International Journal of Chemical Studies

AJ Williams
BTC College of Agriculture &
Research Station, IGKV,
Sarkanda, Bilaspur,
Chhattisgarh, India

P Mishra
College of Agriculture,
Powarkheda, JNKVV,
Hoshangabad,
Madhya Pradesh, India

Study on impact of thermal power plant emission on soil characteristic of Korba industrial area, Chhattisgarh, India

AJ Williams and P Mishra

Abstract
Industrial activities lead to deterioration of soil by physically, chemically and biologically. Determination of physico-chemical properties of soil provides information relating to pollution levels. In the present study an attempt has been made to study the physico-chemical properties of soil collected from Korba Industrial area of Chhattisgarh. The soil samples were collected from eight different sites of Korba Industrial area during different period of the year. The collected sample has been analyzed to determine their physico-chemical characteristics. The soil samples showed that, pH 4.32 – 6.25, Bulk density ranges from 1.32 to 1.66 g cm^{-3} and the porosity values was 40.0% at heavily polluted site against the less polluted. The organic carbon decreased with increasing distances from the source. The total nitrogen, available nitrogen and available phosphorus contents of the soil, reduced at the polluted site. Sulphate-S content decreased at increasing distance from the pollution source except at site near to pollution source receiving highest SO_2 and particulate load.

Keywords: korba industrial area, physico-chemical properties, pH, bulk density, porosity

Introduction
Soil is the loose surface material consisting of inorganic particles and organic matter that covers most of the land surface. Soil provides the structural support and the source of water and nutrients for plants besides these soil surface acts as a major sink for gaseous and particulate pollutants (Shivakumar *et al*., 2012) [26]. Combustion of coal in thermal power plants yields gaseous as well as particulate products like sulphur dioxide, nitrogen oxides, fly ash etc. emitted as pollutants (Williams *et al*., 1996) [33]. Gaseous sulphur dioxide enters the soil system either directly as dry deposition or after dissolving in precipitation as wet deposition (Gupta *et al*., 1995) [9]. Uptake of gaseous sulphur dioxide through vegetation and their subsequent death and release to the soil by decomposition are also important routes of sulphur reaching into the soil system. According to Whitehead (1964) [32], the atmospherically derived sulphur in the soil ranges from 1 kg S ha⁻¹ year⁻¹ for remote unpolluted sites to over 100 kg S ha⁻¹ year⁻¹ in heavily polluted industrial areas. Total S flux of 1.40 & 1.20 g m⁻² year⁻¹ was reported at 0.25 km S & SE direction (heavily polluted) from Korba thermal power plant as compared to 0.52 g S m⁻² year⁻¹ at 20.0 km NW (relatively less polluted) from the source (Gupta *et al*., 1995) [9]. The living roots also release sulphur as sulphate or in organic forms into the soil. Sulphur absorbed from the atmosphere is incorporated and transformed into or on the soil through various microbial, biological, physical and chemical processes.
Particulate pollutants enter the soil system either directly through dry deposition and precipitation scavenging or indirectly via leaf and twig fall. Vegetation is suggested as an efficient collector of particulates where dust first accumulated and is later washed off by rains or blown away by strong winds and enters into the soil system. This lead to the changes in soil pH, and cause mineral imbalance in the soil (Abrahamsen, 1982; Johnson, 1985; Gupta *et ai*., 1995) [9]. The fallout of thermal power plant was shown to alter the physico-chemical properties of the soil (Pandey, 1983) [19]. Fly-ash, which contains considerable amounts of heavy metals and trace elements, seems to be more problematic due to the trace elements build up in the surface horizon (Hutchinson, 1980) [10]. Altered metal cycling (Norton *et al*., 1980) [16], and toxicity to plant growth processes are reported due to heavy metal accumulation (Foy *et al*., 1978; Bowen, 1979) [7, 4].

