Factors Responsible for the Consequences of Acid Rain

Dilip Kumar Singh
SOMC, Sanskriti University, Mathura, Uttar Pradesh, India
Email Id- dilip.me@sanskriti.edu.in

ABSTRACT: ***Acid rain, often referred to as acid drainage or acid precipitation, has a pH of about 5.2 or below. The acid rain source is Sulphur dioxide (SO_2) and nitrogen oxides (NO_X: NO and NO_2 combination) emitted from human activities, such as fossil-fuel combustion. The presence of these acids and other environmental components emits protons which raises acidity of the soil and not only mobilizes but also leaches positive nutrient ions and increases radioactive metals. This improvement in the chemical characteristics of soil reduces fertility and has an adverse impact on agricultural and forest trees production and development. Acid buildup reduces the pH of sea water and causes an acidification of water sources which causes damage to marine organisms. In certain ways, acid rain affects every aspect of the ecosystem and also has a harmful effect on human health. Acid rain also deteriorates air-contaminated soils, deteriorating things built up by man, such as homes and temples of calcareous and marble. Acid rain has drawn broad attention of scientists and the public because of its devastating impact on ecosystems. This review provides an overview of factors responsible for the consequences of acid rain. This review gives the direction to the new research possibilities that needs to be explored in order to mitigate the effect of acid rain.***

KEYWORDS: ***Acid Rain, Acidity, Oxidants, pH, Ecosystem.***

1. INTRODUCTION

While researching rainfall near industrial regions in England and Scotland in 1852, Scottish scientist Robert Angus Smith coined the phrase "acid rain." He was the first to use the word. The subject of the investigation became a prominent topic in his book Air and Rain: The Origins of Chemical Climatology. When acid rain was first identified as a serious environmental problem in the late 1960s and early 1970s, it was considered a breakthrough. Despite the fact that it is a worldwide environmental issue, it is often overshadowed by climate change. Acid rain is a significant environmental problem that the globe is grappling with, and it is produced by both natural and human-made sources of growth. Natural causes include volcanic eruptions, which are caused by humans. Industrial emissions are examples of human-generated sources. Acid rain has the greatest impact on aquatic ecosystems because of its acidity. The acidity of rainfall is raised as a result of the actions of various gases that dissolve in rainwater and react with it to produce different acids[1].

Carbon dioxide, Sulphur dioxide, and nitrogen oxides, as well as any other greenhouse gases that come into contact with water in the atmosphere and are transformed into acidic liquids, are responsible for the formation of acid rain. Acid rain is caused by a combination of factors. Oxidants play a critical role in the formation of acid in a number of these systems. Carbon dioxide dissolves and is transformed into a weak acid, carbonic acid, when it comes into contact with rainwater. Some gases, such as Sulphur and nitrogen oxides, are transformed into heavy acids, i.e. sulphuric and nitric acids, depending on their composition. Rainfall is inherently acidic owing to the presence of carbon dioxide; however, natural emissions of nitrogen and Sulphur oxides, as well as certain organic acids, as a result of human activity, cause rainwater to become more acidic in the natural environment. pH values below 2.4 have been reported in certain instances, particularly in regions near industrial sites[2].

Acid-producing gases in the atmosphere are produced mostly by biological activity and volcanic eruptions that occur on the globe. These are the main natural occurrences that cause acid-producing gases to be released into the atmosphere. It is possible for gases in the atmosphere to travel hundreds of kilometers before being transformed into acids and then stored. Fossil fuels, such as coal, are used by power generating sources, resulting in increased emissions of Sulphur dioxide and nitrogen oxides into the atmosphere as a consequence of this. These factors, together with the transportation sector, are the most significant contributors to increased nitrogen oxide levels in the environment. The problem of acid rain has increased quickly in recent years, becoming a more common source of worry as a result of economic development and population expansion. In order to minimize local emissions, the brick processing sector builds towering smokestacks, which release toxic chemicals into the surrounding environment and contribute to the spread of acid rainfall. Acid rain is caused by a variety of factors, as shown in Figure 1.

