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Effects of Acid Rain and its Prevention: A Review

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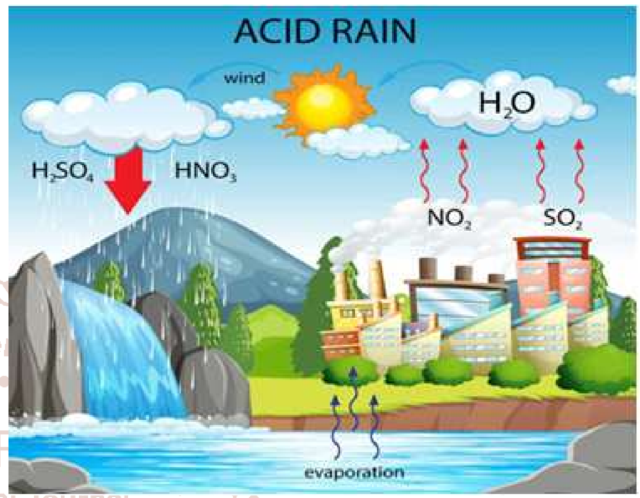
ABSTRACT

Acid rain, a consequence of atmospheric pollutants like sulfur dioxide and nitrogen oxides, poses severe environmental threats. Resulting from industrial emissions and combustion processes, it damages aquatic ecosystems, forests, and infrastructure. To prevent its adverse effects, strict emission controls and sustainable energy practices are imperative. Implementing technologies to reduce sulfur and nitrogen emissions, coupled with international cooperation, can mitigate acid rain's ecological impact. A collective commitment to environmental stewardship is essential for preserving the planet's delicate balance and safeguarding ecosystems from the detrimental consequences of acid rain.

KEYWORDS: *Acid rain, Acidification, pH and Air pollutants*



INTRODUCTION:-

The rapid industrial expansion and advancement of human civilization has led to the problem of atmospheric pollution which now-a-days have become alarming. Acid rain, characterized by heightened hydrogen ion levels and a pH below the normal range of 6.5–8.5, poses significant ecological threats. It is one of the major environmental threats since the 19th century (Sharma and Kumar, 2019). With an average pH of 4–5, more acidic instances exacerbate its detrimental effects. The repercussions extend to plants, aquatic life, and infrastructure. Standard water, including drinking water, typically maintains a neutral pH. The primary culprits behind acid rain are emissions of sulfur dioxide and nitrogen oxide. Apart from Sulphur dioxide (SO_2) and Nitrogen oxides (NO_2), a variety of other emissions also influence acidity, notably Hydrochloric acid (HCl), Ammonia (NH_3), volatile organic compounds and alkaline dust (Lee et.al. 1993). These pollutants undergo atmospheric reactions, forming acidic compounds. The consequences of acid rain unfold as it infiltrates ecosystems, disrupting plant metabolism and imperiling aquatic organisms. Furthermore, it corrodes buildings and infrastructure, exacerbating environmental and economic concerns. Mitigating the sources of sulfur dioxide and nitrogen oxide remains crucial in addressing this environmental challenge.

HISTORY:-

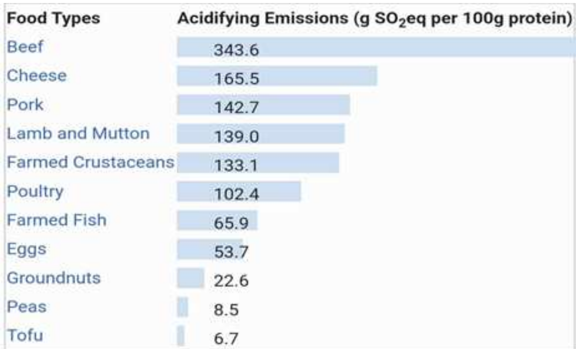
Acid rain, first noticed in the 17th century, became a serious concern during the 1960s and 1970s. Industrial activities released pollutants into the air, causing rain to become acidic. The term "acid rain" was coined in 1872. Scientists, starting with **Robert Angus Smith** in 1852, linked atmospheric pollution to acid rain. Initially, research focused on local effects, but later, the international impact, such as pollutants traveling from the UK to Norway, gained attention. Swedish scientist **Svante Odén** played a crucial role in raising awareness about Europe's acid rain problem.

