

A Study on Acid Rain: Effects and Control Measures

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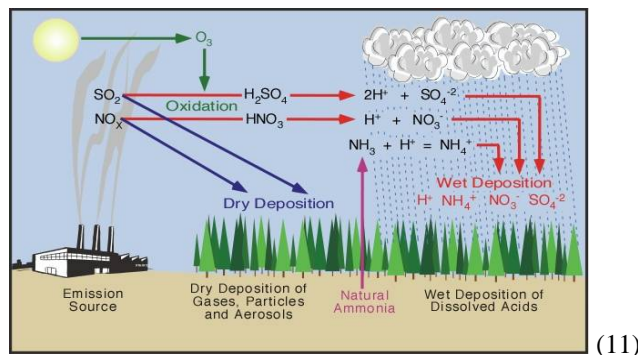
ABSTRACT: Acid rain affects each and every components of ecosystem. Acid rain also damages man-made materials and structures. Acid rain is one of the most serious environmental problems emerged due to air pollution. Sulphur dioxide (SO₂) and oxides of nitrogen and ozone to some extent are the primary causes of acid rain. These pollutants originate from human activities such as combustion of burnable waste, fossil fuels in thermal power plants and automobiles. These constituents interact with reactants present in the atmosphere and result into acid deposition. Due to the interaction of these acids with other constituents of the atmosphere, protons are released causing increase in the soil acidity, lowering of soil pH mobilizes and leaches away nutrient-cations and increases availability of toxic heavy metals. Such changes in the soil chemical characteristics reduce the soil fertility, which ultimately causes the negative impact on growth and productivity of forest trees and crop plants. Acid rain has also been reported in India. A rainfall of pH 3.5 was reported in Mumbai. The air pollution levels are steadily rising in the metropolitan cities like Kolkata, Delhi, and Mumbai. Acid rain problem in Bihar, West Bengal, Orissa and southern coastal India has been predicted to lead to infertile soil. Acid rain makes the water bodies acidic. The amphibians are also affected by acidification of water bodies'. At low pH; many species of amphibians including frogs, toads and salamander are particularly sensitive. Indirect effect of acid rain on human health involves toxic heavy metals because these are liberated from soil when soil gets acidified. The most common heavy metals are Al, Cd, Zn, Pb, Hg, Mn and Fe. These mobilized contaminants are dissolved in soil and water make their way to groundwater that is drunk by humans and contaminate the food (Fish, meat, and vegetables) eaten by humans. These heavy metals get accumulated in the body and resulted into various health problems like dry coughs, asthma, headache, eye, nose and throat irritations. Acid rain problem has been tackled to some extent in the developed world by reducing the emission of the gases causing acid rain.

I.INTRODUCTION

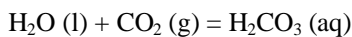
Dictionary definition - Most rainfall is generally slightly acidic due to the carbonic acid from carbon dioxide in atmosphere. But 'acid rain' is caused when sulfur (Sulphur) dioxide and nitrogen oxides (from automobile exhausts and industrial emissions) are washed out from the atmosphere by rain as weak sulfuric (sulphuric) and nitric acid. Acid rain can cause serious damage to crops, and leaches calcium ions from soil and plant leaves causing an ionic imbalance. (1) Since the beginning of civilization, human beings have used various natural resources for their benefit. To make their life easier, they have produced facilities that use many of the Earth's energy resources. Energy is mainly produced by burning fuels such as coal, oil and natural gases. On one side this kind of development makes our lives easier, but on the other hand it results into pollution by release of harmful substances into the environment. Burning of fossil fuels in industries and transport sector, industrialization and urbanization have led to increase in concentrations of gaseous and particulate pollutants in the atmosphere leading to air pollution. Acid rain is one of the most serious environmental problems emerged due to air pollution. Acid rain is a broad term that describes several ways through which acid falls out from the atmosphere. Acid rain includes acidic rain, fog, hail and snow. Robert Angus Smith first used this term in 1872 to describe the acidic nature of rain around industrial town of Manchester; U.K. in a paper entitled "The air and rain beginning of chemical climatology". Scientists often refer to "acid deposition" as a more accurate term for acid rain. Along with the wet deposition there are also dry depositions of acids, which can be transformed into salts in the soil and cause the same environmental damage, as do the wet deposits. Dry deposition generally occurs close to the point of emission. Wet deposition, however, may occur thousands of kilometers away from the original source of emission. The problem of acid rain is widely believed to result from the washout of oxides of Sulphur, nitrogen and other constituents present in the atmosphere. Main sources of these oxides are coal fired power stations, smelters