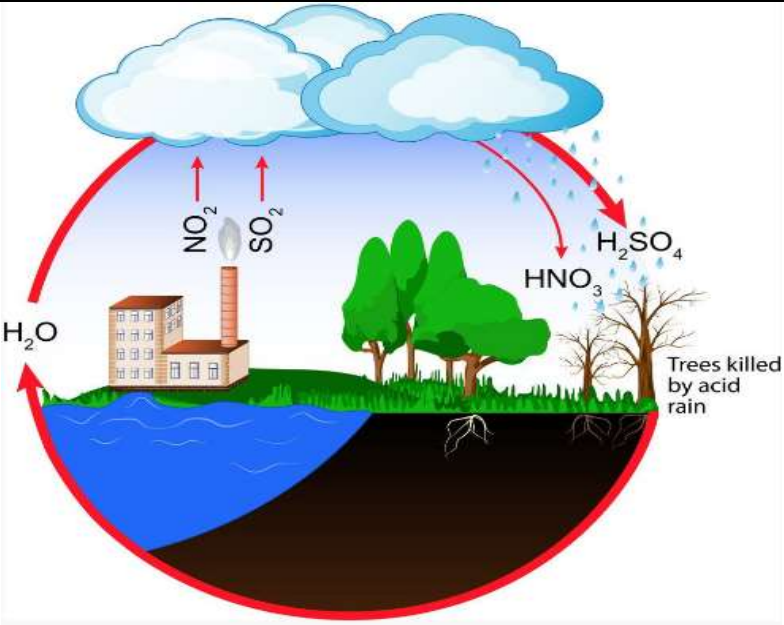

Figure 1: Illustrates the Different Causes of Acid Rain [INTERNETGEOGRAPHY].

1.1 Acid Rain Is Caused by A Variety of Factors:

In the atmosphere, acid rain occurs when Sulphur dioxide (SO_2) and nitrogen oxides (NO_X) are produced and carried about by wind and air currents. Sulfuric and nitric acids are formed when SO_2 and NO_X combine with water, oxygen, and other molecules, respectively. These are then mixed with water and other elements before being released to the atmosphere[3].

Even though some of the SO_2 and NO_X that contribute to acid rain originate from natural sources such as volcanoes, the vast majority of the pollution is caused by the combustion of fossil fuels. The following are the primary sources of SO_2 and NO_X in the atmosphere:

1) The combustion of fossil fuels in order to produce electricity. Electric power generators are responsible for two-thirds of the SO_2 and one-fourth of the NO_X in the environment.
2) The use of automobiles and heavy equipment
3) Manufacturing, oil refineries, and other sectors are examples of this.
4) As a result of wind-borne SO_2 and NO_X, acid rain may affect people all over the world, not only those who live in close proximity to the sources of the pollution.

1.2 Forms of Acid Deposition:

1.2.1 Wet Deposition:

Wet deposition is the kind of acid rain that most people are familiar with. In the form of rain, snow, fog, or hail, sulfuric and nitric acids that have generated in the atmosphere descend to the earth's surface.

1.2.2 Dry Deposition:

Dry deposition is a term used to describe the deposit of acidic particles and gases from the environment in the absence of moisture. Acidic particles and gases may deposit rapidly on surfaces (such as water bodies, plants, and structures), or they may react with one another during air transit to create bigger particles that are potentially detrimental to human health and welfare. When the collected acids on a surface are washed away by the next rain, the acidic water that results run over and through the ground, causing damage to plants and animals such as insects and fish in the process.

According to the quantity of rainfall received by a region, the amount of acidity in the atmosphere that deposits to the ground via dry deposition is determined. For example, the ratio of dry to wet deposition is greater in arid regions than it is in an area that gets several inches of rain each year, as seen in the chart below[4].

