Acid Rain: Polluting Our World its Causes and Effects

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Abstract

One of the most important environmental challenges of a transboundary character is the acidity of rainfall. Depending on the relative proportions of production of nitrogen and sulphur oxides, acid rain is generally a combination of nitric and sulphuric acids. Protons explode as the outcome of these acids' actions with other air elements, enhancing the pH levels of the soil. A lower soil pH mobilises and eliminates nutritious cations while simultaneously making detrimental heavy metals easier to find.

Keywords: nitrogen, contaminants, nitrogen deposition, causes, and effects of acid rain.

INTRODUCTION

A variety of natural resources have helped humanity ever since civilization first emerged. They have constructed facilities that utilise a lot of the sources of energy found on Earth in an effort to simplify their lives easier. Despite the fact that this type of development makes our lives easier, it also degrades the environment by enabling dangerous substances to enter the atmosphere. The primary environmental issue brought on by air pollution is acid rain. Lakes, streams, woods, and the plants and animals that inhabit these areas suffer considerable harm as a result of acid rain. One of the most important aspects of life, for both people and animals, is rain. Rainfall provides the water that every life on Earth needs to survive. Rain is already acidic by nature, but pollution from homes, workplaces, power plants, and automobiles is making it even more so. It is known as "acid rain" to describe this issue. There has been acid rain for at least 20 to 30 years. This took place over a century ago. All nations have experienced the effects of pollution equally since the majority of the world has become industrialised. Acid rain is one of the primary contributors to this industrialised type of pollution.

It's not surprising that New Delhi's air is polluted with pollutants from the 1,500 new cars that are added to the city's roads every day. 2 million people die from air pollution in Asia each year. Even with more cars, people, and miles traveled, we are breathing better because of strict emissions regulations in the US. Since snow and other types of acidic precipitation are included, acid deposition is another name for acid rain. There are two forms of depot:

1. Wet accretion

2. Dry accretion

Wet Deposition: Acidic precipitation, fog, and snow are all examples of wet deposition. Acid compounds in the air may tumble to the ground as snow, fog, rain, or mist if they are carried by the wind into moist climates. A wide range of animals and plants are impacted by the acidic water as it permeates the ground and runs over it.

Dry Deposition: In areas with dry weather, the acid compounds may combine with smoke or dust and dry deposition to the ground's surface. Then they might stick to the soil, buildings, people, objects, cars, and trees. Rainstorms can clear these surfaces of the dry accumulation of gases and particles, increasing drainage.

OBJECTIVE OF THE STUDY

The project's goal is to comprehend the causes and consequences of acid rain, with a focus on nitrogen pollutants and their deposition. The project intends to understand how acid rain alters the soil pH, mobilizes nutritious cations, and makes hazardous heavy metals more accessible. The project also aims to explore the several types of acid deposition, including wet and dry deposition, and their influence on ecosystems, animals, and plants. Ultimately, the study wants to increase awareness about the negative effects of acid rain on the environment and support the development of methods to minimise air pollution and mitigate the repercussions of acid rain.

HISTORY OF ACID RAIN

Acid rain was first noticed in Europe in the middle of the 19th century. There was leaf degradation in the forests close to big industrial zones. English scientist Robert Angus Smith coined the phrase "acid rain" in 1872 after studying the damage that acidic precipitation caused to foliage. The first effort to lessen acid rain was launched in 1936 at the Battersea facility in London, United Kingdom, but by 1970 the problem had become more serious. The US Congress passed the Acid Deposition Act in 1980 as a result of the rising SO2 levels in the atmosphere brought on by the increased use of coal fuel, after running the National Acidic Precipitation Assessment Programme (NAPAP) consistently for ten years. As a result, there are now more places where acid rain and dry deposition may be monitored for their effects on structures, drinking water, terrestrial ecosystems, and historical sites. The grant helped to foster research on the dynamics of the atmosphere and potential mitigating measures. The biochemical processes of soil and freshwater bodies were altered, as damaged to man-made structures, according to NAPAP's inaugural evaluation report on acid rain from 1991, which found that roughly 5% of New England's lakes were acidic.