(producing SO₂) and motor vehicle exhausts (producing NO_x). These oxides may react with other chemicals and produce corrosive substances that are washed out either in wet or dry form by rain as acid deposition. Initially events of acidic rainfall were frequent only around industrial areas. But with the increased use of tall stacks for power plants and industries, atmospheric emissions are being transported regionally and even globally. Acid rain affects the quality of human life, threatens the environmental stability and the sustainability of food and timber reserves, thus posing an economic crisis. Acid rain has broad economic, social and medical implications and has been called an unseen plague of the industrial age.

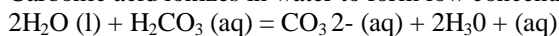
II. STRUCTURE



(CHEMISTRY)



Carbonic acid ionizes in water to form low concentrations of carbonate and hydronium ions.



Carbonic acid is a weak acid. It brings down the pH of the rainwater to 6.0-5.2. With pH levels ranging between 6.0-5.2, rainwater is acidic, but still not dangerous. This is a reversible reaction. Sometimes, the pH level can even become as low as 2. This phenomenon of acidic rainwater precipitation is called acid rain. Rain, snow, sleet, freezing rain, hail, fog and dew are other forms of precipitation. Acid rain is a mild combination of mainly sulfuric and nitric acid. Sulfurous acid and nitrous acid are less stable and are present only in very low amounts. Sulfuric acid and nitric acid are the main acids present in acid rain. The problem occurs when rainwater combines with gaseous oxides of sulfur, nitrogen, and phosphoric and hydrochloric acid mists. The latter two and sulfur are released into the atmosphere from automobile exhausts, industries and electric power plants Sulfuric acid is formed as follows:

1. Sulfur released into the atmosphere combines with atmospheric oxygen to form sulfur dioxide (SO₂)
 2. Sulfur dioxide reacts with atmospheric water to form sulfurous acid - SO₂ (g) + H₂O (l) = H₂SO₃ (aq)
 3. Sulfurous acid is also present in acid rain.
 4. Sulfur dioxide gradually oxidizes to form sulfur trioxide (SO₃) - 2SO₂ (g) + O₂ (g) = 2SO₃ (g)
 5. Sulfur trioxide reacts with water to form Sulfuric acid (H₂SO₄) - SO₃ (g) + H₂O (l) = H₂SO₄ (aq)
- Nitrogen forms a major part of atmospheric composition. These chemicals bring down the acid rain pH level to 5.6-3.5.

Nitrogen dioxide (NO₂) is formed as follows:

1. Nitrogen combines with atmospheric oxygen to form nitrogen dioxide (NO₂).
2. Nitrogen dioxide reacts with water to form nitrous acid (HNO₂) and nitric acid (HNO₃) - 2NO₂ (l) + H₂O (l) = HNO₂ (aq) + HNO₃ (aq)

III. CLASSIFICATIONS

- (Types of decomposition):

1. WET DEPOSITION

Wet deposition refers to acidic rain, fog, and snow. If the acid chemicals in the air are blown into areas where the weather is wet, the acids can fall to the ground in the form of rain, snow, fog, or mist. As this acidic water flows over

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and through the ground, it affects a variety of plants and animals. The strength of the effects depends on several factors, including how acidic the water is; the chemistry and buffering capacity of the soils involved; and the types of fish, trees, and other living things that rely on the water. The process of wet deposition of acidic compounds in particular, acidic deposition has adverse effects on vegetation. This is mainly due to soil acidification and the uptake of substances, which disturb the pH levels within plant cells that may lead to the evolution of reactive radicals

2. DRY DEPOSITION

In areas where the weather is dry, the acid chemicals may become incorporated into dust or smoke and fall to the ground through dry deposition, sticking to the ground, buildings, homes, cars, and trees. Dry deposited gases and particles can be washed from these surfaces by rainstorms, leading to increased runoff. This runoff water makes the resulting mixture more acidic. About half of the acidity in the atmosphere falls back to earth through dry deposition. Acid deposition also occurs via dry deposition in the absence of precipitation. This can be responsible for as much as 20 to 60% of total acid deposition. This occurs when particles and gases stick to the ground, plants or other surfaces. The results suggested that approximately 30% of erosion by dissolution could be attributed to the wet deposition of hydrogen ion and the dry deposition of SO₂ and HNO₃.