1.3 Acid Rain Measuring Techniques:

The acidity and alkalinity of water are measured on a pH scale, with 7.0 representing neutrality. In general, the lower the pH of a material (less than 7), the more acidic it is; the higher the pH of a substance (greater than 7), the more alkaline it is. Normal rain has a pH of about 5.6; it is somewhat acidic due to the dissolution

of carbon dioxide (CO_2) into water, which results in the formation of weak carbonic acid. Acid rain has a pH that ranges between 4.2 and 4.4 on average. Figure 2 shows the pH scale to measure acid rain.

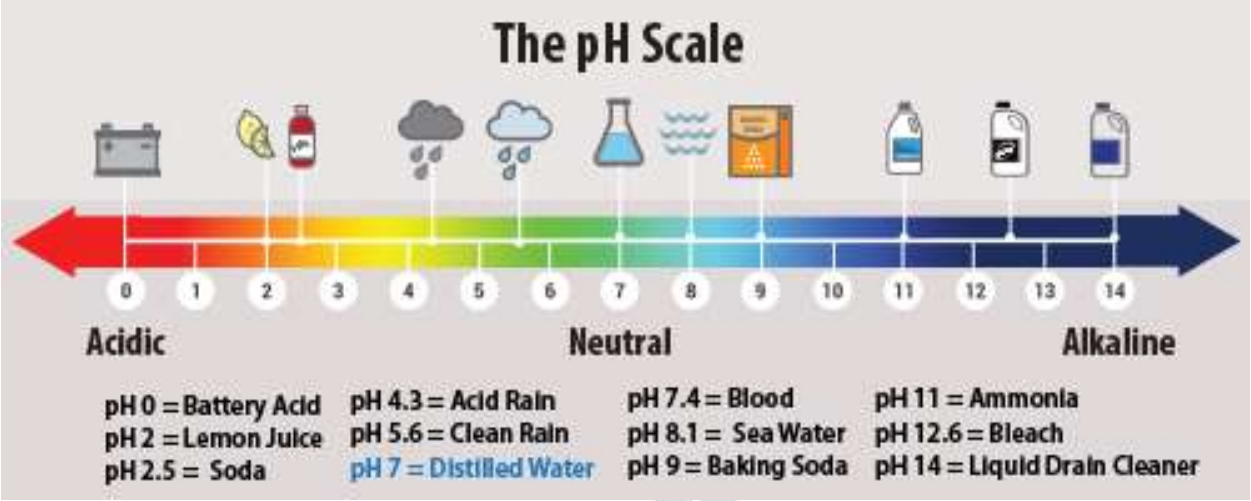

Figure 2: Illustrates the pH Scale to Measure Acid Rain [EPA].

National Trends Network (NTN) observations of wet deposition are relied upon by policymakers, research scientists, ecologists, and modelers as part of the National Atmospheric Deposition Program's (NADP) National Atmospheric Deposition Program. A total of more than 250 monitoring stations in the United States, Canada, Alaska, Hawaii, and the United States Virgin Islands are used by the NADP/NTN to gather acid rain. Dry deposition, in contrast to wet deposition, is more difficult and costly to quantify. The Clean Air Status and Trends Network provides estimates of nitrogen and Sulphur pollution in dry deposition, as well as other contaminants (CASTNET). CASTNET measures the amounts of pollutants in the air at more than 90 sites[5].

When acid deposition is washed into lakes and streams, it has the potential to cause some of them to become alkaline. Using over 280 sites, the Long-Term Monitoring (LTM) Network measures and monitors surface water chemistry to provide valuable information on aquatic ecosystem health and how water bodies respond to changes in acid-causing emissions and acid deposition. The LTM Network is a collaborative effort between the Environmental Protection Agency and the National Institute of Environmental Health Sciences.

1.4 Acid Rain's Consequences:

Acid rain has a negative impact on almost everything. Precipitation has the ability to alter plants, soil, trees, structures, and even sculptures along its path. Acid rain has been shown to be very detrimental to trees. It weakens them by washing away the protective layer that protects the leaves, and it also slows their development. In 2005, a study published in the online edition of the journal of Environmental Science and Technology revealed evidence that acid rain is limiting tree development in the United States.

