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IMPACT OF ACID RAIN ON ECOSYSTEMS AND INFRASTRUCTURE: CAUSES, CONSEQUENCES, AND MITIGATION STRATEGIES: A REVIEW

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ABSTRACT

Rainwater turns like vinegar. It happens because when we burn things like coal or gas they release sulphur and nitrogen oxides into the air. When sulphuric acid and nitric acid mix with air, they create acids. The acid rainwater comes down with raindrops becomes slightly acidic like vinegar. More reasons when they come down soil become more acidic. This causes environment problem to many plants and animals that prefer soil, which is not acidic. When the acidic soil wash away important nutrients that plants need to grow.

Acidification of water is bad for fish and other water creatures. It also affects people indirectly. Acid rain harms everything in nature and even damages buildings. Luckily, we have been able to lessen the problem by reducing the stuff that causes acid rain and using lime in some cases over the past 20 years. We wanted to understand how much people are studying acid rain because it is big concern with more factories and cities. I have researched found that more and more people are paying attention to acid rain. People are more and more putting attention to soil and plant are affecting and how land and water change. Acid rain is known for making soil and water more acidic, especially in places like North America and northern Europe. But it is not just the rain causing the acidity. Natural processes and past human activities have already made the soil acidic made the soil acidic in many areas. In some places, like regions affected by careless land use, there been recovery from the damage done, but acid rain adds another layer of acidity on top of what already there. So, when we are trying to figure out how much good it will do to cut down on the pollutants causing acid rain we need to look closely at how these pollutants interact with already acidic soil and the plants growing in that soil especially on a local level like a watershed.

Keyword: Acidification, power plants, fossils fuels, potential hydrogen, aquatic ecosystem, creating toxins, sediments water exchange, biogeochemistry, water pollution.

INTRODUCTION

Since people started living together, they have been using nature's stuff to make life better. They built thing use the Earth's energy mainly by burning things like coal, oil, and gas. This makes life more convenient but it also causes pollution. When factories and vehicles burn these fuels it releases harmful stuff into the air, making it dirty. This pollution comes from industrial growth and cities getting bigger, causing more gases and particles in the air, which we call air pollution [1].

Acid rain is when acid falls from the sky in different from like rain foghail, and snow. The term was first used by a person named Robert Angus Smith in 1872 [2]. He noticed acidic rain around Manchester a city with lot of industries in the UK. Rain, fog, or snow with acidic properties known as acid deposition in Europe, and north America. Countries like Canada, England, Scotland, Sweden, and others are affected. Acid rain harms human health, damages the environment, and threatens food and timber supplies, causing economics problem. It's often

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called a hidden problem of our industrial society" [3]. Acid rain is when acidic substance fall from the sky. This can include acidic rain fog, hail, and snow. The term "acid rain" was first used in 1872 by Robert angus smith to describe the acidic rain in Manchester, U.K. caused by industrial activity [4]. Scientists prefer to use the term "acid deposition" because its more accurate. Acid rain isn't just rain it can be dry particles that settle on the ground. These dry particles can turn into salts in the soil and cause similar environment damage as the wet deposition can travel thousands of kilometres away [5]. The main cause of acid rain is the release of sulphur and nitrogen oxides into the atmosphere. These come from source like coal fired power plants, factories, and vehicle exhaust. When these oxides mix with other chemicals in the air, they create corrosive substance that are carried by rain or other form of precipitation [6]. Initially acid rain was mostly a problem around industrial areas. But as industries started using taller smokestacks and emission travelled further, the effects of acid rain spread regionally and even globally [7].

Literature Review:

Causes of acidification-

"Acid rain happen mainly because of two things: sulphur dioxide and nitrogen oxides which mostly come from burning stuff like fossil fuels in cars and power plants. These pollutants mix with things in the air and create acid rain. Some sulphur pollution also comes from the ocean and occasionally from volcanoes" [8].