Corresponding Author:
AJ Williams
BTC College of Agriculture &
Research Station, IGKV,
Sarkanda, Bilaspur,
Chhattisgarh, India

The present study aimed at determining the long-term influence of thermal power plant pollutants on soil system in order to assess the change in the physico-chemical propertied of the soil and plant available nutrients.

Material and methods
Study area
Korba Industrial Area is situated between 22°20' N and 82° E in Korba district of Chhattisgarh. The general topography of the area /region is flat with undulating interspersed (minimum and maximum elevation are 274.3 and 304.8 m respectively). The area has a monsoonic climate characterized by seasonal rhythm as prevailing in the rest of India. The whole year can be divided into three distinct seasons, i.e. summer (March to June), rainy (July to October) and winter (November to February).

Sample collection
Representative soil samples of about 20 g were randomly collected in triplicate up to 30 cm beneath the soil surface, at three months' intervals from at selected site (Table 1 Fig. 1). Quarterly collected soils were mixed thoroughly to get a composite soil representing a particular season. From this, samples were taken in triplicate for analyzing pH, organic carbon, sulphur (SO_4^{2-} -S), N, available P and available K. The detailed methodologies are as follows:
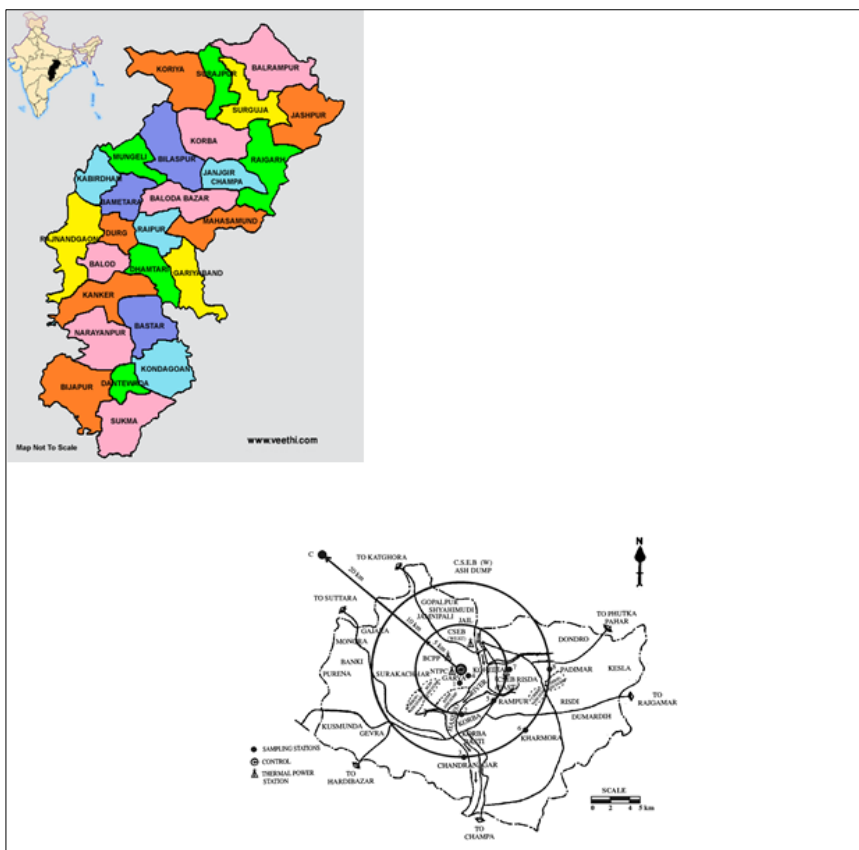

Fig 1: Location map of Korba Industrial area, showing study area and sampling stations.