The Clean Air Act was modified in 1990 by the US Congress. The amendment's Title IV covers SO2 and NOX emission controls. This was accomplished in two steps with the goal of reducing SO2 emissions by 10 million tonnes overall. Most other US power plants are affected by Phase II, which began in 2000. Phase I, which began in 1995, restricted the SO2 emissions from 110 of the biggest electric power facilities. From 211,000 tonnes to 96,500 tonnes between 2000 and 2006, SO2 emissions decreased by 54%. Since 1999, similar measures have been taken to reduce NOx emissions from both industry and cars. The Clean Air Interstate Rule (CAIR), was published in March 2005 by the US EPA. It lessens the amount of pollutants that are transported from one state to another by the emissions from power plants (US EPA, 2014).

WHAT IS ACID RAIN?

Emissions of SO_2 and NO_X from various sources that are released to the atmosphere dissolve in atmospheric water and cause rain to contain acids. When SO_2 interacts with ozone or hydrogen peroxide, it can move further and more rapidly and form SO_3, which is highly soluble in water and produces sulphuric acid. The atmospheric chemicals don't react with SO_2 very much, but they do react with it when it comes into touch with them. Several natural processes, including as volcanic eruptions, sea mist, plankton, decomposing plants, and forest fires, result in the production of sulphur dioxide. sources created by humans Sulphur dioxide emissions from industries account for 69.4% of total emissions, followed by home heating with coal and firewood (area or non-point sources) and 3.7% from transportation (mobile sources). Coal is utilised in many different places, including coal-fired power plants, coal-fired automobile engines, oil refineries, residential and commercial boilers, the production of iron and steel from the smelting of metal ore, and the production of Zn, Ni, and Cu from the processing of pure metals. In addition, it is released during the production of sulfuric acid, which is used to make disinfectants, bleaches, and fumigants. Numerous natural events, such as lightning, bacterial activity, forest fires, and volcanoes, can result in the production of NO_X. Examples of man-made sources include automobiles (43%) and fertiliser, utilities, and other industrial combustion sectors (32%). (2012 book, "Causes and Effects of Acid Rain").

This group includes dry depositions such as particulate matter that is even smaller than PM 2.5, as well as wet depositions like acidic rain, snow, sleet, and fog. Acid rain can have rapid or persistent impacts. While episodic acidification is caused by intense rainstorms, long-term acidification is a result of years of acid rain. Acidification also happens in the spring because melting snow releases concentrated nitrate and sulphate into the environment.

Nitrate levels in the soil rise as a result of acid rain, resulting in nitrogen saturation of the soil. Additionally, nitrate ions draw out more calcium and magnesium from the ground, and an excess of nitrogen causes eutrophication in aquatic habitats. Plants become lacking in aluminum and other minerals as a result of soil aluminum being converted by trees into harmful aluminum nitrate or sulphate. Around 20–60% of the total deposition is caused by dry deposition, in which sulphate and nitrate ions fall as minute particles rather than dissolving in water.

WHAT CAUSES ACIDIFICATION?

The main contributors of acid rain are sulphur dioxide (SO_2), nitrogen oxides, and to some extent ozone. Acid deposition happens when these components combine with air reactants. Oceans and, to a considerably lesser extent, volcanic eruptions are the two main natural sources of sulphur pollution. Burning coal and oil, as well as a number of industrial operations, are examples of man-made sources of SO_2 emissions (Cullis and Hischler, 1980). Sulfuric acid production, the use of petroleum industry acid concentrating machinery, and the melting of iron and other metal (Zn and Cu) ores are further sources. Even while NOx levels are lower than SO2 levels, it is becoming increasingly important in the creation of acid rain.

The pH scale, a condensed representation of potential hydrogen, determines how acidic an object is. Because water partially combines with atmospheric carbon dioxide (CO2) to form carbonic acid, regular rainwater also has an acidic pH.

H2CO3 (carbonic acid) is produced when CO2 and H2O are combined.

Nitric acid, which also contributes to the acidity of normal precipitation, is produced when nitrogen is oxidised in the presence of water during lightning storms.

Nitric acid, or 4 HNO3, is produced when 2 N2, 5 O2, and 2 H2O are combined.

Acidic rain is defined as having a pH level below 5.6 and a concentration of H+ ions more than 2.5 eq-1 (Evans, 1984). Galloway et al. (1982) recommended a pH of 5.0 as the highest level of natural input.

