TAO, Vol.6, No.3, 453-459, September 1995

Acid Deposition in the Vicinity of a Super Thermal Power Plant in India

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(Manuscript received 25 July 1994, in final form 30 December 1994)

ABSTRACT

An Acid deposition study was conducted in the vicinity of a Super Thermal Power Plant at Singrauli, Uttar Pradesh State in India. During the monsoon season of 1992, rain water samples were collected at three sites around the power plant. Measurements of trace gases (SO_2, NO_2, NH_3 and O_3) and Total Suspended Particulates (TSP) were also carried out for a period of 10 days during the monsoon season. Rain water samples were analysed for pH and all major inorganic ionic species. The high concentration of TSP (196 μg m^{-3}) observed near the power plant may have been due to fly ash emissions from coal combustion, coal dust from the nearby coal mines and from soil dust. It was found that the rain water which was acidic in the vicinity of the power plant turned to alkaline as the distance increased from the power plant.

(Key words: Acid deposition, Trace gases, Power plant emission)

I. INTRODUCTION

The experience of industrialised Europe and north America demonstrated the consequences of atmospheric acidity on the natural terrestrial ecosystem. Asia is a region of rapid population growth and industrialisation and one with increased requirement for energy, which is likely to be produced primarily by fossil fuel combustion. Hence, industrial development and higher standards of living in Asian countries in the future might repeat the alarm of acidification as happened in Europe and North America. Already, due to rapid industrialisation, southern China is in the grip of acid rain.

India, like China, has quickly been increasing its energy needs for the sake of industrial development. The Singrauli Super Thermal Power Plant is an example of energy development, and it is of interest to find out just how much precursor acidic gases influence acidic

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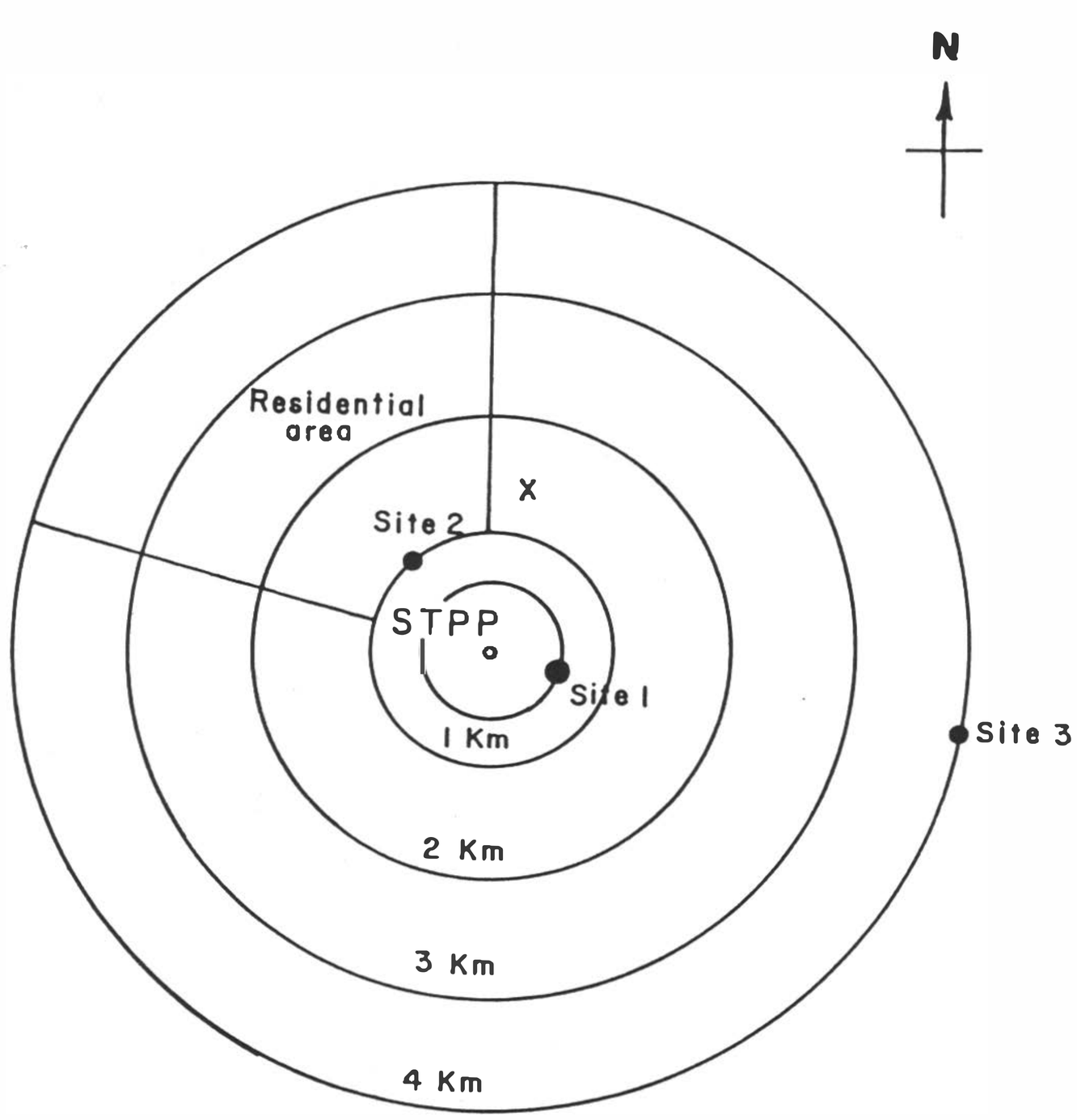
depositions around this plant. For this purpose, field observations of trace gases, aerosols and rain water sampling were carried out around the plant during the 1992 monsoon season. These acidic depositions are discussed in this paper.

