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DETERMINATION OF SOIL POLLUTION INDEX AND SOIL INFILTRATION RATES IN SOME NON-FIRE AND FIRE AREAS OF JHARIA COALFIELD

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ABSTRACT

Jharia coalfield is a major source of prime coking coal in India. This coalfield has witnessed unparallel fire problems since 1916 affecting seams IV to XVII. At present there are as many as 65 active mine fires spread over 17.32 sq. km areas affecting the micro and macro environment adversely. The impact of mine fires has been noticed on all segments of environment viz. air, water and land. This paper discusses the variations in trace elements concentration in top soil and soil infiltration rates in some fire affected coal mines vis-a-vis areas not affected by fire. Soil pollution index was also calculated for each of the study areas taking into consideration the critical concentration of different trace elements in the soil. The soil in fire areas showed higher concentrations of Cu, Fe, Mn, Zn, Cd, Cr and Ni and lower values of B and Mo compared to non-fire and intermediate fire areas. As, Hg and Se were absent in soil of all the stations. Based on the trace element study and soil pollution index, it can be concluded that non-fire areas are slightly polluted, whereas intermediate and active fire areas are moderately polluted. In addition, the soil infiltration rates are higher in fire areas compared to non-fire and intermediate fire areas.

KEYWORDS: *soil pollution index; infiltration rate; coalfield; trace metals; fire areas.*

1. INTRODUCTION

Soil can be broadly defined as “the upper layer of earth’s crust on which most of the plants grow and from where they derive most of their water and nutrients supply”. Unscientific surface mining activities and mine fires affect this precious resource and its quality as well as productive use (Brady, 1995). The problem of mine fires in Jharia coalfield of BCCL is very severe as 17.32 sq. km area of land is affected. Mine fires in this area result in decay of vegetation and degradation of top soil due to high strata temperature. They further cause subsidence, which creates surface cracks and fissures. They enhance the infiltration rate, loss of nutrients and increased mobility of trace elements in the soil. Reclamation of fire affected areas become difficult because of low organic matter, low NPK (Nitrogen, Phosphorous and Potassium) status and moisture content.

In this paper, an attempt has been made to provide a comparative assessment of soil quality with respect to trace elements and infiltration rates in three zones viz. fire, non-fire and intermediate fire zone.

2. STUDY AREA

The study area is located in the eastern part of Jharia coalfield which comprises of non-fire zone: Bastacolla (S1) and Bera (S2); intermediate fire zone: Kuiyan (S3) and Golakdih (S4) and fire zone: North Tisra (S5), Lower Upper Jharia (S6) and Joyrampur (S7). The sites were selected based on the intensity of fire activity in the respective zones. The details of sampling sites in the study area have been summarized in Table 1.

3. SAMPLING AND EXPERIMENTAL PROCEDURE

The representative soil samples were collected from the study area upto a depth of 15 cm as per the standard procedure prescribed by Indian Agricultural Research Institute (IARI), New Delhi (Ghosh et al., 1983). The location of sampling sites was randomized to avoid any biasing of results. Infiltration rates of soil were measured at the selected locations by cylinder infiltrometer method (Dakhinamurthi and Gupta, 1968). The analysis of trace elements in soil was conducted by nitric acid digestion method and the concentration of each element was found using GBC-902 atomic absorption spectrophotometer (AAS).

4. RESULTS AND DISCUSSIONS

The results of the soil analysis have been presented in Tables 2 and 3. From Table 2, it can be observed that the infiltration rate is initially high in all types of soil, but decreases with time and approaches a steady state (Fig.1). This is due to swelling of the clay minerals, which reduces the available pore spaces. The average infiltration rates in general higher in fire areas than the other zones. At higher temperatures, the clay minerals undergo irreversible chemical changes, reducing the adsorbed layer of water. This increases the effective flow area. Further, the resulted coarse texture of the soil, cracks and fissures developed due to subsidence of strata; enhances the infiltration rates considerably. The pH value of different stations was determined using digital pH meter. The values were found to be lower in fire zone than the non-fire and intermediate fire zones (Tripathy, 2001).

Table 1: Description of sampling sites

Category of zones	**Location of sampling sites**	**Description of sampling sites**	**Soil type**
Non-fire zone	Bastacolla colliery (S1)	Top soil close to overburden dumps were collected. The area was having moderate vegetation cover.	Sandy-loam
	Bera colliery (S2)	Top soil near No.14 pit was collected. It was having moderate vegetation cover.	Sandy-loam
Intermediate fire zone	Kuiyan colliery (S3)	Top soil close to underground mine was collected. It had low to moderate vegetation cover.	Sandy-loam
	Golakdih colliery (S4)	Top soil close to the fire located in one side of the Open Cast Project was collected. It had low vegetation cover.	Sandy-loam
Fire zone	North Tisra colliery (S5)	Top soil close to overburden dumps affected by active fire was collected. The fire cracks were present extensively. It had no vegetation.	Loamy-sand
	Lower Upper Jharia colliery (S6)	Top soil close to Lower Upper Jharia pit affected on three sides by fire, was collected. Extensive surface cracks were present. It had negligible vegetation.	Loamy -sand
	Joyrampur colliery (S7)	Top soil close to Joyrampur pit was collected. It was affected by active fire. It had no vegetation.	Loamy-sand

