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Science behind Acid Rain: Analysis of Its Impacts and Advantages on Life and Heritage Structures

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INTRODUCTION

Acid rain is a major problem facing the environment today. It is formed through both natural and anthropogenic sources. Industrial emissions are anthropogenic sources, and a volcano eruption is an example of a natural source. One of the most direct effects of acid rain is on aquatic ecosystems. Acid rain is the term given to increased acidity of rain due to the effects of gases (from industrial and natural processes) which dissolve in rainwater to form various acids. Acid rain forms when certain atmospheric gases (primarily carbon dioxide, sulphur dioxide, and nitrogen oxides) come in contact with water in the atmosphere or on the ground and are chemically converted to acidic substances. Oxidants play a major role in several of these acid-forming processes. Carbon dioxide dissolved in rain is converted to a weak acid (carbonic acid). Other gases, primarily oxides of sulphur and nitrogen, are converted to strong acids (sulphuric and nitric acids). Although rain is naturally slightly acidic because of carbon dioxide, natural emissions of sulphur and nitrogen oxides, and certain organic acids, human activities can make it much more acidic. Occasional *pH* readings of well below 2.4 (the acidity of vinegar) have been reported in industrialized areas. The principal natural phenomena that contribute acid-producing gases to the atmosphere are emissions from volcanoes and from biological processes that occur on the land, in wetlands, and in the oceans. The effects of acidic deposits have been detected in glacial ice thousands of years old in remote parts of the globe. Principal human sources are industrial and power-generating plants and transportation vehicles. The gases may be carried hundreds of miles in the atmosphere before they are converted to acids and deposited.

Since the industrial revolution, emissions of sulphur and nitrogen oxides to the atmosphere have increased. Industrial and energy-generating facilities that burn fossil fuels, primarily coal, are the principal sources of increased sulphur oxides. These sources, plus the transportation sector, are the major originators of increased nitrogen oxides. The problem of acid rain not only has increased with population and industrial growth, it has become more widespread. The use of tall smokestacks to reduce local pollution has contributed to the spread of acid rain by releasing gases into regional atmospheric circulation. On the surface, the argument of caution is used, that steps should not be taken unless backed up by a high degree of technological proof, such that doubt is no longer present, or at least that the doubt is not large enough to outweigh the cost of action. Beneath this scientific, logical, ordered sheen however is the self centered interests of an industry which does not want to change the status quo, one of predictability and security, required ultimately for economic growth and shareholder contentedness. Fundamental to the argument against providing flue gas emission reduction technology is the high cost associated with this, compounded by lack of knowledge on the cause – pathway – effect linkage. The acid rain scenario is repeated and magnified in the case of CO_2 emissions and the suspected anthropogenically induced enhanced greenhouse effect.

I have tried to explain the entire topic in a brief manner, commencing from the very point of ‘acid rain’ and moving over to areas like constituents of acid rain, origin of nitrogen oxide (how its caused by humans), other information about this gas (elements), origin of carbon dioxide (how its caused by humans), other information about this gas (elements), how sulphur dioxide becomes sulphuric acid, explain how nitrogen oxide becomes nitric or nitrous acid, bring out a few hidden areas into light like the advantages of acid rain etc.

ACID RAIN: HISTORICAL BACKGROUND

Robert Angus Smith of England coined the term acid rain in 1852. Term was recognized in 1972 after 20 years and slowly the western industrial world became more and more familiar with this term. It literally implies a change toward more acidic conditions of rain, fog or snow affecting the lakes, rivers, ground water, soil, and forest land. Such changes may occur as a result of slow geo-biological processes occurring in nature or faster episodic emissions from volcanic eruptions. Of late, rapid industrialization all over the globe has resulted in acid forming gases into the atmosphere. In sixties and seventies this phenomenon assumed alarming proportion affecting the main industrial countries of North America and Europe ignoring national and international boundaries. The nature and volume of acid precursor gases evolved from different countries and their trans-boundary movements horrified the western world and their conscious and concerted efforts could arrest the damage in time. These measures have been effective to some extent but through monitoring and R&D work in this continue to enjoy priority in national and international scenario. Acid Rain is the word used to describe rainfall that has a pH level of less than 5.6. This form of air pollution is currently a subject of great controversy because of it’s worldwide environmental damages. For the last ten years, this phenomenon has brought destruction to thousands of lakes and streams in the United States, Canada, and parts of Europe. Acid rain is formed when oxides of nitrogen and sulfite combine with moisture in the atmosphere to make nitric and sulphuric acids. These acids can be carried away far from its origin. This report contains the cause, effects, and solutions to acid rain.[1]