Bulk density and porosity
Bulk density was estimated by taking out a core of undisturbed soil by metal tube. The soil was over-dried and weight was determined. The volume of the soil was calculated by measuring the volume of the tube ($\pi r^2 h$). The bulk density was calculated by dividing the oven dry weight of soil samples (g) by the volume of the soil.

$$\text{Bulk density (g cm}^{-3}\text{)} = \frac{\text{Dry wt. of the soil sample}}{\text{Volume of the soil}}$$

Percent porosity was estimated by using the following formula:

$$\text{Porosity (\%)} = 100 - \left(\frac{\text{Bulk density}}{2.65}\right) \times 100$$

Where, 2.65 is the standard particle density.

pH
Soil pH was measured in the suspension of 1:2.5 (soil: water, w/v) with the help of photovolt pH meter using a glass electrode.

Organic carbon
The percent organic carbon was determined by Walkley and Black's rapid titration method described by Piper (1966) [21].

Total nitrogen
The percentage nitrogen content in the soil was determined by using the micro-Kjeldahl technique (Jackson, 1958) [11].

Available phosphorus
Available P was estimated by Olsen's extractant using Spectrophotometer (Jackson, 1973) [12].

Available nitrogen
Available nitrogen was determined by alkaline permanganate distillation method (Subbiah and Asija, 1956) [28].

Available Potassium

Available K was determined by Flame Photometer from 1 N H_2SO_4 extract (Jackson, 1973) [12].

Sulphate-Sulphur

For extraction of soil SO_4^{2-} -S, the method given by Chesmin and Yien (1950) [6] was followed. To 20 g of air dried soil sample, 100 ml of Morgan's extraction solution (100 g of NaOAC and 30 ml of 99.5% HOAC dissolved and mixed in 500 ml of water and volume made to 1 litre) was added. The suspension was shaken for one and half hours, and then filtered through Whatman no. 42 filter paper. The SO_4^{2-} -S content was determined in the filtrate by using the turbiditimetric method given by Rossum and Villarruz (1961) [24].

Result and discussion

In all the study sites, the soil pH values were towards the acidic side except for control. During winter, the pH values were 4.32, 4.62, 6.13, 5.56, 5.59, 6.25, 5.93 and 6.12 at sites S_1, S_2, S_3, S_4, S_5, S_6, S_7 and S_8, respectively (Table 2). The pH trend was similar during summer and rainy seasons.

The bulk density of the soils from different sites varied from 1.32 to 1.66 g cm^{-3}. Though there was no clear cut side wise variation, but the polluted sites showed higher bulk density values as compared to the relatively unpolluted sites (Table 2). During winter, the bulk density values were 1.66, 1.52, 1.49, 1.51, 1.54, 1.32, 1.34 and 1.36 g cm^{-3} at sites S_1, S_2, S_3, S_4, S_5, S_6, S_7 and S_8, respectively, Similar trend was observed during summer and rainy seasons; the respective values being 1.59 and 1.63 g cm^{-3} at site S_1, 1.50 and 1.54 g cm^{-3} at S_2, 1.50 and 1.44 g cm^{-3} at site S_4 and 1.40 and 1.49 g cm^{-3} at site S_5. The porosity values was 40.00% at heavily polluted site S_1 as against the less polluted S_8 (52.83%) site during summer (Table 2). The porosity values were 40.00%, 38.49% and 37.36% at site S_1; 43.40%, 41.89% and 42.64% at site S_2; 44.15%, 43.02% and 43.77% at site S_3; 43.40%, 45.66% and 43.02% at site S_4; 47.17%, 43.77% and 41.89% at site S_5; 49.06%, 47.92% and 50.19% at site S_6; 49.43%, 51.32% and 49.43% at site S_7 and 52.83%, 52/45% and 48.68% at site S_8 during summer, rainy, and winter seasons, respectively.

The organic carbon decreased with increasing distances from the source. The percentage values ranged from 0.444 at site S_3 to. 908 at site S_7 during winter (Table 2). The organic carbon values were 0.820, 0.566, 0.440, 0.858, 0.562, 0.469, 0.905 and 0.597% at sites S_1, S_2, S_3, S_4, S_5, S_6, S_7 and S_8, respectively during summer.

