Acid rains and atmospheric depositions-an environmental hazard.

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SUMMARY

Acid rain and atmospherrc depositions has become one of the major environmental problems during past recent years It is a challenge to scientist and technocrats all over the world. The most common acid rain and atmospheric deposition includes sulphuric acid and nitric acids. Fossil fuel power plants. various industries and automobile industry emits large quantities of acid forming pollutants which can travel hundreds of miles from source to deposition. However, if acid precipitation is allowed to continue at the present rate, by far the greatest impact on humans will be in the deterioration and loss of lakes, and forests and their associated economic, ecological and aesthetic values. It is very essential to control the emissions of acid forming nitrogen and sulphur compounds to avoid far more serious problems in the future.

INTRODUCTION :

Everyone realizes how important the rain is. Without it the continent would be barren. The rain, brings a scene of hope, vitality and a promise for the future. The natural rains mixes with pollutants, in atmosphere polluted with oxides of nitrogen and sulphur, emitted from power plants, industries, auto exhaust and other fossil fuel combustion process and upset the natural ecobalance. The natural rains and snow react with the oxides of pollutants (nitrogen and sulphur) to produce precipitation (in acidic pH range) to bring down their respective acids i.e. nitric acid and sulphuric acid, to the earth surphace. What we refer to as acid rain and acid precipitation (Fig 1).

In the absence of any pollution, the pure rain fall is naturally slightly acidic, having a pH value around 5.6, and this is because carbondioxide, present in the atmosphere readity dissolve in and combines with rain water to produce a weak acid, known as carbonic acid (Fig. 2), which further dissolves minerals present in the earth's crust, making them available to flora and fauna, yet not acidic enough to cause damage. Other atmospheric substances from volcanic eruptions, forest fires and similar natural phenomenon also contibute to the natural sources of acidity in rain, but even then the natural rainfall is able to assimilate them to the point where they cause little if any, known damage. It is mankind's contribution, which throw off artificial acidic substances in the atmosphere, distrubing the natural ecobalance to convert the natural and mildly acidic rain into precipitation with far reaching environmental effects. The acid precipitation that is of concern is that rain or snow, sleet or bails with a pH value below 5.6. The main components of acid rain are nitric acid and sulphuric acid with traces of other acids.

Acid precipitation now is recognised as an international problem. The air of industrial towns, emitted partly by chimneys of factories, which push the pollution high into the atmosphere, making the things, better locally by dispersing the pollutants, but aggravated the international difficulties. The sulphur and nitrogen compounds emitted as a result of burning fossil fuels can be blown thousands of kilometers by the winds, to cause acid rain in countries far from their points of origin.