Table 2: Infiltration rate (cm/hr) in soil

Station	Elapsed time, min								Avg. Infiltration Rate
	15	30	45	60	90	120	180	240	
S1	4.530	2.094	1.860	1.415	0.623	0.566	0.424	0.396	0.973
S2	6.220	2.260	1.755	1.550	0.650	0.622	0.453	0.390	1.100
S3	7.360	2.350	2.066	1.840	0.976	0.820	0.424	0.382	1.277
S4	9.900	3.480	2.378	2.200	1.415	1.302	0.736	0.672	1.810
S5	13.580	12.170	10.950	9.060	5.800	5.290	2.970	2.547	5.610
S6	12.740	10.190	9.620	8.200	5.260	4.810	2.980	2.690	5.220
S7	13.300	11.880	9.630	7.920	5.520	4.640	3.080	2.880	5.430

Table 3: Trace elements concentration in soil (μg/g)

Trace elements	Trace elements concentration at different stations							Critical soil concentration (S_i) [Bowen, 1979]
	S1	S2	S3	S4	S5	S6	S7	
Lead (Pb)	29.40	23.95	18.60	21.00	25.00	23.00	21.40	100-400
Zinc (Zn)	33.80	55.00	59.60	78.60	81.80	92.60	87.50	70-400
Copper (Cu)	15.40	23.80	36.20	39.68	48.60	54.70	48.80	60-125
Iron (Fe)	255.20	333.00	445.00	470.00	546.00	637.70	553.00	-
Cadmium (Cd)	0.15	0.180	0.32	0.45	0.62	0.70	0.65	3-8
Mercury (Hg)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	3-5
Arsenic (As)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	20-50
Selenium (Se)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	5-10
Chromium (Cr)	20.30	10.21	14.30	16.40	19.60	24.50	21.30	75-100
Cobalt (Co)	1.30	1.60	2.10	2.60	3.10	3.70	3.60	25-50
Manganese (Mn)	30.56	41.29	47.30	48.00	55.50	83.50	60.20	1500-3000
Nickel (Ni)	0.22	0.31	0.52	0.47	0.73	0.675	0.70	100
Boron (B)	4.23	4.17	4.10	3.55	3.10	2.11	2.16	5-10
Molybdenum (Mo)	0.091	0.07	0.042	0.034	0.031	0.02	0.022	2-10

BDL(Below detection limit): (< 0.001 μ g/g)

It may be observed from Table 3 that:

- The Pb content in soil of non-fire zones: S1 and S2 were 29.4 and 23.95 ppm respectively; intermediate fire zones: S3 and S4 were 18.6 and 21 ppm respectively and fire zones: S5, S6 and S7 were 25.0, 23.0 and 21.4 ppm respectively. Its source in soil of non-fire zones may be due to vehicular pollution. In fire zones and intermediate fire zones it may be due to burning of coal, traffic movement, overburden removal and low pH of soil. The critical concentration of Pb in soil is 100 ppm. The observed values were within the critical limit in all the zones.

- Zinc content in soil were at S1:33.8 ppm, S2:55 ppm, S3: 59.6 ppm, S4:78.6 ppm, S5: 81.8 ppm, S6: 92.6 ppm and S7:87.5 ppm. There is an increase in Zn concentration from S1 to S7. The values are higher than its critical soil concentration at S4, S5, S6 and S7. Fire areas showed higher Zn levels due to intense opencast mining and coal mine fires. The solubility of Zn increases with decrease in pH. Lower concentration of Zn in non-fire and intermediate fire zones may be due to the formation of insoluble Zn compounds due to relatively higher pH.

- Copper concentration was found to be decreasing from stations S1 to S7 and is within its lower critical concentration limit in soil i.e. 60 ppm. Sources of Cu in soil in different areas may be due to refuse burning, coal combustion, upturning of soil and fugitive emissions.
- Iron concentration in non-fire areas was at S1 : 255.2 ppm, at S2 : 330.0 ppm; intermediate fire zones: at S3 : 445 ppm, at S4 : 470 ppm; in fire zones: at S5 : 546 ppm, at S6 : 637.7 ppm and at S7 : 553 ppm. In fire areas it was high due to the formation of oxides of iron at high temperatures. An increase in iron concentration is observed with decrease in pH.
- Manganese concentrations at stations S1 to S7 are very low as compared to critical concentration of 1500 ppm. Higher Mn levels in the fire zones may be due to cumulative effects of coal burning, fugitive emissions and soil acidity.
- All the observed values of chromium concentration at stations S1 to S7 are less than the lower critical soil concentration of 75 ppm.
- Fire zones showed a higher concentration of Cd as compared to the other zones and are less than the critical soil concentration of 3 ppm. Higher concentration of Cd in soil of fire areas may be due to combustion of coal and subsequent deposition.
- Due to low pH, low organic carbon and coal burning the concentrations of Ni and Co are found to be higher in fire zones as compared to other zones. However, these values are within their critical limits in soil.
- Boron concentrations at stations S1 to S7 are less than the critical soil concentration of 5 ppm. It showed a decreasing trend with decrease in pH values.
- Mo concentration showed a decreasing trend from non-fire to fire zones. The concentrations of As, Hg and Se were below the detection limits at all the stations (Tripathy, 2001; Singh and Srivastava, 1997; Singh and Singh, 1994; Alloway, 1990; Bowen, 1979).