Total nitrogen, available nitrogen and available phosphorus contents of the soil reduced at the polluted sites (Table 3). The annual average nitrogen content (%) at sites S_1, S_2, S_3, S_4, S_5, S_6, S_7 and S_8 were 0.030, 0.058, 0.060, 0.040, 0.060, 0.065, 0.061 and 0.065%, respectively. The mean annual values of available nitrogen and available phosphorus were 31, 78, 114, 31, 78, 104, 47 and 78 µg/g and 2.94, 3.53, 5.30, 3.53, 5.89, 7.65, 3.53 and 5.59 µg/g at sites S_1, S_2, S_3, S_4, S_5, S_6, S_7 and S_8, respectively.

The available potassium content of soil from heavily polluted sites was higher as compared to relatively less polluted sites (Table 3). The annual mean values of available K at sites S_1, S_2, S_3, S_4, S_5, S_6, S_7 and S_8, were 375, 262, 112, 300, 250, 150, 300 and 150 µg/g, respectively.

Sulphate-S content decreased at increasing distances from the pollution source except at site S_1 receiving highest SO_2 and particulate load (Table 3). The annual mean sulphate sulphur contents at sites S_1, S_2, S_3, S_4, S_5, S_6, S_7 and S_8, were 1400, 1100, 720, 1200, 1130, 650, 540 and 535 µg/g, respectively.

In the present investigation considerable changes in physical and chemical properties of soil were observed at sites receiving higher gaseous and particulate emission. Soil pH changes significantly in the area. The trend of soil pH finds explanation in relation to the levels of fly-ash and SO_2 fallout. Individually, fly-ash and SO_2 are known to increase alkalinity (Page et al., 1979; Adriano et al., 1980; Gupta et al., 1995) [18, 2, 9] and acidity (Strayer and Alexander, 1981; Pandey, 1983) [27, 19] of soil, respectively.

An increase in the bulk density and decrease in porosity of the soil were observed in the vicinity of the power plants. This may be attributed to the addition of particulates into the soil. Porosity is an assessment of the size, quality, and distribution of cavities within the soil mass and is related to the texture and structure of the soil. Since thermal power plant emission constitutes larger and heavy particles also, which lead to an increase in bulk density with consequent decrease in porosity. However, Chang et al. (1977) [5] observed a decrease in bulk density of soil from 1.60 to 1.01 g cm^{-3} after amending 10% (w/w) fly-ash.

Soil samples collected from heavily polluted sites showed higher organic carbon. It has been suggested that prolonged exposure to SO_2 causes inhibition of microbial activity in soil systems (Grant et al., 1979) [8]. Ruhling and Tyler (1973) [25] observed delayed decomposition of litter in presence of heavy metals ions. Tyler (1972) [29] has proposed that heavy metal ions bind with colloidal matter and increase resistance to decomposition or exert a toxic effect directly on decomposing microbes or the enzymes they produce. Arthur et al. (1984) [3] observed that high rates of fly-ash amended to soil (400 to 700 tons ha^{-1}) adversely affect the soil heterotrophic microbial population. The observed higher content of available K at heavily polluted sites could be attributed to the acidity of the plant growth medium affect the relative uptake of cations and anions by the plants growing there (Reuss, 1976) [23]. The increased acidity associated with H^+ ions in the system may result in cation-anion imbalances affecting the growth of plants. This assumption may account for higher amounts of K in soils collected from the highly polluted sites. It is possible that K being monovalent is released from soil under acidic conditions leading to higher available K in soils of polluted sites. Patel and Pandey (1986) [20] reported that considerable input of alkali and alkaline earth metals occurs in the soil around thermal power plant due to dust fallout. Significant positive correlations (r = 0.639, $p<0.05$) were observed between dustfall rate and K contents at different study sites (Table 4). A highly disturbed soil biological activity of the polluted soil has been reported (Tyler, 1974) [30]. The observed decline in total N content may be attributed to the reduced nitrogen mineralization as a result of trace element contamination of the soil. Liang and Tobatabi (1978) [14] found 14 to 96% inhibition of soil nitrification following 10 days incubation with various trace elements at 5 µ moles g^{-1} soil under laboratory conditions. High concentrations of Cu and Zn have been found to inhibit the activity of acid phosphatase enzyme markedly (Tyler, 1974, 1976) [30], leading to reduced decomposition of organic phosphorus compounds in the soil. The atmospheric depositions of gaseous pollutants have been shown to reduce the soil phophorus content (Mcclenahen and Brown, 1988) [15]. The SO_4^{2-} -S accumulation in the soil was more at the sites receiving higher annual SO_2 concentrations as compared to those sites having low annual SO_2 averages. Significant

