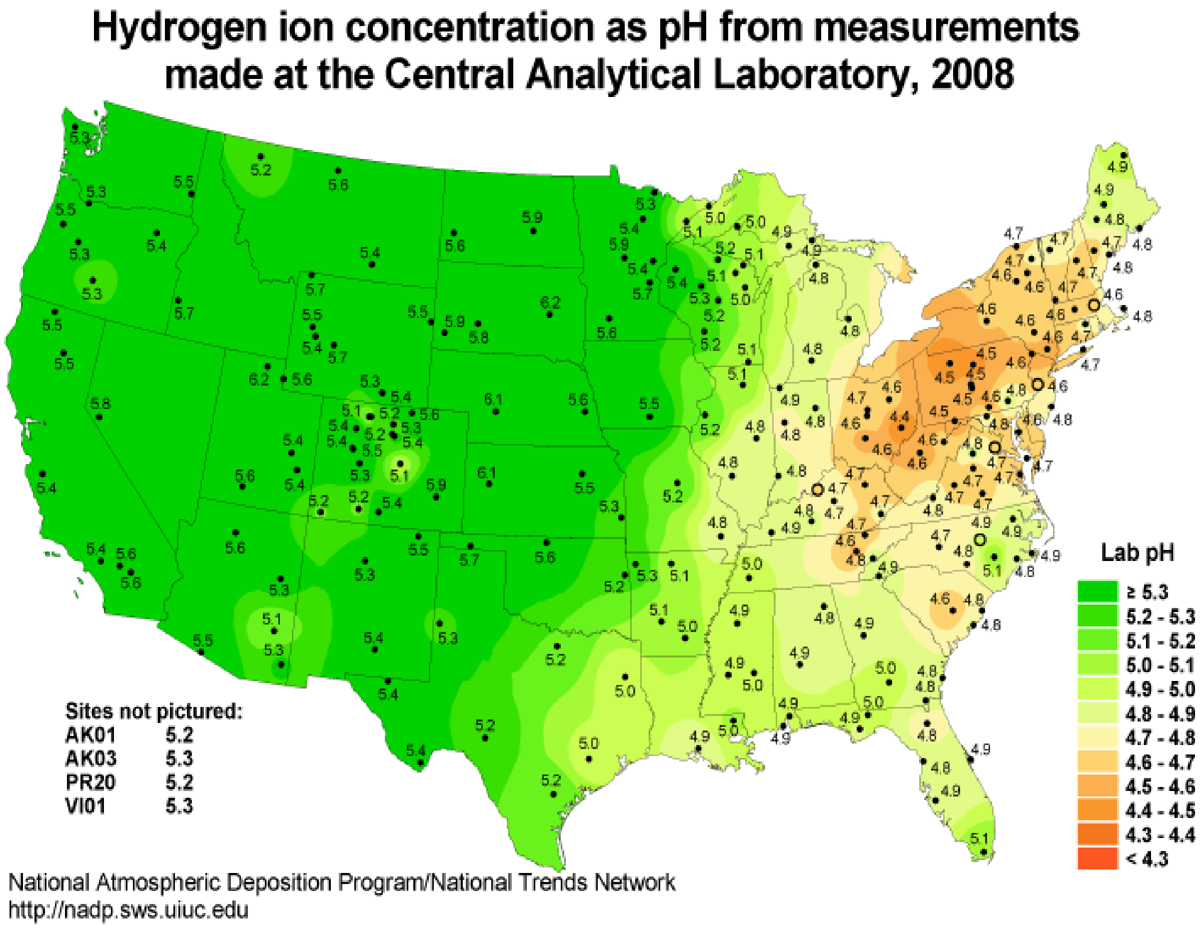

Figure 2. Deposition pH levels across the U.S.

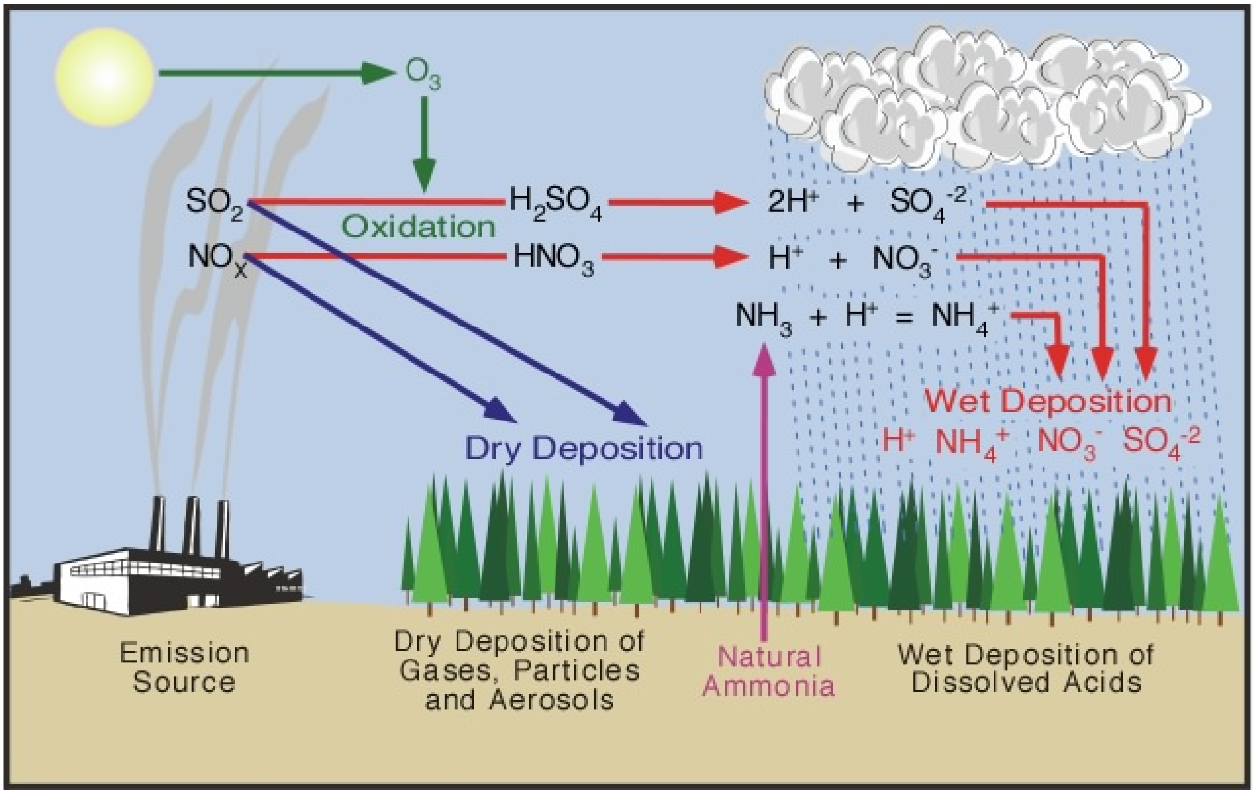

Figure 3. Acid deposition formation process (Pidwirny).

