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Assessment of Geochemistry of Soils of Iron Ore Belt of Bolani and Barbil Odisha, India: A Factor Model

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Abstract: ***Natural processes such as weathering and erosion control the metal load of soils making it suitable for plant growth. However, mining and industrial activity in a region can greatly obliterate this natural balance by accelerated accumulation of undesirable trace metals in soils, rendering it unsuitable for plant growth. Hence, geochemical study of soils of such area is necessary. Factor analysis was carried out on soil geochemical data to establish various processes responsible for metal accumulation. Five factors were retained from post-monsoon soil data. First and second factors are attributed to iron and manganese mining in the area. The third, fourth and fifth factors are attributed to natural processes such as chemical alteration of iron minerals, weathering of rocks and formation of clay minerals.***

Keywords: Geochemistry, Soil, Post-monsoon, Factor analysis, Bolani and Barbil

1. Introduction

Natural processes such as weathering and erosion control the metal load of soils making it suitable for plant growth. However, mining and industrial activity in a region can greatly alter this natural balance by accelerated accumulation of undesirable trace metals in soils, thereby making it unsuitable for plant growth. Alluvial soils are most favorable sinks for heavy metals in a polluted mining environment (Forstner and Wittmann, 1979). Several investigations carried out on soils (Hren *et al.*, 2001; McGregor *et al.*, 1998; Lin and Herbert, 1997; Bullock and Bell, 1997; Clark *et al.*, 2001; and Gabler and Schneider, 2000; Ratha and Nayak, 2005) reveal that the soils and the sediments of the nearby mining area are severely contaminated by metals in most part of the world. Again, several studies (Nair et al., 1990; Bodo, 1989; and Ansari et al., 2000) reveal that rainfall or snowmelt in the upland regions increases the metal load in lower regions. Ansari et al. (2000) recorded higher load of metal pollutants in the sediments and soils of Ganga plain after monsoon. Hence, it is necessary to carryout study of metal load in soils and establishes their sources in post-monsoon period. For this purpose soil samples were collected during 2012-14.

Geological Setting

Bolani and Barbil are located in Keonjhar district of Orissa and are known for their iron and manganese deposits. Rocks of the area belong to Iron Ore Group (IOG) comprising mainly Banded Iron Formation (BIF) and associated volcano-sedimentary rocks. The Banded Iron Formation more or less circumscribes the Singhbhum granite batholith. BIF occurrences in Joda-Barbil-Noamundi, Gorumahisani, Daitari are rich in iron ore deposits. These have been classified into 3 major stratigraphic belts such as BIF-I, BIF-II and BIF-III. The last one is exposed in Bonai-Keonjhar belt of Sundergarh-Keonjhar district (Acharya, 1984).

2. Materials and Methods

Soil samples were collected from 27 locations (Fig.1) during post-monsoon periods covering the Bolani and Barbil region. From each location about 4kg sample was collected in polythene packet. Then the samples were dried and sieved. Coarse materials were removed. One gram of <74μm size fraction was taken for metal analysis. One gram of soil (<200mesh fraction) was treated with concentrated acid, dissolved in a closed system. About 25ml of aqua-regia (3 parts HNO_3 and 1 part HCl) was used for dissolution. The reduced volume of the sample solution was then treated with HNO_3 and HClO4 acids in 1:1 proportion and again concentrated to minimum volume. The solution was then extracted with distilled water and the volume was made to 250 ml. The sample solution was then aspirated into atomic absorption spectrophotometer (Perkin Elmer-3100) under optimum operational conditions to measure the concentration of different elements such as Ca, Na, K, Mg, Fe, Mn, Co, Zn, Ni, Cd, Pb, Cr and Cu (Table-1).

3. Results and Discussion

Calcium concentration in soils of Bolani varies from 40 to 900 µg/g and that of Barbil from 10 to 1420 µg/g. Magnesium concentration recorded in post-monsoon soil varies from 600 to 5900 µg/g in Bolani and from 250 to 6750 µg/g in Barbil. Sodium concentrations recorded in soils range from 140 to 2300 µg/g in Bolani whereas in Barbil these range from 130 to 4200 µg/g. Potassium levels in soils of Bolani vary from 267 to 9500 µg/g whereas in Barbil these range from 1170 to 23500 µg/g. Fe in soils of both areas varies from 2.12-60.87%. Soils nearer to mines show higher Fe content than samples away from mines. Manganese in soils of Bolani is low and varies from 0.05-0.8% whereas Barbil soils are richer in Mn, which varies from 0.001 to 10.18%. Cu in soils varies from 28 to 80 µg/g in Bolani and range from 18 to 140 µg/g in Barbil. Zn in soils varies from 40 to 120 µg/g in

Bolani and range from 58 to 260 µg/g in Barbil. Ni in soils varies from 140 to 260 µg/g in Bolani and range from 20 to 440 µg/g in Barbil. Co in soils varies from 80 to 180 µg/g in Bolani and range from 13 to 120 µg/g in Barbil. Cr in soils varies from 200 to 1200 µg/g in Bolani and range from 65 to 970 µg/g in Barbil. Pb content in soils is 5 to 40 µg/g in Bolani and range from 7 to 90 µg/g in Barbil. Cd content in soils varies from 140 to 160 µg/g in Bolani and 1 to 7 µg/g in Barbil. Fe, Mn, Cr, Co, Pb and Cd are higher in soil samples than the world averages reported for soils. Cr contamination is more in soils of Bolani whereas Barbil soils are more contaminated by Pb. Mn contamination is found more in soils of Barbil. Soils of Bolani are more contaminated with heavy metals compared to soils of Barbil due to the location of the area nearer to iron ore mining sites.

