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A CONCEPTUAL UNDERSTANDING OF SCIENTIFIC AND LEGAL PERSPECTIVE OF ACID PRECIPITATION AND ITS IMPACTS: A REVIEW

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ABSTRACT

Over the past decade, acid precipitation (acidification of rain water) has been transformed from a relatively unobserved area of scientific inquiry into a serious environmental problem of transboundary nature. Alternatively it has become a major regional, national, and international issue of concern. A large variety of chemical wastes such as sulfur and nitrogen oxides (which produce acid rain), ammonia, ozone, metals, and hydrocarbons are added to our atmosphere from numerous human activities like burning of fossil fuels. Some of these emitted chemical wastes have breached sustainable concentrations levels in industrialized and urbanized regions of the globe resulting in ecological crisis of high order. The problem of acid rain is perhaps one of the main environmental and debatable issues facing the community of people not only of the industrialized nations but also the fast developing economies of the world. In this research paper I am presenting a balanced approach to understand wide array of opinions on the current state of knowledge in acid precipitation research with respect to examination source of acid rain, its advantages, disadvantages, atmospheric processes, environmental effects, measurement procedure, legal, and political perspectives surrounding the acid precipitation. This study attempts to decode acid precipitation, its Indian context, its comparison with international laws, and its impacts on humanity.

Key words: Acid rain, Environment Pollution, Sustainability, Precipitation, Sulphur Oxide, Nitrogen Oxides, pH

INTRODUCTION

Acid rain has destroyed forests, lakes, and livesⁱ throughout the United Statesⁱⁱ and many other developed countries around the world. Numerous issues of concern to research scientists also have a significant impact on the perception of general population and as such Political, Economic, Social, Technological, Legal, and Environmental issues (PESTLE) often revolve around questions that can be resolved only through scientific inquest and analysis. Such questions frequently arise from man's unabated use of natural resources and their exploitation by use of technology. One environmental issue in which technology and industrialization has created at least part of the problem and is currently attracting growing public attention and scientific research is that of acid precipitation.

While acid precipitation is a major barrier to sustainable environment today, it is causing growing concern around the world; however public perceptions of the problem vary.

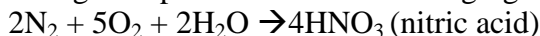
Since the beginning of civilization, human beings have exploited various natural resources for their advantage. On one side this kind of development makes our lives easier, but on the other hand it results into pollution by release of harmful substances into the environment. Burning of fossil fuels in industries, transport sector, rapid industrialization, and unabated urbanization have led to increase in concentrations of gaseous and particulate pollutants in the atmosphere leading to increased air pollution^{iii,iv}. Acid precipitation or acid rain is one of the most severe environmental problems whose origin or formation is due to growing air pollution both due to natural activity (volcano eruption) and anthropogenic sources (Industrial emissions). 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. Alternatively the term "acid rain" is used to describe rain, snow or fog that has been polluted by acid in the atmosphere during the water cycle^v. It is one of the most dangerous and widespread forms of pollution.

Rain water is never totally pure. It always contains some impurities from dust particles or from absorbing gases from the air. 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 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.

The acidity or alkalinity of a liquid is usually measured by its *pH* level. 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 above seven is considered to be basic and nay number below seven is considered to be acidic. A *pH* from 6.5 to 8, is considered the safe zone. Acid rain is precipitation^{vi} that has a pH^{vii} of less than the normal pH^{viii} . Rain that presents a concentration of H^+ ion greater than 2.5 and *pH* value is less than 5.6 is considered acid^{ix}. The lower the *pH* of rain water, the greater is its acidic character. Rain's *pH* level is lowered by pollutants emitted by utilities and industries^x. Normal rainwater has a *pH* of around 5.6 because it naturally absorbs carbon dioxide in the air^{xi} to form a mild 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, certain organic acids, and human activities can makes it more acidic. Small amount of nitric acid is also responsible for the acidity of normal rainwater, which is produced by the oxidation of nitrogen in presence of water during lightening storms.



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^{xii,xiii}.

The same remote glaciers that provide evidence of natural variability in acidic deposition show in their more recently formed layers the increased deposition caused by human activity during the past half century. 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 – impact linkage.

Due to the interactions of these acids with other constituents of the atmosphere, hydrosphere, and lithosphere, 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. Soils contain many substances including aluminum, calcium and magnesium. When acid compounds enter soils, there is some plant uptake, and some of the compounds move into ground and surface waters. Still others stick to soil particles and, in doing so, replace calcium and magnesium, which dissolve and enter ground and surface waters during rains and snowmelt. Acids also mobilize aluminum which is abundant in soils in a harmless, organic form. Once released, however, the organic form is converted to inorganic aluminum, which is toxic to living organisms. 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.