When SO2 and NOx are released into a dry atmosphere the acid chemicals may become incorporated into dust or smoke and fall to the ground through "dry deposition" (Gordon). These chemicals can be blown far away from their sources, sometimes crossing borders and producing problems for those who don't even benefit from the energy being produced (Gordon). The amount of dry deposition is "often equal to the amount deposited in wet form" (Bulger, 59). Acid deposition in wet form or dry form is hazardous and is a problem that should be taken seriously (Pidwirny).

Humans have been producing sulfur dioxide and nitrogen oxides heavily since the Industrial Revolution of the late 18th and 19th centuries. In Europe, "Sulfur emissions had increased so much by the middle of the 19th century that they were causing effects far away from their sources" (Brimblecombe, 42). Acid rain wasn't on the population's or scientist's radar at that time, but the soot “produced by burning coal was visible everywhere; shepherds in upland Britain described the sooty coating on the fleeces of sheep as ‘moorgrime’, and as far away as Scandinavia, falls of ‘black snow’ were frequently blamed on coal burning in Britain” (Brimblecombe, 42). December 5, 1952, London awoke to a “choking dark cloud hanging over their city: a corrosive cocktail of fog mixed with smoke and gas from domestic fires and power stations” (Brimblecombe, 43). The cloud hung around for four days, and “that week there were more deaths in London than at the height of the cholera epidemic of 1866 […] 4000 people died of bronchitis after inhaling a concoction of smoke particles and acid that inflamed the lining of their lungs” (Brimblecombe, 43). After that fateful week in 1952, the public and politicians decided that they needed to do something about the air quality of their city as the complaints compiled from neighboring countries. But it wasn’t until after ground breaking studies in the 1970s, that acid deposition became a prominent environmental issue. With campaigns by environmental groups such as “Greenpeace and Friends of the Earth, the industrial and political climates in Europe and North America have changed radically” (Brimblecombe, 46). Great reductions in sulfur emissions have been achieved by “switching to low-sulfur fuels, such as natural gas, and in large coal-burning power plants, by scrubbing exhaust gases free of sulfur dioxide in a process known as flue gas desulfurization” (Brimblecombe, 48). Even with these improvements, acid deposition is still harming our environment. The world still mainly uses fossil fuels as our source of energy; coal is our major source of electricity, natural gas is cleaner but still produces sulfur dioxide and nitrous oxides, also more and more petrol powered automobiles drive out onto the streets daily. The reductions are a good step in the right direction, and thankfully there hasn’t been, on record, another week like there was in 1952, but the effects of acid deposition are clearly evident. The evidence can be seen in the effects of acid deposition on soils, trees, plants, streams, lakes, coastal waters, animals, humans, and human structures. All of these direct effects of acid deposition are like a falling rain drops into a pond. The effects ripple out and cause others things to be injured, harmed or weakened.

The goal of this project is to report on acid deposition as one of many energy/pollution-related problems. The emissions of CO2 and other greenhouse gases into the atmosphere are equally as detrimental, if not more. All of these problems need to be addressed, especially by industrialized nations, if we want generations that follow to live in a healthy world. The developed countries, which have studied and are studying the impacts of acid rain and other anthropogenic pollutants, and can observe the damage that has been done by their own industrialization, need to set an example for developing nations to follow. They also need to warn the developing nations of the harmful aftermath of industrialization by way of fossil fuels. It is up to the industrialized nations, for they are the ones with enough money and educated people to develop and put-into-use clean, affordable, renewable sources of energy. When the project is completed, hopefully anyone who reads this paper will understand the impacts that acid rain has on the world, as well as the importance of developing and switching to efficient, clean, renewable sources of energy.

Soils

Without healthy soil, nothing will flourish. Healthy soil is the base for all life. Healthy plant growth begins with healthy soils. Without healthy soils, plants don’t grow, and the whole food chain is affected. Also, soils mitigate the quality of water feeding into streams. Healthy soils are the foundations for healthy life and acid deposition has wreaked havoc on this delicate system.

Acid deposition mainly affects three elements in soils: aluminum, calcium, and magnesium. According to Greg Lawrence, a forest and terrestrial systems specialist at the U.S. Geological Survey, “calcium in the soil is very important” (Lawrence, 75). Calcium is “essential for wood formation in trees […] and trees have a very high demand for calcium” (Lawrence, 75). If trees don’t get the proper amount of calcium, their growth will be stunted; slowed to an unhealthy rate which leaves them susceptible to their foes: foreign insects and extreme weather events. In the soil, calcium “is the primary element that neutralizes acidity, whether the acidity was generated through natural organic acids in the soil or by acid rain” (Lawrence, 75). Calcium acts as a buffer to acidity, and when soil is healthy, all acidity is fully buffered out by calcium.

Tree core chemistry studies taken from 300 to 400 spruce trees in the northeast U.S. help to prove that acid deposition has reduced calcium in the soil. From 1910 to 1950 there was a very consistent level of calcium in tree cores. In the 1950s there was a significant rise, then in the 1960s, the level of calcium rose even more. Lawrence explains, “At the early stages of acid rain, calcium was more available. The hydrogen ion, which is derived from sulfuric and nitric acids, was actually freeing up the calcium in the soil, making it easier for the tree roots to take it up” (79). But after that massive rise in available soil calcium, by 1970 the level of available calcium was at a never before seen low, and continued to fall all the way to the end of the study in the year 2000. Lawrence explains, “As the acids continued to be deposited on the soils, the calcium continued to be leached (by the hydrogen ion) at a higher rate […] and you end up getting lower levels of available calcium” (79).

At different depths, soil chemistry differs; this has a big influence on the amount of calcium available to trees. Organic materials (leaves, branches, and other decomposing matter) that fall from trees or have somehow ended up on the forest floor, and certain types of rocks, when weathered, produce calcium that is available to plants. Carbonate bedrock, such as limestone “provides substantial buffering of acid” (Bulger, 60) whereas “basaltic, granitic, and siliciclastic bedrock types represent a series of decreasing levels of buffering capacity” (Bulger, 60). On and near the surface of a forest floor, there is a layer called the organic horizon. In the organic horizon “there is very, very intense root activity, and recycling of calcium” (Lawrence, 77). The organic horizon is fairly low in calcium, “so as soon the plant material decomposes and releases some calcium, there are plenty of roots there to grab it, and that prevents it from leaching out of the soil” (Lawrence, 77). Deeper down in the soil, below the organic horizon, is a layer called the mineral horizon. Calcium is usually maintained in the mineral horizon by the weathering of rocks, but in this layer, the “recycling by roots is not nearly as strong” (Lawrence, 77). When you lower the root available calcium levels, which we saw in the 1970s, the soil loses its ability to buffer harmful elements, the pH of the soil decreases, and mobilization of aluminum begins which is very detrimental to trees.

