ACID RAIN

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Normal Rain (Natural Rain):

Normal unpolluted rain, though said to be consisting of almost pure water, is mildly acidic with a pH of 5.6 to 5.7. This is mainly due to the reaction of atmospheric Carbon dioxide with rainwater to produce Carbonic acid.

$$H_2O + CO_2 \rightarrow H_2CO_3$$

In addition to above, the substances generated from the natural phenomena such as volcanic eruptions, forest fires, etc also contribute to a smaller extent to the natural sources of acidity in rain.

This small amount of acidity is however, sufficient to dissolve minerals in the earth's crust and make them available to plant & animal life without causing any damage.

Acid Rain (Polluted Rain)

Over the last few decades, it is observed that, in some parts of the world, the natural rain has to pass through an atmosphere polluted with oxides of sulphur (SO_x) and nitrogen (NO_x).

The falling rain & snow react with these oxide pollutants to produce a mixture of Sulphuric acid, Nitric acid & water. This is known as acid rain / acid precipitation.

$$H_2O + SO_3 \rightarrow H_2SO_4$$

$$H_2O + N_2O_5 \rightarrow 2HNO_3$$

Chemistry of Acid Rain

Conversion of SO_x & NO_x in to H_2SO_4 & HNO_3 droplets is due to a series of chemical & photochemical reactions. These reactions are catalysed by atmospheric species (SPM) like soot particles, HCs, metal ions, etc.

Some HCl is also found in acid rain, which may be natural or manmade.

Acid droplets are partially neutralized by basic atmospheric species such as Lime, NH_3, etc.

As pH of natural rainwater is about 5.6 at 20°C, the pH of acid rain is less than 5.6.

Sulphuric Acid forming Reactions

Almost all S present in gaseous & liquid fuels and that about 80% from solid fuels appears as SO_x in flue gases with a concentration from 0.05-0.4%. In metallurgical operations it is 5-10%.

$$S + O_2 \rightarrow SO_2$$

SO_2 is oxidized to SO_3 in air by photolytic and catalytic processes involving O_3 , NO_x & HCs. Soot, dust & metal oxide particles act as catalyst.

$$SO_2 + [O] \rightarrow SO_3$$

$$H_2O + SO_3 \rightarrow H_2SO_4$$

$$n\,H_2SO_4 \rightarrow [H_2SO_4]_n$$

Nitric Acid forming Reactions

NO_x are produced by the combustion of coal, oil, NG & organic matter and thus introduced in the atmosphere from automobile exhausts, furnace stacks, incinerators, power plants, etc.

NO formation from N_2 & O_2 is favoured at high temperatures (1200-1765 ^0C).

$$N_2 + O_2 \rightarrow 2\ NO$$

NO_2 formation from NO is also favored at 1100^o C in combustion or by photolytic reactions in air.

$$2\ NO + O_2 \rightarrow 2\ NO_2$$

$$2\ NO_2 + O_3 \rightarrow N_2O_5 + O_2$$

$$H_2O + N_2O_5 \rightarrow 2\ HNO_3$$

Analysis of Acid Rain

Acid rain on analysis is found to contain the following ionic impurities:

Cations:- H^+, NH_4^+, Na^+, K^+, Ca^{++}, Mg^{++} , etc.

Anions:- SO_4^{--}, NO_3^-, Cl^- , etc.

H_2SO_4 >

HNO_3 >

HCl

Cause of Acid Rain

Acid rain is mainly due to the high extent of air pollution caused by emissions of SOx & NOx.

Industrial operations and fossil fuel combustion are the major sources of SOx & NOx emissions.

These acid forming gases are retained in the atmosphere for many days and by which time they travel several thousand kilometers.

Longer the SOx & NOx remain in the atmosphere greater the chances of their chemical / photochemical oxidation in to the H_2SO_4 & HNO_3.

Hydrogen chloride emission forms hydrochloric acid.

Acid Rain Deposition

All these acidic pollutants are deposited as under:

Wet Deposition:- Pollutants are deposited in rain & snow, hence commonly termed as Acid Rain. This happens mainly in upland areas where rainfall is high.

Dry Deposition:- Acidic gases & particulates are deposited directly into the land (soil & vegetation).

Cloud Deposition:- Acidic pollutants over the high ground are deposited in the clouds.

Consequences of Acid Rain

Acid rain causes a number of harmful effects below pH 5.1. In aquatic systems effects are visible even at pH below 5.5.

Acid rain may cause extensive damage to the material goods and territorial ecosystems such as soil, stone, water, steel, paint, vegetation, fishes and mankind.

Non-biological damage:

1. Corrosive damage:- to the metals like steel, zinc, etc, oil base paints, automobile coatings, etc

2.Potential effects:-such as decreased alkalinity, mobilization of metals like Al, on aquatic systems

Consequences of Acid Rain …cont…

3. Structural damage:- architectural monuments and structural materials of marble, limestone, sandstone, etc undergo pitting, mechanical weakening, deformation & degradation

Biological damage:

1.Foliar damage:- alteration of seed germination, leaching of leaves nutrients, damage to young growing tissues, adverse effect on photosynthesis etc seriously affect growth and survival of plants.

2. Reduction of soil productivity:- acidification of soil adversely affects soil & microbiological fauna, N_2 fixation that reduces soil productivity.

Consequences of Acid Rain …cont…

3. Damage to living beings:

- Acidification of drinking water affects badly the human health. Acidification of soil increases the metal ions (Al, Hg, Mn, Zn, Pb, etc) concentration in water that affects lungs, skin, hairs, etc
- Increased acidity seriously affects Aquatic biota, causing decrease in productivity of fishes, amphibians, invertebrates, vegetation, etc. Species composition is affected, skeletal deformities are caused, mortality is increased.

Extent of damage depends upon the factors such as climate, topography, geology & human activity.

EFFECTS OF ACID RAIN

· It causes deterioration of buildings especially made of marble *e.g.* monuments like Taj Mahal.

· It damages stone statues. Priceless stone statues in Greece and Italy have been partially dissolved by acid rain.

· It damages metals, rubber and car finishes.

· It damages foliage & weakens trees. It makes trees more susceptible to stresses like cold temperature, drought, etc.

· Aquatic life especially fish are badly affected by lake acidification. Aquatic animals suffer from toxicity of metals such as Al, Hg, Mn, Zn, Pb, etc that leak from surrounding rocks due to acid rain.

ACID RAIN: control measures

- De-sulphurization and De-nitrification of fossil fuels used in the industries and power plants
- Reduction in SOx & NOx emissions by making use of pollution control equipments in industries and power plants
- Liming of lakes and soils to neutralize the acid
- Coating of protective layer of inert polymer on the interior of water pipes used for supply of drinking water
- Use of alternative energy sources.