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Website: www.aarf.asiaEmail : editor@aarf.asia , editoraarf@gmail.com

STUDY OF PHYSICO-CHEMICAL CHARACTERISTICS OF OVERBURDEN DUMP SOIL IN SELECTED COAL MINING AREAS OF RANIGANJ COAL FIELDS, WEST BENGAL, INDIA

Debalina Kar [1], Debnath Palit [2]

[1] Department of Conservation Biology, Durgapur Government College, India.

[2] Department of Botany, Durgapur Government College, India.

ABSTRACT

At the early stages of an ecosystem development, soils constitute a critical controlling component. Without the progress of natural processes of soil development, ecosystems would remain in an under-developed condition. Open cast coal mining activities at a particular site dumps all residues of excavation in form of overburden. These overburdens, when dumped in unmined areas in the vicinity of coal mines, create mine spoil dumps. The dumping of overburden destroys the surrounding vegetation and leads to severe soil and water pollution, resulting into massive damages to landscapes and biological communities of the earth. Present study revealed the physic chemical analysis of selected seven sites for experiment at Raniganj coal field. The overburden (OB) samples were collected from the month of March 2011 to February 2012. The result shows sharp seasonal changes of parameters in seven overburden dumps. The quality of soil depends upon physico chemical factors found in principal component analysis. Cluster analysis designates the relationship among different parameters in three seasons.

Keywords - Open Cast Mine, Overburden Dump, Physico-Chemical Characters, Raniganj, Seasonal Changes.

1. Introduction

Coal and allied mining activities render changes in the landscape to a considerable extent resulting in the degradation of the stable ecosystems. In course of mining activities the land surfaces are subjected to permanent alteration, causing loss of vegetation and thus the productivity of the ecosystems (Kundu and Ghose, 1997 “a”, “b”, “c”; Ghose, 2005). Consequently, the ecosystem functions are stalled, and requires huge time gap for gaining stability in natural courses. The magnitude of mining for the utilization of the mineral resources and fossil fuel is continuously increasing owing to the development activities and the population demand (Wong, 2003; Sheoran et al., 2008). A trade-off between the demand of the coal and allied products with the stable ecosystem conditions is required to follow the norms of sustainable development. The fulfillment of the demands for coal may increase the destabilized conditions of the ecosystems in the land mining areas, which is contrary to the objectives of the sustainable development. Thus to continue with the coal extraction and reduce the damage to the terrestrial ecosystem, simultaneous monitoring and remediation strategies need to be adopted to keep the pace of the economic development without affecting the ecosystem balance of the concerned landscape.

Soil quality acts as an indicator of environmental pollution. Soil pollution affects the availability of nutrients, soil structure and water quality of the area. This in turn affects the growth of flora and fauna in various ways. Soil is polluted due to disposal of industrial/mining and domestic solid wastes, wet and dry deposition from the atmosphere, infiltration of contaminated water and acid mine drainage (Singh and Singh, 2004). Mining operations, which involve mineral extraction from the earth's crust, tends to, make a notable impact on the environment, landscape and biological communities of the earth (Bell et al., 2001). The chief environmental impacts due to mining are changes in soil stratification, reduced biotic diversity, and alteration of structure and functioning of ecosystems; these changes ultimately influence water and nutrient dynamics and trophic interactions (Ghose, 2004). The overlying soil and the fragmented rock removed during coal mining are heaped in the form of overburden dumps. Overburden (OB) materials are nutrient-poor, loosely adhered particles of shale, stones, boulders, cobbles, and so forth devoid of true soil character (Deka Boruah, 2006) and containing elevated concentrations of trace metals. The overburden dumps when deposited in un-mined areas create mine spoils affecting the landscape of the area and causing various environmental problems.

Assessment of soil physico-chemical characteristics of coal mine overburden spoils in a chronosequence is of utmost important because it not only paves the way of greater understanding the direction of improving soil fertility and bioremediation, but also is pre-requisite for assessing the process of spoil reclamation, leading to the vegetational development/succession with respect to time (Maharana and Patel, 2013). Thus, an attempt has been made in the present study to determine the spoil physical and chemical properties in currently mining site.