"By providing the only preserved soil in the world that was collected before the era of acid rain, the Russians assisted our international team in tracking tree growth for the first time in conjunction with changes in soil caused by acid rain," said Greg Lawrence, a scientist with the United States Geological Survey who led the project. In the past, we've seen how acid precipitation affects surface waterways, but this is the first time we've been able to compare and monitor tree development in forests that have experienced soil erosion as a result of the acid rain."

Acid rain may also alter the chemical makeup of soil and bodies of water, making them unsuitable for native animals and plants to survive. Healthy lakes, for example, have a pH of 6.5 or above. As the amount of acidity in the environment increases as a result of acid rain, fish populations decline. The majority of fish species cannot live in water with a pH below 5. According to the National Atmospheric Deposition Program, when the pH of a lake reaches 4, the lake is deemed dead. Additionally, it has the potential to degrade limestone and marble structures and monuments, such as gravestones[6].

1.5 Acid Rain Remediation Alternatives:

Stopping acid rain caused by humans may be accomplished via a variety of means. According to the Environmental Protection Agency, regulating emissions from cars and buildings is an essential first step.

This may be accomplished by limiting the usage of fossil fuels and concentrating on more environmentally friendly energy sources such as solar and wind power instead.

Additionally, each individual may contribute by decreasing their usage of motor vehicles. According to the Environmental Protection Agency, using public transit, walking, riding a bike, or carpooling are all excellent ways to start. People may also decrease their use of electricity, which is mostly produced by burning fossil fuels, or convert to a solar-powered energy system. There are several energy providers that offer solar packages to their clients that do not need installation and are very inexpensive[7].

1.6 What Causes Acid Rain and How It Works:

When hiking in the Appalachian Mountains, you'll come across stands of dead and weaker trees that need to be removed. A city dweller may observe weathered stone structures, streaks on the top of his or her vehicle, and rusted or corroded metal railings and sculptures. Acid rain's impacts can be seen almost wherever you walk, but with media and public attention now focused on the more frightening possibility of global warming, acid rain has been pushed to the back of the agenda. The scourge from the sky nearly seems to be a problem of the twentieth century — a problem that was addressed by laws in the 1980s and 1990s[8].

Acid rain is mostly found in the Northern Hemisphere, which is the more industrialized and polluted part of the world. Winds have the ability to sweep up emissions from tall smokestacks and transport pollutants long distances away from their original sources, traversing state boundaries and national borders in the course of their journey. Although acid rain does not include the whole spectrum of greenhouse gases found in the atmosphere, it is a transboundary, and thus worldwide, problem[9].

Chemical pollutants such as Sulphur dioxide (SO_2) and nitrogen oxides (NO_x) emitted by power plants, automobiles, and industries contribute to acid rain, also known as acid deposition. Volcanoes, forest fires, and lightning strikes are all examples of natural sources of pollution that contribute to man-made pollution. When SO_2 and NOx are released into the environment and combine with water vapor, they form acids. The sulfuric and nitric acids formed as a consequence of this reaction may fall as wet or dry depositions. Wet deposition is precipitation, such as acid rain, snow, sleet, fog, or hail. Acidic particles or gases are deposited as a result of dry deposition[10].

2. DISCUSSION

Acid rain poses a danger to all of the components of ecosystems as well as to human beings. Acid rain pollution, which includes nitrogen oxide and Sulphur dioxide, causes irritation of the skin, nose, and throat. Not only that, but it may also lead to respiratory issues such as asthma, dry cough, headaches, and bronchitis. The excessive application of urea and animal waste in agricultural regions leads to a buildup of acid in the environment, which is harmful to the ecosystem. Acid rain has a significant impact on fiscal, social, and medical concerns, and it is now regarded to be one of the most severe problems in the world because to the exponential growth of industry as well as automobiles.