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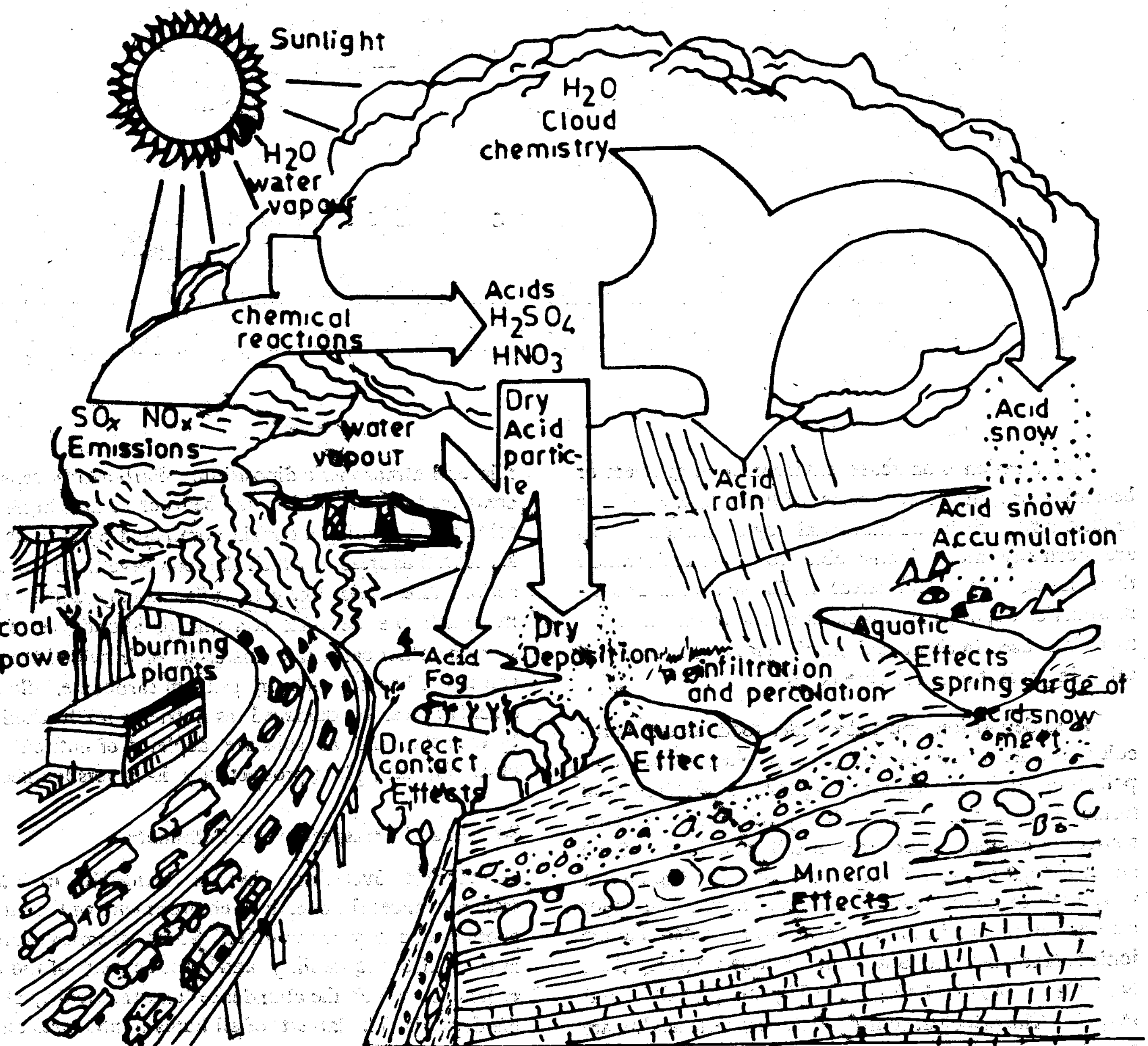

Fig.1: Processess and environmental effects of acid precipitation

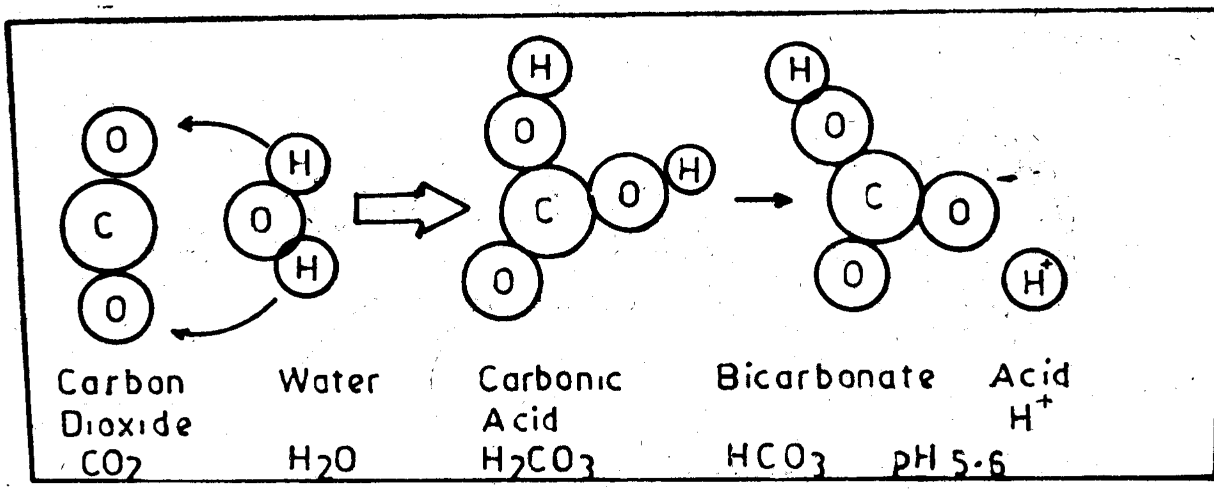

Fig. 2: Reaction of carbon dioxide with water, produces a weak acid.