ACID RAIN: SOURCES

The two primary sources of acid rain are sulphur dioxide (SO_2), and oxides of nitrogen (NO_x). Sulphur dioxide is a colourless, prudent gas released as a by-product of combusted fossil fuels containing sulphur. A variety of industrial processes, such as the production of iron and steel, utility factories, and crude oil processing produce this gas. In iron and steel production, the smelting of metal sulfate ore, produces pure metal. This causes the release of sulphur dioxide. Metals such as zinc, nickel, and copper are commonly obtained by this process. Sulphur dioxide can also be emitted into the atmosphere by natural disasters or means. This ten percent of all sulphur dioxide emission comes from volcanoes, sea spray, plankton, and rotting vegetation.[2]

The principal natural phenomena that contribute acid-producing gases to the atmosphere are emissions from volcanoes and from biological processes that occur on the land, in wetlands, and in the oceans. The effects of acidic deposits have been detected in glacial ice thousands of years old in remote parts of the globe. Principal human sources are industrial and power-generating plants and transportation vehicles. The gases may be carried hundreds of miles in the atmosphere before they are converted to acids and deposited. The other chemical that is also chiefly responsible for the make-up of acid rain is nitrogen oxide. An oxide of nitrogen is a term used to describe any compound of nitrogen with any amount of oxygen atoms. Nitrogen monoxide and nitrogen dioxide are all oxides of nitrogen. These gases are by-products of firing processes of extreme high temperatures (automobiles, utility plants), and in chemical industries (fertilizer production). Natural processes such as bacterial action in soil, forest fires, volcanic action, and lightning make up five percent of nitrogen oxide emission. Transportation makes up 43%, and 32% belongs to industrial combustion.[3] **Though in India, it is not as big a problem, but industrial acid rain is a substantial problem in China, Eastern Europe, Russia and areas down-wind from them. These areas all burn sulfur-containing coal to generate heat and electricity.[4]**

Nitrogen oxide is a dangerous gas by itself. This gas attacks the membranes of the respiratory organs and increases the likelihood of respiratory illness. It also contributes to ozone damage, and forms smog. Nitrogen oxide can spread far from the location it was originated by acid rain. As mentioned before, any precipitation with a pH level less than 5.6 is considered to be acid rainfall. The difference between regular precipitation and acid precipitation is the pH level. pH is a symbol indicating how acidic or basic a solution is in ratios of relative concentration of hydrogen ions in a solution. A pH scale is used to determine if a specific solution is acidic or basic. Any number below seven is considered to be acidic. Any number above seven is considered to be basic. The scale is color coordinated with the pH level. Most pH scales use a range from zero to fourteen. Seven is the neutral point (pure water). A pH from 6.5 to 8, is considered the safe zone. Between these numbers, organisms are in very little or no harm.

ACID RAIN: SCIENTIFIC ANALYSIS

Not only does the acidity of acid precipitation depend on emission levels, but also on the chemical mixtures in which sulphur dioxide and nitrogen oxides interact in the atmosphere. Sulphur dioxide and nitrogen oxides go through several complex steps of chemical reactions before they become the acids found in acid rain. The steps are broken down into two phases, gas phase and aqueous phase. There are various potential reactions that can contribute to the oxidation of sulphur dioxide in the atmosphere each having varying degrees of success. One possibility is photo-oxidation of sulphuric dioxide by means of ultraviolet light. This process uses light form the electromagnetic spectrum. This causes the loss of by two oxygen atoms. This reaction was found to be an insignificant contributor to the formation of sulphuric acid. A second and more common process is when sulphur dioxide reacts with moisture found in the atmosphere. When this happens, sulfate dioxide immediately oxidizes to form a sulfite ion.

$$SO_2\ (g) + O_2\ (g) \rightarrow SO_3\ (g)$$

Afterwards, it becomes sulphuric acid when it joins with hydrogen atoms in the air.