2. Materials and Methods

Study Site: Raniganj Coalfield lies between latitudes 23°03' and 23°51' N and longitudes 86°42' and 87°28' E, which falls under Eastern Coalfield Ltd., is the birth place of coal mining in the Country (Figure 1). The study area encompasses a large stretches of old Opencast Coal Pit (OCPs) in the area of Eastern Coalfield Limited (ECL). They are located in the Raniganj Coalfield division of Burdwan district of West Bengal of India. Total area of ECL is 1,620 sq. km. Among which 1530 sq. km is under Raniganj Coalfield spreading over Burdwan, Birbhum, Bankura and Purulia Districts in West Bengal and Dhanbad District in Jharkhand. However, most of the area of Raniganj Coalfield is in Burdwan District and is bounded by Ajoy River in North and Damodar River in South. Heart of Raniganj Coalfields is located on the north of Ajoy while Mejia and Parbelia are on south of Damodar River. In Dhanbad District, Mugma field lies on the west of Barakar River. Formation of coal seems has occurred mainly in two sequences at ECL- Raniganj measures and Barakar measures. Raniganj measures cover the entire coalfield of Raniganj- Pandaveswar, Kajora, Jhanjra, Bankola, Kenda, Sonepurbazari, Kunustoria, Satgram, Sripur, Sodepur and partly at Salanpur Areas.

The climate of the study area is in general dry tropical. The area experiences three prominent seasons, summer (middle of March to middle of June) monsoon rain (middle of June to Middle of October) and winter (November to February). In summer average temperature ranges between 38°C to 43°C, some time it may be rises up to 48°C temperature. The area receives average annual rainfall between 1240 to 1500 mm.

Spoil Analysis: Open cast coal mining activities at a particular site dumps all residues of excavation in form of overburden. The overburden material consists of sandstone, boulders, pebbles, coal and other minerals. Initially, the fragments are larger in size which during the process of dumping become fragmented often assuming the form of dust. The mixture has very low binding capacity and is almost inert to obscure profiling. Since, the biological reclamation initiates in the upper surface of the dump. The samples were collected in three climatic seasons during March 2011 to February 2012. Each sample was preserved in a polythene bag and labelled. About 500 mg of the composite sample was spread over a paper placed on polythene sheet for air-drying under sun. After it was sufficiently dried small stones, pebbles and gravels etc. were manually removed. Then the samples were ground into fine powder by gently pressing them with a mallet. The samples were then strained through 2mm sieve and again air-dried. Analyses were done with the air-dried samples. To characterize the physical and chemical properties of the mine spoil, samples were analysed for different parameters with standard methods (Table 1).

3. Results and Discussion

A correlation study was performed to analyse the relationship among different physico chemical parameters in three consecutive seasons. Table 2 depicts the negative correlation of water holding capacity with bulk density (r=-0.93) in season premonsoon. Soil porosity was positively correlated with particle density (r=0.81) and conductivity (r=0.81). Available nitrogen positively correlated with organic carbon (r=0.78). Available sodium negatively correlated with pH (r=-0.78).

In monsoonal season water holding capacity and pH negatively relate to each other (r=-0.74) that showing in Table 3. Available sodium was positively related with particle density (r=0.94) and soil porosity (r=0.82).

Table 4 indicate the correlation table of post monsoonal season, it was observed that particle density negatively correlated with pH (r=-0.83) and soil porosity (r=0.95). Available nitrogen was positively correlated with organic carbon (r=0.76). Available sodium positively correlated with Available potassium (r=0.91).