Another way of looking at this situation is through the “difference between the base cations and the acid anions” (Lawrence, 77). There are a number of base cations in soil, but “calcium is typically the most abundant” (Lawrence, 77). When the total number of base cations is much greater than the total number of acid anions, aluminum doesn’t mobilize or cause any problems. When the two amounts begin to equal out, we begin to see aluminum mobilizing in the soil. Lawrence has been doing experiments to determine the aluminum to calcium ratios to try to figure out what ratio will impair the growth of a tree. His results show that when the aluminum to calcium ratio is greater than one, meaning that there is a greater amount of aluminum than calcium, then tree growth is being harmed. When Lawrence collected those 300 to 400 spruce tree ring samples he also took soil samples. For the organic horizon, the upper layer of soil, the aluminum to calcium ratios “range from .1, which is very healthy, to 2.2, which is not” (Lawrence, 77). Remember, these results are for the organic horizon, which isn’t affected as much as the mineral layer. The results for the mineral layer, the deeper layer, show that even the lowest ratio “is still over that threshold of 1”(Lawrence, 77) which means that all those sites have had aluminum mobilizing, and trees being harmed.

It is important to note that it has been difficult for soil scientists to gain knowledge about soils of the past, especially in the U.S., due to the fact that soil science is a relatively new science. Not very many soil samples were taken from the past, but the few that were taken have shown significant insight into the changes that have taken place. In a study, done out of the University of Pennsylvania, soil scientists were “able to repeat the sampling of one of the earliest forest soils studies in the country, which was conducted in the Adirondack Mountains” (Lawrence, 76) between 1930 and 1932. The group of scientists determined that at about 50 different sites scattered throughout the Adirondacks, there was about 80 millimoles per kilogram of acid-extractable calcium at each site (Lawrence, 76). The group of scientists then re-sampled the sites, duplicated the original methods, and found that, by 1984, the level of acid-extractable calcium had dropped to about 50 millimoles per kilogram. Additional samples were taken in 1987-88 from the Adirondacks, the results of these samples further indicate that the amount of acid-extractable calcium has dropped even more. One more set of samples from 1992-93, from a wide variety of soils throughout the northeast shows that most of these soils are as low in acid-extractable calcium, if not lower than the 1984 soil study results. The scientists included this data in the study to show that most soils, not just the soils at the 50 different sites in the northeast have been affected by acid deposition and to support the evidence that the "University of Pennsylvania study wasn't presenting data that was atypical to the northeast" (Lawrence, 76). To conclude, this study shows that when comparing the 1930s soil samples to the 1987-88 samples, the amount of acid-extractable calcium has decreased. Taking information from the tree core chemistry study which was mentioned earlier, the soil samples study would, presumably, show an increase in available calcium during the 1950s and 1960s, with a sharp reduction in the 1970s. The fact that the soil sample study shows the reduction in calcium from 1930-32 to 1987-88 correlates well with the tree core chemistry study's findings.

In an article that came out in 2005, written by Frances Backhouse, in American Forests magazine, the discovery of a historic soil sample was documented. In fact, the U.S. Geological Survey scientist Greg Lawrence, whom I mentioned earlier, was the scientist who "learned of the Dokuchaev Central Soil Museum, near St. Petersburg, Russia, a unique repository of soil samples that date back nearly a century" (Backhouse, 22). Lawrence and his team of experts selected archived soils from 1926 and 1964, which had been stored in wooden boxes as intact three-foot-deep profiles, and dug replicate pits to obtain modern samples. Their analysis revealed a trend of decreasing concentrations of calcium in 'root-available' form and increasing concentrations of 'root-available' aluminum" (Backhouse, 22). To see the effects of the altered soils, Lawrence and his team took tree core samples from Norway spruce growing near where they took the soil samples. The soil changes "coincided with decreased diameter growth" (Backhouse, 22) of rings, which indicates that "acid rain had so severely degraded the previously fertile soil that the trees could no longer maintain normal growth rates" (22). Alarmingly, "this decline in tree health occurred despite the regional climate becoming warmer and wetter, a situation that should have increased growth" (Backhouse, 22). To conclude, the article states that while this research was completed in Europe, the findings are relevant to a large area of eastern U.S. forests.

Although the there have been efforts to reduce sulfur emissions, with the hope that all acid deposition-caused harms would vanish, soils have gone through profound changes that are still affecting plants, trees, streams and lakes today. Ecologist Gene Likens of the Institute of Ecosystem Studies in Millbrook, New York: "Soils take hundreds to thousands of years to develop. If their chemistry is changed dramatically, it's a major impact. It will take a very long time for them to recover" (Kaiser, 198). Likens, along with Donald Buso, also of the Institute of Ecosystem Studies in Millbrook, and environmental engineer Charles Driscoll of Syracuse University report that "over the past thirty years, acid rain has been leaching the soil in their study area of vast quantities of the base cations that buffer, or neutralize acids and are essential to plant growth" (Kaiser, 198). The U.S. Forest Service's Hubbard Brook Experimental Forest in New Hampshire's White Mountains is where Likens and his team have been monitoring soil. According to them, the experimental forest has "stopped growing since 1987" (Kaiser, 198). Through years of testing the soil, they found that "as industrial pollution fell in the 1970s, so did sulfate, a marker for acid rain, in Hubbard Brook stream water" (Kaiser, 198). The scientists expected to see this finding, but didn't expect to see that the levels of calcium fell as well. With lower amounts of acid rain, the scientists believed that less calcium, the base cation, would be leached out of the soils, and they would return to a healthy state of equilibrium between acid anions. One hypothesis Likens had was that the "emissions restrictions, while cutting back on acid, had also reduced the amount of calcium rich soot falling on the forest" (Kaiser, 198), his other hypothesis was that "the years of acid deposition had simply leached away much of the

available calcium in the soil" (Kaiser, 198). In any case, to try and find out what had happened, he reconstructed the history of calcium in the Hubbard Brook soil, starting in the 1950s, before acid deposition became severe, to see the degree to which soil lost calcium over time. When comparing the 1950s calcium levels to the 1970 and 1987 levels they found that "the pool of calcium […] had shrunk by more than 50%" (Kaiser, 198). The most important finding happened when they extrapolated their results, and "found that while the calcium loss has slowed in recent years, rock weathering won't replenish the pool of calcium in the near future"(Kaiser, 198) and all plants, trees, streams and lakes that depend on the buffering, and neutralizing capabilities of calcium will continue to be affected. It looks like the efforts to reduce sulfur emissions might not be enough to return forests and waterways to their pristine state, but what should be done?
The scientists who worked on this study believe that cutting emissions further would help, but there is still no guarantee on when or if soils will return to a pristine state. Dave Grigal, a soil scientist at the University of Minnesota suggests we "spread lime on forest soils, as some European countries have done, however that may be too expensive in the United States; there isn't any quick fix" (Kaiser, 198).

Having healthy soils is central to healthy biodiversity. As you are about to read, soils affect just about every living thing including forests.