Aquatic species are affected both by episodic and chronic acidification. The more acidic a lake or stream becomes, the fewer species it can support. Acidification of water bodies causes large scale negative impact on aquatic organisms including fishes. This reduction in biodiversity matters. As diversity is diminished, ecosystems become less stable and productive. When diversity is lost, the quality of life for all is diminished, and there is a greater risk that critical parts of the cycle of life will fail^{xiv}. Acidification has some indirect effects on human health also. Acid rain affects each and every components of ecosystem. Acid precipitation may increase human exposure to several potentially toxic metals by increasing metal concentrations in major pathways to man, particularly food and water, and in some instances by enhancing the conversion of metal species to more toxic forms.

The acid rain scenario is repeated and magnified in the case of CO₂ emissions and the suspected anthropogenically induced enhanced greenhouse effect. Reductions in emissions of acidic compounds have been followed by reductions in deposition, and chemical improvements in some soils and waters have been documented^{xv}. But despite the emissions reductions, the problem of devastated forests, lakes, streams, and ecosystems due to acid rain has not been solved. A growing body of research evidence shows that without significant additional cuts in acid rain-forming emissions many of the problems associated with acid rain will persist for many, more decades to come. The needed reductions can come today from a mixture of energy options including expansion of the nation's use of energy efficiency, clean renewable, cleaner fuels and pollution control equipment.

MATERIALS AND METHODS

HISTORICAL BACKGROUND OF ACID PRECIPITATION

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. He reported that ammonium carbonate $[(\text{NH}_4)_2\text{CO}_3]$ was in the air over farming area, ammonium sulfate in the suburbs and sulfuric acid in the city. They dissolved in rain and rain became to be strong acidic. 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 a form of air pollution is currently a subject of great controversy because of its worldwide environmental damages. For the last ten years, this phenomenon has brought destruction to thousands of lakes and streams in the United States^{xvi}, Canada^{xvii}, and parts of Europe^{xviii}. 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.^{xix}

SOURCES OF ACID RAIN

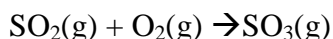
The two primary sources of acid rain are sulphur dioxide (SO_2), and oxides of nitrogen (NO_x). Sulphur dioxide is a colourless, prudent gas released as a by-product of combusted fossil fuels containing sulphur. The man-made sources of SO_2 emissions are the burning of coal and petroleum and various industrial processes^{xx}. 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^{xxi}. 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. Oxides of nitrogen are 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 percent, and 32 percent belongs to industrial combustion.^{xxii} Though in India, it is not as big a problem, but industrial acid rain is a substantial problem in China, Eastern

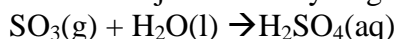
Europe, Russia and areas coming under down-wind from them. All these areas burn sulfur-containing coal to generate heat and electricity^{xxiii}. Nitrogen oxide is a dangerous gas by itself. This gas attacks the membranes of the respiratory organs and increases the likelihood of respiratory illness. It also contributes to destruction of ozone and forms smog. Nitrogen oxide can spread far from the location it was originated by acid rain.

ACID RAIN: SCIENTIFIC ANALYSIS

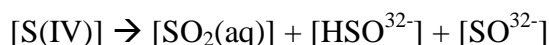
Not only does the acidity of acid precipitation depend on emission levels, but also on the chemical mixtures in which sulphur dioxide and nitrogen oxides interact in the atmosphere. Sulphur dioxide and nitrogen oxides go through several complex steps of chemical reactions before they become the acids 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 sulphur dioxide by means of ultraviolet light. This process uses light from 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.



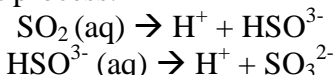
Afterwards, it becomes sulphuric acid when it joins with hydrogen atoms in the air.



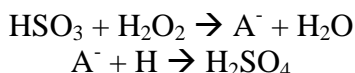
This reaction occurs quickly, therefore the formation of sulphur dioxide in the atmosphere is assumed to lead this type of oxidation to become sulphuric acid. Another common reaction for sulphur dioxide to become sulphuric acid is by oxidation by ozone. The presence of oxidizing agents and the characteristics of the reaction affects the rate of acid generation^{xxiv}. 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 110 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:



This dissociation occurs in a two part process:

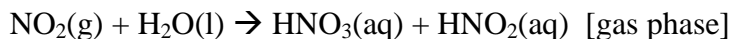


The oxidation process of aqueous sulphur dioxide by molecular oxygen relies on metal catalyst such as iron and manganese. This reaction is unlike other oxidation process, which occurs by hydrogen peroxide. It requires an additional formation of an intermediate (A^-), for example peroxy monosulphurous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

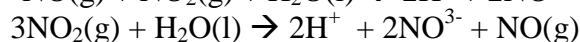
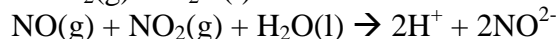
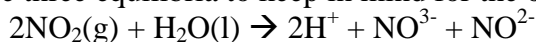


Sulphur dioxide oxidation is most common in clouds and especially in heavily polluted air where compounds such as ammonia and ozone are in abundance. These catalysts help convert more sulphur dioxide into sulphuric acid. But all sulphur dioxides is not converted to sulphuric acid. In fact, a substantial 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 form nitric or nitrous acid.