positive correlations (r = 0.842, $p < 0.05$) were observed between sulphur dioxide and soil sulphate- sulphur contents at different study sites (Table 4). According to Rasmussen et al. (1974) [22], the deposition velocity of sulphur dioxide generally ranges between 0.2 to 0.7 cm sec⁻¹. Factors like fine texture, high soil organic matter, high pH, presence of free $CaCO_3$, high soil moisture, and abundance of soil microorganisms favour SO_2 uptake by the soil (Nyborg et al., 1977) [17]. After entering into the soil, SO_2 gets converted to sulphate by chemical and microbiological processes. The present study clearly indicates that thermal power plant emissions have altered the physico-chemical properties of the soil. The increase in the SO_4^{2-} -S content of the polluted sites is directly related to the S pollution load around thermal power plants. The reduction in major plant nutrients, nitrogen and phosphorus may hamper the plant growth and

productivity. The SO_4^{2-} -S build up in the area is an important consequence of environmental pollution, as this can contaminate the food chain.

Table 1: Location of sampling sites around thermal power station

Sampling site no.	Direction	Distance (Km)
1	S	0.25
2	S	5
3	S	10
4	SE	0.25
5	SE	5
6	SE	10
7	E	5
8	E	10
Control – Wind blows from NW to SE	NW	20

Table 2: Physical characteristics of soils at different study sites around HTPS and Korba super thermal power station during 2009- 2010 & 2010-2011

Study Site	Summer				Rainy				Winter			
	pH	Bulk density (g cm⁻³)	% porosity	Organic carbon (%)	pH	Bulk density (g cm⁻³)	% porosity	Organic carbon (%)	pH	Bulk density (g cm⁻³)	% porosity	Organic carbon (%)
S₁	4.36	1.59	40.00	.820	4.38	1.63	38.49	.824	4.32	1.66	37.36	.828
S₂	4.60	1.50	43.40	.566	4.68	1.54	41.89	.570	4.62	1.52	42.64	.572
S₃	6.15	1.48	44.15	.440	6.23	1.51	43.02	.450	6.13	1.49	43.77	.444
S₄	5.48	1.50	43.40	.858	5.50	1.44	45.66	.860	5.56	1.51	43.02	.862
S₅	5.66	1.40	47.17	.562	5.62	1.49	43.77	.566	5.59	1.54	41.89	.568
S₆	6.18	1.35	49.06	.469	6.11	1.38	47.92	.470	6.25	1.32	50.19	.472
S₇	5.92	1.34	49.43	.905	5.89	1.29	51.32	.905	5.93	1.34	49.43	.908
S₈	6.10	1.25	52.83	.567	6.01	1.26	52.45	.598	6.12	1.36	48.68	.660
Control	7.01	1.16	56.23	.546	7.00	1.11	58.11	.545	7.06	1.19	55.09	.545

Table 3: Sulphate –S, total nitrogen, available phosphorus, available nitrogen, available potassium and C/N ratio in soils of different sites during 2009-2010 & 2010-2011