Factor Analysis

Factor analysis, one of the possible multivariate analyses has been widely used for the interpretation of geochemical data on sediments, soil and water. The technique was first used in geological evaluation by Krumbein (1957). Factor analysis is a useful explanatory tool in multivariate statistical analysis and it can be applied to discover and interpret relations among variables including samples or to test hypotheses. The general purpose of factor analytic technique is to find a way of condensing the information contained in a number of original variables into a smaller set of new composite dimensions with minimum loss of information (Davis, 1986; Ratha and Sahu, 1993; Ratha, 1997). In order to establish the natural processes and the anthropogenic processes responsible for pollution, the R-mode factor analysis with rotation was applied to normalized major and trace element data of soils (Kaiser, 1958; Kumru and Bakac, 2003).

Five factors were retained (Table-2) for interpretation. These five factors explain 82.16% of total variance.

First factor explains 27.14% of variance and is positively loaded on Fe-Ni-Co-Cr-Cd and negatively on Pb. This factor explains the dominant contribution from iron ore mining activity.

Second factor explains 18.73% of total variance and is loaded on Mn-Cu-Zn-Pb suggesting contribution from manganese mining.

Third factor explains 17.02% of total variance and is positively loaded on Ca-Mg suggesting development of clay minerals in the soil. Negative loading on Fe-Mn-Co reveals the formation of goethite containing manganese and cobalt in its matrix.

Fourth factor explains 9.73% of total variance and is negatively loaded on K-Zn. This is a negative unipolar axis suggesting contribution from shaly host rock.

Fifth factor explains 9.54% of total variance and is positively loaded on Na suggesting absorption of sodium in clay matrix and development of montmorillonite in impeded drainage condition.

4. Conclusion

The application of multivariate statistical analysis for the assessment of geochemical data has led to the determination and classification of different sources of metal loads. Analyses of the metals of the soils of the Bolani and Barbil area show that they are highly contaminated due to mining and related industrial activity of the area. Hence, appropriate remedial steps may be taken to prevent contamination of the soils from mining and industrial activity in rainy season.

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Table 1: Varimax factor matrix for elemental data of post-monsoon soil samples

	(bold values are significant at 95% level of confidence)					
	Factor-1	Factor-2	Factor-3	Factor-4	Factor-5	Communality
Fe	**0.721**	0.009	**-0.557**	0.248	-0.107	0.903
Mn	-0.215	**0.674**	**-0.457**	0.196	-0.224	0.797
Ca	-0.246	-0.050	**0.800**	0.182	0.286	0.818
Mg	0.155	-0.176	**0.856**	-0.026	-0.045	0.791
Na	-0.223	-0.026	0.179	0.028	**0.922**	0.934
K	-0.327	0.128	-0.006	**-0.869**	-0.012	0.877
Cu	0.024	**0.944**	-0.089	-0.107	0.130	0.928
Zn	0.087	**0.771**	-0.124	**-0.497**	-0.044	0.867
Ni	**0.826**	0.134	0.050	-0.022	-0.029	0.704
Co	**0.681**	0.120	**-0.396**	0.156	0.073	0.664
Cr	**0.785**	-0.234	0.048	0.116	-0.227	0.739
Pb	**-0.540**	**0.552**	0.247	0.178	-0.348	0.810
Cd	**0.813**	-0.231	0.206	0.220	-0.216	0.852
Eigen values	3.5288	2.4353	2.2130	1.2649	1.2399	
% of trace	27.1444	18.7328	17.0230	9.7301	9.5376	
Cumulative % of trace	27.1444	45.8772	62.9002	72.6303	82.1679	

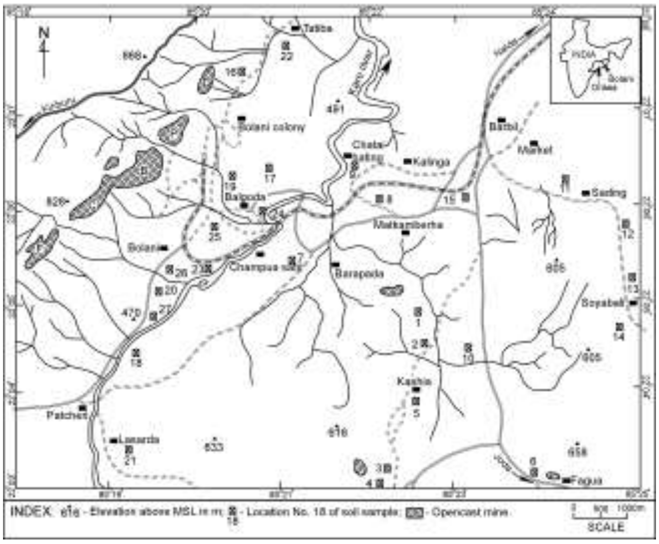

Figure 1: Location map of soil samples