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



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.

EFFECT OF ACID PRECIPITATION ON AQUATIC ECOSYSTEMS

The interactions between living organisms and the chemistry of their aquatic habitats are extremely complex. The effects of acid deposition on water quality, although complicated and variable, have been well documented. Impacts from these acidic compounds in the atmosphere can occur directly, by deposition on the water surface, or indirectly, by contact with one or more components of the terrestrial ecosystem before reaching any aquatic system. The interactions of acid deposition with the terrestrial ecosystem, including vegetation, soil, and bedrock, result in chemical alterations of the waters draining these watersheds, eventually altering conditions in the lakes downstream. 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. Due to acidic precipitation, fishes showed increases in mortality rate, reproductive failure, reduced growth rate skeletal deformities and increased uptake of heavy metals^{xxv}. The amphibians are also affected by acidification of water bodies^{xxvi}. Below pH of 5.0, the water is largely devoid of fish, the bottom is covered with un-decayed material, and the areas close to shore may be dominated by mosses. Terrestrial animals dependent on aquatic ecosystems are also affected. As these food sources are reduced or eliminated, the quality of habitat declines and the reproductive success of the birds is affected. High concentrations of Aluminum (Al) and other heavy metals, such as Cadmium (Cd), Mercury (Hg), Iron (Fe), and sometimes Zinc (Zn) were found in acidified lakes and the sources of these metals are leaching of ions from soils and rocks in the catchments^{xxvii}. In the Hubbard's Brook Experimental forest in New Hampshire, USA, detailed measurements of water chemistry have shown that acidification causes increase in concentrations of Aluminum (Al), Cadmium (Cd), Magnesium (Mg), and Potassium (K), mobilized from sediments on the stream bed^{xxviii}.

EFFECT OF ACID PRECIPITATION TERRESTRIAL PLANT LIFE

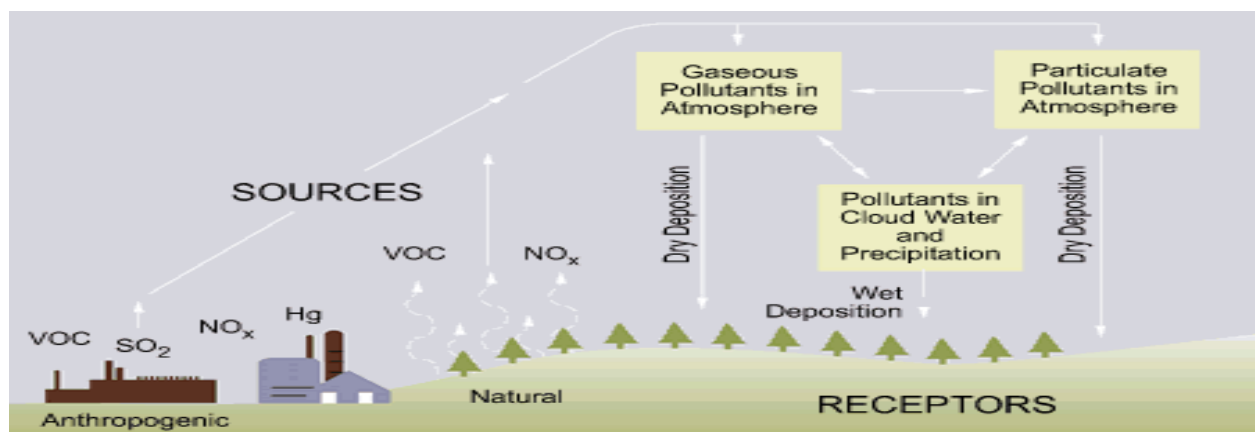
Possible effects of acidic deposition and its precursors on forests have been the topic of intensive research efforts in both Europe^{xxix} and the United States^{xxx}. Acid rain damages forests, especially those at higher elevations. It robs the soil of essential nutrients and releases aluminum in the 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. The only way to fight acid rain is by curbing the release of the pollutants that cause it. This means burning fewer fossil fuels. Many governments have tried to curb emissions by cleaning up industry smokestacks and promoting alternative fuel sources. These efforts have met with mixed results. But even if acid rain could be stopped today, it would still take many years for its harmful effects to disappear. Both natural vegetation and crops can be affected.