Forests

Forests are an incredibly important and necessary ecosystem for humans and most all living things. Forests act as a huge carbon sink and are essential to keeping the carbon cycle in order, they are home to a huge number of plants and animals, and the biodiversity of forests is amazing. In fact, forests very likely could be home to a plant or insect or animal that could be used as a miracle medicine. Sadly, forests are being destroyed everyday by human deforestation and climate change. As this happens, we are upsetting the food chain and habitats of plants and animals, some of which may have provided miracle medicines. Compared to cutting of forests,, acid deposition induces only a small bit of damage to forests. But as we can see, forests are very, very important, and any bit of damage is detrimental to life on earth.

Unfortunately, much of the research done about forest plants, is limited to only two types of trees: the red spruce and the sugar maple. As we all know, trees grow out of soil. The health of the soil plays a big part in how the tree grows and how healthy the tree will be. Another factor that plays into the health of the tree is air quality. According to a study done by Greg Lawrence, the ecologist from the U.S. Geological Survey, a combination of affected soils and acidic moisture has wreaked havoc on red spruce trees in of Maine, New Hampshire, Vermont, New York, and Quebec. First of all, acid deposition on the forest floor leaches the soil of the essential base cations: calcium and magnesium. Second, a high number of winter injuries occur when acidic moisture in the form of mist and/or fog strips away essential nutrients in their needles. The combination of these two factors leaves the trees “much more susceptible to stresses, in this case, defoliation from native insects is a big stress” (Lawrence, 80) as well as extreme drought, heat, or cold. Most commonly, trees in higher elevations are worse off. Lawrence states, “The ridge tops have the least amount of calcium (in the soil). They probably had the least amount of calcium before acid rain. Therefore, they are the most sensitive”(80). In addition low calcium soils and higher elevation trees interact with acid in clouds much more often than lower elevation trees. Studies done in the Adirondack, Green and White Mountain show that “20 to 50 percent of the canopy spruce have died in high elevation sites, but dieback is not limited to high elevations, pretty much throughout its range we can find it (dieback caused by acid deposition)" (Lawrence, 80).

In studies done by the U.S. Forest Service on sugar maple trees, "a strong link between low concentrations of calcium and magnesium in the soil and leaves, and unusually high mortality" (Lawrence, 80) has been made. One particular study shows us that "if there is sufficient magnesium and calcium, then trees can recover from the defoliation" (Lawrence, 80). But, if there are low levels of magnesium and calcium, then we find dead trees. The low levels of magnesium and calcium don't kill trees directly, but reduce their health to the point where, when they are met with a stressor, they are unable fight, and eventually the stressor or a combination of stressors get the upper hand.

A study, done by Zhen-Ming Pei, a Duke University researcher, explains why plants that have been growing in acid deposition-laden soil have a stunted growth. He explains that "as water circulates through a plant, dissolved calcium gets shuttled where it is needed, giving cells their structural rigidity or promoting new cell growth" ("Plant", 7). Plants use "molecular sensors and flows of chemical messengers to detect and regulate the storage and distribution of vital nutrients such as calcium" ("Plant", 7). Pei says, "If the sensors detect there is not enough calcium, they may tell the plant to hold off on growing, at least until it gets more calcium. They may misinterpret 'less' calcium as 'too little' and send for unnecessary growth shutdowns" ("Plant", 7). As we know, acid deposition leaches calcium from soils, so these plants are detecting less calcium due to acid deposition's interaction with soil chemicals. Pei's explanation ties in very well with Lawrence's findings of red spruce seedlings stalling in their growth. Pei's explanation furthermore ties in well with Lawrence's tree ring findings. When the level of available calcium was recorded low in a forest, the tree ring for that year was thin. The tree's sensors were telling it that there wasn't enough calcium in the soil, so they told the plant to slow or halt growth.

One would hope that soils and forests would buffer the rest of the wilderness from acid deposition effects, but this just isn't the case. Streams, lakes and the inhabitants of these aquatic realms are also affected.

Freshwater Habitat

The decimation of fish in lakes in the eastern third of the U.S. has been shocking. Of all the damage done by acid deposition, this is the most horrific. Arthur J. Bulger Jr. a scientist from the University of Virginia has conducted extensive testing and research on freshwater habitats and finds that in the eastern third of the U.S., the "volume-weighted, annual average pH of rainwater starts with a four, […] ten times as acid as estimated for rainwater pH in pre-industrial times" (Bulger, 59). This means that even "'pure' rainwater in the eastern United States in acutely lethal to all native fish species" (Bulger, 59).

Not all lakes and streams are affected by acid deposition. Whether or not acid deposition produces negative effects on the animals living in streams and lakes "depends largely on the bedrock geology of their catchments" (Bulger, 59). Since "buffering capacity ultimately depends on the weathering of acid-neutralizing material from the bedrock, we find that hard bedrock types produce less buffering capacity for streams than soft bedrock types" (Bulger, 60). As I mentioned earlier, soft, carbonate bedrock, such as "limestone, provides substantial buffering of acidity, and negative effects due to acidification are neither expected nor seen" (Bulger, 60). On the contrary, hard, basaltic, granite, or siliciclastic bedrock types have a lower buffering capability, and therefore the streams and lakes with this type of bedrock geology are highly vulnerable to the problems caused by acid deposition. High elevation streams and lakes are more affected than low elevation streams and lakes. This is because "mountains by their very nature are more resistant to weathering than their surrounding lowlands (that's why the mountains are still there), so mountain streams and lakes are usually the most sensitive to acidification due to the lower buffering capacity of their catchments" (Bulger, 60). In contrast, large valley streams and lakes are "often the recipients of upstream weather products, and are less sensitive to acidification as the result of their greater buffering capacity" (Bulger, 60). All soils have a sulfur and a nitrogen capacity. There is a mechanism for the accumulation of sulfur within soils, but the sulfur doesn't stay there forever. It eventually works its way out, but as it works its way out, it causes acidification in nearby streams and lakes. A good amount of sulfur is released and severe acidification episodes can occur when there is an extended dry period followed by rain. Nitrogen, "under pristine conditions, is the growth limiting nutrient in forest ecosystems" (Lawrence, 78), but is accumulating in forest soils to the point where the plants and trees aren't very effective at retaining all of it. At this point it acts very much like sulfur. When it rains after an extended dry period, nitrogen, in the form of nitric acid, is carried away to streams and lakes causing acidification episodes.

Aluminum (and the hydrogen ion, to a lesser extent) are deadly to fish. Aluminum is "the most abundant metal on the earth's surface, […] non-toxic and insoluble, or incapable of being dissolved under acid-neutral conditions, but very toxic to fish and other aquatic species under acidic conditions"(Bulger, 60). It is toxic to fish under acidic conditions because "the solubility of aluminum increases exponentially as pH falls below 5.6; its maximum toxicity occurs at about pH 5.0" (Bulger, 60). As we know, when acid deposition falls on soils, aluminum is mobilized or released. When it rains, aluminum is carried in solution form to streams and lakes. Both aluminum and the hydrogen ion are toxic to fish, but in most streams and lakes aluminum is the primary poisonous element. According to Bulger's studies, "fish can survive more acidic conditions (i.e. lower pH) in the laboratory in the absence of aluminum" (60). Unfortunately, aluminum is very abundant in nature, and really does kill fish.