5. SOIL POLLUTION INDEX (SPI)

In order to determine the soil pollution index, concentration of individual trace element (C_i) is divided by its lower limit of the critical soil concentration value (S_i) as given in Equation (1).

Let $$D_i = \frac{C_i}{S_i} \times 100 \qquad (1)$$

Soil pollution index is calculated by taking the geometric mean of D_i for all the stations (Table 4). SPI for fire zones are found to be higher than the other two areas.

Considering the rating scale (Table 5), it can be concluded that the non-fire areas are slightly polluted; intermediate and fire areas are moderately polluted with respect to trace elements concentration in soil (Tripathy, 2001).

Table 4: Determination of soil pollution index in the study areas

Trace elements	Trace elements concentration at different stations							**Lower Critical soil conc., S_i**	**Mean C_i/S_i for all the areas**
	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**		
Pb	29.4	23.95	18.6	21.0	25.0	23.0	21.4	100	23.19
Zn	48.3	78.5	85.1	112.2	116.8	132.0	125.0	70	99.7
Cu	25.6	39.6	60.3	66.1	81.0	91.0	81.0	60	63.51
B	84.0	83.0	82.0	71.0	62.0	42.0	41.0	5	66.6
Cd	5.0	6.0	10.6	15.0	21.0	23.0	22.0	3	14.6
Mo	4.55	3.5	2.1	1.7	1.55	1.0	1.1	2	2.21
Cr	27.0	13.6	19.0	21.8	26.1	32.6	28.4	75	23.44
Co	5.2	6.4	8.4	10.35	12.4	14.8	14.4	25	10.28
Mn	2.0	2.7	3.1	3.2	3.7	5.5	4.0	1500	3.45
Ni	0.22	0.31	0.52	0.47	0.73	0.675	0.7	100	0.51
SPI	15.99	17.65	21.45	23.59	28.35	28.83	26.54		24.58
Rating	Slightly polluted	Slightly polluted	Mode-rately polluted	Mode-rately polluted	Mode-rately polluted	Mode-rately polluted	Mode-ately polluted		Moderately polluted

The rating scale for soil pollution index is given in Table 5.

Table 5: Rating for soil pollution index (Alloway,1990)

Index value	**Degree of pollution**
≤10.0	Unpolluted
>10-20.0	Slightly polluted
>20-30.0	Moderately polluted
>30-40.0	Severely polluted
>40.0	Dangerously polluted

6. CONCLUSIONS

- Soil infiltration rates are higher in fire areas compared to non-fire and intermediate fire areas.
- Soil in fire areas showed higher concentrations of Cu, Fe, Mn, Zn, Cd, Cr and Ni and lower values of B and Mo compared to non-fire and intermediate fire areas. As, Hg and Se were absent in soil at all the stations.

- Based on the trace element study and soil pollution index, it can be classified that non-fire areas are slightly polluted, whereas intermediate and fire areas are moderately polluted.

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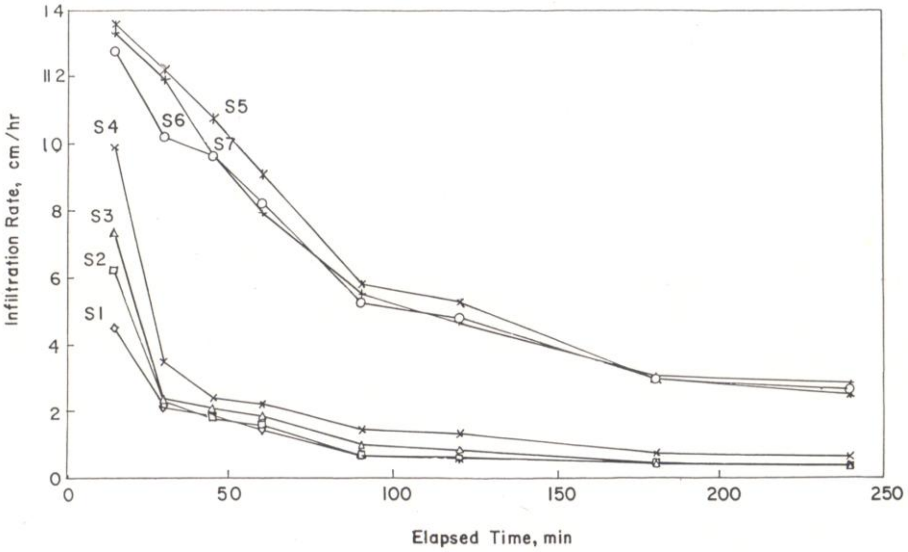

Figure 1: Variation in infiltration rate in soil with time at different stations