Study sites	Distance (km.)	Direction	Sulphate-S (µg/g)	Total N (%)	Available N (µg/g)	Available P (µg/g)	Available K (µg/g)	C/N Ratio
S₁	0.25	S	1400	0.030	31	2.94	375	27.5
S₂	5	S	1100	0.058	78	3.53	262	9.8
S₃	10	S	720	0.060	114	5.30	112	7.4
S₄	0.25	SE	1200	0.040	31	3.53	300	21.3
S₅	5	SE	1130	0.060	78	5.89	250	9.4
S₆	10	SE	650	0.065	104	7.65	150	7.2
S₇	5	E	540	0.061	47	3.53	300	14.9
S₈	10	E	535	0.065	78	5.59	150	9.2
Control	20	NW	520	0.063	141	8.83	200	8.7

Table 4: 'r' values indicate the simple correlation between the variables for soil characteristics

	pH	Bulk density	% porosity	Organic carbon	Sulphate - S	Total N	Available N	Available P	Available K	C/N Ratio
	1	2	3	4	5	6	7	8	9	10
pH	1	-0.866**	0.866**	-0.406	-0.841**	0.690*	0.722*	0.815**	-0.694*	-0.633
Bulk density	-0.866**	1	-1.000**	0.210	0.868**	-0.693*	-0.590	-0.730*	0.475	0.541
% porosity	0.866**	-1.000**	1	-0.210	-0.868**	0.693*	0.590	0.730*	-0.475	-0.541
Organic carbon	-0.406	0.210	-0.210	1	0.333	-0.627	-0.856**	-0.690*	0.825**	0.823**
Sulphate - S	-0.841**	0.868**	-0.868**	0.333	1	-0.817**	-0.619	-0.605	0.690*	0.674*
Total N	0.690*	-0.693*	0.693*	-0.627	-0.817**	1	0.715*	0.639	-0.768*	-0.947**
Available N	0.722*	-0.590	0.590	-0.856**	-0.619	0.715*	1	0.867**	-0.788*	-0.821**
Available P	0.815**	-0.730*	0.730*	-0.690*	-0.605	0.639	0.867**	1	-0.673*	-0.680*
Available K	-0.694*	0.475	-0.475	0.825**	0.690*	-0.768*	-0.788*	-0.673*	1	0.856**
C/N Ratio	-0.633	0.541	-0.541	0.823**	0.674*	-0.947**	-0.821**	-0.680*	0.856**	1

**Significant at the 0.01 level
*Significant at the 0.05 level

References
1. Abrahamsen G. Sulphur pollution: Ca, Mg and Al in soil and soil water and possible effects on forest trees. In: B. Ulrich and J Pankrath (eds.) Effects of Accumulation of Air Pollutants in Forest Ecosystem. Proceeding of a Workshop held at Gottingen, West Germany. D. Reidal Publ. Co. Dordrecht, Holland/Boston, U.S.A./London, England, 1982, 207-218.
2. Adriano DC, Page AL, Elseewi AA, Chang AC, Straughan I. Utilization and disposal of fly-ash and other coal residues in terrestrial ecosystems: A review. J of Environ. Quality. 1980; 9:333-343.

3. Arthur MF, Zwick TC, Tolle DA, Van Voris P. Effects of flyash on microbial CO_2 evolution: one of the lethal effects of SO_2. Oecologia (Beri). 1984; 28:147-151.

4. Bowen HJM. Environmental Chemistry of the Elements. Academic Press, New York, 1979, 333.

5. Chang AC, Lund LJ, Page AL, Warneke. Physical properties of flyash amended soil. J Environ. Quality. 1977; 6(3):267-270.

6. Chesnin L, Yien CH. Turbidimetric determination of available sulphates. Soil Science Society of American Journal. 1950; 15:149-151.

7. Foy CD, Chaney RL, White MC. The physiology of metal toxicity in plants. Ann Rev. Plant Physiol. 1978; 46:511-566.

8. Grant IF, Baneroft K, Alexander M. SO_2 and NO_2 effects on microbial activity in an acid forest soil. Microbial. Ecol. 1979; 5:85-89.

9. Gupta BN, Williams AJ, Banerjee SK. Impact of Thermal Power Plant Emission on Vegetation and Soil. Proc. Indian natna. Sci. Acad. B61. 1995; (6):457-470.