The gills of a fish are the site of toxic death. The gill is a "complex organ responsible for oxygen and carbon dioxide exchange, as well as maintaining the proper salt and water balance in the fish's body" (Bulger, 60). Respiration and proper salt and water balance are always threatened by acid and aluminum stress. Bulger explains the importance of maintaining the proper salt concentrations, and how fish maintain the proper salt concentration in their blood:

> Freshwater fish maintain salt (sodium chloride) in their blood at concentrations similar to those in humans and most other vertebrates. The proper functioning of most body cells, and especially blood cells in this context, depends on keeping salt concentrations in body fluids within rather narrow limits. Since salt concentrations in the blood are much higher than the water in which they swim, fish constantly lose a small amount of sodium and chloride from the blood by passive diffusion across the thin skin of the gills. The lost sodium and chloride are replaced by an energy-requiring process (active transport) using biochemical "pumps" in the gill membranes which transport sodium and chloride from low concentration in the external stream water to higher concentration in the blood. (61)

As we can see, the process to maintain proper salt concentration is a complex and delicate one, but essential to understanding how aluminum and hydrogen ion poison the fish. When aluminum and/or hydrogen ion are present in the water, they "poison the biochemical pumps which transport sodium and chloride into the body; they also weaken the junctions between gill cells, making them leak more sodium and chloride than they otherwise would" (Bulger, 60). The swift loss of sodium and chloride causes a surge of harmful physiological effects in the body. When the concentrations of sodium and chloride in the blood plasma fall more than 30% below normal, death occurs within hours. Bulger explains that the "proximal cause of death is ionic dilution of the blood plasma. This causes blood and body fluid disturbances which ultimately kill the fish through circulatory collapse" (61):

> Under normal conditions, plasma ionic(electrolyte) concentrations and body cell ionic concentration are in equilibrium. Under acute acid stress, ions are lost more rapidly from the blood plasma than from blood and muscle cells; as a result, there is an osmotically-driven shift of water to the cells from the plasma; blood plasma volume may drop as much as 30%; at the same time, the red cells swell due to the osmotically-driven shift of water from the plasma; the result is a doubling of blood viscosity. The heart is unable to circulate this much thicker blood at a rate sufficient to supply oxygen to body tissues, including the heart itself, so the fish dies of circulatory collapse secondary to ionic imbalance. (62)

In short, the heart cannot supply its own tissues with sufficient oxygen to sustain normal heart activity. Eventually the fish has a lethal heart attack.

Acidity "eliminates the most sensitive species first"(Bulger, 61) and the least sensitive last. And we aren't just talking about fish. All aquatic species react differently to different pH levels. As the chart (figure 4) shows, clams and snails are the most sensitive to even the slightest acidic increase in their waters, whereas certain frog species can survive a very acidic aquatic environment. Even if a species can survive in acidic waters, it doesn't mean that their existence is made any easier. Usually, as a lake or stream becomes more acidic, the biodiversity and food chain of the ecosystem is disrupted. Also, "low pH and increased aluminum levels can cause chronic stress that may not kill individual inhabitants, but leads to lower body weight and smaller size which makes that inhabitant less able to compete for food and habitat" ("Effects").

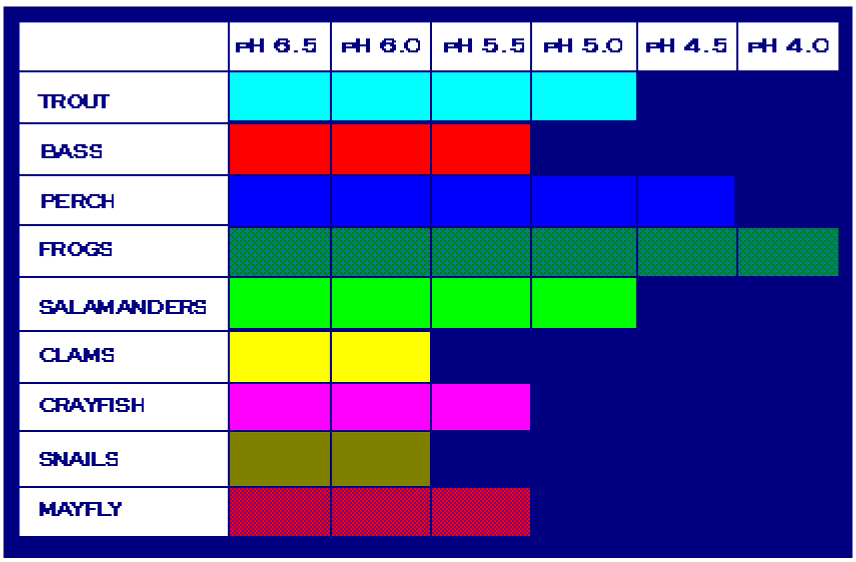

Figure 4. Types of freshwater species and their tolerance of acidic waters. Once their color stops, they cannot survive (Bulger, 63).

In a study done by the Environmental Protection Agency, called the National Surface Water Survey (NSWS), they tested 1,000 lakes larger than 10 acres and thousands of miles of streams to find out the percentage of "chronically acidic" lakes, meaning that they have acidic waters year round. Of the lakes and streams tested, they found "acid rain caused acidity in 75 percent of the acidic lakes and about 50 percent of the acidic streams" (Baker, 1151). Of the areas that were found to be acidic due to acid deposition, "the Adirondacks and Catskill Mountains in New York state, the mid-Appalachian highlands along the east coast, the upper Midwest, and mountainous areas of the western United States were noted as the most affected" (Baker, 1151). Keep in mind that the survey only tested lakes that were larger than 10 acres, if they were to include smaller lakes, which are abundant in the Adirondacks (one of the most affected places), the percentage of acid deposition affected lakes would be much higher. Of the streams they surveyed, “approximately 580 of the streams in the Mid-Atlantic Coastal Plain are acidic, and in the New Jersey Pine Barrens alone, over 90 percent of the streams are acidic, this is the highest rate of acidic streams in the nation” (Baker, 1152). Over 1,350 of the streams in the Mid-Atlantic Highlands (mid-Appalachia) are acidic, primarily due to acidic deposition (Baker, 1152). Something that is worth noting is that this survey doesn’t take into account acidification episodes which are brief periods during which lake and stream pH levels increase. These episodes happen after spring runoff from melting snow or heavy downpours and can be deadly to aquatic species. Many lakes and streams are affected by these acidic episodes, in fact “70 percent of sensitive lakes in the Adirondacks are at risk of episodic acidification. This percentage is over three times the amount of chronically acidic lakes in the Adirondacks. In the mid-Appalachians, approximately 30 percent of sensitive streams are likely to become acidic during an episode. This level is seven times the number of chronically acidic streams in that area” (Baker, 1154).

