Research Article

Deleterious Impact of Acid Rain and Its Mitigation Measures

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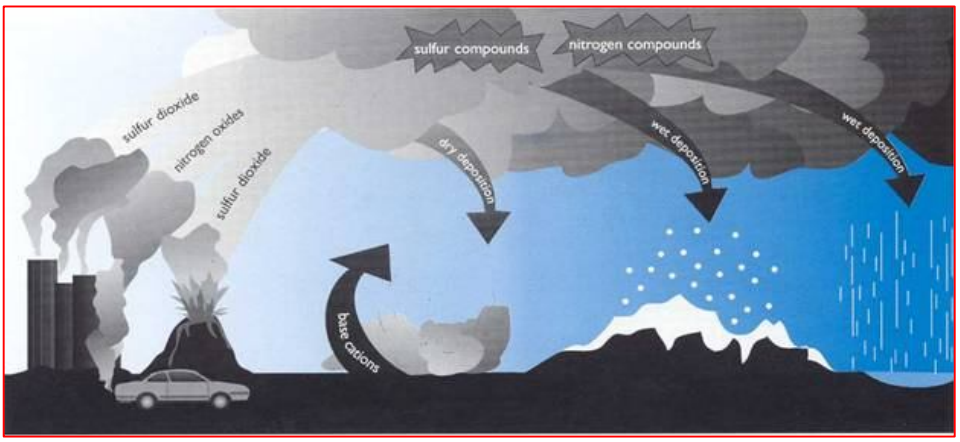
ABSTRACT

Acid rain is rain consisting of water droplets that are unusually acidic because of atmospheric pollution - most notably the excessive amounts of sulphur and nitrogen released by cars and industrial processes. Acid rain is also called acid deposition because this term includes other forms of acidic precipitation such as snow. Acidic deposition occurs in two ways: wet and dry. Wet deposition is any form of precipitation that removes acids from the atmosphere and deposits them on the Earth's surface. Dry deposition polluting particles and gases stick to the ground via dust and smoke in the absence of precipitation. This form of deposition is dangerous however because precipitation can eventually wash pollutants into streams, lakes, and rivers. In this manuscript cause of acid rain formation, its deleterious impact and mitigation strategies are delineated precisely.

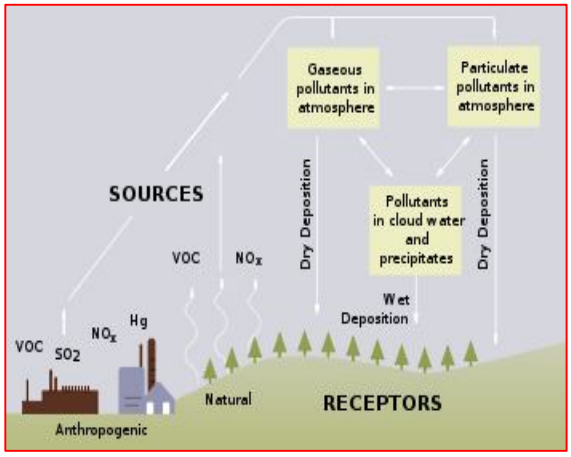
Keywords: SO_2; NOx; Sulphuric acid; Nitric acid; Industrial revolution; Wet deposition.

INTRODUCTION



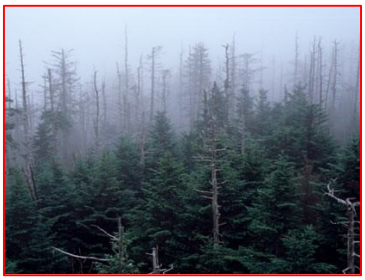
Acid deposition can occur via natural sources like volcanoes but it is mainly caused by the release of sulphur dioxide and nitrogen oxide during fossil fuel combustion. When these gases are discharged into the atmosphere they react with the water, oxygen, and other gases already present there to form sulphuric acid, ammonium nitrate, and nitric acid. These acids then disperse over large areas because of wind patterns and fall back to the ground as acid rain or other forms of precipitation. The gases responsible for acid deposition are normally a byproduct of electric power generation and the burning of coal. As such, it began entering the atmosphere in large amounts during the Industrial Revolution and was first discovered by a Scottish chemist, Robert Angus Smith, in 1852. In that year, he discovered the relationship between acid rain and atmospheric pollution in Manchester, England. Although it was discovered in the

1800s, acid deposition did not gain significant public attention until the 1960s and the term acid rain was coined in 1972. Public attention further increased in the 1970s when the New York Times published reports about problems occurring in the Hubbard Brook Experimental Forest in New Hampshire[1-6].