In the 1970s, scientists first detected acid rain in the US at Hubbard Brook Valley. The New York Times' report increased public awareness. **Gene Likens** and his team found acidic rain in the White Mountains in 1972. The rain had a pH of 4.03 at Hubbard Brook. Studies by the Hubbard Brook Ecosystem followed, revealing environmental impacts. The rain's acidity was neutralized by soil alumina. In 1980, the US Congress passed the Acid Deposition Act, launching a research program led by NAPAP to assess and address acid rain over 18 years. Monitoring sites measured precipitation acidity and established a network for dry deposition.

The very most important gas which leads to acidification is sulfur dioxide. Emissions of nitrogen oxides which are oxidized to form nitric acid are of increasing importance due to stricter controls on emissions of sulfur compounds.70 Tg (S) per year in the form of SO2 comes from fossil fuel combustion and industry, 2.8 Tg(S) from wildfires, and 7–8 Tg (S) per year from volcanoes.

➢ **Natural phenomena**

Mean acidifying emissions (air pollution) of different foods per 100g of protein.



The principal natural phenomena that contribute acid-producing gases to the atmosphere are emissions from volcanoes. Nitric acid in rainwater is an important source of fixed nitrogen for plant life, and is also produced by electrical activity in the atmosphere such as lightning. In the case of SO_2, man-made emissions are primarily the results of fossil fuel combustion while natural emissions arise in approximately equal proportions from terrestrial and marine resources (Moller, 1984).

➢ **Human activity**

The principal cause of acid rain is sulfur and nitrogen compounds from human sources, such as electricity generation, animal agriculture, factories, and motor vehicles. These also include power plants, which use electric power generators that account for a quarter of nitrogen oxides and two-thirds of sulfur dioxide within the atmosphere. Industrial acid rain is a substantial problem in China and Russia and areas downwind from them. These areas all burn Sulfur-containing coal to generate heat and electricity.

FORMATION OF ACID RAIN :-

Naturally occurring substances including oxidized Sulphur and Nitrogen gases can yield more acidic solutions at remote continental and marine sites (Galloway et.al. 1982, Charlson and Rhodesia 1982). Combustion of fuels produces sulfur dioxide (SO_2) and Nitric oxides (NO_2). They are converted into **sulfuric acid** (H_2SO_4) and **Nitric acid** (HNO_3).

➢ **Gas phase chemistry :-**

In the gas phase sulfur dioxide (SO_2) is oxidized by reaction with the hydroxyl radical via an inter-molecular reaction:

$SO_2 + OH \rightarrow HOSO_2$

which is followed by:

$HOSO_2 + O_2 \rightarrow HO_2 + SO_3$

In the presence of water (H_2O), sulfur trioxide (SO_3) is converted rapidly to sulfuric acid:

$SO_3\,(g) + H_2O\,(l) \rightarrow H_2SO_4\,(aq)$

Nitrogen dioxide (NO2) reacts with OH to form nitric acid:

$NO_2 + OH \rightarrow HNO3_3$

➢ **Chemistry in cloud droplets:-**

When clouds are present , the loss rate of SO2 is faster than can be explained by Gas phase chemistry alone. This is due to reactions in the liquid water(H2O) droplets.

$$SO_2\,(g) + H_2O \rightleftharpoons SO_2 \cdot H_2O$$

$$SO_2 \cdot H_2O \rightleftharpoons H^+ + HSO_3^-$$

$$HSO_3^- \rightleftharpoons H^+ + SO_3^{2-}$$

EFFECT OF ACID RAIN :-

Acid rain has been shown to have adverse impacts on forest, freshwater and soil, killing insects and aquatic life forms as well as causing damage to buildings and having impacts on Human health.

➢ **Surface waters and aquatic animals:-**

Acid rain causes acidification of lakes and rivers with resultant damage to fish and other components of aquatic ecosystems. Both the lower pH and higher aluminum concentrations in surface water that occur as a result of acid rain can cause damage to fish and other aquatic animals. At pH lower than 5 most fish eggs will not hatch and lower pH can kill Adult Fish. As lakes and rivers become more acidic, biodiversity is reduced. Acid rain has eliminated insect life and some fish species in some lakes, and streams, in geographically sensitive areas, such as the Adirondack mountains of the United States.