- It can alter the protective waxy surface of leaves, lowering disease resistance.
- It may inhibit plant germination and reproduction.
- It accelerates soil weathering and removal of nutrients.
- 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.^{xxxix}



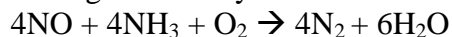
The lower plants including algae, fungi and lichen are also negatively affected by acid rain. Various microorganisms and microbial processes get affected because of changes in soil properties due to acid rain^{xxxii,xxxiii}.

EFFECT OF ACID PRECIPITATION HUMAN BEINGS

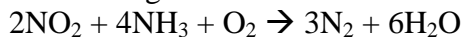
Most importantly, acid rain can affect health of a human being. It can harm us through the atmosphere or through the soil from which our food is grown and eaten from. Acid rain causes toxic metals to break loose from their natural chemical compounds. Indirect effect of acid rain on human health involves toxic heavy metals because these are liberated from soil when soil gets acidified. The most common heavy metals are Aluminum (Al), Cadmium (Cd), Zinc (Zn), Lead (Pb), Mercury (Hg), (Magnese) Mn, and Iron (Fe)^{xxxiv}. Toxic metals themselves are dangerous, but if they are combined with other elements, they are harmless and the release of toxic metals will 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. 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 damaging when combined with aerosols, and mists, and suspended smoke.^{xxxv} 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. 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 where 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 O₂ 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.



Then it will react with NO₂ by the following reaction.



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.^{xxxvi} 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

cannot 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.

EFFECT OF ACID PRECIPITATION ON BUILDINGS AND MONUMENTS (HERITAGE STRUCTURES)^{xxxvii}

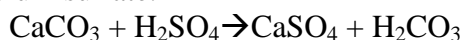
In 1856, Robert Angus Smith - the scientist who first used the term acid rain - wrote: *"It has often been observed that the stones and bricks of buildings crumble more readily in large towns where much coal is burnt.... I was led to attribute this effect to the slow but constant action of acid rain."*

Acid rain does not only damage the natural ecosystems, but also man-made materials and structures. The impact of acid deposition on stone monuments made of marble and limestone and on building materials containing large amounts of carbonate have been recognized for over a century and many studies have addressed the effect of acid wet deposition on stone materials of historic buildings and monuments. High buildings made of concrete in urban areas have damaged due to exposure to cloud water with high acidity for a long time^{xxxviii}. 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 aluminum are more resistant metals.

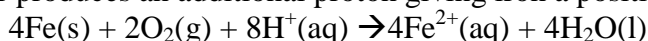
Dry deposition of SO_x and NO_x on the surfaces of stones contributes to salt enrichment on carbonate stones and plays a major role in the deposition of acid substances on buildings^{xxxix}. Structural damage to underground pipes, cables and foundations submerged in acid waters can also occur, in addition to damage to buildings, bridges and vehicles above ground. The impact of local wet and dry deposition of acid compounds was investigated by exposing different materials such as copper, bronze, marble, etc. under indoor and outdoor conditions and the results showed the corrosion was directly correlated with local pollution, especially the ratio of SO₂/NO_x and climate^{xl}. The incremental effects of wet and dry deposition on carbonate stone erosion due to hydrogen ion, SO₂ and NO_x were quantified^{xli}.

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. Acid rain causes chemical deterioration on carbonate stones and formation of soluble Ca⁺², HCO₃⁻, SO₄⁻². 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.

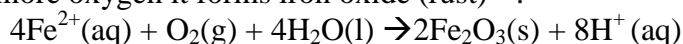
Once the pollutants are on the surface, interactions will vary depending on the amount of exposure, the reactivity of different materials and the amount of moisture present. The last factor is particularly important because the sulphur dioxide that falls as dry deposition is oxidised to sulphuric acid 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. Manmade 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.



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



When iron reacts with more oxygen it forms iron oxide (rust)^{xliii}.



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^{xliiii}. A five-year research program in the UK has suggested that if sulphur dioxide emissions were reduced by 30 percent, 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 and Red Fort in India are showing signs of damage by sulphur dioxide^{xliiv}, 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.

ADVANTAGES OF ACID RAIN

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.^{xlv} 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 percent 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 gauging the emission level of methane, found that its emission was significantly suppressed due presence of sulphate. All experimental sites displayed 30 to 40 percent 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 percent global warming which is caused due to human activities.

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.^{xlvi} 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.

