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Impact of Thermal Power Plant on Soil Chemical Properties; A Case Study Around Bellary thermal Power Station, Karnataka, India

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Abstract—*An exploratory study was conducted during November 2013 in five different villages around Bellary thermal power station (BTPS) inorder to assess the effect of pollutants emitted from thermal power plant on ambient air quality and soil chemical proprties. Various non-volatile combustion products of coal were estimated in ambient atmosphere. Pollutants concentrations were found higher in Thimmalapur village located nearer to BTPS in the prevailing downwind direction (2 km in North-West of BTPS). Soil chemical properties were also monitored in these villages at varying distances from BTPS, with the village farthest away from BTPS (Yelubenchi) as control. Particulate matter which are good indicators of the effect of emissions from coal based power plants were found highest in Thimmalapur village and that were lowest in Yelubenchi.*

Keywords*: Power plant, Pollution, Soil, SPM, RSPM*

1. INTRODUCTION

Soil is an important non-renewable natural resource with immense, though finite production potentials under optimum conditions. Energy is indispensable as far as human needs are considered. Rapid urbanization and industrialization have resulted in accentuation of energy requirement and pollution (WHO/UNEP, 1992). It is estimated that nearly 75% of power generation capacity in India is thermal, of which about 84% relays on coal as fuel source (Chandra and Chandra, 2004). About 260 mt of coal, which accounts for 65% of annual coal produced in India, is being used by thermal power plants as energy source (Kumar and Singh, 2006). At present, combustion of coal in various thermal power plants all along the country results in generation of 225 mt of fly ash, of which one third goes into the environment and the rest, dumped either into the land or water bodies (Shamshad *et al*., 2012). The present study was envisaged to determine the effect of thermal power plant on soil chemical properties of villages around BTPS.

2. MATERIAL AND METHODS

Bellary Thermal Power Station (BTPS), a power generating unit working under Karnataka Power Corporation Limited (KPCL) is located about 22 km away from Bellary town, adjacent to State Highway-29 and National Highway-63. The plant is surrounded by Thimmalapur in North side, Kudithini in East side, Sultanpur in South and Toranagallu in West side. The topography around the plant site is fairly undulating. Total requirement of coal will be 14,000 Mt per day. Indigenous coal blended with imported coal in the ratio 70:30 is used as the fuel source. The fuel has sulphur content of 0.4% and 34% ash content.

The region belongs to Zone-III, Northern dry zone of Karnataka **(Anon., 2012)** and characterized with distinct seasonal variations of summer (months of March, April and May), monsoon (June, July, and August), post-monsoon (September, October and November) and winter (December, January, and February). The study period (June- November) was monsoon and post-monsoon seasons; the temperatures were moderate and humidity relatively high.

3. SELECTION OF SAMPLING SITES FOR THE STUDY

Exploratory field visits were undertaken in the month of May and June 2013 for identifying suitable sampling sites for the research work. It was observed that scrub forests cover the southern direction of the power plant while farmlands are found in the north, east and west directions. Starting from Kudithini village which is 2 km away from the power plant, visits were made to villages in the North and North-West direction including Thimmalapur, Daroji and Hosadaraoji which are irrigated from Tungabhadre canal. Yelubenchi and Siddamanahalii villages in the north and northeast directions were also visited; however Siddamanhalli was found to be influenced by emissions from other factories like ACC cements and Satavahana Ispat Limited. In the east direction towards Bellary, Venivirapur village was also visited, but this is in the vicinity of Agarwal steel factory. Based on the location of other factories which could interfere with measurements of pollutants from BTPS, it was decided to avoid villages in North-East direction. Sampling sites were finally fixed at Kudithini, Thimmalapur, Hosadaroji, Yelubenchi and Sultanpur villages.

The sampling sites consist of Thimmalapur (At a distance of 2 km in the NW of BTPS, 15^{o} 22′ 24″ N latitude and 76^{o} 72′ 09″ E longitude), Sultanpur (2 km in W of BTPS, 15^{o} 17′82″ N latitude and 76^{o} 72′ 09″ E longitude), Kudithini (2.5 km in E of BTPS, 15^{o} 20′ 08″ N latitude and 76^{o} 74′ 97″ E longitude), Hosadaroji (6 km in NW of BTPS, 15^{o} 21′ 88″ N latitude and 76^{o} 71′ 52″ E longitude) and Yelubenchi (8 km in N of BTPS, 15^{o} 24′ 35″ N latitude and 76^{o}73′ 98" E longitude). The rationale for fixing these sites arises from their location in the predominant down-wind direction (NW) which determines dispersion of pollutants and the availability of farmlands in these sites for impact assessment of pollutants. Further, these sites broadly represent a cross-sectional scenario of the power plant location upto 8 km and also emissions from other factories located in the area could be excluded from interfering with the sampling on these sites.