IV. CONCERNS/PROBLEM/ISSUES/ CHALLENGES

Acid rain has many ecological effects, but none is greater than its impact on lakes, streams, wetlands, and other aquatic environments. Acid rain makes waters acidic, and causes them to absorb the aluminum that makes its way from soil into lakes and streams. This combination makes waters toxic to crayfish, clams, fish, and other aquatic animals. Some species can tolerate acidic waters better than others. However, in an interconnected ecosystem, what impacts some species eventually impacts many more throughout the food chain—including non-aquatic species such as birds. Acid rain also damages forests, especially those at higher elevations. It robs the soil of essential nutrients and releases aluminum in the soil, which makes it hard for trees to take up water. Trees' leaves and needles are also harmed by acids. The effects of acid rain, combined with other environmental stressors, leave trees and plants less able to withstand cold temperatures, insects, and disease. The pollutants may also inhibit trees' ability to reproduce. Some soils are better able to neutralize acids than others. In areas where the soil's "buffering capacity" is low, the harmful effects of acid rain are much greater. [2]

EFFECTS ON ENVIRONMENT AND HUMAN

• BUILDINGS AND MONUMENTS:

Acid rain causes severe damage to buildings and marble statues. Acid rain reacts with the calcium carbonate (CaCO₃) to form soluble calcium hydrogen carbonate or calcium bicarbonate, Calcium bicarbonate is a powdery substance, which is easily washed away with water or more specifically, rainwater. This is the way acid rain has partly eroded many world-famous monuments and buildings like the Taj Mahal in India, St. Paul's Cathedral in London, and the Statue of Liberty in New York. High buildings made of concrete in urban areas have damaged due to exposure to cloud water with high acidity for a long time. Acid precipitations with pH level ranging between 3.0 and 5.0 have affected the cement and concrete. Delhi Red fort and Jama Masjid are also showing signs of damage from sulphur pollution. Acid rain can destroy stained glass windows in churches, bridges made of steel, and railway tracks. It corrodes metal, ruins the paint color, weakens leather and forms a crust on glass surfaces. $Ca(HCO_3)_2 - CaCO_3 + \text{Acid rain} = Ca(HCO_3)_2(aq)$ [3]

V. ACID RAIN EFFECTS ON TAJ MAHAL

The air in that place contains serious levels of sulphur and nitrogen oxides. This is due to the large number of industries set up nearby Taj Mahal and pollution of Yamuna River. As per metrological studies the wind direction is usually move in the direction where Taj is situated. All these led to acid rain. Acid rain reacted with the marble (calcium carbonate) of Taj Mahal and this causing damage to heritage structure. To protect Taj Mahal, a government of India institute called NEERI targets at clearing the air in 'Taj Trapezium'. Taj Trapezium refers to an area that includes towns of Agra,

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Mathura, Bharatpur and Firozabad. As a result of this plan, over 2000 industries situated inside the trapezium had transferred. Still the current situation is critical because of nearby leather industry.[8]

• LAKES AND RIVERS (AQUATIC ECOSYSTEM)

It is in aquatic habitats that the effects of acid rain are most obvious. Acid rain runs off the land and ends up in streams, lakes and marshes - the rain also falls directly on these areas. As the acidity of a lake increases, the water becomes clearer and the numbers of fish and other water animals decline. Some species of plant and animal are better able to survive in acidic water than others. Freshwater shrimps, snails, mussels are the most quickly affected by acidification followed by fish such as minnows, salmon and roach. The roe and fry (eggs and young) of the fish are the worst affected as the acidity of the water can prevent eggs from hatching properly, can cause deformity in young fish which also struggle to take in oxygen. The acidity of the water does not just affect species directly; it also causes toxic substances such as aluminum to be released into the water from the soil, harming fish and other aquatic animals. Lakes, rivers and marshes each have their own fragile ecosystem with many different species of plants and animals all depending on each other to survive. If a species of fish disappears, the animals which feed on it will gradually disappear too. If the extinct fish used to feed on a particular species of large insect, that insect population will start to grow, this in turn will affect the smaller insects or plankton on which the larger insect feeds. [4]