EFFECTS OF ACID RAIN

After studying the Hubbard Brook Forest and other areas today, there are several important impacts of acid deposition on both natural and man-made environments. Aquatic settings are the most clearly impacted by acid deposition though because acidic precipitation falls directly into them. Both dry and wet deposition also runs off of forests, fields, and roads and flows into lakes, rivers, and streams. As this acidic liquid flows into larger bodies of water, it is diluted but over time, acids can accrue and lower the overall pH of the body. Acid deposition also causes clay soils to release aluminum and magnesium further lowering the pH in some areas. If the pH of a lake drops below 4.8, its plants and animals risk death and it is estimated that around 50,000 lakes in the United States and Canada have a pH below normal (about 5.3 for water). Several hundred of these have a pH too low to support any aquatic life. Aside from aquatic bodies, acid deposition can significantly impact forests. As acid rain falls on trees, it can make them lose their leaves, damage their bark, and stunt their growth. By damaging these parts of the tree, it makes them vulnerable to disease, extreme weather, and insects. Acid falling on a forest's soil is also harmful because it disrupts soil nutrients, kills microorganisms in the soil, and can sometimes cause a calcium deficiency. Trees at high altitudes are also susceptible to problems induced by acidic cloud cover as the moisture in the clouds blankets them[7-10].



Causes of Acid rain

Sulphur dioxide (SO_2) is generally a by-product of industrial processes and burning of fossil fuels. Ore smelting, coal-fired power generators and natural gas processing are the main contributors. The main source of NOx emissions is the combustion of fuels in motor vehicles, residential and commercial furnaces, industrial and electrical-utility boilers and engines, and other equipment. Effect of acidic rain on aquatic ecosystems Most biological life survives best within a narrow range of pH levels, near neutral or 7.0. Aquatic vegetation and animal life vary in their susceptibility to changes in pH; some species are more acid-tolerant than others. Species higher up the food chain that relies on these organisms for food will be affected. If the pH levels drop

below 5.0 most fish species are affected[11-14].

Effect of acidic rain on soils and plant growth

Some plants are tolerant of acidic conditions, while others are not. Acidic soils may affect microorganisms in the soil, which play important roles in plant growth. Acidity affects the availability of nutrients that are essential for plant growth . Nitrogen is a nutrient and at certain levels, nitrogen deposition from air emissions has increased growth of vegetation; however, at higher levels, excess nutrients can reduce plant growth. Plant leaves get burnt and dry. Effect of acid rain on buildings and materials

Acidic rain is corrosive of metals and alkaline building materials such as marble and limestone. Urban areas subject to high levels of automobile exhaust and other sources of acidic rain have experienced significant weathering of statues and building materials. The important example of this is Taj Mahal, which looks darkened or yellow due to Acid rain caused by oil refinery near by[15-17].

Effect of acid rain on health

Acidic rain does not affect human health directly; however, the particulate matter associated with acid rain has been shown to have adverse health effects, particularly among those who have respiratory disorders. There is also some concern that acidic rain could contribute to leaching of toxins such as mercury that could be carried by runoff into bodies of water, contributing to environmental sources of this toxin.

Damage to forests by acid rain is seen all over the world, but the most advanced cases are in Eastern Europe. It's estimated that in Germany and Poland, half of the forests are damaged, while 30% in Switzerland have been affected. Finally, acid deposition also has an impact on architecture and art because of its ability to corrode certain materials. As acid lands on buildings (especially those constructed with limestone) it reacts with minerals in the stones sometimes causing it to disintegrate and wash away. Acid deposition can also corrode modern buildings, cars, railroad tracks, airplanes, steel bridges, and pipes above and below ground. Rain from an unpolluted atmosphere has a pH close to 6.0 (slightly acidic)[18-20].

This acidity is due to the reaction of water vapour and non-metal oxides in the atmosphere, such as carbon dioxide and nitrogen oxide, forming dilute acids.

- carbon dioxide reacts with water to form carbonic acid:

$$CO_{2(g)} + H_2O_{(l)} \rightleftharpoons H_2CO_{3(aq)}$$

Since carbonic acid is a weak acid it partially dissociates:

$$CO_{2(g)} + H_2O_{(l)} \rightleftharpoons H^+_{(aq)} + HCO_3^-{}_{(aq)}$$

- nitrogen dioxide reacts with water to form a mixture of nitrous acid and nitric acid:

$$2NO_{2(g)} + H_2O_{(l)} \rightleftharpoons HNO_{2(aq)} + HNO_{3(aq)}$$

Acid rain has a pH below 5.6 due mainly to the reaction of water vapour with sulphur dioxide and the oxides of nitrogen.