4. COLLECTION AND ANALYSIS OF AMBIENT PARTICULATE MATTER IN ATMOSPHERIC SAMPLES

High volume air sampler is used for the atmospheric sampling purpose. These are kept on stationary platform at a height of 6 m above the ground level in each of the five sampling location. Ambient air consisting of suspended particulates is drawn through the sampler inlet and as the air passes through the cyclone, coarse, non respirable dust (larger than 10 microns) is separated from air stream by centrifugal forces. These separated particulates fall through the cyclone's conical hopper and collect in the sampling cup (thimble) placed at the bottom. The fine dust forming the respirable fraction of suspended particulates (RSPM) or PM10 (10 µ and less in size) passes through the cyclone and is carried by the air stream before retaining it on a 20.3 x 25.4 cm (8 x 10 inches) Whatman glass fibre microfilter. The carrier air devoid of SPM is exhausted from the system through the blower. After the requisite sampling duration, the filter is removed and stored carefully in an interlocking polythene bag. Before the sampling process, filter papers are properly dried by keeping in an oven at 100^{0}C for one hour. Appropriate ID numbers are provided to each filter paper and thimble. The mass of these particles is determined by the difference in filter/ thimble weights prior to and after sampling. The concentration of suspended particulate matter in the designated size range is calculated by dividing the weight gain of the filter/thimble by the volume of air sampled (Olin and Kurz, 1975 and Robson and Foster, 1962).

5. COLLECTION AND ANALYSIS OF SOIL SAMPLES

Composite soil samples from surface (0-15 cm) and subsurface (15-30 cm) were collected from selected sampling locations. The soil was air dried, powdered and allowed to pass through 2 mm sieve and analyzed for various chemical properties.

Soil pH was measured potentiometrically in 1:2.5 soil water suspensions (w/v) as described by Jackson (1973) using digital pH meter 335. Electrical conductivity was measured in 1: 2.5 soil water suspensions (w/v) as described by Jackson (1973) using digital conductivity meter 304 and expressed as dS m^{-1}. Organic carbon was determined by Walkley and Black (1934) wet oxidation method, available nitrogen by alkaline potassium permanganate method (Subbiah and Asija, 1956) using Kjeldhal flasks, phosphorus by Olsen's method as described by Jackson (1973). Available potassium was extracted with neutral normal ammonium acetate (pH 7.0). The quantity of potassium in the extractant was determined by flame photometry (Jackson, 1973). Available sulphur was extracted from the soil using 0.15% $CaCl_2$ solution and sulphur was determined spectrophotometrically at 420 nm (Jackson, 1973). Microwave assisted digestion was followed for estimation of micronutrients in soil samples. Slightly modified EPA 3051A (EPA, 2007) protocol was used for the digestion purpose. Exact 0.20 g soil is digested with 10 ml of aquaregia (HNO_3: HCl in the ratio 3:1) in Teflon digestion tubes based on operator manual guidelines. Thereafter the procedure was similar to ISO 11466 (ISO 1995) followed by the estimation of zinc, copper, iron and manganese in the digested sample using atomic absorption spectrophotometer (contrAA 700 model) and estimation of toxic elements selenium, arsenic and lead using inductively coupled plasma optical emission (ICP-OES) spectroscopy in International Crop Research Institute for the Semiarid Tropics (ICRISAT), Hyderabad, Andhra Pradesh, India.

6. RESULTS AND DISCUSSIONS

Particulate matter deposition

Atmospheric pollutants emitted during November 2013 has been recorded highest concentration in Thimmalapur with 255.44 µg m^{-3} for SPM (coarser particles above 10 µm) and 45.35 µg m^{-3} for Respirable Suspended Matter (RSPM or PM_{10}) (Table 1). Impact of thermal power plant on soil health is not short term; rather it is due to the continual and long term deposition of fly ash particle around the nearby villages, especially those which are located on the predominant down wind direction. Pollutant concentration gradually decreases along the prevailing wind direction as observed in changes in soil properties along the gradient in distance from thermal power station. In India, a similar observation was made by around Obra thermal power station, Mirzapur, Uttar Pradesh, India (Pandey, 1983).

Table 1: Range of ambient atmospheric SPM and RSPM concentration (μg m^{-3}) in different sampling locations during November 2013

Village	SPM	RSPM	RSPM:SPM Ratio
Thimmalapur	255.44	45.35	0.18
Sultanpur	183.60	29.53	0.16
Kudithini	143.26	28.43	0.20
Hosadaroji	127.21	30.60	0.24
Yelubenchi	119.11	25.21	0.21
Range	136.33	20.14	0.08
S.D.	55.97	7.83	0.03

7. SOIL PH, ELECTRICAL CONDUCTIVITY AND ORGANIC CARBON CONTENT OF SURFACE AND SUBSURFACE

Analysis of soils from the selected sampling locations indicated that average surface and sub surface soil pH varied from 8.03 to 8.20 and 8.08 to 8.26 in Yelubenchi and Thimmalapur respectively (Table 2), which could be attributed with to the fly ash derived residual alkalinity. Higher deposition of particulate matter (fly ash) was recorded in Thimmalapur (2 km North West). The salt content (EC) also followed similar trend with depth and distance from BTPS. Highest EC among surface soil samples was noticed on Thimmalapur (0.41 dS m^{-1}) located on NW direction from BTPS. Lower pH and EC in Hosadaroji and Yelubenchi was mainly because of the advantage in its geographic location (6 and 8 km distance respectively) from the thermal power plant, thereby resulting in minimal influence of pollutants. Highest electrical conductivity noted in Thimmalapur could be attributed to deposition of particulate matter as fly ash.