RELATIVE POSITIONS OF VARIOUS COUNTRIES ON ACID PRECIPITATION

A. THE INDIAN POSITION

India, a fast developing economy, got into the race of industrialization in the early fifties. The large-scale industrial growth and reliance on the use of coal and crude oil distillates like diesel have led to increases acidification of the atmosphere. As a result of pollution due to industries, INDIA faces an increasing threat from acid rain earlier believed to be the scourge of the West. Scientists then were somewhat aware of the manifestation of air pollution originating from industrialization resulting in the rain water acidity. Scanty efforts to monitor acid rain started in 1950s. Mukharjee documented the hydrogen ion concentration of monsoon rainwater at Calcutta. It was observed that there was no factory to the south or south-west of the site since prevailing wind at Calcutta was southerly. It was established that natural rainwater has a pH of 5.7 due dissolved CO₂ in water scavenged from air/atmosphere. Sulphur dioxide emissions were reported in 1979 to have nearly tripled in India since the early 1960s, making them only slightly less than the then-current emissions from the Federal Republic of Germany.^{xlvi} The effects of acid rain have been recorded in parts of the United States, the late Federal Republic of Germany, Czechoslovakia, Netherlands, Switzerland, Australia, Yugoslavia and many other Euro zone countries. It is also becoming a significant problem in Japan^{xlvi}, China^{xlvi}, Korea¹ and in Southeast Asia as well.

The Ministry of Environment and Forest, Government of India, has been continuously trying to lessen down the causes and prevent sever damages from being caused because of acid rains. It identifies fossil fuel combustion and biomass combustion as one of the major contributors^{li} of acid precipitation. Therefore Ministry of environment and forests has been asked to go for proposed emission guidelines for sulphur dioxide and oxides of nitrogen. It says that the existing emission standards for particulate matter in India are higher (150 mg/m³) than the proposed World Bank (WB) standards of 50mg/m³. Alternatively, World Bank guidelines propose that particulate removal efficiency should be designed for 99.9 percent if 50 mg/m³ are not achievable and operated at least at 99.5 percent efficiency. With rapid industrialization, and keeping cumulative effects of the different activities in mind, improvement of existing ESP may be the viable options where adequate and appropriate space is available. This includes increasing plate area, widening plant spacing, and providing flue gas conditioning through the addition of moisture, SO₃ or NH₃ and retrofitting technology. Similarly, there is a lack of experience in operation and maintenance of bag house in India. But, bag house would be the most cost effective solution for stipulated WB standard of 50 mg/m³.

The existing SO₂ emission level in India is not expected to lead to major increase in ambient SO₂ concentration. But, with further industrialization in India and increase in power generation, local impacts of SO₂ and sulphate on health and long range transport-acidification and visibility, SO₂ emission will also be an important issue and concern in the country. At the moment, the typical SO₂ emission levels for thermal power plants in India are lower than the recommended World Bank guidelines. NO_x has been recognized as one of the major pollutants of power generation. NO_x like SO₂ is responsible for acid rain. NO_x also take part in number of chemical reactions with hydrocarbon present in urban air to produce toxic pollutants like ground level ozone. At present,

emission guidelines prescribed for NO_x in India is even more stringent than the proposed World Bank guidelines.

JUDICIAL DECISIONS IN INDIA

A. *M.C. Mehta (Taj Trapezium Matter) v. Union of India*^{lii}

This was one of the most recent cases decided by the apex court in India on the matter pertaining to acid rains. The contention of the petitioners was that the foundries, chemical/hazardous industries and the refinery at Mathura are the major sources of damage to the Taj Mahal. The Sulphur Dioxide emitted by the Mathura Refinery and the industries when combined with Oxygen with the aid of moisture in the atmosphere forms sulphuric acid called 'Acid rain' which has a corroding effect on the gleaming white marble. Industrial/Refinery emissions, brick kilns, vehicular traffic and generator-sets are primarily responsible for polluting the ambient air around Taj Trapezium (TTZ). The petition states that the white marble has yellowed and blackened in places. It is inside the Taj Mahal that the decay is more apparent. Yellow pallor pervades the entire monument. In places the yellow hue is magnified by ugly brown and black spots. Fungal deterioration is worst in the inner chamber where the original graves of Shah Jahan and Mumtaz Mahal lie. According to the petitioner the Taj Mahal -- a monument of international repute -- is on its way to degradation due to atmosphere pollution and it is imperative that preventive steps are taken and soon. The petitioner has finally sought appropriate directions to the authorities concerned to take immediate steps to stop air pollution in the TTZ and save the Taj.