In most of the cases of three seasonal data correlated values were significant at $P < 0.05$, thus justifying the use of multivariate statistics (PCA). Table 5 (a-c) shows that factor analysis extracts important factors according to Eigen values (>1) for the three studied seasons. For pre monsoon season, the highest factor loadings for 1st, 2nd, 3rd and 4th components were considered and these were for water holding capacity (FL = 0.861) in the 1st component, particle density (FL = 0.963) in the 2nd component, available phosphate phosphorus (FL = 0.891) in the 3rd component and available nitrogen (FL= 0.924) in the 4th component. In monsoon, the highest factor loadings for 1st, 2nd and 3rd components were considered and these were for available sodium (FL = 0.933) in the 1st component, available potassium (FL = 0.948) in the 2nd component and pH (FL = 0s.816) in the 3rd. For post monsoon season, the highest factor loadings for 1st, 2nd, 3rdand 4th components were considered and these were for soil porosity (FL = 0.945) in the 1st component, available nitrogen (FL = 0.853) in the 2nd component, available potassium (FL = 0.980) in the 3rd component and water holding capacity (FL= 0.837) in the 4th component.

With the help of hierarchical cluster analyses based on physicochemical parameters of premonsoon, monsoon and post monsoon (Figure 2) the sampling sites could be clustered and categorized into several small groups. In Premonsoon, three clusters were formed among Sankarpur bankola and Sonepurbazari, Bankola and Sankarpur Kenda, Jambat and Sidhuli. Nagrakonda separately formed a cluster with Jambat and Sidhuli pair. Other pairs were distantly related from each other. In case of monsoon season, Bankola, Sankarpur bankola and Sankarpur kenda parametrically closely related. Such pair related with Sonepurbazari. On the other hand Jambat and Sidhuli formed another closed pair which was distantly related with Nagrakonda. For postmonsoon, Sankarpur kenda, Nagrakonda, Sankarpur bankola and Sonepurbazari forming a closely related cluster which is distantly related with another pair of Bankola and Jambat. In this case Sidhuli distantly related among all pairs. The resulting clusters of objects should then exhibit high internal (within cluster) homogeneity and high external (between clusters) heterogeneity (Shrestha and Kazama, 2007).

4. Figures and Tables

Table 1: Analytical Methods of Spoil Analysis Followed in the Present Work

	Parameters	Methods followed
1.	Soil pH	Electronics pH meter in 1:10 soil water suspension as described by Jackson (1972)
2.	Soil Conductivity (µs)	Electronics conductivity meter in 1:2 soil water suspension as described by Jackson (1972)
3.	Bulk Density (g/cm^3)	Gupta 2004
4.	Particle Density (g/cm^3)	Black 1965
5.	Porosity (%)	Black 1965
6.	Water Holding Capacity (%)	Saxena 1998
7.	Organic carbon (%)	Volumetric method (Walkley 1947) as described by Muhr et al. (1965)
8.	Available nitrogen ($kg.ha^{-1}$)	Kjeldahl method as described by Subbiah and Asija (1956)
9.	Available phosphorus ($kg.ha^{-1}$)	Olsens method as described by Olsen et al. (1954)
10.	Available potassium ($kg.ha^{-1}$)	Flame photometer method as described by Black (1965)
11.	Available sodium ($kg.ha^{-1}$)	Flame photometer method as described by Black (1965)

Table 2: Correlations (Marked Correlations are Significant at P < .05000) Between Physicochemical Parameters of 7 Different OBDs of Pre Monsoon Season

	PH									
BD	-0.43	**BD**								
PD	0.03	0.04	**PD**							
SP	0.33	-0.55	**0.81**	**SP**						
WHC	0.57	**-0.93**	-0.32	0.29	**WHC**					
CON	0.32	-0.37	0.73	**0.81**	0.18	**CON**				
OC	0.06	0.23	0.33	0.17	-0.22	0.45	**OC**			
AN	-0.06	-0.15	0.05	0.12	0.18	0.45	**0.78**	**AN**		
AP	-0.41	-0.36	0.47	0.55	0.1	0.62	0.25	0.57	**AP**	
AS	**-0.78**	0.4	0.25	-0.04	-0.57	-0.35	-0.18	-0.24	0.25	**AS**
APP	-0.33	-0.53	0.05	0.3	0.3	0.34	-0.1	0.18	0.66	0

Table 3: Correlations (Marked Correlations are Significant at P < .05000) Between Physicochemica Parameters of 7 Different OBDs of Monsoon Season