The soil system is very complicated, and it is often regarded as one of the most important ecological elements in the world, since it provides every plant and tree with the nutrients and water necessary for development. Acid rain causes soil acidification, which enhances the interaction of ions in the soil between hydrogen and nutritional cations such as calcium, magnesium, and potassium. Acid rain is a major contributor to soil acidification. As a result of the release of such cations into the soil, the soil solution and sulphate from the acid input are quickly leached away. Due to acid-induced leaching, nutrient shortage develops in soils that have been impacted by acid rain. This results in a decrease in soil fertility, which further limits the development of plants and trees. A negative impact on nitrogen cycling and decomposition has been seen as a result of increased soil acidity. The presence of significant acidification has also been found to reduce the nutritional content of the soil to a larger extent.

The optimal pH range for plant growth is between 5 and 8, and plants grown in soil with a pH value outside of this range have difficulty germinating, and no plants can thrive if the pH is less than 3.7. Plants grown in soil with a pH value other than this range have difficulty germinating, and no plants can thrive if the pH is less than 3.7. Acid rain reduces the amount of essential soil nutrients supplied by calcium, magnesium, nitrogen, and potassium, among other elements, and therefore reduces the amount of growth and yield produced by plants. Aluminum, mercury, cadmium, manganese, and lead are naturally occurring non-toxic metals that occur in high quantities in the soil. However, when acid rain is introduced, these elements are transformed into toxic forms that not only kill but also cause the death of plants and trees. Because of the calcium shortage in the wood, trees become less cold resistant and are more susceptible to winter damage,

which may result in death. Acid rain has an effect on the chemical composition of leaf surfaces, which results in a reduction in fertilization, pollen germination, fruit development, and seed growth. In the soil, it contributes to the formation of positive hydrogen ions, which react with the calcium, magnesium, and potassium compounds found in soil particles to form acidic compounds. It is believed that acidification is responsible for the destruction of helpful microorganisms that aid in the release of essential nutrients from decaying organic matter into the soil. This, in turn, contributes to the depletion of nutrients from plants and trees. Acid rain causes harm to, and ultimately the extinction of, plant and tree seeds. Despite their survival, acid rain plants have very little effect on the environment and are unable to withstand natural disasters such as strong winds, heavy rainfall, and drought. Compared to trees, it has been discovered experimentally that plants with fragile stems are more vulnerable to acid rain-related harm. Acid rain depletes the availability of cell components such as chlorophyll. Both living creatures are reliant on one another, but if a species at the bottom of the food chain is harmed, it has a knock-on effect on the other dependent species.

It becomes acidic as a result of the addition of acid rain to the water supply sources. Because these water sources have a limited capacity to handle acid inputs in comparison to soils and plants, the obvious signs of acidification may be seen in streams and lakes. By affecting all elements of the maritime ecosystem, acid rain has an impact on the marine ecology. During the 1970s, fish populations in more than 20 percent of the water bodies in southern Norway were decimated. Canada's acidified water sources are seeing a decrease in the sport fish population, which is a troubling development. Animals responded to acidic precipitation by increasing their death rate, heavy metal intake, and reduction in the incidence of skeletal abnormalities and the frequency of reproductive failure. The acidity of frogs' excrement has a negative impact on lakes and rivers as well. Several amphibian species, including toads, frogs, and salamanders, are very sensitive to low pH conditions. The quantity of snails and phytoplankton decreased when the pH fell below 5.5 and decreased even more when the pH fell below 5.2. Zooplankton disappeared when the pH fell below 5.0 because the acidity level made it difficult for the embryos to develop. After falling below pH 4.0, the fish species suffered a rapid depletion of its nutrients. Any species, on the other hand, may adapt to and thrive in the arid environment created by acid rain.