Acid deposition leaches soil of its precious calcium and other essential base cations, and mobilizes harmful aluminum, which in turn affects forest’s trees and plants and those who depend on these to survive. Also, due to the change in soil chemistry which reduces the soil’s ability to buffer acidic waters, streams, lakes, and the aquatic inhabitants of these ecosystems and those that depend on these aquatic inhabitants for survival are also affected. So, the list of plants and animals that are negatively affected by acid deposition is long, but it doesn’t stop there. Acid deposition’s negative effects are documented in coastal ecosystems, as well.

Coastal Ecosystems

Acid deposition affecting coastal ecosystems is a relatively new train of thought and study. Acid deposition, as it falls from the sky, doesn't affect oceans directly. Seawater is "very well buffered and handles the toxicity of acid deposition just fine" (Howarth, 66). Also, sulfur doesn't do any damage either. Seawater systems contain "tremendous amounts of sulfur in them and adding sulfur makes no difference" (Howarth, 66). Instead, excessive nitrogen, in coastal rivers and bays, is the culprit. The nitrogen that precipitates in acid rain hasn't been considered a factor causing coastal-ecosystem-problems until recently. The reason for this is because there are so many sources of nitrogen such as "fossil fuel combustion, inorganic fertilizer use, nitrogen fixation in agricultural systems and the in and out of a region in food and animal feeds" (Howarth, 68). Of all the nitrogen being released, "approximately 20% reaches the coast, and the rest is retained in the landscape by various mechanisms" (Howarth, 69). It has been difficult to determine the damage or influence acid deposition, specificly, has had on coastal ecosystems because of all the other sources of nitrogen. What we do know is that "globally, an estimated two-thirds of the nitrogen that is created from human activity for agriculture and through fossil fuel combustion is transferred through the atmosphere at some point" (Howarth, 65). Also, we know that "globally, fertilizer use is a bigger source of nitrogen use and pollution than is nitrogen deposition from fossil fuel sources"(Howarth, 65). But, as Dr. Robert Howarth from the department of ecology & evolutionary biology at Cornell University has found, "in the United States generally, most of the nitrogen deposition comes from fossil fuel combustion […] and in the northeastern U.S. specifically, nitrogen deposition from fossil fuel combustion is the major nitrogen source" (69). So, to have a better understanding of how acid deposition from fossil fuel combustion affects coastal habitats, we will be looking the coastal rivers, bays, and waterways of the northeastern U.S.

An anomaly in the biochemistry of forests has recently been discovered. The implications of the analysis completed by Howarth and his team is that “a significant amount of the nitrogen deposition that falls onto the landscape, including forests, must be exported to rivers” (70). According to Howarth, this might come as a surprise to a lot of scientists since the production of a forest is limited by nitrogen and forests do a really good job of retaining nitrogen. But, “when you add so much nitrogen that the forest is no longer limited by nitrogen, then it starts to leach out as nitrate” (Howarth, 70). The nitrate then leaves the forest, drains into streams and lakes, and some of it eventually reaches the coast and contributes to coastal nutrient pollution. Nitrogen, as we know, is a nutrient. Nitrogen, most often, “is the limiting nutrient in coastal marine ecosystems, and when added, we observe more algal and plant growth” (Howarth, 66). In moderation, added nitrogen to coastal marine ecosystems can result in greater harvests of species living there. However, “excessive nitrogen inputs lead to a series of deleterious ecological effects, such as eutrophication, the accumulation of nutrients that support a dense growth of algae and other organisms, the decay of which depletes the shallow waters of oxygen, which harm fish and other marine life” (Howarth, 66). Eventually, conditions of hypoxia, low levels of oxygen, and anoxia, the complete absence of dissolved oxygen in seawater occur, which are unable to support fish and other higher forms of life (Howarth, 66). In a report from the National Academy of Sciences that came out last summer called Clean Coastal Waters: Understanding and Reducing the Effects of Coastal Nutrient Pollution, it was found that these “dead zones” are located all over the globe. Here in the U.S., a couple of the most affected coastal waters are the Chesapeake Bay and Long Island Sound. In one particularly severe case, an area the size of New

Jersey, located off the coast of Louisiana, is suffering from these conditions and cannot support fish or any other higher life forms (Howarth, 66). Another affect of added nitrogen to coastal waters is the “increases in the incidence and duration of harmful algal blooms” (Howarth, 66). Some algal blooms are natural events, but events like “brown tides, red tides, and physteria blooms can all be increased greatly in their severity and length of duration by adding nitrogen to coastal waters” (Howarth, 67). As we can see from the differences between figures 5 and 6, biodiversity of these areas is also on the decline. The picture on the left portrays a healthy seagrass meadow with between 10-15 different species; a wonderful nursery ground for fish and shellfish. The picture on the right displays a seagrass meadow that has been receiving elevated nutrient inputs. It only has about two species left, and is not a good nursery ground for fish or shellfish. If more nitrogen pollution were to be added to the picture on the right, eventually, even the seagrasses would die out.

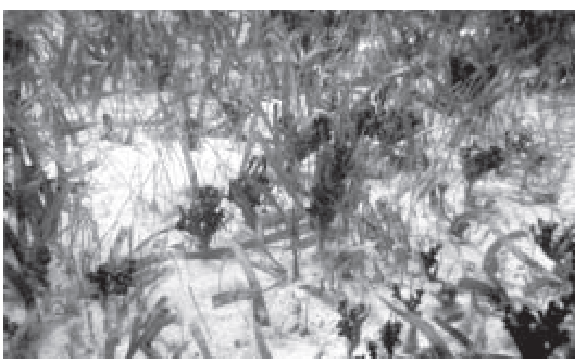

Figure 5. A seagrass meadow receiving only low amounts of nutrient inputs (Howarth, 67).

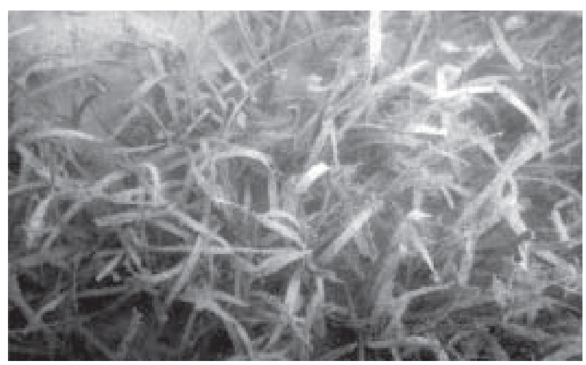

Figure 6. A seagrass meadow receiving elevated nutrient inputs (Howarth, 67).

A study released in 1999, by NOAA, the National Oceanic and Atmospheric Administration, concluded that “approximately two thirds of the coastal rivers and bays of the United States are moderately to severely degraded (roughly one third moderately degraded and one third severely degraded) by this problem (Howarth, 67).

It is important to remember that nitrogen deposition from the combustion of fossil fuels and acid deposition are only part of the increased nitrogen problem. Nonetheless, it is the human interference with mother nature's delicate nitrogen balance that has increased nitrogen levels and associated detrimental problems.