- Sulphur dioxide reacts with water to form sulphurous acid (H_2SO_3):

$$SO_2(g) + H_2O(l) \rightleftharpoons H_2SO_3(aq)$$

Sulphur dioxide (SO_2) can be oxidised gradually to sulphur trioxide (SO_3):

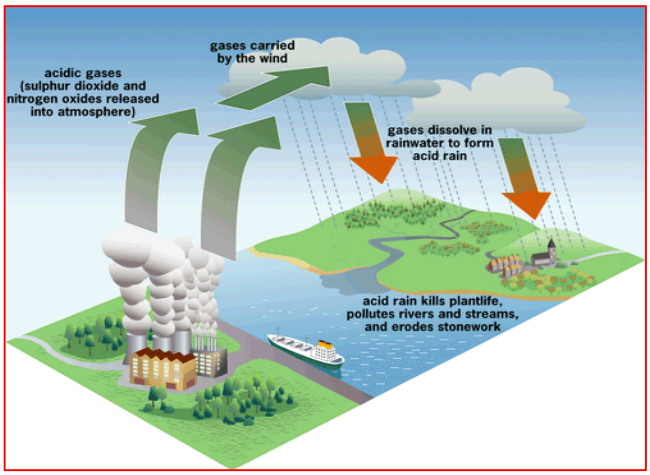
$$2SO_2(g) + O_2(g) \text{ -----> } 2SO_3(g)$$

Sulphur trioxide (SO_3) reacts with water to form sulphuric acid (H_2SO_4):

$$SO_3(g) + H_2O(l) \text{ -----> } H_2SO_4(aq)$$

- Oxides of nitrogen, particularly nitrogen dioxide (NO_2) react with water to form nitrous acid (HNO_2) and nitric acid (HNO_3):

$$2NO_2(g) + H_2O(l) \text{ -----> } HNO_2(aq) + HNO_3(aq)$$



Sources of the Acids in Clean and Polluted Air

Acid	Clean air	Polluted air
Carbonic acid (H_2CO_3)	natural carbon dioxide (CO_2) produced during plant and animal respiration produced during decomposition of organic matter	Carbon dioxide (CO_2) released from the combustion of fuels The complete combustion of coal: $C(s) + O_2(g) \rightarrow CO_2(g)$ The complete combustion of petrol (for example octane, $C_8H_{18}(l)$): $2C_8H_{18}(l)+25O_2(g) \rightarrow 16CO_2(g)+18H_2O(g)$ Complete combustion of ethanol (ethyl alcohol): $C_2H_5OH(l)+3O_2(g) \rightarrow 2CO_2(g)+3H_2O(g)$
Formic acid (Methanoic acid) (HCOOH)	Oxidation of natural methane (CH_4) formed during the anaerobic decomposition of organic matter	Increased oxidation
Sulphuric acid (Sulphuric acid) (H_2SO_4)	Natural decay of organic matter releases hydrogen sulfide gas (H_2S) which can be oxidised to sulphur dioxide (SO_2): $2H_2S(g)+3O_2(g) \rightarrow 2SO_2(g)+2H_2O(l)$ Sulphur dioxide can be oxidised to sulphur trioxide (SO_3): $2SO_2(g)+O_2(g) \rightarrow 2SO_3(g)$ Sulphur trioxide then reacts with water to form sulphuric acid: $SO_3(g)+H_2O(l) \rightarrow H_2SO_4(aq)$ Volcanoes emit sulphur dioxide which can be oxidised to sulphur trioxide which then reacts with water forming sulphuric acid. Ocean algae release sulphur gases such as dimethyl sulfide which is oxidised to form sulphuric acid.	Combustion of coal and other fossil fuels account for about 80% of the man-made sulphur dioxide in the atmosphere (sulphur is present in the proteins of the original living matter that has been fossilised to produce the fossil fuel such as coal, oil or petroleum). Most of this is from coal-fired power stations, motor vehicle emmissions account for only about 1% of the sulphur dioxide present. Sulphur dioxide is also produced when sulphur ores are roasted: $2ZnS(s)+3O_2(g) \rightarrow 2ZnO(s)+2SO_2(g)$ Sulphur dioxide is also produced in the manufacture of sulphuric acid by the contact process, in petroleum refining and in the manufacture of coke from coal
Nitric acid (HNO_3)	Lightning flashes lead to a reaction between atmospheric nitrogen and oxygen in the presence of water vapour which forms nitric acid	Combustion of fossil fuels Nitric oxide (nitrogen monoxide, NO) is produced in internal combustion engines as a result of the reaction between oxygen and nitrogen at high temperatures: $N_2(g)+O_2(g) \rightarrow 2NO(g)$ Nitrogen monoxide is readily oxidised to nitrogen dioxide (NO_2): $2NO(g)+O_2(g) \rightarrow 2NO_2(g)$ Nitrogen dioxide reacts with water to form nitrous acid (HNO_2) and nitric acid (HNO_3): $2NO_2(g)+H_2O(l) \rightarrow HNO_2(aq)+HNO_3(aq)$
Methanesulfonic acid (Methanesulphonic acid)	Ocean algae emit dimethyl sulfide which oxidises in air to produce methanesulfonic acid.	methanesulfonic acid is only produced naturally

Acid rain is a form of environmental pollution that damages buildings and marble statues by reacting with the calcium carbonate to form soluble calcium hydrogen carbonate (calcium bicarbonate, $Ca(HCO_3)_2$.