➢ **Soils:-**

Acid rain causes acidification and demineralisation of soil. Soil biology and chemistry can be seriously damaged by Acid Rain. Few microbes are unable to tolerate changes to low pH and are killed. The enzymes of these microbes are denatured by the acid rain. The hydronium ions of acid rain also mobilize toxins, such as Aluminium (Al), and leach away essential Nutrients and Minerals, such as Magnesium (Mg). Soil chemistry can be dramatically changed when base cations, such as calcium (Ca) and magnesium, are leached by acid rain, thereby affecting sensitive species, such as sugar maple (Acer saccharum).

➢ **Soil acidification:-**

Impacts of acidic water and soil acidification on plants could be minor or in most cases major. Most minor cases which do not result in fatality of plant life can be attributed to the plants being less susceptible to acidic conditions and the acid rain being less potent. However, even in minor cases, the plant will eventually die due to the acidic water lowering the plants natural pH.

➢ **Forests and other vegetation:-**

Acidification and demineralisation of soil causes reduction in crop and forest productivity. Adverse Effects may be indirectly related to acid rain. High altitude forests are especially vulnerable as they are often surrounded by clouds and fogs which are more acidic than rain. Acid precipitation on vegetation reduces photosynthesis and growth. It also increases the susceptibility to drought and diseases, process called 'dieback'. Younger seedlings are more susceptible than older plants (Asthana and Asthana, 2001).

➢ **Ocean acidification:--**

Acid rain has a much less harmful effect on oceans on a global scales, but it creates an amplified impact in the shallower waters of coastal areas. Acid rain can cause the ocean's pH to fall, known as ocean acidification, making it more difficult for different coastal species to create their exoskeletons that they need to survive.

➢ **Human health effects:-**

Acid rain, while not directly harmful to human health due to its dilution, poses risks through its components like sulfur dioxide and nitrogen oxides. Over time, exposure to these particles may cause skin and eye irritation, lung issues, and dental damage. Fine particulate matter in the air, a result of acid rain, contributes to heart and lung problems, impacting individuals with conditions like asthma. Particulate deposition of particles can even reach the bloodstream via lungs and can even cause lung cancer.

- **Other adverse effects:-**

Acid rain deteriorates man made materials and harms structures, particularly those composed of calcium carbonate-rich materials like limestone and marble. The acids react with these materials, leading to the formation of gypsum, causing damage to buildings, historic monuments, and statues over time.

PREVENTION :-

Acid rains can be prevented by encouraging the production and use of renewable energy instead of fossil fuels, reducing the energy consumption of factories and companies and by promoting innovation and new technologies aimed at optimising energy consumption and developing renewable energy. Acid rains can further be controlled by planting trees to absorb polluted air. Flue-gas desulfurization (FGD) in coal-fired power stations uses a wet scrubber to remove over 95% of sulfur dioxide (SO2) from stack gases. This involves a tower where lime or limestone reacts with the gases, forming calcium sulfate. This sulfate can be sold as gypsum or placed in landfills. FGD helps curb acid rain effects, preventing long-lasting harm to water sources and aquatic life. Fluidized bed combustion and vehicle emissions control further reduce sulfur and nitrogen oxide emissions from power production and vehicles, respectively.

CONCLUSION:-

Available data indicate that approximately 60-70% of the acidity is ascribed to Sulphuric acid and 30-40% to Nitric acid. The pH of rainfall which strikes the soil can change the rate at which nutrients are recycled, the speed at which litter and other organic materials are broken down through microbial action in the soil and the rate at which both macronutrients and micronutrients are leached from the soil into surface water or into groundwater. Acid fog also reduces visibility by 50-70%. Acid rain remains a significant environmental challenge with far-reaching consequences for ecosystems, aquatic life, and infrastructure. Driving cars and trucks also produces large amounts of nitrogen oxides, which cause acid rain. To help cut down on air pollution from cars, you can carpool or take public transportation, such as buses and trains. Also, ask your parents to walk or bike with you to a nearby store or friend's house instead of driving. The intricate interplay of human activities and atmospheric processes underscores the need for concerted global efforts to curb emissions and protect the delicate balance of the Earth's ecosystems. As we continue to strive for sustainable practices, the mitigation of acid rain stands as a testament to the importance of environmental stewardship in safeguarding our planet for future generations.

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