Aeidification is an acute environmental problem or becoming one, in various parts of the world, especially around large urban and industrial coglomerations. Soils are normally much better able to resist acidification than lakes, rivers and streams. The acid rains and atmospheric depositions accelerates corrosion in most materials used in construction of historic buildings and other important cultural objects.

Acid deposition must be understood as one particular manifestation of the general phenomena of air pollution and atmospheric deposition. Precipitation formed in an atmosphere relatively free from man made sources of contamination theoritically would vary from about pH 4.8 to pH 6.5 depending on the amount of CO_2 and other substances dissolved in air. The major cations and anions in precipitation which determine the ionic balance and resultant acidity include H^+, NH_4^+, K^+, Na^+, Ca^{++}, Mg^{++}, HCO_3^-. SO_4^{--}, NO_3^-, Cl^- and PO_4^{---}. The principal sources of atmospherie acidity are emissions of sulpher and nitrogen oxides which interact with moisture in the atmosphere to give high concentrations of H^+, SO_4^{--} and NO_3^-. Emissions of NH_3 and NH_4^+, although neutralizing the acidity in air and precipation, become acidifying after they are deposited into terrestrial and aquatic ecosystems.

Geology, Climate and Acid Rain :

Geology, Climatic patterns as well as types of vegetation and soil composion all affect potential impact of acid rain and atmospheric diposition. Particularly sensitive areas are those in which the bedrock cannot buffer the acid rain, including a terrain dominated by granitic rocks, as well as areas in which the soils have little buffering action. Areas least likely to suffer damage will be those in which the bedrock contains an abundance of lime stone or other carbonate material or in which the soils contain a horizon rich in calcium carbonate. Soils in sensitive areas are damaged as nutrients are leached out by the acid, and as soils are depleted of nutrients and other minerals, plant productivity is adversily affected.

Sources and Transport of Air Pollutants :

Almost everything human beings do on a large scale influences the chemical environment of the atmosphere in one way or the other. These chemical changes in turn affect the stability and productivity of the ecosystems on which the abundance and the quality of our life depends. The largest of all human influences on the chemical environment are combustion of fossil fuels, urban development and the cleaning of forest to make way for agriculture.

Human activities of various type are changing the chemical climate of atmosphere day by day. Some of these changes are beneficial for agriculture and forestry because they provide valuable nutrients for the growth of crops and trees or accelerate the natural weathering of soil minerals. On the other hand, other changes are detrimental because they cause stress in plants and animals, alter water quality, aggrevate nutrient deficiencies in soils, or accelerate the natural weathering or corrosion of man made structure and materials.

In industrial regions, these activities include the generation of electricity, mining and smelting of metals, industrial processes of many kinds, use of transportation vehicles, space and water heating, incineration and decomposition of sanitary and solid wastes, use of explosive devices in peace and war, launching of space vehicles, land cleaning and land disposal and industrial and urban wastes and agricultural and silvi cultural operations including plowing, planting, cultivating, spraying, disposal of plant and animal wastes and the burning of farm and forest residues.

Deposition of substances/pollutants from the atmosphere into ecosystems is accomplished by one or more of the following three processes :

1. Absorption or adsorption of gases from the air.
2. Gravitational settling and impaction of coarse fly ash and dust particles as well as fine aerosols, and
3. Wet fall out of substances dissolved, suspended, or adsorbed in rain drops, snow flakes, dew, fog droplets, and hail or frost particles.

Processes 1 and 2 are component parts of so-called dry deposition while the process 3 includes all forms of wet deposition including rain, snow, dew, fog and frost.

Gaseous emissions of sulphur and nitrogen oxides resulted from the combustion of fossil fuels are the principal man made sources of acidifying substances in the atmosphere. These materials, which are emitted mainly from power plants, smelters, industrial boilers and transportation vehicles are deposited wherever they are carried by winds, over urban, industrial, rural, and remote areas.

The distance of transport of gaseous emissions leading to wet and dry deposition of acidic and acidifying substances varies from only a few to several hundred or even a thousand kilometers or more. In general the amount of atmospheric deposition in any given r gion is inversely proportional to the distance from major sources, although very strong winds and tall stacks cause some deviations from this generalisation.

