ACID DEPOSITION: AN ENVIRONMENTAL ISSUE

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INTRODUCTION

Acid rain was discovered in the 19th century by Robert Angus Smith, a pharmacist from Manchester (England), who measured high levels of acidity in rain falling over industrial regions of England and contrasted them to the much lower levels he observed in less polluted areas near the coast. Little attention was paid to his work until the 1950s, when biologists noticed an alarming decline of fish populations in the lakes of southern Norway and traced the problem to acid rain. Similar findings were made in the 1960s in North America (the Adirondacks, Ontario, Quebec). These findings spurred intense research to understand the origin of the acid rain phenomenon.Rain is naturally acidic due to the dissolution of carbon dioxide forming weak carbonic acid. Acid rain refers to rain that has a higher hydrogen ion concentration than about 10^{-5} M. Acid rain occurs due to the dissolution of acidic oxides in the atmosphere. Sulfur dioxide is one such acidic oxide which is produced by natural means such as volcanoes and geothermal hot springs and industrial processes such as the burning of fossil fuels (brown coal) and metal extraction from sulfide ores.The acidity of solutions is measured on a logarithmic pH scale from 0 to 14 with 0 being most acidic and 14 being most alkaline and 7 as neutral. Distilled water is at 7 with normal rainwater naturally being from 5.3 to 6.0. Any measurement below 5.3 is commonly considered to be acid rain.Sulfur dioxide and nitric oxides can be produced either by human activity or by nature. Burning coal and oil and volcanic eruptions produce sulfur dioxide while the cars and lightning strikes produce nitric oxides.

Acid clouds can grow on SO_2 emissions from refineries, as seen here in Curaçao

FORMATION OF REACTANTS

Burning of Fossil Fuels: $S_{(in\ compounds)} + O_{2(g)} \rightarrow SO_{2(g)}$

Burning of Zinc Sulfide: $2ZnS_{(s)} + 3O_{2(g)} \rightarrow 2ZnO_{(s)} + 2SO_{2(g)}$

The other major acidic oxide that contributes to the formation of acid rain is nitrogen dioxide. Nitric oxide is formed in high localized temperatures created by lightning strikes and naturally reacts in the atmosphere to produce nitrogen dioxide. Nitrogen dioxide is also produced in the high temperatures of combustion chambers of power stations and motor vehicles.

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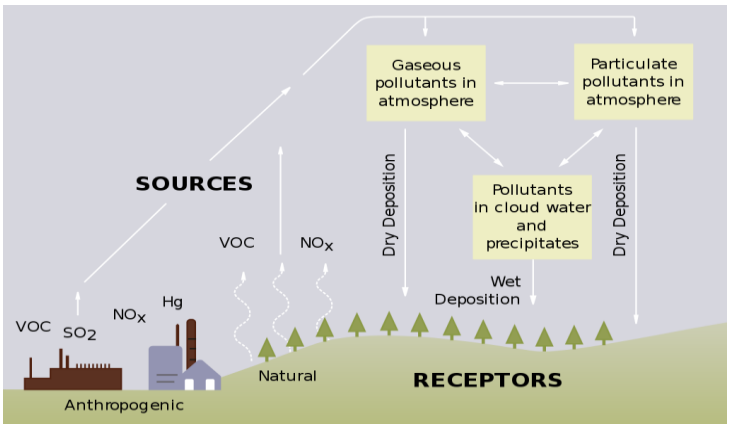


Processes involved in acid deposition (only SO_2 and NO_x play a significant role in acid rain)

CHEMICAL EQUATIONS FOR THE FORMATION

Formation of Nitrogen Dioxide: $N_{2(g)} + 2O_{2(g)} \rightarrow 2NO_{2(g)}$
Both sulfur dioxide and nitrogen dioxide are acidic oxides and react with water to form acids.