Table 2: Soil pH, electrical conductivity (dS m^{-1}) and organic carbon content (g kg^{-1}) of surface and subsurface soil samples

Villages	pH		EC		OC	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Thimmalapur	8.20	8.26	0.41	0.44	4.00	3.90
Sultanpur	8.14	8.21	0.39	0.41	4.10	3.90
Kudithini	8.08	8.18	0.35	0.38	4.10	4.00
Hosadaroji	8.06	8.10	0.34	0.36	4.30	4.10
Yelubenchi	8.03	8.08	0.33	0.36	4.30	4.10
S.Em±	0.04	0.02	0.01	0.01	0.24	0.20
CD at 5 %	0.11	0.05	0.03	0.04	NS	NS

NS: Non significant

Further, highest electrical conductivity was noted on subsurface soil as compared to surface soils, which could be due to leaching of soluble salts by percolating water from, the rainfall that happened in July and August months. Singh *et al.* (1995) reported changes in soil properties around Shaktinagar and Renusagar thermal power plant of Uttar Pradesh, India and showed that soil pH was mostly alkaline at polluted sites. Off site effect of fly ash application on increasing soil pH has reported by Srivastava and Chhonkar (2000) and Kalra *et al*. (2003).

Organic carbon decreases with depth, which could be attributed to the higher surface soil organic matter content and it ranges between 4.00 and 4.30 g kg^{-1} in surface soils as compared to 0.39 and 0.41 g kg^{-1} in sub surface soils, indicating low fertility status. There was a marginal increase in soil organic carbon content with distance from BTPS, which indicates that thermal power plant do not have any impact on soil organic carbon content. This could be linked to the oxidation of organic carbon present in coal as oxides of carbon during the combustion of coal (Bern, 1976). The results is contradictory to the findings of Singh *et al.* (1995), who reported that fly ash deposition cause increase in organic carbon content around thermal power plant.

8. AVAILABLE MAJOR NUTRIENT STATUS OF SURFACE AND SUBSURFACE SOIL SAMPLES

Analysis of surface and subsurface soil samples indicated that available nitrogen was low in selected villages (Table 3) and ranged from 237.10 to 248.65 kg ha-1 and 225.83 to 239.15 kg ha-1, respectively. Lower nitrogen content in Yelubenchi was attributed to lower organic matter content in soils as evidenced in Table 2. Relatively higher nitrogen content was observed on surface soil samples as compared to sub surface soil. There was a decrease in phosphorus and potassium content with distance from 62.25 to 50.14 kg ha-1 and 316.40 to 304.18 kg ha-1 in surface soils respectively. There was a decrease in available phosphorus content with depth however potassium showed a reverse trend which is mainly due to the leaching of potassium from surface to sub surface soils due to heavy rainfall occurred during June (250.00 mm) and July (41.60 mm) months. The lower potassium content in surface soil compared with sub surface is attributed to the leaching of potassium from surface to subsurface soil. The available sulphur decreases with depth and distance and it ranged from 46.00 to 55.96 kg ha-1 and 42.20 to 49.96 kg ha-1 in surface and sub surface soils, respectively indicating high fertility status. Further, higher value for phosphorus, potassium and sulphur in surface soil was observed on Thimmalapur located 2 km away from BTPS in North West direction which indicated that deposition of fly ash contribute more to these elements and the observation matches well with the the predominant wind direction (South East). Bhoyar (2002) showed that fly ash has relatively higher amount of phosphorus and potassium, whose addition to soil increases the availability of these elements to crop plants. Similar trend of increasing nitrogen and decreasing potassium content around Shakthinagar and Renusagar thermal power plant of Uttar Pradesh, India, were reported by Singh et al. (1995). Also, increasing trend of potassium and sulphur contents with decrease in distance from thermal power plant were reported by Pandey (1983).

Table 3: Available major nutrient status (kg ha^{-1}) of surface and subsurface soil samples

Villages	N		P_2O_5		K_2O		SO_4-S	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Thimmalapur	237.10	225.83	62.25	55.75	316.40	338.70	55.96	49.96
Sultanpur	240.05	227.15	59.06	50.60	315.40	336.50	54.86	50.78
Kudithini	241.45	228.95	54.94	50.51	312.80	330.70	47.38	45.89
Hosadaroji	245.85	234.70	52.30	49.32	310.70	325.70	46.52	43.54
Yelubenchi	248.65	239.15	50.14	46.99	304.18	316.50	46.00	42.20
S. Em±	4.02	4.84	1.11	0.75	1.63	2.68	1.40	1.09
CD at 5 %	NS	NS	3.42	2.30	5.03	8.24	4.33	3.35

NS: Non significant

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