Substantial vertical and horizonal mixing of air pollutants from many different and geographically separate sources occurs during transport over long distances. Thus, the direction of transport often is not the same as the direction of so-called prevailing winds. All emissions of sulphur and nitrogen oxides return to the surface of the earth either over the continents or over the oceans. It is now generally accepted that regional changes in emissions of sulphur and nitrogen oxides will result in corresponding changes in amounts of dry depositions. The extent of expected deviations from linearty for wet deposition will probably vary inversely with distance from major emission sources and directly with the density of emission sources.

Effect of Acid Precipitation on Eco-System :

Significant quantities of plant nutrients, including nitrogen and sulphur, are added to soil in dry deposition and in precipitation. These atmospheric inputs of beneficial nutrient elements are especially important in forests and rangelands, where nutrients from other sources are scarce and fertilization by man is not a normal management practice. Short term fertilization effects due to atmospheric deposition of ammonia and nitrate offset long term nutrient leaching and other detrimental effects of acld precipitation on forest ecosystems. Negative effects on forest growth are most likely when nut ient deficiencies or imbalances are increased by acid deposition (Fig.-3).

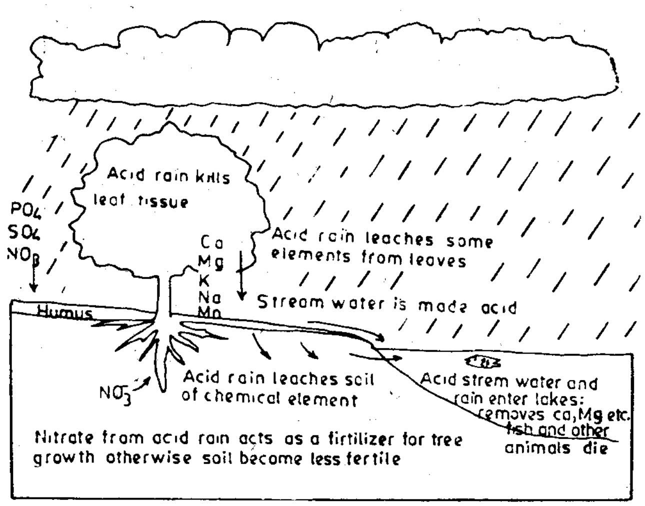

Fig-3: The Ecological Effects Of Acid Rain

Whether the net effect of atmospheric deposition is beneficial or injurious to plants and animals depends on the chemical composition of the deposition (wet and dry), the duration and intensity of deposition episodes, the species and genetic characteristics of the organisms on which the substances are deposited, and physiological condition, structure and stages of maturity of the organisms.

Impact on Aquatic Ecosystems :

The most straight forward impact of acid precipitation on aquatic ecosystems is a decrease in pH. Different species within a lake have differing sensitivies to pH. Dropping pH from 7 to 6 may alter community composition as some species find it more difficult to compete, a few species may be eliminated, but there is still is a complex, healthy ecosystem. As pH drops to 5.0, a large number of species is eliminated and others are placed under increasing stress. As pH drops towards 4.0 virtually all organisms die off except certain species of algae that cover the bottom and grow along the edges (Fig. 4).

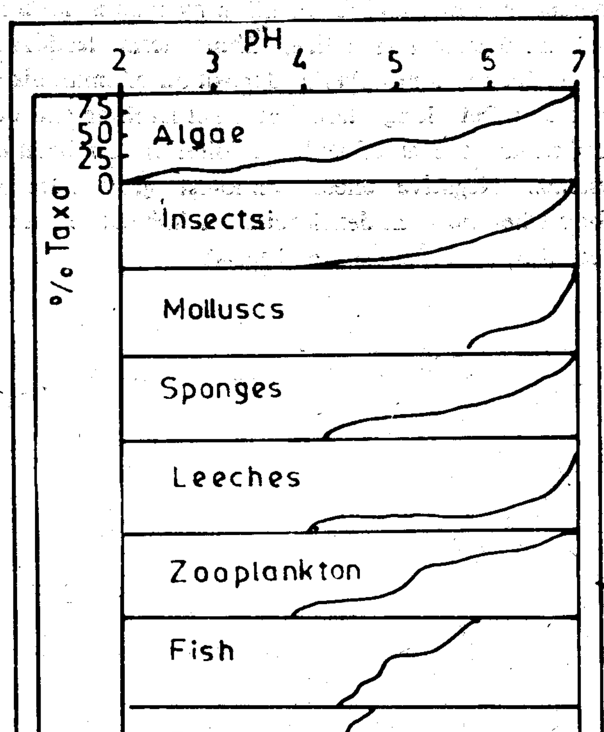

Fig.4: Effect of pH on the survival of various organisms.