Sulfur dioxide reacts with water to form sulfurous acid.
$SO_{2(g)} + H_2O_{(l)} \rightarrow H_2SO_{3(aq)}$

Substances in the upper atmosphere then catalyse the reaction between sulfurous acid and oxygen to form sulfuric acid.

$2H_2SO_{3(aq)} + O_{2(g)} \rightarrow 2H_2SO_{4(aq)}$

Similarly, nitrogen dioxide reacts with water to form a mixture of nitric acid and nitrous acid.
$2NO_{2(g)} + H_2O_{(l)} \rightarrow HNO_{3(aq)} + HNO_{2(aq)}$

Substances in the atmosphere then catalyse the reaction between nitrous acid and oxygen causing the formation of more nitric acid.

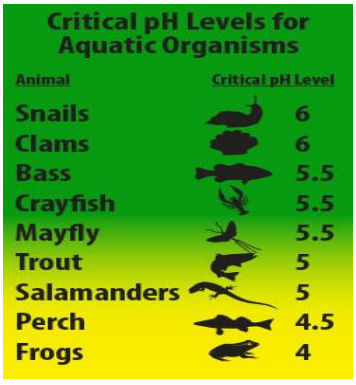
$2HNO_{2(aq)} + O_{2(g)} \rightarrow 2HNO_{3(aq)}$

Both sulfuric acid and nitric acid are soluble in water and are the major acids present in acid rain. As this forms and falls onto the Earth's surface, these strong acids are also brought to the surface causing harmful effects on the built and the natural environment.

EFFECTS OF ACID RAIN

On Ecosystems: An ecosystem is a community of plants, animals and other organisms along with their environment including the air, water and soil. Everything in an ecosystem is connected. If something harms one part of an ecosystem – one species of plant or animal, the soil or the water – it can have an impact on everything else.

On Fish and Wildlife: The ecological effects of acid rain are most clearly seen in aquatic environments, such as streams, lakes, and marshes where it can be harmful to fish and other wildlife. As it flows through the soil, acidic rain water can leach aluminum from soil clay particles and then flow into streams and lakes. The more acid that is introduced to the ecosystem, the more aluminum is released.



Some types of plants and animals are able to tolerate acidic waters and moderate amounts of aluminum. Others, however, are acid-sensitive and will be lost as the pH declines.

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Generally, the young of most species are more sensitive to environmental conditions than adults. At pH 5, most fish eggs cannot hatch. At lower pH levels, some adult fish die. Some acidic lakes have no fish. Even if a species of fish or animal can tolerate moderately acidic water, the animals or plants it eats might not. For example, frogs have a critical pH around 4, but the mayflies they eat are more sensitive and may not survive pH below 5.5.

On Plants and Trees: Dead or dying trees are a common sight in areas affected by acid rain. Acid rain leaches aluminum from the soil. That aluminum may be harmful to plants as well as animals. Acid rain also removes minerals and nutrients from the soil that trees need to grow.

At high elevations, acidic fog and clouds might strip nutrients from trees' foliage, leaving them with brown or dead leaves and needles. The trees are then less able to absorb sunlight, which makes them weak and less able to withstand freezing temperatures.

Buffering Capacity: Many forests, streams, and lakes that experience acid rain don't suffer effects because the soil in those areas can ***buffer*** the acid rain by neutralizing the acidity in the rainwater flowing through it. This capacity depends on the thickness and composition of the soil and the type of bedrock underneath it. In areas such as mountainous parts of the Northeast United States, the soil is thin and lacks the ability to adequately neutralize the acid in the rain water. As a result, these areas are particularly vulnerable and the acid and aluminum can accumulate in the soil, streams, or lakes.

Episodic Acidification: Melting snow and heavy rain downpours can result in what is known as episodic acidification. Lakes that do not normally have a high level of acidity may temporarily experience effects of acid rain when the melting snow or downpour brings greater amounts of acidic deposition and the soil can't buffer it. This short duration of higher acidity (i.e., lower pH) can result in a short-term stress on the ecosystem where a variety of organisms or species may be injured or killed.