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

This reaction occurs quickly, therefore the formation of sulphur dioxide in the atmosphere is assumed to lead this type of oxidation to become sulphuric acid.

Another common reaction for sulphur dioxide to become sulphuric acid is by oxidation by ozone. This reaction occurs at a preferable rate and is sometimes the main contributor to the oxidation of sulphuric acid. This, hydroxy radical is produced by the photodecomposition of the ozone and is very highly reactive with any species (type of chemical compounds). It does not require a catalyst and it is approximately 108-109 times more abundant in the atmosphere than molecular oxygen. Other insignificant reactions include oxidation by product of alkene-zone reactions, oxidation by reaction of N_xO_y species, oxidation by reactive oxygen transients, and oxidation by peroxy radicals. These reactions unfortunately prove to be insignificant for various reasons. All the reactions mentioned so far, are gas phase reactions. In the aqueous phase, sulphur dioxide exists as three species:

$$[S\ (IV)] \rightarrow [SO_2\ (aq)] + [HSO^{32-}] + [SO^{32-}]$$

This dissociation occurs in a two part process:

$$SO_2\ (aq) \rightarrow H^+ + HSO\ ^{3-}$$

$$HSO\ ^{3-}\ (aq) \rightarrow H^+ + SO_3\ ^{2-}$$

The oxidation process of aqueous sulphur dioxide by molecular oxygen relies on metal catalyst such as iron and manganese. This reaction is unlike other oxidation process, which occurs by hydrogen peroxide. It requires an additional formation of an intermediate (A-), for example peroxymonosulphurous acid ion. This formation is shown below.

$$HSO_3 + H_2O_2 \rightarrow A^- + H_2O$$
$$A^- + H \rightarrow H_2SO_4$$

Sulphur dioxide oxidation is most common in clouds and especially in heavily polluted air where compounds such as ammonia and ozone are in abundance. These catalysts help convert more sulphur dioxide into sulphuric acid. But not the entire sulphur dioxide is converted to sulphuric acid. In fact, a substantial amount can float up into the atmosphere, transport to another area and return to earth unconverted.

Like sulphur dioxide, nitrogen oxides rise into the atmosphere and are oxidized in clouds to form nitric or nitrous acid. These reactions are catalyzed in heavily polluted clouds where traces of iron, manganese, ammonia, and hydrogen peroxide are present. Nitrogen oxides rise into the atmosphere mainly from automobile exhaust. In the atmosphere it reacts with water to from nitric or nitrous acid.

$$NO_2\,(g) + H_2O\,(l) \rightarrow HNO_3\,(aq) + HNO_2\,(aq)\ \text{[gas phase]}$$

In the aqueous phase there are three equilibria to keep in mind for the oxidation of nitrogen oxide.

$$2NO_2\,(g) + H_2O\,(l) \rightarrow 2H^+ + NO^{3-} + NO^{2-}$$
$$NO\,(g) + NO^2\,(g) + H^2O\,(l) \rightarrow 2H^+ + 2NO^{2-}$$
$$3NO_2\,(g) + H_2O\,(l) \rightarrow 2H^+ + 2NO^{3-} + NO\,(g)$$

These reactions are limited by the partial pressures of nitrogen oxides present in the atmosphere, and the low solubility of nitrogen oxides, increase in reaction rate occurs only with the use of a metal catalyst, similar to those used in the aqueous oxidation of sulphur dioxide.