2. LOCATION, SAMPLING AND ANALYSIS

The Singrauli Super Thermal Power Plant (24°13'N, 82°53'E) with a 2000 MW capacity is located in the Utter Pradesh State of India. Burning about 1000 tonnes of coal per hour (with 0.5 per cent S content), it emits about 9680 Kg of SO_2 per hour from the four stacks, each 226 m in height. The plant is well equipped with electrostatic precipitators which remove particulates from plume emissions. Rain water samples were collected on rainy days during the July-September 1992 monsoon season at three places: 500m away from the power plant in an ESE direction (Site 1), 1 km away in a NW direction (Site 2) and 4 km away in an ESE direction (Site 3) (Figure 1). The predominant prevailing wind direction during the monsoon season was W-SW and speed varied between 3 and 5 m/s.

Measurements of SO_2, NO_2, NH_3, O_3 and Total Suspended Particulates (TSP) were made for a period of 10 days in September 1992. Three samples of trace gases of 3-hour duration each were collected daily in the morning (0600-0900 hrs), afternoon (1200-1500 hrs) and evening (1800-2100 hrs) alongside one sample daily of TSP of 24-hour duration. The locations of sampling of aerosols and trace gases are shown in Figure 1.



●: Rain water collection sites
×: Observational site for trace gases and aerosols

Fig. 1. Locations of the sampling sites.

Rain water samples were collected at a height of about 10 m above ground level through a stainless steel funnel with a 30 cm diameter which had previously been rinsed with deionised water. The duration of each sample was 24-hours. The funnel was washed twice daily to avoid contamination from dry deposition, however, the possibility of this occurring cannot be completely ruled out. The samples were immediately analysed for pH and stored under refrigeration for subsequent analysis to prevent changes in chemical composition. The samples were analysed for major cations and anions as per standard methods described elsewhere (Khemani *et al.*, 1985). The trace gases were measured by the wet scrubbing method (Khemani *et al.*,1980). Total Suspended Particulates were collected on Whatman 41 filter paper using a high volume air sampler with a flow rate of 1.2 m^3/min.

3. VARIATION OF TRACE GASES AND TSP

The daily average concentration of trace gases and TSP for a period of 10 days during the month of September 1992 are given in Table 1.

The concentrations of SO_2, NO_2 and NH_3 in the upwind of the power plant were substantial and comparable to those of other polluted cities in India. However, in comparison with the values reported for Beijing (127 $\mu g/m^3$) and Guiyang (393 $\mu g/m^3$) in China (Zhao and Xiong, 1988) the concentration of SO_2 was quite low near the power plant. It is surprising to note that the concentration of O_3 was quite low and comparable to the background values.

The concentration of TSP was 196 $\mu g/m^3$ and varied from 131 to 240 $\mu g/m^3$. The average concentration of TSP in this area during monsoon season was quite high. Apart from fly ash from coal combustion, wind blown dust is another primay source of TSP. Also, the coal dust coming from neighbouring mines might have been contributing to the TSP. The influence of TSP and acid precursor gases such as, SO_2 and NO_2 on acidification of rain water is discussed below.

Table 1. Variations of trace gases and TSP around the Singrauli Thermal Power Plant.