VI.FUTURE CHANGE IN EFFECTS

If acidic deposition were to increase, all effects would, of course, be increased. Experimental data and calibrated models allow us to estimate the degree of enhancement where the effects at ambient levels of acid deposition have been quantified, such as with lakes. Since the public and the political leadership are committed to reducing air pollution, acid rain will not be allowed to increase. In fact, the proposed legislation would require a substantial decrease in SO₂ emissions. The only issues being debated are the rate and extent of the reduction. Therefore, it is not useful to analyze the effects of increased emissions. In the short term over the next several decades a worst-case scenario might assume that present levels of emission and acidic deposition would continue unchanged. If so, the situation described above with regard to human health, the rate of building materials' damage, the decline of high elevation red spruce trees, crops, visibility, and the percent of lake area made inhospitable to fish would not change. In the very long term, sustained acid rain at present levels might cause the leaching of sensitive soils to the extent that tree nutrition could be affected and some additional lakes and streams would become too acid to sustain healthy fish populations. Effects on other receptors would remain unchanged. If the emissions of SO₂ were abruptly cut in half, as proposed by some legislation, acidic deposition would be decreased by only about 30 percent since the relationship is not linear. Such a decrease would presumably be beneficial to all receptors, but in the cases where no significant negative effects have been demonstrated crops, forests, building materials, and human health we cannot quantify any improvement. Visibility would improve over the long term, but since only a fraction of the interference is due to sulfate aerosols, the improvement would be proportionally less than the 30 percent reduction in acid formation. In the glaciated and other areas where the lake and stream chemistry is essentially in equilibrium with the acidity of the rain, a new equilibrium would be reached in less than a decade.

VII.HUMAN HEALTH

Acid rain looks, feels, and tastes just like clean rain. The harm to people from acid rain is not direct. The acid in the rainwater is too dilute to have direct adverse effects. However, the particulates responsible for acid rain (sulfur dioxide and nitrogen oxides) do have an adverse effect. Increased amounts of fine particulate matter in the air do contribute to heart and lung problems including asthma and bronchitis. Walking in acid rain, or even swimming in an acid lake, is no more dangerous than walking or swimming in clean water. However, the pollutants that cause acid rain—sulfur dioxide (SO₂) 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. Fine particles can also penetrate indoors. Acids are very small and fine particles. They are normally in a liquid state. When they are present in the atmosphere, they easily enter the lungs while breathing. Research has proven that these particles can even lead to cancer. SO₂ causes more adverse impact to human health in gas and aerosol forms. Concentrations above 1.6 ppm breathing becomes detectable more difficult and eye irritation increases SO₂ is much more toxic and

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damaging when combined with aerosols, and mists, and suspended smoke, because these mixture of chemicals form finer suspensions that penetrate the lungs further than the gas alone. In Tokyo the polluted drizzle droplets were resulted into eye and skin irritation. 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. Based on health concerns, SO₂ and NO_x have historically been regulated under the Clean Air Act, including the Acid Rain Program. Decreases in NO_x emissions are also expected to have a beneficial impact on human health by reducing the nitrogen oxides available to react with volatile organic compounds and form ozone. Ozone impacts on human health include a number of morbidity and mortality risks associated with lung inflammation, including asthma and emphysema. Acid rain is harmful to human health. [5]