Human Structures

Human structures are affected by acid deposition. Sulfur dioxide, not nitrogen, is the cause of damage to stone structures. Both dry and wet acid deposition deteriorates stone structures. As Mary F. Striegel, from the National Center for Preservation Training and Technology, tells us, "once the pollutant has deposited onto the stone, it can interact to create an alteration crust on the stone, that alteration crust is usually calcium sulfate, which is more water soluble than the stone itself and, with subsequent rains, the alteration crusts are removed" (94). What we end up with is a permanently altered structure (Figure 7). Unlike ecosystems that could, hypothetically, recover from the acid deposition-caused effects over a period of time, once a stone structure has been affected by acid deposition, there is no recovering.

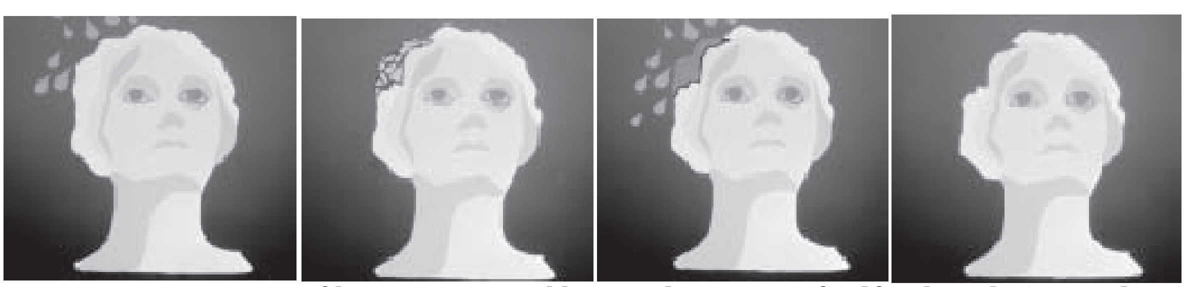

Figure 7. Deterioration of limestone caused by wet deposition of sulfur dioxide (Striegel, 95).

A few characteristics of stones help determine the amount of deterioration. One such characteristic is the surface roughness. Striegel ran tests using the "Environmental Exposure

Chamber, a machine constructed by the National Oceanic and Atmospheric Administration, that allows scientists to test the uptake of pollution onto materials while controlling temperature, humidity, wind speed and turbulence" (95). Her results show us that rougher stones will have greater deposition than smoother stones. Another characteristic is the porosity of the stones. The more spongy, or porous a stone, the easier it is for the sulfur dioxide to get into the stone and the harder it is for us, if we try, to get the sulfur dioxide out (Striegel, 95). A porous stone experience deterioration much longer than an impermeable stone. Ridges and valleys on a stone's surface also affect the amount of deterioration a stone will experience. Valleys will enhance deposition and deterioration, while ridges, or protruding areas will limit deposition and deterioration (Striegel, 96).

It is easy to see the stone deterioration caused by acid deposition, just look for statues without heads, and that are turning to blobs of stone rather than fine pieces of art (Figure 8). A deeper understanding of stone decay is limited by the long response time. A stone might "see air pollution today […] but it may react 25, 50 or 100 years from now" (Striegel, 94). A deeper understanding is also limited by resources, as "there are very few scientists worldwide looking at this problem, and this limits the ability to make further progress" (Striegel, 96). The fact that there are limited resources is strange because usually humans put a lot of interest into the things they create or cherish, such as statues, buildings, monuments, and archaic structures of antique civilizations.

Figure 8. The structure on the left and the statue on the right have been severely affected by acid deposition (Striegel, 96).

Human Beings

Humans aren’t directly affected by wet acid deposition. We aren’t going to melt if we walk around outside during acid rain. In fact, acid rain “looks, feels, and tastes just like clean rain […] and even swimming in an acid lake is no more dangerous than walking or swimming in clean water” (“Effects”). However, the pollutants that cause acid rain, “sulfur dioxide (SO2) and nitrogen oxides (NOx), do damage human health by interacting in the atmosphere to form fine sulfate and nitrate particles that can be inhaled deep into people's lungs” (“Effects”). Fine particles can even penetrate indoors. Many scientific studies have “identified a relationship between elevated levels of fine particles and increased illness and premature death from heart and lung disorders, such as asthma and bronchitis” (“Effects”).

Acid deposition affects humans indirectly in many ways. The damage to soils results in many problems relating to human needs. Damaged soils results in unhealthy forests where humans get wood for building, and heat, and where animals and insects essential to biodiversity and the food chain reside. We need healthy forests to convert carbon dioxide into oxygen. Severely damaged forests cannot act as a carbon sink, which is one of their most important functions. Acid deposition causes soils to lose their buffering capabilities by leaching calcium and mobilizing aluminum. Due to these effects, streams and lakes lose biodiversity. Humans suffer due to the loss of fish and other edible freshwater creatures. Nitrogen from acid deposition reaches coastal waters, and causes hypoxia, and anoxia, conditions that cannot support fish or any other higher species. Humans, again, lose biodiversity and food sources. Acid deposition falls on human-made stone structures and causes them to deteriorate and slowly fall apart. As this happens we lose cultural artifacts, human shelters, transportation facilities, and decrease the economic value of the affected built environment. Humans benefit from the combustion of fossil fuels by getting energy. But, can fossil fuel-made energy replenish soils, replace forests, de-acidify lakes and streams, put oxygen back into coastal waters, replace stone on buildings and historical artifacts, or replace the life lost to acid deposition related causes?

Conclusion

Acid deposition negatively effects soils, trees, plants, streams, lakes, coastal waters, human structures and human health. Scientists were able to observe the changes in these systems, and figure out the cause of these changes. Europe and the U.S. were the first regions to industrialize, and in doing so, severely affected their environments and populations. At the time, humans didn’t know what the environmental and human costs of industrializing were, but ended up suffering the consequences anyways. Now, after extensive research and numerous studies, scientists from Europe and the U.S. understand what caused the changes in their ecosystems: fossil fuel combustion. There are many negative effects of using fossil fuels as an energy source, especially when there are insufficient regulations requiring a certain level of cleanliness. Acid deposition is just one of these negative effects. The research and studies that have been completed and that are currently being pursued are incredibly important for the future of the earth. Some post-industrial nations have responded to the information, and used it as evidence to prove that changes needed to be made in the way they produce energy. And, changes have been made: cleaner fuels, energy efficient products, and government enforced regulations on emissions just to name a few. But, the effects of acid deposition are still observed. In many cases, industrializing has caused nearly irreparable damages. And, while there have been improvements in the way we produce energy, we are still polluting enough to not allow these systems to return to a healthy state. It seems we have the brain power to develop or improve upon renewable, clean energy sources, but the money required seems to all be tied up in fossil fuels.