Acids and other soluble substances containcd in polluted snow are released quickly over a short period in the spring, when the snow melts. Tne resulting release of pollutants can cause major and rapid changes in acidity and other chemical properties of stream and lake waters, making a bad situation worse, this pH drop coincides with the time many fish, frogs and other organisms spawning and their eggs and developing youngs are most vulnerable imputs into aquatic ecosystems. A second cause of dieoffs of fish and other organisms in water with a normal pH has been traced to increased concentrations of certain cations-notably Al^{+++} in acidified lake and stream waters. Aluminium compounds vary greatly in toxicity to fish and other aquatic life, causing numerous abnormalities in the development of embryos. In general, ionic forms of aluminium ore more toxic than organic complexes of aluminium. Aluminium is an extremely common element, substantial quantities are present in many rock and soil minerals. Normally, these minerals are very insoluble and thus harmless, but unaer the attack of acid they break down and release the Al^{+++} in to solution. The process is frequently referred to as mobilisation. Other toxie elements such as lead and mercury may also be mobilized as well. Synergistic interactions between toxic elements and low pH may also occur. The loss of wild life does not stop with the die off of fish and other aquatic organisms. Through the complexity of food web, nearly all wild life depends atleast to some extent on the productivity of lakes. The buffering capacity of the lake play an important role for adjusting the pH of the lake water. If the water shed (the land area draining into a lake) contains adequate lime-stone, most of the water entering the lake will be well buffered and the pH will be maintained. However, in the absence of buffering minerals, the lakes may quickly turn acidic. In short, it is found that lakes that still support healthy ecosystems despite acid precipitation have adequate buffering capacity and those lacking in this capacity have become acidic.

Impact On Forests And Agriculture :

India's abysmally low forest cover could create an environmental imbalance with adverse consequences and further the Impact of acid precipitation on forests and agriculture may also be severe. In certain industrial regions of the world, substantial damage to crops is caused by dry deposition of toxic gases. SO_2, O_3, NO_x F^-, and HCl cause serious economic damage to crops and forests, this must be considered together with the possib'e effects of acid deposition. Simulate acid rain studied in green houses, shows that the acid damages the cuticle, the wax like protective layer of leaves, making plants more vulnerable to attack by insects, fungi, or other plant pathogen as well as reduce the rate of photosynthesis. This effect may be particularly severe when crops and forests exposed to intensely acid fogs or the accumulation of dry acid deposition. The studied conducted on water draining from various natural areas under different conditions indicated that acid precipitation greatly increases the leaching of nutrient. Hydrogen ions H^+ effectively displays nutrient ions from their places in the soil and humus. In addition, low pH also retards the activity of decomposers and nitrogen fixing bacterias, causing even further nutrient shortages. Finally acid precipitation washing over vegetation has been shown to leach nutrients and other metabolities from leaves. In all, the acid precipitation may cause nutrient defficiencies in a number of ways, which are responsible for the reduced growth of the plant kingdom. Many plants are highly sensitive to certain cations e.g. Al^{+++}. The mobilization of aluminium and certain other elements may thus have a serious toxic effect on terrestrial plants as well as on aquatic organisms. e.g. mushrooms, mosses, lichens and other lesser vegetations in the forest accumulate heavy metals from the atmosphere, especially lead and cadmium, and wild life feeding of those plants accumulate these metals and thus both plants and wild life can be hazardous for human consumption. The major cause of concern is the fact that all of these acid related effects may intensify with precipitous suddenness as buffering capacities are exhausted. As a result of rapid dieback of plants, changes occur in forests, one can surmise the effect on other wild life populations. If a sudden collapse of the forest ecosystems occurs, the ramifying effects of soil erosion, sedimentation of water ways, flooding, and deterioration of water supplies will be catastrophic (Fig. 5).