ACID RAIN: EFFECT ON AQUATIC ECOSYSTEMS

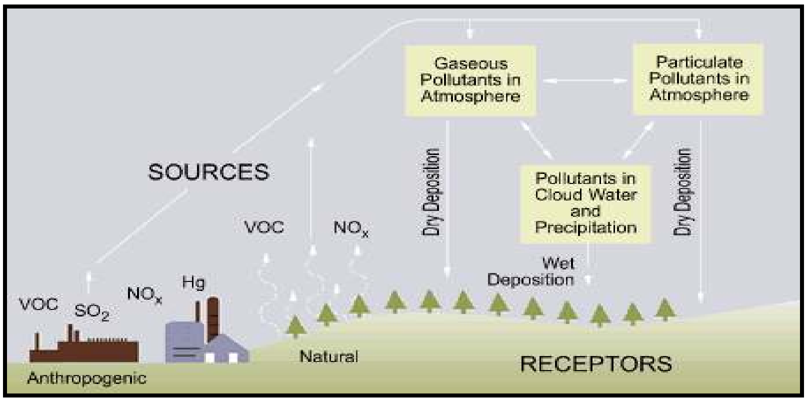
The interactions between living organisms and the chemistry of their aquatic habitats are extremely complex. If the number of one species or group of species changes in response to acidification, then the ecosystem of the entire water body is likely to be affected through the predator-prey relationships of the food web. At first, the effects of acid deposition may be almost imperceptible, but as acidity increases, more and more species of plants and animals decline or disappear. As the water pH approaches 6.0, crustaceans, insects, and some plankton species begin to disappear. As pH approaches 5.0, major changes in the makeup of the plankton community occur, less desirable species of mosses and plankton may begin to invade, and the progressive loss of some fish populations is likely, with the more highly valued species being generally the least tolerant of acidity. Below pH of 5.0, the water is largely devoid of fish, the bottom is covered with undecayed material, and the areas close to shore may be dominated by mosses. Terrestrial animals dependent on aquatic ecosystems are also affected. Waterfowl, for example, depend on aquatic organisms for nourishment and nutrients. As these food sources are reduced or eliminated, the quality of habitat declines and the reproductive success of the birds is affected.

ACID RAIN: EFFECT ON TERRESTRIAL PLANT LIFE

1. Both natural vegetation and crops can be affected.
2. It can alter the protective waxy surface of leaves, lowering disease resistance.
3. It may inhibit plant germination and reproduction.
4. It accelerates soil weathering and removal of nutrients.
5. It makes some toxic elements, such as aluminum, more soluble. High aluminum concentrations in soil can prevent the uptake and use of nutrients by plants.

Over the years, scientists have noticed that some forests have been growing more and more slowly without reason. Trees do not grow as fast as they did before. Leaves and pines needles turn brown and fall off when they are supposed to be green. Acid rain does not kill trees immediately or directly. Instead, it is more likely to weaken the tree by destroying its leaves, thus limiting the nutrients available to it. Or, acid rain can seep into the ground, poisoning the trees with toxic substances that are slowly being absorbed through the roots. When acid rain falls, the acidic rainwater dissolves the nutrients and helpful minerals from the soil. These minerals are then washed away before trees and other plants can use them to grow.

Not only does acid rain strip away the nutrients from the plants, they help release toxic substance such as aluminum into the soil. This occurs because these metals are bound to the soil under normal conditions, but the additional dissolving action of hydrogen ions causes rocks and small bound soil particles to break down. When acid rain is frequent, leaves tend to lose their protective waxy coating. When leaves lose their coating, the plant itself is open to any possible disease. By damaging the leaves, the plant can not produce enough food energy for it to remain healthy. Once the plant is weak, it can become more vulnerable to disease, insects, and cold weather which may ultimately kill it. Sometimes when acid rainfall runs off the land, it carries fertilizers with it. Fertilizer helps stimulate the growth of algae because of the amount of nitrogen in it. However, because of the increase in the death of fish the decomposition takes up even more oxygen. This takes away from surviving fish. In other terms, acid rain does not help aquatic ecosystems in anyway. The following picture shows the entire process happening:[5]



Acid rain does not only damage the natural ecosystems, but also man-made materials and structures. Marble, limestone, and sandstone can easily be dissolved by acid rain. Metals, paints, textiles, and ceramic can effortlessly be corroded. Acid rain can downgrade leather and rubber. Man-made materials slowly deteriorate even when exposed to unpolluted rain, but acid rain helps speed up the process. Acid rain causes carvings and monuments in stones to lose their features. In limestone, acidic water reacts with calcium to form calcium sulfate.