What kind of example are we setting for newly industrializing nations? We know the harmful environmental effects of industrialization, but we still use the same forms of energy. And now, newly industrializing nations are looking to follow in our footsteps to give their citizens a good life and are using the same fossil fuels that the U.S. and Europe used when they industrialized. One big difference is that the population in these newly industrializing nations has increased greatly and continues to do so. As the population increases, and people move from rural to urban settlements, the energy demand rises, and unregulated fossil fuel combustion happens at an increasing rate, it seems inevitable that the same problems that the U.S. and Europe encountered will and are happening in these newly industrializing nations as well. In fact, studies have already shown that acid deposition is already present in some of these nations. A brief article in *The Ecologist* states that “in Thailand’s industrial areas, rain collectors wait an hour before collecting, since the rain is generally as acidic as tomato juice” (“Thailand”, 13).

Gareth Phoenix of the University of Sheffield, UK, claims that the following four biodiversity hotspots, which currently receive 5.3 kilograms of nitrogen per hectare, are most under threat (Pearce, 9). Using a combination of emission predictions, models of atmospheric chemistry, Phoenix predicted that by 2050, they will likely receive more than 20 kilograms of nitrogen per hectare:

> -South-west China, a botanical Shangri La hosting thousands of endemic plants. "The temperate coniferous forests of south-west China are similar to ecosystems in Europe and stand out as of immediate concern," says co-author Kevin Hicks of the University of York, UK.
>
> -The Atlantic forest of eastern Brazil, which is cut off from other South American forests and has its own unique biology; some 8000 of its plants, including half its tree species, are found nowhere else.
>
> -The Western Ghats, the forested Indian mountain chain that extends to Sri Lanka and contains more than 3000 endemic plants. "The soils there are known to be sensitive to acidification," Hicks says. The mountains face an average nitrogen fallout of 33 kilograms per hectare by 2050.
>
> -South-east Asia, a botanically rich region known to ecologists as Indo-Burma and identified as especially vulnerable to global warming. There are a thousand orchid species in Thailand alone, and new species of mammal are still regularly discovered.(9)

As we can see, there is a lot at stake. The post-industrial nations really need to set a better example and change the way they produce energy. Industrializing nations need to take a look at the history of this phenomena, and realize the potential damage being done to their environment.

Wouldn’t it be great if one of the industrializing nations stepped up, set an example, and started primarily using a renewable, clean source of energy?

Acid deposition affects many things, either directly or indirectly. It looks to be a continuing problem in the future as it becomes more widespread. Scientists have studied the history of acid deposition; they know why it happens, the sources, and the consequences. Hopefully things will change in the future, because we know that nothing good will come from producing more acid deposition.

Bibliography

Backhouse, Frances. "No Silver Lining." American Forests 111.3 (Autumn 2005): 22. Expanded Academic ASAP. Gale. California Polytechnic State University. 9 May 2009 <http://find.galegroup.com.ezproxy.lib.calpoly.edu:2048/itx/start.do?prodId=EAIM>.

Baker, Lawrence A., Alan Herlihy, Philip R. Kaufmann, and Joseph M. Eilers. “Acidic Lakes and Streams in the United States: The Role of Acidic Deposition.” Science 252.n5009 (May 1991): 1151-55. Expanded Academic ASAP. Gale. California Polytechnic State University. 15 Aug. 2009 <http://find.galegroup.com.ezproxy.lib.calpoly.edu:2048/gtx/start.do?prodID=EAIM>.

Brimblecombe, Peter. "Acid Drops." New Scientist 174.2343 (May 2002): 42-48. Expanded Academic ASAP. Gale. CSU San Luis Obispo. 2 Nov. 2009 <http://find.galegroup.com.ezproxy.lib.calpoly.edu:2048/gtx/start.do?prodId=EAIM&userGroupName=csupoly>.

Bulger Jr., Arthur J. “Blood, Poison and Death: Effects of Acid Deposition on Fish.” Proc. of the Conference “Acid Rain: Are the Problems Solved” from the Center for Environmental Information. 2-3 May 2001, Washington D.C. Ed. James C. White. 26 Apr. 2009 <http://www.ceinfo.org/resources/Acidrain/32_Bulger.pdf>.

“Effects of Acid Rain- Human Health.” 8 June 2007. U.S. Environmental Protection Agency. 5 May 2009 < http://www.epa.gov/acidrain/effects/health.html>.

Gordon, John, Mark Nilles, and LeRoy Schroder. “USGS Tracks Acid Rain.” April 2003. United States Geologic Survey. 25 April 2009. <http://bqs.usgs.gov/precip/reports/arfs.htm>.

Howarth, Robert. “Coastal Ecosystems.” Proc. of the Conference “Acid Rain: Are the Problems Solved” from the Center for Environmental Information. 2-3 May 2001, Washington D.C. Ed. James C. White. 26 Apr. 2009 <http://www.ceinfo.org/resources/Acidrain/33_Howarth.pdf>.

Hydrogen Ion Concentration as pH. National Atmospheric Deposition Program. 17 Sept. 2009. 21 Oct. 2009 <http://nadp.sws.uiuc.edu>.

Kaiser, Jocelyn. "Acid Rain's Dirty Business: Stealing Minerals From Soil." Science 272.n5259 (April 12, 1996): 198. Expanded Academic ASAP. Gale. California Polytechnic State University. 8 May 2009 <http://find.galegroup.com.ezproxy.lib.calpoly.edu:2048/itx/start.do?prodId=EAIM>.

Lawrence, Greg. “Forest and Terrestrial Systems.” Proc. of the Conference “Acid Rain: Are the Problems Solved” from the Center for Environmental Information. 2-3 May 2001, Washington D.C. Ed. James C. White. 26 Apr. 2009 <http://www.ceinfo.org/resources/Acidrain/34_Lawrence.pdf>.

Pearce, Fred. “Diversity Hotspots Face Fatal Dousing with Acid.” New Scientist 109.2546 (April 2006): 9. Expanded Academic ASAP. Gale. California Polytechnic State University. 15 Aug. 2009 <http://find.galegroup.com.ezproxy.lib.calpoly.edu:2048/gtx/start.do?prodID=EAIM>.

Pidwirny, M. "Introduction to Geography". *Fundamentals of Physical Geography, 2nd Edition.* 5 June 2009. University of British Columbia Okanagan. 15 Aug. 2009 <http://www.physicalgeography.net/fundamentals/1a.html>.

“Plant Calcium and Acid Rain.” Environment 49.4 (May 2007): 7. Expanded Academic ASAP. Gale. California Polytechnic State University. 15 Aug. 2009 <http://find.galegroup.com.ezproxy.lib.calpoly.edu:2048/gtx/start.do?prodID=EAIM>.

Striegel, Mary F. “Materials and Cultural Resources.” Proc. of the Conference “Acid Rain: Are the Problems Solved” from the Center for Environmental Information. 2-3 May 2001, Washington D.C. Ed. James C. White. 26 Apr. 2009 <http://www.ceinfo.org/resources/Acidrain/36_Striegel.pdf>.

“Thailand’s Industrial Areas.” The Ecologist 30.5 (July 2000):13. Expanded Academic ASAP. Gale. California Polytechnic State University. 15 Aug. 2009 <http://find.galegroup.com.ezproxy.lib.calpoly.edu:2048/gtx/start.do?prodID=EAIM>.