Date--	Concentration ($\mu g/m^3$)				
	SO_2	NO_2	NH_3	O_3	TSP
20.9.1992	10.2	2.6	24.6	13.6	–
21.9.1992	26.4	6.0	19.8	6.1	247.8
22.9.1992	29.1	8.0	26.2	6.6	195.6
23.9.1992	26.7	6.5	18.5	8.1	131.3
24.9.1992	52.5	15.3	19.6	5.6	163.3
25.9.1992	43.3	7.9	22.9	5.1	157.6
26.9.1992	33.8	7.0	27.1	4.6	215.3
27.9.1992	40.6	9.6	21.4	7.6	209.9
28.9.1992	56.1	11.6	20.8	3.1	235.6
29.9.1992	23.7	9.5	26.0	10.1	214.3
30.9.1992	23.1	9.9	20.5	10.6	193.6
Average	33.2	8.5	22.5	7.4	196.4

4. IONIC COMPOSITION OF RAIN WATER

The major ionic components of the rain water samples collected at three sites alongwith pH values are given in Table 2. SO_4^{2-}, NO_3^- and Ca^{2+} are the major ions present in rain water. The concentration of SO_4^{2-} was found maximum at Site 1 at 0.5 km away from the power plant where also, the only average pH value was found acidic. It is of interest to note that the concentration of Ca^{2+} at Site 1 was found minimum. However, at Sites 2 and 3, the concentrations of Ca^{2+} were significantly higher than that at Site 1. The pH values at Sites 2 and 3 were alkaline. Also, pH showed a significant positive relationship (r=0.62) with Ca^{2+} but a negative one (r=0.56) with SO_4^{2-}. This indicates that rain acidity is determined by the relative strength of SO_4^{2-} on the one hand, and Ca^{2+} on the other.

Table 2. Concentrations of major ions in rain water samples at 3 sites at Singrauli and other places for comparison.

Location	Concentration (mg/l)								
	Cl^-	SO_4^{2-}	NO_3^-	NH_4^+	Na^+	K^+	Ca^{2+}	Mg^{2+}	pH
STPP									
Site 1	0.46 (0.14)	3.10 (0.19)	1.08 (0.44)	0.36 (0.07)	0.25 (0.07)	0.11 (0.04)	0.63 (0.17)	0.16 (0.08)	5.3
Site 2	0.67 (0.15)	2.55 (0.17)	1.21 (0.28)	0.41 (0.10)	0.37 (0.12)	0.28 (0.20)	1.10 (0.44)	0.16 (0.05)	5.9
Site 3	0.49 (0.10)	2.64 (0.44)	0.85 (0.28)	0.23 (0.05)	0.30 (0.10)	0.25 (0.14)	1.30 (0.20)	0.20 (0.10)	5.9
*ITPP									
Delhi	1.26	1.67	2.35	0.35	0.74	0.63	1.10	0.28	5.5
@Bowen Power Plant,USA									
Target	0.18	4.03	0.46	0.03	0.05	0.02	0.04	0.01	4.4
Control	0.13	2.04	0.37	0.03	0.06	0.02	0.05	0.01	4.8

* Momin, 1990 @ Patrinos *et al.*, 1983

Figures in brackets denote standard deviations The rain water composition at the Singrauli Thermal Power Plant (STPP) was compared with those around the Indraprasta Thermal Power Plant, (ITPP), Delhi and around the Bowen Power Plant (3160 MW), the largest coal-fired power plant in the southeastern USA (Table 2).The concentration of SO_4^{2-} at the STPP (2000 MW) was higher than that at the ITPP (250 MW). This is due to the higher capacity of STPP and its higher rate of SO_2 emissions. The concentrations of sea salt components (Na^+ and Cl^+) and soil originated ions (K^+, Ca^{2+} and Mg^{2+}) were substantially higher at the ITPP than those at the STPP. This indicates that the power plant emissions were not contributing much to these ions. The same can also be seen from the data reported for the

Bowen Power Plant in the USA where no significant variation was observed in concentrations of cations (NH_4^+, Na^+, K^+, Ca^{2+} and Mg^{2+}) between the target and control stations. It can be seen from Table 2 that the chemical composition of acid rain and non-acid rain do not differ much in the concentrations of anions (SO_4^{2-} and NO_3^-) but differ much in the concentrations of cations (Ca^{2+}, NH_4^+ and K^+). Thus, the formation of acid rain depends not only on the acid present in the rain, but also, to a great extent, on the amount of alkaline matter acting as a neutralising agent, which perhaps plays a decisive role in the resulting acidity of precipitation.