"Sulphuric dioxide (SO_2) mostly comes from burning coal and oil, and from some industries like metal smelting and making sulphuric acid. Nitrogen oxides (NOx) also add to acid rain, mostly from cars and factories. We measure how acidic something is using pH, where lower numbers mean more acid. Even regular rain is a bit acidic because it mixes with carbon dioxide in the air" [9].

Other activities like melting iron and other metals, making sulphuric acid, and running machines in the oil industry add to the problem. They do not release as much NOx as they do SO_2, but the amount of NOx they release is growing and adds to acid rain. The acidity level is measured using a scale called Ph. Its short for "potential hydrogen", Normal rainwater is a bit acidic became it mixes with carbon dioxide in the air, making carbonic acid [10]. Ocean acidification is a big problem for coral reefs because it makes it harder for coral to build their skeletons. It also messes with the partnership between corals and tiny plants living inside them, which affect how much food they can make. But we don't know a lot about exactly how acidification affect coral and how it mixes with warmer temperatures, so, we did a study for 8 weeks where we looked at different types of coral and algae. We put them in tanks and changed the levels of CO_2 to mimic what might happen in the future, making it like there's more CO_2 in the air. We also looked at what happens when it is warm and when it is not so warm. We found out that the coral and algae reacted differently to the changes. Some corals got bleached, meaning they lost their colour, while other didn't also their ability to make food and build their skeletons changed depending on the conditions.

Both natural and human activities create acid rain. But burning fossils fuels releases chemicals like sulphur dioxide (SO_2) and nitrogen oxides (NOx), which play a big role in making acid rain [11]. Studying places like Hubbard brook Forest, we've seen how acid rain affect nature and human made things, it really hits aquatic

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places hard because the acidic rain falls straight into them. But even places like forests, fields, and roads get affected because the acid can wash into lakes, rivers, and streams from there [12].

Acids rain isn't just bad for nature it's bad for people too. The chemicals it releases can irritate our eyes, noses, throats, and even cause lung problems like coughs, asthma, and bronchitis. Also stuff like urea and animal poop can add to the problem by releasing ammonia into the air, which can lead to more acid rain over time. Acid rain causes lots of problem for our economy, society and health. It's been called a hidden problem of the modern age. Acid rain usually has a PH between 4.2 and 4.4 [13].

Effect of acid rainon aquatic ecosystem-

Acid rain is like sour rain that falls from the sky because of pollution in the air. When this sour rain gets into lakes and stream. It makes them more acidic, which is not good for the plants and animals living there. In a place called the Adirondack region in New York, study found that almost half Lakes were either already very acidic or could easily become that way. This change in the lakes chemistry is harmful to the environment [14].

Acid rain doesn't just affect lakes in New York, it has also been found to harm lakes in countries like Belgium, West Germany and the Netherlands. All parts of the water ecosystem are affected by acid rain, from tiny plants to big fish. In southern Norway in the 1970s, more than one-fifth of the lakes lost all their fish because of acid rain. Even in Canada, popular fishing spots have seen declines in fish population because of acid rain. Fish are dying more, having troubles reproducing [15].

Effect of acid rain on soil-

Soil acidity caused by acid rain can mess with the balance of important nutrients like potassium, magnesium and calcium in the soil. This imbalance leads to these nutrients being washed away along with sulphate from the acid rain, leaving the soil deficient in essential nutrients [16]. This deficiency hampers plant growth, including trees, and slows down the natural breakdown of organic matter like leaves and wood. Therefore, in simpler terms, acid rain messes up the soil making it hard for plants to grow properly and for dead stuff to break down, as it should [17]. It has been seen properties like how soils hold onto nutrients, the types of nutrients present in the soil, the level of soluble salts, the presence of substance like carbonate and gypsum, soil acidity, and how much lime is needed to adjust pH [18].