10. Hutchinson TC. Impact of heavy metals on terrestrial and aquatic ecosystem. In: PR. Miller (ed.) Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems. USDA Forest Service Report PSW-4, 1980, 158.

11. Jackson ML. Soil Chemical Analysis. Asia Publ. House, Bombay, India, 1958.

12. Jackson ML. Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd. New Delhi, India, 1973.

13. Johnson DW, Richter DD, Lovett GM, Lindberg SE. The effects of atmospheric deposition on potassium, calcium, and magnesium cycling in two deciduous forests, Can. J For. Res. 1985; 15:773-782.

14. Liang CN, Tabatabai MA. Effects of trace elements on nitrogen mineralization in soils. Environ. Qual. 1978; 7:291-293.

15. McClenahen JR, Brown JH. Air pollution and *Pinus strobus* height growth: a soil/site modeling approach. Forest Ecol. Manag. 1988; 25:221-37.

16. Norton SA, Hanson DW, Campana RJ. The impact of acidic precipitation and heavy metals on soils in relation to forest ecosystem. In: P.R. Miller (ed.) Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems. USDA Forest Service Report PSW-4, 1980, 152.

17. Nyborg M, Crepin J, Hocking D, Baker J. Effect of culphur dioxide on precipitation and sulphur content and acidity of soil in Albertev, Canada. Water, Air and Soil Pollut. 1977; 7:439-448.

18. Page AL, Elseewi AA, Straughan IR. Physical and chemical properties of flyash from coal-fired power plants with reference to environmental impacts. Res. Rev. 1979; 71:83-120.

19. Pandey SN. Impact of thermal power plant emissions on vegetation and soil. Water, air and soil pollution. 1983; 19(1):87-100.

20. Patel CB, Pandey GS. Alkalinization of soil through thermal power plant flyash fallout. The Sci. of the Total Environ. 1986; 57:67-72.

21. Piper CS. Soil and plant analysis. Maver Publisher, Bombay, India, 1966.

22. Rasmussen KM, Taheri M, Kabel RL. Source of natural removal processes for some atmospheric pollutants. US Environmental Protection Agency Publication. No. EPA-650/4-74-032 U.S.A.P.A., Washington D.C., 1974, 121.

23. Reuss JO. Proc. 1st Int. Symp. Acid Precipitation and the Forest Ecosystem. USDA Forest Service, General Technical Report NE - 23, 1976, 791.

24. Rossum John R, Villarruz Primo A. Suggested method for turbidimetric determination of sulfate in water. Journal (American Water Works Association). 1961; 53(7):873-876.

25. Ruhling A, Tyler G. Heavy metal pollution and decomposition of spruce needle litter. Oikos. 1973; 24:402-416.

26. Shivkumar D, Srikantaswamy S, Kiran BM, Sreenivssa S. Study of impacts of imdustries on soil characteristics of Mysore City India. International Journal of Geology, Earth and Environmental Sciences. 2012; 2(2):25-33.

27. Strayer RF, Alexander M. Effects of simulated acid rain on glucose mineralization and some physico-chemical properties of forest soils. J Environ. Qual. 1981; 10:460-465.

28. Subbiah BV, Asija GL. A rapid procedure for the estimation of available nitrogen in soils. Current Sci. 1956; 25:259-260.

29. Tyler G. Heavy metals pollute nature, may reduce productivity. Ambio. 1972; 1:53-59.

30. Tyler G. Heavy metal pollution and soil enzyme activity. Plant Soil. 1974; 41:303-311.

31. Tyler G. Heavy metal pollution, phosphatase activity and mineralization of organic phosphorus in forest soils. Soil Biol. Biochem. 1976; 8:327-332.

32. Whitehead DC. Soil and plant nutrition aspects of the sulphur cycle. Soils Fert. 1964; 27:1-8.

33. Williams AJ, Gupta BN, Banerjee SK. Effect of Thermal Power Plant Emissions on Vegetation. Indian Journal of Forestry. 1996; 19(4):330-334.