CHEMICAL REACTIONS THAT LEAD TO THE DEVELOPMENT OF ACID RAIN:

The interaction of SO2, NOx, and O3 leads to the chemical process that generates acid rain. Huge smokestacks release molecules of SO2 and NOx into the air, which are collected in the wind currents and react with vapours in the presence of sunlight to generate sulphur dioxide and nitric acid mists. The recurrent high-temperature circumstances have caused these acids to remain in a vapour state. Condensation occurs as the temperature falls, resulting in aerosol droplets, which are by nature black, acidic, and carbonaceous because they contain unburned carbon particles.

Acid reactions involving O3:-

O3 $\longrightarrow$ O2 + O

O+H2O $\longrightarrow$ OH• (hydroxy radical)

OH•+S02 $\longrightarrow$ HSO3

HSO3- + OH $\longrightarrow$ H2SO4

OH+NO2- $\longrightarrow$ HNO3

HSO3 + O2- $\longrightarrow$ SO32-+ HO•2 (peroxy radical)

Acid rain becomes 5-20% more acidic overall when peroxy radicals mix with formaldehyde and acetaldehyde to create formic and acetic acids as well as a number of other organic acids.

Acid reactions containing sulphur:

Sulphur is very abundant in coal. Burning coal causes its components to get oxidised.

S + O2 $\longrightarrow$ SO2

Sulphur is directly oxidised to SO_2 in the flame, and as a result, SO_2 is released from smoke stacks into the environment. The prevailing wind carries SO_2 along as it slowly oxidises to SO_3^{2-} at room temperature.

$2 SO_2 + O_2 \longrightarrow 2 SO_3^{2-}$

$SO_3^{2-} + H_2O \longrightarrow H_2SO_4$

$SO_2 + H \longrightarrow H_2SO_3$ $(H^+ HSO_3)$

$HSO_3 + O_3 \longrightarrow SO_4^{2+}{+} H^+ + O_2$

The conversion of SO_3^{2-} to SO_4 depends on the atmosphere's oxidant characteristics. The most common place for sulphur dioxide oxidation to take place is in clouds, particularly in air that is heavily polluted and contains large quantities of elements like ammonia and O_3. The enhanced conversion of SO_2 to sulfuric acid is made possible by these catalysts.

$H_2O_2 + HSO_3 \longrightarrow -HSO_4^- + H_2O$

Acid reactions containing nitrogen:-

$NO_2 + OH \longrightarrow HNO_3$ Nitric Acid

$NO_2 + O \longrightarrow NO_3$

$NO_2 + NO_3 \longrightarrow N_2O_5$

$N_2O_5 + H_2O \longrightarrow 2HNO_3$ Nitric Acid

CONSEQUENCES OF ACID RAIN:

There are a number of significant effects of acid precipitation on both natural and artificial ecosystems, as can be shown by researching the Hubbard Brook Forest and other locations today.

However, because acidic precipitation directly enters aquatic environments, aquatic settings are where acid deposition is most visibly felt. Aside from forests, fields, and highways, wet and dry deposition also enters streams, rivers, and lakes when it runs off those surfaces.

HEALTH EFFECTS OF ACID RAIN INCLUDE:

Acid rain resembles clean rain in terms of taste, texture, and appearance. Acid rain has a ripple effect on people. The risk of swimming or strolling in clean water is the same as the risk of doing so in acid rain. Sulphur dioxide (SO_2) and nitrogen oxides (NO_x), the chemicals that generate acid rain, are dangerous to human health. By combining these gases, fine sulphate and nitrate particles are created in the atmosphere, which is easily carried by winds across great distances and absorbed by people. Also possible is the entry of tiny particles. Numerous studies in the scientific community have found a link between high levels of tiny particles and an increase in heart and lung diseases, including bronchitis and asthma, along with earlier death.

ACID RAIN HARMS OTHER PLANTS:

Along with trees, other plants can also be harmed by acid rain. Acidic rainwater can dissolve important soil nutrients like calcium and magnesium that plants require to flourish. This can lead to nutrient deficiency in plants, reducing their growth and making them more vulnerable to diseases and pests. Moreover, acid rain can directly damage the leaves of plants by burning them, and this can reduce the plant's ability to carry out photosynthesis, which is crucial for its survival.