The Supreme Court appreciated the efforts of the *Varadharajan Committee*,^{liii} also citing the case of *Vellore Citizens Forum*^{liv} for the protection of the environment, and in the preparation of the Report called the Report on Environmental Impact of Mathura Refinery, which had identified the presence of sulphur dioxide as a potential danger to the environment^{lv}. It was pointed out that there is substantial level of pollution of sulphur dioxide and particulate matter in the Agra region. The possible sources are all coal users consisting of two power plants, a number of small industries mainly foundries (approximately 250) and a Railway Shunting Yard. As far as suspended particulate matters are concerned, because of use of coal, contribution will be substantial. Even though the total amount of emission of SO₂ from these sources may be small, on account of their proximity to the monuments, their contribution to the air quality of the zone will be considerably high. The Court also considered the publication of Central Board for the Prevention and Control of Water Pollution, New Delhi, called (Control of Urban Pollution Series CUPS/7/ 1981-82) under the title Inventory and Assessment of Pollution Emission in and around Agra-Mathura Region, and also the National Environment Engineering Research Institute (NEERI) which gave an 'Overview Report'^{lvi} regarding status of air pollution around the Taj Mahal in 1990.

B. *Indian Council for Enviro-Legal Action v. Union of India*^{lvii}

The High Court of Karnataka, in response to a PIL filed by the New Delhi based NGO, Indian Council for Enviro-Legal Action said that magnitude of air emissions could have an adverse impact on the biodiversity and ecology of the Western ghats through acid rain. Here again, the Court considered the findings of the Ministry of Environment and Forests which said that the daily emission upto 77 tons of SO₂ plus NO_x and various other highly poisonous gasses along with minute metal particulates, will concentrate over the western ghats only to flow down in the form of acid rain during monsoon. It accounted that air pollution emissions from industrial processes, industrial boilers and captive power facilities in industrial process and vehicles may overload the air dispersion capability and subsequently accumulate beyond the ambient air quality standards and carrying capacity of the region.

***C. Municipal Council, Tonk v. Serve Seva Sansthan Tonk*^{lviii}**

The Court discussed the potential dangers being caused to the human health. It said that air pollution can affect the earth's heat balance, wind can transport pollution many miles from its source, causing such effects as acid rain, and inversions can cause pollutants to accumulate in an area in dangerous concentrations. The presence of substances in the ambient atmospheres, resulting from the activity of humans or from natural processes, cause adverse effects to the environment. It makes interference with the comfortable engagement of life. Air pollutants enter the body through respiratory system. Cleaning mechanism for the lungs brings some particles upto where they are swallowed or expelled. These toxic substances are injurious to human health.

THE INTERNATIONAL SCENARIO

Since 1979 the Convention on Long-range Transboundary Air Pollution^{lix} was the first multilateral treaty that has addressed some of the major environmental problems of the UNECE region through scientific collaboration and policy negotiation for dealing with air pollutants. The Convention has been extended by eight protocols that identify specific measures to be taken by Parties to cut their emissions of air pollutants. It aimed initially at reducing the effects of acid rain through control of the emissions of sulphur, its scope was later widened to include nitrogen pollutants, volatile organic compounds and photochemical oxidants. Heavy metals and persistent organic pollutants were subsequently also added.

A proposal for an international convention on long-range transboundary air pollution, to be adopted by countries in the ECE region, was put forward by Norway early in 1977. Then, referring to the declaration of the 1972 UN Conference on the Human Environment in Stockholm, saying that states have an obligation to ensure that activities carried out in one country do not give rise to environmental damage in others (Principle No. 21), the Scandinavian countries jointly presented a draft for a convention. After some hard negotiating, the Convention on Long-range Transboundary Air Pollution (CLRTAP) was signed in Geneva in November 1979 by all of the thirty-five countries that were then members of ECE. After ratification by twenty-four of the signatories, it came into force in March 1983. More countries have since acceded, bringing the total number of parties to the Convention (in 2003) to forty-nine.^{lx}

The Convention does not in itself call for any binding commitments to undertake concrete measures for the reduction of specific pollutants. The text only says that countries shall 'endeavour to limit and, as far as possible, gradually reduce and prevent air pollution,' and that, in order to achieve this, they shall use 'the best available technology which is economically feasible.'