$CaCO_3 + H_2CO_3$ -----> $Ca(HCO_3)_{2(aq)}$

$CaCO_3$ (s) + H_2SO_4 (aq) $\rightarrow$ $CaSO_4$ (aq) + CO_2 (g) + H_2O (l)

Acid rain can leach aluminium from the soil into ground water, lakes and rivers, poisoning fish and plant roots. The sulphates and hydrogen sulphates in acid rain can can leach essential plant nutrients such as calcium and magnesium, from the soil. Acid rain disrupts the process of photosynthesis resulting in damage to plant life. At low concentrations it retards the production of chlorophyll and at high concentrations it forms sulphuric acid which kills the plant. Some organisms are sensitive to changes of acidity in water which can affect their ability to reproduce and in some cases may kill them. Acidity itself is determined based on the pH level of the water droplets. pH is the scale measuring the amount of acid in the water and liquid. The pH scale ranges from 0 to 14 with lower pH being more acidic while a high pH is alkaline; seven is neutral. Normal rain water is slightly acidic and has a pH range of 5.3-6.0. Acid deposition is anything below that scale. It is also important to note that the pH scale is logarithmic and each whole number on the scale represents a 10-fold change. Today, acid deposition is present in the northeastern United States, southeastern Canada, and much of Europe including portions of Sweden, Norway, and Germany. In addition, parts of South Asia, South Africa, Sri Lanka, and Southern India are all in danger of being impacted by acid deposition in the future[21-28].

WHAT'S BEING DONE?

Because of these problems and the adverse effects air pollution has on human health, a number of steps are being taken to reduce sulphur and nitrogen emissions. Most notably, many governments are now requiring energy producers to clean smoke stacks by using scrubbers which trap pollutants before they are released into the atmosphere and catalytic converters in cars to reduce their emissions. Additionally, alternative energy sources are gaining more prominence today and funding is being given to the restoration of ecosystems damaged by acid rain worldwide[28-36].

The following are some more specific suggestions on what you, as an individual, can do

In the home

- Run the washing machine with a full load.
- Hang dry some-or all-of the laundry.
- Buy energy-efficient appliances.
- Avoid the use of air conditioners altogether.
- Turn out the lights in empty rooms and when away from home.
- Consider installing compact fluorescent bulbs instead of high-wattage incandescent bulbs.
- If you have a forced-air furnace, change or clean its filters at least once a year.
- Avoid burning trash or leaves

While shopping

- Look for products bearing the EcoLogo. They minimize the use of environmentally hazardous substances and maximize energy efficiency and the use of recycled materials.
- Buy locally produced or grown items from local stores and businesses. They don't require the transportation energy of imported products.
- Transportation
- Walk, ride your bike or take a bus to work.
- Share a ride with a friend or co-worker.

- Have your engine tuned at least once every six months.
- Check your car tyre pressure regularly.
- Use alternative fuels, such as ethanol, propane or natural gas.
- Avoid unnecessary idling.
- Reduce the number of trips you make in your car.
- Drive at moderate speeds.
- Take the train or bus on long trips.
- Go CFC-Free. Control emission from vehicle. Check it regularly. Conserve energy. Reduction in demand for oil and coal reduces the amount of acid rain.

CONCLUSION

Asia is currently the region most affected by acidification.
Acid rain primarily results from the transformation of sulphur dioxide (SO_2) and nitrogen oxides into sulphuric acid (H_2SO_4), ammonium nitrate (NH_4NO_3) and nitric acid (HNO_3). The transformation of SO_2 and NO_2 to acidic particles and vapours occurs as these pollutants are transported in the atmosphere over distances of hundreds to thousands of kilometres. Wet deposition is acid rain, the process by which acids with a pH normally below 5.6 are removed from the atmosphere in rain, snow, sleet or hail. The gases can then be converted into acids when they contact water.
A pH scale is used to measure the amount of acid in liquid-like water. Because acids release hydrogen ions, the acid content of a solution is based on the concentration of hydrogen ions and is expressed as "pH." This scale is used to measure the acidity of rain samples.The smaller the number on the pH scale, the more acidic the substance is. Rain measuring between 0 and 5 on the pH scale is acidic and therefore called "acid rain." Small number changes on the pH scale actually mean large changes in acidity.

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