It also counts different types of tiny organism living in soil, as well as ways to analyse the overall activity of these microorganisms. It has been seen that specific groups like fungi, bacteria that live without oxygen, those involved in nitrogen cycling, and other like algae, protozoa, and small animals such as nematodes and miles [19]. Contamination of soil with heavy metals, especially lead, is a widespread issue worldwide. This contamination includes industries like chemical, petrochemical, and metallurgical, as well as the disposal of lead based paint, emission from vehicles using leaded gasoline, waste incineration, and mining activities [20].

Countries experiencing rapid industrial growth and urbanization, like china and other developing nation often face significant soil contamination with heavy metals including lead. This contaminated poses serious risks to both public health and the environment. Therefore, its crucial environmental expects to urgently address the remediation of soils contaminated with lead to protect both people and ecosystems [21]. When assessing how lead leaches out of soils stabilized with cement over time experts typically use a method based on Fick's theory. This method calculates effective diffusion coefficients, which represent how easily lead moves through the soil. We assume that the cement stabilized soil acts like an infinite space meaning that the amount of lead released

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from the soil is less than 20% of the total lead present in the soil. This assumption allows us to simplify the calculation [22].

Effect on fish and other Aquatic life-

Acid rain messes up water bodies like ponds, rivers, lakes, and oceans by making them too acidic for fish and other aquatic creatures to survive. It directly messes with fish by messing up their blood and eggs, and indirectly by messing with their food supply and creating toxins. [23]. Some lakes in Sweden are so messed up by acid rain that fish cannot even live there anymore. If the water gets too acidic, fish and other critters cannot survive. Even tiny changes in acidity can mess things up, likemaking fish eggs not hatch or killing adult fish [24]. Antibiotic are medicines used to fight infection caused by bacteria. They are also given to animals to help them grow faster and to prevent diseases. However, when we use antibiotics a lot they end up in the environment especially in water.

Even though antibiotics are supposed to kill harmful bacteria they can still harm other organism in the environment including us. This is because even in small amounts, antibiotics can stay in the water for a long time and keep affecting living things. This is becoming a big problem because even tiny amounts of antibiotics in water can be dangerous to the food chain, which means it can affect the animals and plants we eat. So, we need to be careful about how we use antibiotics to protect our environment and ourselves [25].

The chemical nature of acid rain-

I have researched that when acid rain falls, it can make the soil release aluminium into lakes and streams. This aluminium is harmful to many water creatures. In the US about 75% of lakes and 50% of stream have become acidic meaning their PH level drops below 5. In Canada, around 14,000 lakes have been affected. Lakes with soft water and low level drops of certain minerals are more likely to become acidic [26]. Acidification makes rocks release more aluminium. This aluminium stresses out fish making them smaller and weaker. They struggle to find enough food and a good place to live. In addition, when the water gets too acidic, fish eggs often do not hatch and some adult fish might die. Other creatures like snail and clam's cants survive well in water with pH below 5.5 [27].

As per it has been read from Direct/Delayed Response Project (DDRP) is a study by the Environment Protection Agency in the U.S. It aims to understand the risk of acidic rain to surface waters, especially in the eastern part of the country. As part of DDRP researchers collected data about how land is used including wetlands and forests in 1445 lakes and 35 streams in the Northeast and southern blue ridge province. They then used this data to make prediction about other similar areas [28].

By looking at data they can see how different types of land use affect water quality. This helps them understand the impact of human activities on the environment and make decisions to protect it [29].

Effect of acid rain on vegetation-

For over a hundred years' scientists have known that the stuff released when we burn fossil fuels affects how plants grow. Lately people are paying more attention to somethings called acidic deposition where pollutants from burning fuels end up in rain. This is a big deal because its causing problems for crops, leading to economic losses. Researched are trying to figure out exactly how much this acid rain hurts crops but many studies on crops have limitation. Acid rain can vary a lot in how acidic it is how much rainfalls and how much sulphur and nitrogen it contains. In addition, how crops respond to these factors might not be straightforward [30]. We do not

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know everything about how acid rain affects plants, but we can see that it can cause damage and lower crop yields. For example, when soybeans were exposed to simulated acid rain in outdoor experiments, they produced fewer seeds compared to those treated with normal rain. Studies have shown that different crops can be harmful by acid rain in both labs and field settings. Plants like soybeans for example, can have lower yields when exposed to acid rain [31].