A. POSITION OF UNITED STATES OF AMERICA AND CANADA

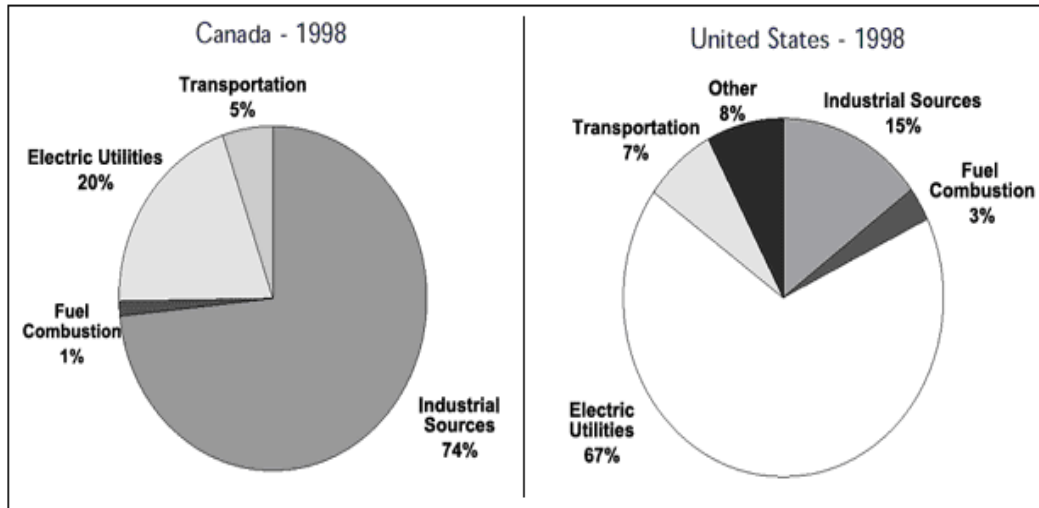
The American legislature passed 13 bills to which it gave positive environmental ratings in 2000, compared with two in 1999.^{lxi} Major legislation enacted in 2000 included a pesticide notification law, an attempt to limit acid rain in New York by restricting the sale of sulphur dioxide.

***THE CLEAN AIR ACT, 1991 (CAA)*^{lxii}**

Title IV^{lxiii} of the Clean Air Act set a goal of reducing annual SO₂ emissions by 10 million tons below 1980 levels. To achieve these reductions, the law required a two-phase tightening of the restrictions placed on fossil fuel-fired power plants.

Phase I began in 1995 and affected 263 units at 110 mostly coal-burning electric utility plants located in 21 eastern and mid-western states. An additional 182 units joined Phase I of the program as substitution or compensating units, bringing the total of Phase I affected units to 445. Emissions data indicate that 1995 SO₂ emissions at these units nationwide were reduced by almost 40percent below their required level. Phase II, which began in the year 2000, tightened the annual emissions

limits imposed on these large, higher emitting plants and also set restrictions on smaller, cleaner plants fired by coal, oil, and gas, encompassing over 2,000 units in all. The program affects existing utility units serving generators with an output capacity of greater than 25 megawatts and all new utility units.



The Act also called for a 2 million ton reduction in NO_x emissions by the year 2000. A significant portion of this reduction has been achieved by coal-fired utility boilers that will be required to install low NO_x burner technologies and to meet new emissions standards. The Clean Air Act is the comprehensive federal law which regulates air emissions from stationary and mobile sources. This law authorizes the U.S. Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) to protect public health and the environment.^{lxiv}

A. ACID RAIN PROGRAM: Empowered by the Act, the Executive started the Acid Rain Program which was implemented through an integrated set of rules and guidance designed to accomplish three primary objectives:

- Achieve environmental benefits through reductions in SO_2 and NO_x emissions.
- Facilitate active trading of allowances and use of other compliance options to minimize compliance costs, maximize economic efficiency, and permit strong economic growth.
- Promote pollution prevention and energy efficient strategies and technologies.

Together these measures ensure the achievement of environmental benefits at the least cost to society.

B. EMISSIONS MONITORING AND REPORTING: Under the Acid Rain Program, each unit must continuously measure and record its emissions of SO_2 , NO_x , and CO_2 , as well as volumetric flow and opacity. In most cases, a continuous emission monitoring (CEM) system must be used. There are provisions for initial equipment certification procedures, periodic quality assurance and quality control procedures, recordkeeping and reporting, and procedures for filling in missing data periods. Units report hourly emissions data to EPA on a quarterly basis. This data is then recorded in the Emissions Tracking System, which serves as a repository of emissions data for the utility industry. The emissions monitoring and reporting systems are critical to the program. They instill

confidence in allowance transactions by certifying the existence and quantity of the commodity being traded and assure that NO_x averaging plans are working. Monitoring also ensures, through accurate accounting, that the SO₂ and NO_x emissions reduction goals are met.

C. PENAL LIABILITY: If annual emissions exceed the number of allowances held, the owners or operators of delinquent units must pay a penalty of \$2,000 (adjusted for inflation) per excess ton of SO₂ or NO_x emissions. In addition, violating utilities must offset the excess SO₂ emissions with allowances in an amount equivalent to the excess. A utility may either have allowances deducted immediately or submit an excess emissions offset plan to EPA that outlines how these cutbacks will be achieved.