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2CO_3$$

For iron, the acidic water produces an additional proton giving iron a positive charge.

$$4Fe(s) + 2O_2\,(g) + 8H\,(aq) \rightarrow 4Fe^{2+}\,(aq) + 4H_2O\,(l)$$

When iron reacts with more oxygen it forms iron oxide (rust).

$$4Fe^{2+}\,(aq) + O_2\,(g) + 4H_2O\,(l) \rightarrow 2Fe_2O_3(s) + 8H^+\,(aq)$$

ACID RAIN: EFFECT ON HUMAN BEINGS

Most importantly, acid rain can affect health of a human being. It can harm us through the atmosphere or through the soil from which our food is grown and eaten from. Acid rain causes toxic metals to break loose from their natural chemical compounds. Toxic metals themselves are dangerous, but if they are combined with other elements, they are harmless. They release toxic metals that might be absorbed by the drinking water, crops, or animals that human consume. These foods that are consumed could cause nerve damage to children or severe brain damage or death. Scientists believe that one metal, aluminum, is suspected to relate to Alzheimer's disease. One of the serious side effects of acid rain on human is respiratory problems. The sulphur dioxide and nitrogen oxide emission gives risk to respiratory problems such as dry coughs, asthma, headaches, eye, nose, and throat irritation. Polluted rainfall is especially harmful to those who suffer from asthma or those who have hard time breathing. But even healthy people can have their lungs damaged by acid air pollutants. Acid rain can aggravate a person's ability to breathe and may increase disease which could lead to death. In 1991, the United States and Canada signed an air quality agreement. Ever since that time, both countries have taken actions to reduce sulphur dioxide emission. The United States agree to reduce their annual sulphur dioxide emission by about ten million tons by the year 2000. A year before the agreement, the Clean Air Pact Amendment tried to reduce nitrogen oxide by two million tons. This program focused on the source that emits nitrogen oxide, automobiles and coal-fired electric utility boilers. Reducing nitrogen oxide emission in a utility plant starts during the combustion phase. A procedure called over fire air is used to redirect a fraction of the total air in the combustion chamber. This requires the combustion process, which is redirected to an upper furnace. This causes the combustion to occur with less O_2 than required, thus slowing down the transformation of atmospheric nitrogen to nitrogen oxide. After combustion, a system of catalytic reductions is put into effect. This system embraces the injection of ammonia gas upstream of the catalytic reaction chamber. The gas will react with nitrogen oxide by this reaction.

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$$

Then it will react with NO_2 by the following reaction.

$$2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$$

The safe nitrogen can be released into the atmosphere.

To reduce sulphur dioxide emission utility plants are required to do several steps by the Clean Air Act Amendment.[6] Before combustion, these utilities plants have to go through a process call coal cleaning. This process is performed gravitationally. Meaning, it is successful in removing pyritic sulphur due to its high specific gravity, but it is unsuccessful in removing chemically bound organic sulphur. This cleaning process is only limited by the percent of pyritic sulphur in the coal. Coal with high amount of pyritic sulphur is coal in higher demands. Another way to reduce sulphur dioxide before combustion is by burning coal with low sulphur content. Low sulphur content coals are called subituminous coal. This process in reducing sulphur dioxide is very expensive due to the high demand of subituminous coal. Acid rain is an issue that can not be over looked. This phenomenon destroys anything it touches or interacts with it. When acid rain damages the forest or the environment it affects humans in the long run. Once forests are totally destroyed and lakes are totally polluted animals begin to decrease because of lack of food and shelter. If all the animals, which are our food source, die out, humans too would die out. Acid rain can also destroy our homes and monuments that humans hold dearly.

ACID RAIN: EFFECT ON BUILDINGS AND MONUMENTS (HERITAGE STRUCTURES)

In 1856, Robert Angus Smith - the scientist who first used the term acid rain - wrote:

> *"It has often been observed that the stones and bricks of buildings crumble more readily in large towns where much coal is burnt.... I was led to attribute this effect to the slow but constant action of acid rain."*