Although acid rain has very minor indirect impacts on human health, it is a significant source of pollution that is undetectable to the naked eye. When people come into contact with acidification-affected items, such as food and water supplies, the indirect impacts of acid rain may cause significant disturbance. SO2 is very toxic in both gaseous and aerosol form, and it has more severe consequences for human health. Breathing becomes very difficult, while ocular irritation becomes less severe at concentrations higher than 1.6 parts per million (ppm). So2, when combined with aerosols, mist, and suspended smoke, which results in the formation of finer suspensions from these chemical combinations, becomes much more volatile and hazardous, allowing it to penetrate the lungs more deeply than if it were only gas. It was discovered in Tokyo that polluted raindrops caused irritation of the skin and eyes to develop. Acidification of the soil results in the release of toxic heavy metals, which have an adverse effect on human health when they enter the environment. Metals such as aluminum (Al), cadmium (Cd), zinc (Zn), lead (Pb), mercury (Hg), magnesium (Mn), and iron are the most often encountered heavy metals (Fe).

3. CONCLUSION

Technological advancements, industry, government policy, and public works all work together to lay the groundwork for effective acid rain management. Acid rain has been identified as one of the most serious and destructive environmental issues of the twenty-first century, and its management must be effective. Past experience has shown us that science-based policy advice is most effective when the knowledge provided is used to the greatest extent possible, and when the actual problems are examined and the most appropriate solution is found. It is critical to develop and evaluate the policy options that are accessible, as well as to monitor the impacts of policy enforcement and make any necessary changes to them. Science advisers and politicians must have mutual respect for one another's views and objectives, and both groups must be honest with one another about their respective positions and priorities as a result, a positive discussion about critical problems will be fostered throughout society, and a variety of mitigating measures may be used to combat the problem of acid rain pollution.

Despite the fact that acid rain has a plethora of negative consequences, there are certain benefits to be gained from it, which have been discussed in this article. Acid rain is no exception; it comes with its own set of advantages and disadvantages. The numerous methods were discussed in order to monitor the effects of acid rain, such as liming, pollution control, and policy intervention, on various aspects of society. The potential

issues associated with acid rain on the environment are explored, as well as the requirements for innovative ways of reducing acid rain. At the conclusion, several suggestions are made in order to deal with acid rain.

REFERENCES

[1] A. Singh and M. Agrawal, "Acid rain and its ecological consequences," *Journal of Environmental Biology*. 2008.

[2] E. Du, D. Dong, X. Zeng, Z. Sun, X. Jiang, and W. de Vries, "Direct effect of acid rain on leaf chlorophyll content of terrestrial plants in China," *Sci. Total Environ.*, 2017, doi: 10.1016/j.scitotenv.2017.06.044.

[3] R. A. Livingston, "Acid rain attack on outdoor sculpture in perspective," *Atmos. Environ.*, 2016, doi: 10.1016/j.atmosenv.2016.08.029.

[4] Z. Bakhshipour, A. Asadi, B. B. K. Huat, A. Sridharan, and S. Kawasaki, "Effect of acid rain on geotechnical properties of residual soils," *Soils Found.*, 2016, doi: 10.1016/j.sandf.2016.11.006.

[5] F. C. Menz and H. M. Seip, "Acid rain in Europe and the United States: An update," *Environ. Sci. Policy*, 2004, doi: 10.1016/j.envsci.2004.05.005.

[6] T. Li *et al.*, "Swift Acid Rain Sensing by Synergistic Rhizospheric Bioelectrochemical Responses," *ACS Sensors*, 2018, doi: 10.1021/acssensors.8b00401.

[7] M. Mahdikhani, O. Bamshad, and M. Fallah Shirvani, "Mechanical properties and durability of concrete specimens containing nano silica in sulfuric acid rain condition," *Constr. Build. Mater.*, 2018, doi: 10.1016/j.conbuildmat.2018.01.137.

[8] US EPA, "Acid Rain Program," *US EPA*. 2017.

[9] Y. Wang *et al.*, "Vermicompost and biochar as bio-conditioners to immobilize heavy metal and improve soil fertility on cadmium contaminated soil under acid rain stress," *Sci. Total Environ.*, 2018, doi: 10.1016/j.scitotenv.2017.10.121.

[10] B. Debnath *et al.*, "Exogenous melatonin mitigates acid rain stress to tomato plants through modulation of leaf ultrastructure, photosynthesis and antioxidant potential," *Molecules*, 2018, doi: 10.3390/molecules23020388.