- **SOIL:**

Soil contains many harmful minerals such as mercury and aluminum. These elements can't be absorbed by plants and trees and are thus harmless. Upon contact with acid rain, these chemicals undergo chemical reactions with the acids. Soil chemistry can be dramatically changed when base cations, such as calcium and magnesium, are leached by acid rain thereby affecting sensitive species, such as sugar maple. As a result, compounds of aluminum, lead and mercury are formed. Plants and trees can easily absorb these compounds. Such elements, which are extremely harmful to living forms, ultimately affect the entire food chain. These chemicals not only harm the flora, but also the animals that feed on them. Soil biology and chemistry can be seriously damaged by acid rain. Some microbes are unable to tolerate changes to low pH and are killed. The enzymes of these microbes are denatured (changed in shape so they no longer function) by the acid. The hydronium ions of acid rain also mobilize toxins such as aluminum, and leach away essential nutrients and minerals such as magnesium. [6]

VIII.PREVENTIVES MEASURE

REDUCE EMISSIONS:

- Burning fossil fuels is still one of the cheapest ways to produce electricity so people are now researching new ways to burn fuel which don't produce so much pollution.
- Governments need to spend more money on pollution control even if it does mean an increase in the price of electricity.
- Sulphur can also be 'washed' out of smoke by spraying a mixture of water and powdered limestone into the smokestack.
- Cars are now fitted with catalytic converters which remove three dangerous chemicals from exhaust gases.

FIND ALTERNATIVES SOURCES OF ENERGY:

- Governments need to invest in researching different ways to produce energy.
- Two other sources that are currently used are hydroelectric and nuclear power. These are 'clean' as far as acid rain goes but what other impact do they have on our environment?
- Other sources could be solar energy or windmills but how reliable would these be in places where it is not very windy or sunny?
- All energy sources have different benefits and costs and all these have to be weighed up before any government decides which of them it is going to use.
- Sulfur and nitrogen are mostly released into the atmosphere from the burning of fossil fuels (e.g. Coal). Switching over to alternative forms of energy such as geothermal, water, wind, and solar power would help to a great extent. All the above measures are simple steps that can easily be adopted on an individual level. Acid rain has become an international issue because of its serious and definite danger to life on earth. Many international treaties have been signed i.e. the Sulfur Emissions Reduction Protocol and the Convention on Long-Range Transboundary Air Pollution. Installing Flue Gas Desulfurization e.g. wet scrubber in coal-burning power plants to remove sulfur-containing gases - is one of the steps taken by the USA, and is followed by a number of developed and developing countries.

CONSERVING RESOURCES:

- Greater subsidies of public transport by the government to encourage people to use public transport rather than always travelling by car.

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- Every individual can make an effort to save energy by switching off lights when they are not being used and using energy-saving appliances - when less electricity is being used, pollution from power plants decreases.
- Walking, cycling and sharing cars all reduce the pollution from vehicles.[7]

IX. CONCLUSION

The ecological effects of acid rain are most clearly seen in the aquatic, or water, environments, such as streams, lakes, and marshes. Acid rain flows into streams, lakes, and marshes after falling on forests, fields, buildings, and roads. Acid rain also falls directly on aquatic habitats. Acid rain affects each and every component of ecosystem. Acid rain also damages man-made materials and structures. Acid rain is one of the most serious environmental problems emerged due to air pollution. Sulphur dioxide (SO₂) and oxides of nitrogen and ozone to some extent are the primary causes of acid rain. These pollutants originate from human activities such as combustion of burnable waste, fossil fuels in thermal power plants and automobiles. These constituents interact with reactants present in the atmosphere and result into acid deposition. Due to the interaction of these acids with other constituents of the atmosphere, protons are released causing increase in the soil acidity, lowering of soil pH mobilizes and leaches away nutrient cations and increases availability of toxic heavy metals. As acid rain flows through soils in a watershed, aluminum is released from soils into the lakes and streams located in that watershed. So, as pH in a lake or stream decreases, aluminum levels increase. Both low pH and increased aluminum levels are directly toxic to fish. In addition, low pH and increased aluminum levels cause chronic stress that may not kill individual fish, but leads to lower body weight and smaller size and makes fish less able to compete for food and habitat. Acid rain causes a cascade of effects that harm or kill individual fish, reduce fish population numbers, completely eliminate fish species from a water body, and decrease biodiversity. These mobilized contaminants are dissolved in soil and water make their way to groundwater that is drunk by humans and contaminate the food (Fish, meat, and vegetables) eaten by humans. These heavy metals get accumulated in the body and resulted into various health problems like dry coughs, asthma, headache, eye, nose and throat irritations.

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