D. LICENSES AND PERMITS: The Designated Representative for each source is required to file an acid rain permit application for the source and a compliance plan to the Title V permitting authority for each affected unit at the source. The Acid Rain permits and compliance plans are simple, allow sources to fashion a compliance strategy tailored to their individual needs, and foster trading. For example, they allow sources to make real-time allowance trading decisions through the use of automatic permit amendments. Acid rain permits, which are also issued by the relevant Title V permitting authority, require that each unit account hold a sufficient number of allowances to cover the unit's SO₂ emissions in each year, comply with the applicable NO_x limit, and monitor and report emissions. Permits are subject to public comment before approval.

B. POSITION OF UNITED KINGDOM

It was perhaps felt in parts of the UK government that the problem of air pollution was resolved with the introduction of the 1956 and 1968 Clean Air Acts. As is now well appreciated, by using a policy of dispersal in preference to reduction, the building of higher smoke stacks to broadcast the pollution merely passed it on to someone else. In 1982, aware perhaps of mounting concern but unwilling to jump into as yet weakly founded precautionary action, the government reversed a previous decision to cut acid rain research funding. The anticipated release later that year of a Department of Environment preliminary report on acid rain may have acted as an additional incentive for prior government action, albeit small. The final release of the UK Review Group on Acid Rain Report^{lxv} showed the first significant evidence of acid deposition in the UK.

Prerequisite to any acid deposition is a source of pollutants, to which the UK contributed significantly. The UK government, and in their shadow, the Central Electricity Generating Board, subscribed to the common line of denial of acid rain, demanding more research before taking binding decisions. Lacking a history of precautionary action prior to evidence, various arguments were put forward to justify minimum action, such as nitrogen oxides from transport being more significant than gases from electricity generation and that abnormal fish mortality in lakes of Norway, Wales, Scotland and Sweden was caused by aluminium leaching from soils, not acid rain. Whilst most other European countries were subscribing to cuts of at least 30 percent of existing emissions, the '30 percent club', in accordance with the LRTAP Convention (ECE, 1979), the UK remained unmoved. In 1984 sulphur deposition in the UK stood at amongst the highest levels in Europe being ranked 5th out of 14 countries sampled (Park, 1984), and yet, in this same survey, of the total UK deposition, little of it was imported. The UK was 80 percent self sufficient in acid pollutants.

In contrast, Scandinavian countries received the highest proportion of imported acid deposition and whilst the actual amount of pollutant was much less than the UK, the igneous geology and thin drift deposits meant that little buffering capacity existed. This contrasted with the calcareous chalk and

limestone scenery that is found throughout large parts of the UK which significantly reduce the effect of any acid deposition. The combination of the high cost of retro fitting pollutant reduction systems to power stations and the lack of visible environmental impact in the UK were probably the single main reasons why the government at the time was so persistent in following the hard cause - effect policy instead of the precautionary principle adopted by many others. As scientific evidence of acid rain mounted, along with pressure from countries receiving most acid rain damage, in 1986 the British government admitted that UK sulphur emissions from fossil fuel power generation was causing acid rain in Norway. Despite this, the UK was slow to complete ratification of the LRTAP Convention. Although ultimately the UK did ratify most parts of the treaty, the formal undertaking to reduce sulphur was still outstanding in 1998 (Acid Rain, 2001).

The UK handling of the acid rain situation shows typical British lethargy in this field which is endemic in some other industrialized nations, notably the United States. 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. The acid rain scenario is repeated and magnified in the case of CO₂ emissions and the suspected anthropogenically induced enhanced greenhouse effect. At a stroke, an incoming US president is able to abandon moves towards a tentative acceptance of the enhanced greenhouse effect, on the basis that it is not scientifically proven. Under this cover, the familiar ugly story is manifest, that the new administration is heavily sponsored by the fossil fuel industry who, understandably do not want to see change. Ironically, this same industry is ensuring it enacts its own form of precautionary principle by opening up research into renewable energy sources. Let us hope that the energy change is not too late.

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 surface of earth they do not cause damage just to the environment but also impact humans, plants, and monuments to a great extent. 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. Indian Government have passed laws^{lxvi,lxvii,lxviii,lxix,lxx} to reduce pollution and 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.

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^{lxxi}, 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. With the rapid economic development and energy consumption throughout the world, fossil fuel consumption has increased significantly during the last few decades. Use of fossil fuel is the major cause of large-scale generation of acid precursors in the atmosphere. Earlier it has been identified as the problem of developed countries, but with increased industrialization and urbanization developing countries are also facing this problem. Acid rain is the result of many steps of chemical reactions between air borne pollutants (sulphur and nitrogen compounds) and atmospheric water and oxygen. 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. Acid rain problem has been tackled to some extent in the developed world by reducing the emission of the gases causing acid rain. Such efforts need to be done in developing world particular so by BRICS nations or fast developing economies so as to avoid the magnitude of potential of problem as faced by industrialized world.

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