While other air pollutants like ground-level ozone can also harm plants, food crops are usually not significantly affected by them. This is because farmers constantly amend the soil with fertilisers, which can help replenish nutrients lost due to pollution. Additionally, food crops are typically grown for short periods, which minimizes their exposure to pollutants. However, prolonged exposure to high levels of air pollution can still have negative impacts on food crop production, including reduced yield, poor quality, and contamination with toxic substances. Therefore, it's important to reduce air pollution to ensure healthy crop growth and food security.

EFFECTS ON THE FOREST:

Over time, certain woods' development has slowed, according to scientists, foresters, and others. When they ought to appear green and healthy, leaves and needles start to brown and fall off. In extreme circumstances, specific trees or entire tracts of forest may abruptly disappear.

Acid precipitation has a negative impact on vegetation, which causes a reduction in photosynthesis and growth as well as an increase in vulnerability to disease and drought. 'Dieback' is the term for this process, which is characterised by leaf browning and dropping (as seen in Figure 4). Additionally, it has consequences including a loss in biomass (due to delayed growth) and a reduction in the thickness of yearly growth rings. A decrease in soil fertility is finally brought on by acid precipitation, which also harms the fine root system, interferes with root mycorrhiza (owing to elevated levels of aluminum and acidity), and lowers lichen populations. Additionally, the soil loses potassium and has lower phosphorus levels, which reduces the amount of fruit that may be produced. The buildup of harmful elements like zinc and aluminum inhibits root growth and lowers chlorophyll levels, which leads to aluminum poisoning (Sharma and Kaur, 1994). Compared to adult plants, young seedlings are more susceptible (Sthana and Asthana, 2001; modified from Verma et al., 2010). Lime can be used to reduce soil acidity because it is alkaline, which balances out the acid's negative ions.

EFFECTS OF ACID RAIN ON STONE STRUCTURES AND MONUMENTS:

Long-lasting structures and monuments have traditionally been made of marble and limestone. Calcium carbonate ($CaCO_3$) is the main component of both limestone and marble; they only differ in terms of their crystalline structure. Compared to marble, limestone is more permeable and has smaller crystals, hence it is utilised more frequently in construction. Marble can achieve a high polish and is therefore favoured for statues and monuments due to its bigger crystals and smaller holes.

Although it is well known that limestone and marble are exceptionally durable materials, acid rain is already steadily eating away structures and external monuments composed of these materials. Sulfuric acid, the primary acid in acid rain, breaks down $CaCO_3$ into aqueous ions, which are subsequently rinsed away by the water flow.

$$CaCO_3 + H_2SO_4 \longrightarrow Ca^{2+}(aq) + SO_4^{2-} + H_2O + CO_2$$

While the fine details of relief work, such as the faces on sculptures, may be harmed by acid rain due to this process taking place on the outside of the structures or monuments, the structural stability of the building is often unaffected.

PREVENTING ACID RAIN:

These methods can be used to do this:

Liming:- Lime can be added to water bodies to prevent harm to lakes as well as other aquatic environments. The most widely used compounds for boosting the pH of acidified water include compounds caustic soda, carbonate of sodium, slacked lime, and limestone (Khemani et al., 1985).

Liming costs money and only temporarily relieves some acidity issues.

POLICY ADJUSTMENT:

Northeastern America and northwest Europe both saw a sharp rise in public concern about the consequences of acid rain on habitats and natural resources during the 1970s and 1980s. In order to force the US Environmental Protection Agency to take action to reduce acid precursor emissions coming from states in the federal government, a number of Northeastern States and the Province of Ontario, Canada, filed a lawsuit against the agency in 1980. The National Acid Precipitation Assessment Programme (NAPAP) was established by the US Congress, and the Acid Precipitation Act of 1980 gave it the authority to carry out a ten-year scientific, technological, and economic examination of the acid rain problem. The study's objective was to gather knowledge about:

1. Particular geographic areas and resource areas impacted by acidic deposition.
2. How are precursor emissions to acids dispersed and altered?
3. Do the impacts require mitigation because they are severe?
4. What methods and strategies are available for reducing emissions

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