economically viable. . ... nuclear power plants are still not

10.1.5 Acid Rain

It has been mentioned in the preceding section that much of the NO_x and SO_x entering the atmosphere are converted into HNO_3 and H_2SO_4 respectively. The detailed photochemical reactions in the atmosphere are summarized:

$$NO + O_3 \rightarrow NO_2 + O_2 \quad (31)$$

$$NO_2 + O_3 \rightarrow NO_3 + O_2 \quad (32)$$

$$NO_2 + NO_3 \rightarrow N_2O_5 \quad (33)$$

$$N_2O_5 + H_2O \rightarrow 2HNO_3 \quad (34)$$

HNO_3 is removed as a precipitate or as particulate nitrates after reaction with bases (NH_3, particulate lime).

$$SO_2 + \frac{1}{2}O_2 + H_2O \xrightarrow[\text{Soot particles (metal oxide)}]{(HC,\ NO_x)} H_2SO_4 \quad (35)$$

The presence of hydrocarbons and NO_x steps up the oxidation rate of the reaction. In water droplets, ions such as Mn(II), Fe(II), Ni(II) and Cu(II) catalyse the oxidation reaction. Soot particles are also known to be strongly involved in catalysing the oxidation of SO_2.

HNO_3 and H_2SO_4 combine with HCl from HCl emission (both by natural and anthropogenic sources) to generate acidic precipitation which is widely known as *acid rain*. Acid rain is now a major pollution problem in some areas.

Acid rain causes extensive damage to building and sculptural materials of marble, limestone, slate, mortar, etc. These materials become pitted and weakened mechanically as the soluble sulphates are leached out by rainwater.

$$\underset{\text{Limestone}}{CaCO_3} + H_2SO_4 \rightarrow CaSO_4 + CO_2 + H_2O \quad (36)$$

In Greece and Italy, invaluable stone statues have been partially dissolved by acid rain (Fig. 10.8). The Taj Mahal in India faces the same fate at present.

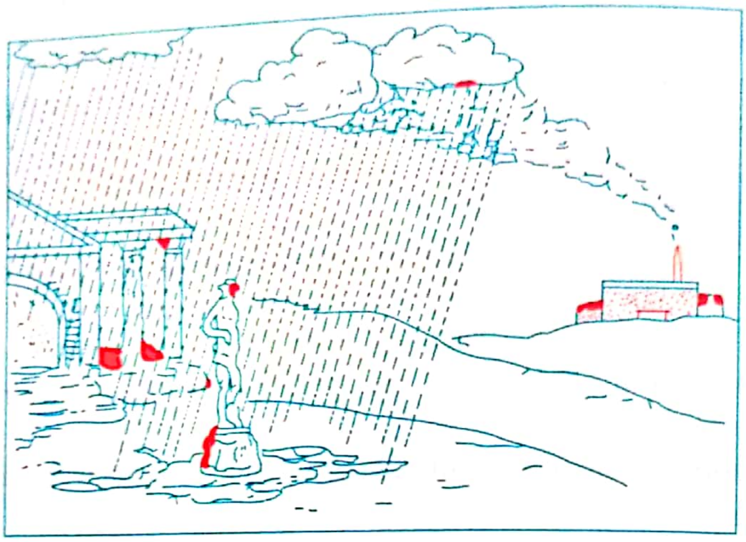

Fig. 10.8 Acid precipitation causes severe damage in some areas. Priceless stone statues have been partially dissolved by "acid rain" in Greece and Italy. (Reprinted by permission of Brooks/Cole Publishing Company, Monterey, California 93940, USA from *Environmental Chemistry* 3rd edn., S.E. Manahan, p. 326, 1979, Willard Grant Press, Statler Office Building, Boston, Massachusetts)

In 1958, rain in Europe showed a pH of 5.0, but by 1962 it was 4.5 in the Netherlands. Sweden experienced rainfall at pH 4.5 in 1966. The acid rain damaged leaves of trees and plants and retarded the growth of Swedish forests. It may be noted that these forests are important natural resources for production of wood pulp, paper and board. In 1979, it was estimated that 20,000 lakes of Sweden were suffering loss of flora and fauna—the fish mortality was increasing. The pollution sources were emission from UK, the Ruhr and Germany. The sulphur emission rate for Europe was up to [illegible] metric tonnes per year. H_2SO_4 and particles of Cd and Pb are deposited on the winter snows and when these melt, the pollutants enter the rivers and lakes. This occurs at a time when fish spawning and hatching occur thereby destroying the fish eggs.

It is intriguing that *while 33-Nation UN Conference on acid rain was in session at Stockholm (July, 1982), the venue received heavy downpour of acid rain for the entire week*. The conference was designed to focus world attention on acid rain, the most potent ecological threat to Scandinavia and Canada, for which UK and USA are responsible.

The acid rain that fell during the conference was depositing Sulphur at the rate of 3.5 gm^{-2} every year (safe level is 0.5 gm^{-2} per year). An estimated 25% of this rain came from UK which deposited on Sweden in the year 40,000 tonnes of Sulphur in smoke from heavy industry carried by prevailing winds across the North Sea.

Elsewhere Sweden's 85,000 lakes were slowly being killed by the deluge—plant and fish life was damaged and 4000 lakes were completely dead.

In Canada, trees and lakes are also being killed by acid rain, 60% of which originates from USA.

Typical analytical data of acid rain is shown in Table 10.3.

Table 10.3 Analysis of typical acid rain sample (pH = 4.25)

Cation	Concentration mole/l × 10^6	Anion	Concentration mole/l × 10^6
H^+	56		
NH_4^+	10	SO_4^{2-}	51
Ca^{2+}	7	NO_3^-	20
Na^+	5	Cl^-	12
Mg^{2+}	3		Total = 83
K^+	2		
	Total = 83		

The actual values, however, are subjected to variation depending on the time and location of collection of the acid-rainwater sample. The trend, however, remains the same—H_2SO_4 is the major contributor to acid precipitation, HNO_3 ranks second and HCl the third in this respect.

Acid precipitation shows a correlation with the prior movement of the airmass over major sources of anthropogenic sulphur and nitrogen oxide emissions. This has been demonstrated in southern Norway and Sweden, which receive a heavy load of air pollution from densely-populated industrial areas of Europe, including UK.