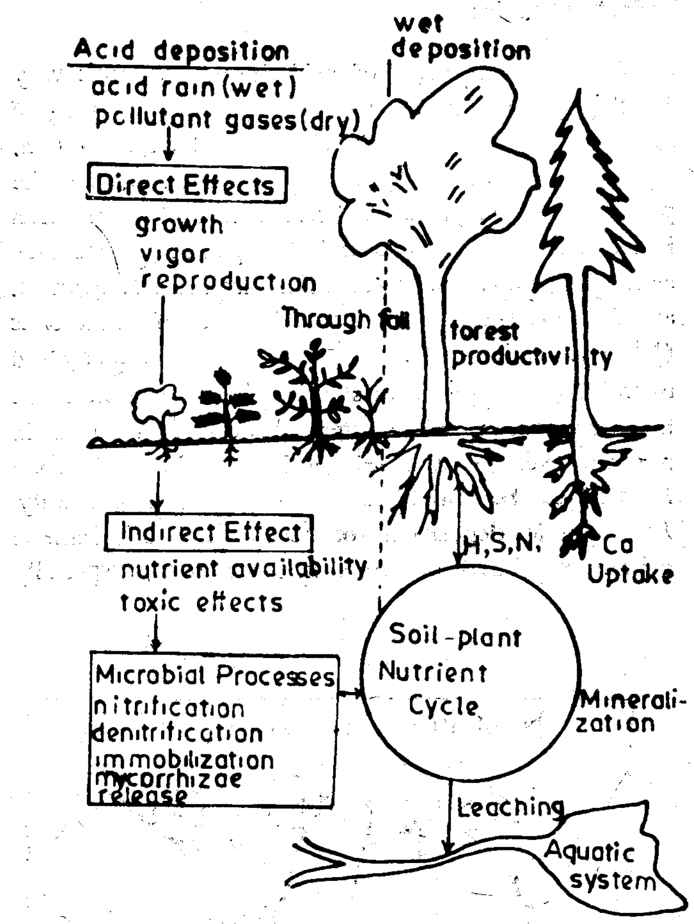

Fig. 5: Key components and processes to be cnsidered in evaluating effects of acid rain deposition on forested ecosystems.

Impacts on Materials :

The impact of acid precipitation on materials was the first effect observed, and this impact has not dimished, but increasing day by day. Lime stone and marble are favoured materials for the outside of buildings and monuments, and these materials react readily with acid rain and deposition converting them into soluble calcium, i. e. erosion of these materials takes place at a tremendously accelerated pace. Monuments and/or buildings that stood for hundreds of years with little change are now literally dissolving and crumbling very fast. Concreate also contains lime, and acid precipitation may be hastening the deterioration of roadways and bridges, however, roads salt seems more significant in this regard. Acid precipitation and deposition also have a negative impact on paint and they accelerate the corrosion of metals including iron, steel and various other non-ferrous metals and soil, disfigure and damage building material. It also affect electrical equipments including transmission lines and contacts, thereby increasing the maintenance cost of distribution system.

Impacts on Soils :

The consequences of acid inputs to soils vary greatly, depending on the rates and recent history of atmospheric acid inputs, the character of the vegetation, natural rates of acid formation in the soil, and the physico-chemical properties of the soil. Soil acidification increases leaching of exchangeable plant nutrients such as calcium, magnesium, potassium, iron and manganese, and increases the rate of weathering of most minerals (Fig. 6). Acidification decreases the rate of many soil microbiological processes such as nitrogen fixation and breakdown of organic matter. Processes important in nutrient cycling, and critical in most ecosystems are known to be inhibited by increasing soil acidity. Atmospheric deposition of heavy metals also inhibits certain microbial processes in forest litter, especially decomposition of organic matter. Acidification of soils reduces the availability of phosphorus to plants and increases the solubility of other elements, some of which may be toxic to plants. Aluminium is the most abundant toxic element in forest and agricultural soils. Increasing soil acidity leads to greatly increased solubility and toxicity of aluminium to many plants. Soils differ by orders of magnitude in their susceptibility to acidification. Calcareous soils are likely to damage by acid inputs, but may be affected by metal deposition. Soils with low cation exchange capacity and degree of base saturation are very susceptible to increased acidification. Large quantities of hydrogen ions are added to soils as acid precipitation, as a result of cation uptake processes and soil-amendment and fertilization practices Acidification by these processes can be controlled through normal management practices.