Acid rain does not only damage the natural ecosystems, but also man-made materials and structures. Buildings have always been subject to attack by weathering; the effects of rain, wind, sun, and frost. Acid rain can accelerate the rate of this damage. Throughout the world, emissions of sulphur dioxide and nitrogen oxides contribute to the international problem of acidification. Acid deposition affects most materials to some degree. Limestone, marble and sandstone are particularly vulnerable, whilst granitic-based rocks are more resistant to acidity. Other vulnerable materials include carbon-steel, nickel, zinc, copper, paint, some plastics, paper, leather and textiles. Stainless steel and aluminium are more resistant metals. Structural damage to underground pipes, cables and foundations submerged in acid waters can also occur, in addition to damage to buildings, bridges and vehicles above ground. Whilst dry deposition contributes to the corrosion of materials, in most areas with substantial rainfall it is the effect of wet deposition on building surfaces which is more damaging. Building stone can be damaged when calcium carbonate in stone dissolves in acid rain to form a crust of calcium sulphate or gypsum. The sulphated layers are more readily washed away by rainfall or removed by the action of frost and other weather conditions, resulting in more stone being exposed. This permanent alteration of stone surfaces by the action of acid deposition is known as sulphation.

Sulphur dioxide is the main pollutant in respect to corrosion but others also take their toll, including nitrogen oxides, carbon dioxide, ozone (on organic materials) and sea salt from sea spray. Research has revealed that when nitrogen dioxide is present with sulphur dioxide, increased corrosion rates occur. This is because the nitrogen dioxide oxidises the sulphur dioxide to sulphite thereby promoting further sulphur dioxide absorption. The interactions between building materials and pollutants are very complex and many variables are involved. Deposition of pollutants onto surfaces depends on atmospheric concentrations of the pollutants and the climate and microclimate around the surface. Once the pollutants are on the surface, interactions will vary depending on the amount of exposure, the reactivity of different materials and the amount of moisture present. The last factor is particularly important because the sulphur dioxide that falls as dry deposition is oxidised to sulphuric acid in the presence of moisture on the surface. The effects of acid deposition on modern buildings are considerably less damaging than the effects on ancient monuments. Marble, limestone, and sandstone can easily be dissolved by acid rain. Metals, paints, textiles, and ceramic can effortlessly be corroded. Acid rain can downgrade leather and rubber. Man-made materials slowly deteriorate even when exposed to unpolluted rain, but acid rain helps speed up the process. Acid rain causes carvings and monuments in stones to lose their features.

In limestone, acidic water reacts with calcium to form calcium sulfate.

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When iron reacts with more oxygen it forms iron oxide (rust).[7]

$$4Fe^{+2}(aq) + O_2 (g) + 4H_2O (l) \rightarrow 2Fe_2O_3(s) + 8H^+ (aq)$$

The repairs on building and monuments can be quite costly. Limestone and carbonate stones which are used in most heritage buildings in the UK are the most vulnerable to corrosion and need continued renovation. Cathedrals such as York Minster and Westminster Abbey have been severely eroded in recent years. In Westminster, England, up to ten million pounds was spent necessitated on repairs damaged by acid rain. In 1990, the United States spent thirty-five billion dollars on paint damage. In 1985, the Cologne Cathedral cost the Germans approximately twenty million dollars in repairs. The Roman monuments cost the Romans about two hundred million dollars.[8] A five-year research program in the UK has suggested that if sulphur dioxide emissions were reduced by 30%, savings over 30 years could be as high as £9.5 billion. Many other countries have noticed an acceleration of damage to their cultural heritage. The Taj Mahal in India, the Colosseum in Rome and monuments in Krakow, Poland are continuing to deteriorate. In Sweden, medieval stained glass windows are thought to have been affected by acid rain.

ACID RAIN: ADVANTAGES

Acid rain, considered hazardous until recently, helps in slowing the process of global warming, according to US scientists. The sulphate present in the rain helps in retarding the process of global warming, an international research published in the Proceedings of the National Academy of Sciences has said.[9] In an experiment, Dr. Vincent Gauci and his colleagues at an Open University in the US chose several wetlands in the country, UK and Sweden and dosed them with various amounts of sulphate. They decided to experiment in wetlands which provide fertile ground for the microbes that emit methane. Methanogenic microbes, which produce methane in large quantities, are inhibited by a type of bacteria that thrives on sulphate present in acid rain, the report said. Microbes produce about 32 per cent of the methane present in the environment, they said adding '160m out of 500m tonnes of methane is produced by those microbes.' The team, interested in guaging the emission level of methane, found that its emission was significantly suppressed due presence of sulphate. All experimental sites displayed 30 to 40 per cent reduction in methane production as the team simulated low level of acid rain, the report said. Methane exists in smaller quantities in the atmosphere as compared to carbon dioxide and accounts for about 22 per cent global warming which is caused due to human activities, it said.