In greenhouse, researchers have found that various crop less and produce fewer crops when exposed to simulated acid rain. Some plants are less affected by acid rain than others are. For examples, plants with one seed leaf are often less harmed by acid rain [32]. Young parts of plants, like roots, leaves, and shoots, are usually more sensitive to acid rain. But acid rain can harm other parts of plant too, and it can even change the makeup of the soil water, which affect how plants get their nutrients. When acid rain touches plant leaves, it can enter the plant through the outer layer and cause different problems. Larger leaves can catch more acid rain, increasing the chance of damage [33]. Farmers are worried about acid rain harming their crops. Some studies have shown that simulated acid rain can either help or hurt crops to simulated acid rain, they found it could sometimes boost yield, but not always, especially for trees like resort pines [34]. One big sign of plant stress from acid rain is changes in plant pigments. Acid rain does not just mess with soil and water; it can also hurt lakes and rivers and make groundwater more acidic. How bad the damage is depends on things like the type of soil and how much it rains. For example, in places like Bombay rain can be as acidic as pH 3.8. in some parts of the US and Canada, rain with a PH of around 4.0 is common, and it can even get as low as PH 3.0 sometimes. Acid rain affects differently as shown by studies on wheat in Ontario and the US. Overall, lots of research has been done worldwide on how acid rain affects crops [35].

Research studies cabbage plants exposed to simulated acid rain in a controlled environment. They sprayed rain with different levels of acidity, from pH 5.6 to 2.8 on 10-day-old plants. The rain at pH 3.0 caused the young leaves to curl downward and be damaged, but older leaves were mostly fine. They found that the type of wax on the leaves played a big role in how much damage occurred. When the same acidic rain was sprayed on plants at later stages of growth, it did not really affect their growth [36].

Maize plants were grown in plots in a greenhouse and exposed to simulated acid rain after pollination. Rain with PH levels of 4.5, 3.5, or 2.5 reduced the number of seeds produced by 7%, 29%, and 34%, respectively. Compared to rain with pH 4.4, rain with pH 5.5 reduced seed production by 24%. Interestingly, rain before pollination didn't affect seed production [37].

Physiological activities of animals-

Acid rain does not just harm the environment, it also messes with animals and even humans. Take brown trout, for example. Acid rain messes up their love lives by messing with their sexual behaviour. It also stops them from digging nests properly [38]. For people acid rain can cause health issues. It weakens our immune system, making it harder for our bodies to fish off sickness. When we are exposed to acid rain, the levels of antibodies in our blood drops a lot which is not good for staying healthy [39].

CONCLUSION

Acid rain is a big problem for the environment because it has a pH level lower than 5.6. This happen when gases like sulphur dioxide and nitric oxide mix with water in the air, creating sulphuric acid and nitric acid. These

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acids fall to the ground as rain, fog, or snow. They come from things humans do, like burning fossil fuels in cars and power plants. Acid rain hurts forests, plants, buildings, river, lakes, and even human health.

We can lessen the harm of acid rain by adding lime to lakes, rivers, and soil. Lime helps to balance out the acid. Laws also need to be made to control acid rain better. But there is still a lot we don't understand about how plants and environment deals with acid rain. We need more research to figure out how to protect them better. The research shows that both natural and simulated acid rain can affect many aspects of plant growth and health, such as how seeds sprout, how plants grow, and how well they produce flowers and seeds. Acid rain can also mess with processes inside plants cells, like photosynthesis and enzyme activity. This can have both short term and long-term effect on plants.

Most crops are sensitive to acid rain, so we really need to find or develop types of plants that can handle it better, especially in areas where acid rain is a big problem. As acid rain gets worse, it can make it inside of plant cells more acidic, which can mess up their normal functions. We still do not fully understand how plants cope with this acidity and what can be done to help them.

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