Nitrogen Pollution: It's not just the acidity of acid rain that can cause problems. Acid rain also contains nitrogen, and this can have an impact on some ecosystems. For example, nitrogen pollution in our coastal waters is partially responsible for declining fish and shellfish populations in some areas. In addition to agriculture and wastewater, much of the nitrogen produced by human activity that reaches coastal waters comes from the atmosphere.

On Materials: Not all acidic deposition is ***wet***. Sometimes dust particles can become acidic as well, and this is called ***dry deposition***. When acid rain and dry acidic particles fall to earth, the nitric and sulfuric acid that make the particles acidic can land on statues, buildings, and other manmade structures, and damage their surfaces. The acidic particles corrode metal and cause paint and stone to deteriorate more quickly. They also dirty the surfaces of buildings and other structures such as monuments.

The consequences of this damage can be costly:

- damaged materials that need to be repaired or replaced,
- increased maintenance costs, and
- Loss of detail on stone and metal statues, monuments and tombstones.
- Limestone and Marble
    - $CaCO_{3(s)} + H_2SO_{4(aq)} \rightarrow CO_{2(g)} + H_2O(l),, + Ca(NO_3)_{2(aq)}$
- Metal Corrosion

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- Metal + Acid -> Salt + Water
- i.e. $Fe_{(II)(s)} + H_2SO_{4(aq)} \rightarrow FeSO_{4(aq)} + 2H^+$

Visibility: In the atmosphere, SO_2 and NO_X gases can be transformed into sulfate and nitrate particles, while some NO_X can also react with other pollutants to form ozone. These particles and ozone make the air hazy and difficult to see through. This affects our enjoyment of national parks that we visit for the scenic view such as Shenandoah and the Great Smoky Mountains.

Human Health: Walking in acid rain, or even swimming in a lake affected by acid rain, is no more dangerous to humans than walking in normal rain or swimming in non-acidic lakes. However, when the pollutants that cause acid rain —SO_2 and NO_X, as well as sulfate and nitrate particles— are in the air, they can be harmful to humans.

SO_2 and NO_X react in the atmosphere to form fine sulfate and nitrate particles that people can inhale into their lungs. Many scientific studies have shown a relationship between these particles and effects on heart function, such as heart attacks resulting in death for people withincreased heart disease risk, and effects on lung function, such as breathing difficulties for people with asthma.

CONTROL MEASURES

The numbers of possible solutions for acid rain that are available to us are aplenty:

1. One of the most fundamental acid rain solutions is to utilize fuels that burn more cleanly, or to burn coal more efficiently. This will greatly reduce the possibilities of acid rain developing in the atmosphere.
2. As fast as industrial power plants are concerned, the best solution is to attach devices known as ‘scrubbers’ in the chimneys of these plants. These scrubbers reduce the amount of sulfur produced in the smoke by 90 – 95%.
3. Vehicles and cars must be mandatory required to comply with very tight and efficient emission standards. Fitting catalytic converters into the exhaust pipes of vehicles also reduces the amount of sulfur dioxide produced by the vehicles.
4. For industrial power plants, there are many more acid rain solutions that must be enforced, as they are clearly the biggest contributors to the formation of acidified water droplets in the atmosphere. Industries must regularly inspect and clean all their emission equipment and chimneys and pipes.
5. All these acid rain solutions will be pointless unless people are informed and educated about the ill-effects and harms of acid rain. A widespread and nationwide effort must be made to make people aware. Only after that is done will all the acid rain solutions actually make a difference.

CONCLUSION

Acid rain is one of the biggest environmental hazards that we are facing today, and strong measure must be taken to prevent it, before it is too late. Governments need to sit up and take notice, and do much more than what they are already doing.Acid rain adversely affects plants, animals and human beings, and as a result it is not something that we can afford to ignore. It is our duty towards ourselves and towards our fellow human beings to do all we can to prevent and reduce the presence and increase of acid rain in our environment.

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