Also, after taking a close new look into soil chemistry and where calcium comes from, scientists have said that acid rain may be doing less damage to forests than anticipated.[10] In a report published in Nature, researchers said some trees, especially spruce and firs, cooperate with soil fungi to dissolve calcium directly from a mineral called apatite. This alternate source of calcium may account for what has been seen as excess calcium that scientists see leaving the forests via streams. In the past, the extra calcium flow was blamed on acid rain, corrosive enough to leach out the mineral nutrient, said the study, by Joel Blum of the University of Michigan - done in collaboration with scientists from Cornell University, Yale University, Syracuse University, the U.S. Forest Service and the Institute for Ecosystem Studies, in Millbrook. These new findings should improve their understanding of what happens to forests that live downwind from the huge power plants that produce acid rain.

CONCLUSION

The two primary sources of acid rain is sulphur dioxide and nitrogen oxide. Automobiles are the main source of nitrogen oxide emissions, and utility factories are the main source for sulphur dioxide emissions. These gases evaporate into the atmosphere and then oxidized in clouds to form nitric or nitrous acid and sulphuric acid. When these acids fall back to the earth they do not cause damage to just the environment but also to human health. Acid rain kills plant life and destroys life in lakes and ponds. The pollutants in acid rain causes problem in human respiratory systems. The pollutants attack humans indirectly through the foods they consumed. They affected human health directly when humans inhale the pollutants. Governments have passed laws to reduce emissions of sulphur dioxide and nitrogen oxide, but it is no use unless people start to work together in stopping the release of these pollutants. If the acid rain destroys our environment, eventually it will destroy us as well. Since there are so many changes, it takes many years for ecosystems to recover from acid deposition, even after emissions are reduced and the rain becomes normal again. For example, while the visibility might improve within days, and small or episodic chemical changes in streams improve within months, chronically acidified lakes, streams, forests, and soils can take years to decades or even centuries (in the case of soils) to heal.

Materials and pollutants interact in a complicated manner. Dry deposition, the direct deposition of gaseous pollutants onto a surface, varies with factors such as wind speed, building orientation and relative humidity. For sulphur dioxide, for example, the reaction of the gas with limestone is enhanced if relative humidity is above 80%. Wet deposition, the delivery of gaseous pollutants to a surface via their incorporation into water, varies with factors such as the geometry of the surface. Where a surface is exposed to rainfall and runoff, then wet deposition can occur and chemical reactions such as dissolution can take place. The interaction between pollutants and materials highlights the importance of specific physical properties for the vulnerability of materials.

A matrix of calcium carbonate or a calcium carbonate rock is highly susceptible to reactions with acid solutions. Porous materials, whatever their chemical composition, are likely to be vulnerable to degradation by acid solutions, as their large pore volume provides a large surface area for chemical reactions. Similarly porous or fractured material will also be susceptible to the actions of salt, as salts can penetrate into confined spaces where their expansion can exert great stress upon the material. Lastly, the presence and movement of moisture within a material, facilitated by high porosity, can enhance and alter the concentration of weathering agents and aid their damaging activity.

However, there are some things that people do to bring back lakes and streams more quickly. Limestone or lime (a naturally-occurring basic compound) can be added to acidic lakes to 'cancel out' the acidity. This process, called liming, has been used extensively in developed countries like Norway, Sweden and the United States. Liming tends to be expensive, has to be done repeatedly to keep the water from returning to its acidic condition, and is considered a short-term remedy in only specific areas rather than an effort to reduce or prevent pollution.

Furthermore, it does not solve the broader problems of changes in soil chemistry and forest health in the watershed, and does nothing to address visibility reductions, materials damage, and risk to human health. However, liming does often permit fish to remain in a lake, so it allows the native population to survive in place until emissions reductions reduce the amount of acid deposition in the area. Acid deposition penetrates deeply into the fabric of an ecosystem, changing the chemistry of the soil as well as the chemistry of the streams and narrowing, sometimes to nothing, the space where certain plants and animals can survive.

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