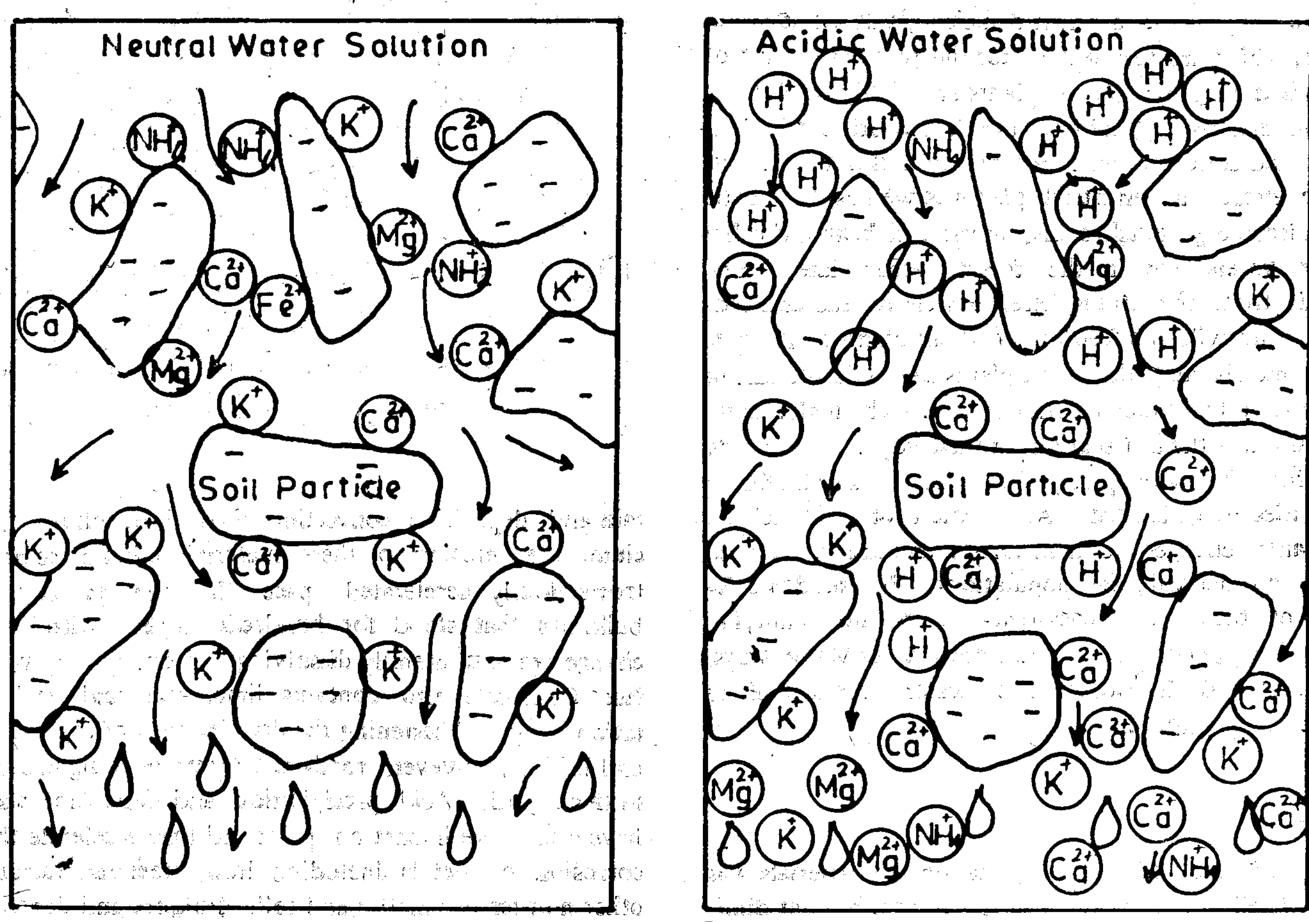

Fig-6: Leaching Of Soil Nutrients By Acid Precipitation

Impact on Water Quality :

Acid precipitation increases the solubility and mobility of many cations in soil. This increases the concentrations of toxic metal cations, including aluminium, manganese, and zinc in the soil solution. It also increases the leaching of nutrient cations, including potassium calciuum, and magnesium. These toxic and nutrient ions are transferred from soils into surface and groundwaters supplies.