5. RESULTS

5.1 Acidic Deposition

The monthly minimum, maximum and average pH values and H^+ ion depositions at Sites 1, 2 and 3 during the 3-month period are given in Table 3. The average pH at Site 1 was acidic in August and September and was slightly alkaline during the month of July. However, at Sites 2 and 3 it was in alkaline range (pH > 5.6). The relative contribution of acidic and alkaline components is the reason for such a difference in the pH values. The average weighted mean pH values during the 3-month period at Sites 1, 2 and 3 were 5.3 (acidic), 5.9 and 5.9 (alkaline), respectively. Out of 28 rainy days, the rain was acidic (pH < 5.6) on 8 occasions at Site 1. However, it was acidic on one occasion at Sites 2 and 3 out of 19 and 16 rainy days, respectively. This feature could be attributed to the characteristics of aerosol which seem to be alkaline in nature and which neutralise the acidity in rain water even at a distance of 1 Km (Site 2). The acidity in the rain water was limited within a distance of 0.5 Km from the power plant i.e at Site 1, and it decreased beyond 1 Km. It is also reported that the lowest pH (3.0) was observed in the immediate vicinity of the thermal power plant, and the pH increased as the distance increased from the power plant (Li and Landsberg, 1975). The total acidic deposition during the monsoon season at Site 1 was 28.7 eq/ha, whereas at Sites 2 and 3, they were around 5.0 eq/ha. The acidic deposition (H^+) in rain water reported for southern China varied between 132 and 1110 eq/ha/y; for urban and rural areas of the USA it varied between 417 and 981 eq/ha/y, and for a remote location at Katherine, Australia, it was 191 eq/ha/y (Galloway *et al.*, 1987). Relative to these values, the H^+ ion deposition was negligible around the Thermal Power Plant at Singrauli. Since the soil in north India is alkaline and may not be sensitive to acidification, it may be expected that the potential ecological deterioration may be considered low in this region.

5.2 Depositions of Sulfur and Nitrogen

Wet and dry deposition fluxes of sulfur and nitrogen were also computed by assuming suitable dry deposition velocities (Fowler, 1980) which are given in Table 4. It can be seen that the dry deposition of the gaseous S and N components were found to be very high compared to those of particulate S and N. The wet deposition of S at Site 1 was higher than the values at Sites 2 and 3 due to the proximity of Site 1 to the power plant. In contrast, in the case of N, no significant variation was noticed among the three Sites. The dry deposition fluxes of S and N were found to be nearly 5 and 3 times respectively higher than those of the wet deposition fluxes. The dominance of the dry deposition close to the source and the increasing contibution made by the wet deposition as one moves away from the source was previously reported (Fowler, 1980).

Table 3. Variation of pH and H+ deposition (eq/ha) at Sites 1, 2 and 3 around Singrauli Thermal Power Plant.

Months	Number of Samples			pH values									Deposition of H^+ (eq/ha)		
				Minimum			Maximum			Average					
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
July	7	7	6	5.3	5.9	5.9	6.2	6.5	6.4	5.7	6.0	6.1	4.4	1.9	1.3
August	12	9	7	4.6	5.5	5.5	6.0	6.3	6.2	5.1	5.9	5.7	21.3	2.5	3.0
September	3	3	3	5.5	6.0	5.9	5.7	6.1	6.1	5.5	6.0	6.0	3.0	0.6	0.6

Table 4. Relative contributions of wet and dry deposition of S and N components.

	Deposition Velocity Vd	Site 1		Site 2		Site 3	
	cm/s	Conc. $\mu g/m^3$	Deposition kg/ha/y	Conc. $\mu g/m^3$	Deposition kg/ha/y	Conc. $\mu g/m^3$	Deposition kg/ha/y
DRY							
Gas SO_2	0.5	-	-	33.2	26.2	-	-
Gas NO_2	0.5	-	-	8.5	4.0	-	-
Aerosol SO_4	0.1	-	-	6.57	0.69	-	-
Aerosol NO_3	0.1	-	-	2.31	0.16	-	-
	Rainfall mm/y	Conc. mg/l	Deposition kg/ha/y	Conc. mg/l	Deposition kg/ha/y	Conc. mg/l	Deposition kg/ha/y
WET							
Rain SO_4	608	3.1	6.3	2.55	5.1	2.64	5.3
Rain NO_3	608	1.08	1.5	1.21	1.7	0.85	1.2

6. CONCLUSION

This study points out that acidic depositions from the Singrauli Super Thermal Power Plant are limited within a distance of 0.5 km and that then decrease with distance in the downwind or in the upwind of the power plant. The alkaline nature of aerosol is the main major factor not allowing the spread of acid rain in the region.

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