Impact On Humans :

Among the various forms of pollution, air pollution is the most crucial, from the public health point of view. This is because, on an average, an individual breathes 22000 times a day, inhaling 15 kg. of air, which contribute about 80% of the daily intake by weight. It is well known that inhalation of polluted air is the major cause of breathing/respiratory problems and apart from this polluted air can cause eye irritations and even cardiovascular disorders in some peoples. In addition, evidences showed that inhalation of such particles renders lung tissues more susceptible to the carcinogenic effects of other pollutants The CO is readily absorbed by blood to form carboxyhaemoglobin, reducing the oxygen carrying capacity of blood. However if the acid precipitation is allowed to continue at the present rate, by far the greatest impact on humans will be in the deterioration and loss of lakes and forests and their associated economic, ecological and aesthetic values.

Control Strategies :

Total emissions of nitrogen and sulphur oxides can be estimated from the amounts and kind of fuels that are being used for various purposes. Therefore, the only truly practical approach to the problem lies in reducing nitrogen and sulpher emissions. Many innovative schemes have been suggested from time to time, for altering production and combustion to recovery and conversion of sulphur. The economics of such processes of course must be considered vis-a-vis the cost of damage due to acid deposition. Following are the general options for the reduction of many nitrogen and sulphur emissions alongwith other harmful pollutants.

1. **Energy Conservation** : It is related with reduced fuel consumption or more effective utilization of fuel i.e. conservation of fuel via more efficient thermal conversion processes and through improved thermal insulation processes etc.

2. **Proeesses change to a less polluting process**—A process change can be either a change in operating procedure for an existing process or the substitution through a completely different process and this can be achieved by studying the shortcomings of the existing process and to modify it as modified by developed nations of the world to derive benefits.

3. **Fuel Change** :—A change to less polluting fuel gives an ideal solution for a pollution problem e g. using natural gas instead of coal will certainly avoid SO_2 and fly ash emissions from power plants. In fact, the Indian coal used for power generation contains 0·5 to 3% sulphur and 20 to 35% ash. Similarly for automobiles, liquified petroleum gas (LPG) can be tried instead of petrol The denitrification and desulphurization of fuels or stack gases and increased use of such fuel which are having naturally low sulphur content or use of new technologies that reduces emissions are also alternative methods for reducing pollution load.

4. **Pollutants Removal** : There is no effective control of air pollution unless the pollutants put into the atmosphere are removed. Generally, filters, electrostatic precipitators, settling chambers, dust removing cyclones, collectors, and scrubbers are commonly used for preventing the pollutants from escaping to the atmosphere. These measures are quite efficient, if maintained well. Among the gas removal methods are the absorption, adsorption and condensation processes. But still, some quantity of pollutants gets released through the stack, which is the final line of defence from industrial pollution.

A number of techniques to reduce sulphur emission are already in practice and are in further developmental stages. These includes :

(i) **Pre–combustion** : In this stage, the sulphur contents are being removed prior to fuel burning and these includes the coal cleaning/washing, coal gasification and desulphurization of liquid fuels.

(ii) **Combustion** : The sulphur contents are being removed during combustion, as in fluidized-bed combustion process.

(iii) **Post-Combustion** : The sulphur emissions are being removed after combustion, as in stack or flue gas desulphurization systems or scrubbers etc.

Some of these techniques such as coal cleaning/washing, flue gas desulphurization/scrubbers and fluidized-bed combustion are in full scale use. A brief examination of each strategy leads to the conclusion that scrubbers are one of the practical solution for the near term, and acid precipitation must be controlled in the near term as well as the long term. The future of sulphur exides control from traditional fuel sources lies in the perfection of these techniques.

For reducing nitrogen emission from stationary combustion sources, the main method involves the modification of operating conditions. It may be done by reducing the combustion temperatures, because at lower flame temperature, less nitrogen is formed. Other techniques include staging combustion, preferabely controlling air, injecting water during combustion, recirculating fuel gases and alteration of design of firing chambers. Todate, the primary technique for reducing automobile nitrogen emission has been by lowering combustion temperature in the engine.

Improvement in the environment must be considered a public (voluntary) movement so that no further deterioration in our environment occurs. We must also ensure that the quality of environment improves progressively. The pollution is entirely a man made feature and as and when man stops all those activities which lead to the degradation of the environment normal conditions return. Thus there appears to be no conflict between development and environment. What is really important is awareness towards all such developmental cativities which do not affect the environment.

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