	PH									
BD	0.26	**BD**								
PD	0.43	0.53	**PD**							
SP	-0.23	0.08	0.68	**SP**						
WHC	**-0.74**	-0.6	-0.61	-0.06	**WHC**					
CON	0.16	-0.24	0.27	0.32	-0.34	**CON**				
OC	0.22	-0.41	-0.39	-0.41	-0.27	0.29	**OC**			
AN	-0.27	-0.01	-0.69	-0.59	0.26	0.02	0.04	**AN**		
AP	0.11	-0.52	-0.12	-0.12	-0.1	0.8	0.56	0.11	**AP**	
AS	0.11	0.43	**0.94**	**0.82**	-0.4	0.31	-0.46	-0.66	-0.05	**AS**
APP	-0.26	0.02	-0.66	-0.41	0.27	-0.41	0.05	0.68	-0.45	-0.71

Table 4: Correlations (Marked Correlations are Significant at P < .05000) Between Physicochemical Parameters of 7 Different OBDs of Post Monsoon Season

	PH									
BD	0.16	**BD**								
PD	**-0.83**	-0.55	**PD**							
SP	-0.7	-0.68	**0.95**	**SP**						
WHC	0.39	0.25	-0.6	-0.53	**WHC**					
CON	-0.37	0.34	0.23	0.06	0.29	**CON**				
OC	-0.33	0.1	0.47	0.34	-0.4	0.63	**OC**			
AN	-0.4	0.28	0.37	0.11	-0.39	0.67	**0.76**	**AN**		
AP	0.13	0.32	-0.18	0.01	0.18	-0.1	-0.19	-0.44	**AP**	
AS	0.23	-0.07	-0.1	0.17	0.11	-0.36	-0.32	-0.66	**0.91**	**AS**
APP	-0.04	0.47	-0.31	-0.53	0.46	0.51	-0.12	0.42	-0.41	-0.64

Table 5: Principal Component Analysis (3 Components Extracted) With Varimax Rotation And Kaiser Normalization In A) Pre-Monsoon, B) Monsoon And C) Post-Monsoon Seasons

a

Rotated Component Matrix[a]

	Component			
	1	2	3	4
pH	**.880**	.247	-.403	-.040
BD	-.715	-.183	-.629	.160
PD	-.252	**.963**	-.043	.085
SP	.237	**.913**	.280	-.019
WHC	.861	-.080	.433	-.099
CON	.271	**.804**	.229	.398
OC	-.051	.239	-.181	**.917**
AN	.110	.013	.303	**.924**
AP	-.213	.434	.778	.348
AS	-.866	.064	.156	-.275
APP	.013	.091	**.891**	.004
Eigen Value	3.954	2.838	1.944	1.578
% of variance	35.947	25.800	17.676	14.349
Cumulative %	35.947	61.746	79.423	93.772

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

b

Rotated Component Matrix[a]

	Component		
	1	2	3
pH	.044	.227	**.816**
BD	.101	-.614	.693
PD	**.838**	-.178	.509

SP	**.852**	-.182	-.154
WHC	-.202	-.153	-.945
CON	.043	.744	.454
OC	-.340	.755	.137
AN	-.798	.017	-.073
AP	.077	**.948**	-.038
AS	**.933**	-.175	.242
APP	-.813	-.362	-.108
Eigen Value	4.317	2.868	1.909
% of variance	39.244	26.076	17.354
Cumulative %	39.244	65.32	82.675
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.			

c				
Rotated Component Matrix[a]				
	Component			
	1	2	3	4
pH	-.808	-.337	.091	-.107
BD	-.654	.565	.189	.293
PD	**.937**	.232	-.073	-.238
SP	**.945**	.033	.137	-.286
WHC	-.332	-.257	.138	.837
CON	.211	.741	-.086	.573
OC	.249	**.836**	-.089	-.262
AN	.128	**.853**	-.457	-.048
AP	-.112	.008	**.980**	.067
AS	.013	-.315	**.933**	-.110
APP	-.278	.231	-.542	.704

Eigen Value	4.068	3.358	1.633	1.082
% of variance	36.984	30.53	14.848	9.834
Cumulative %	36.984	67.514	82.362	92.196
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.				

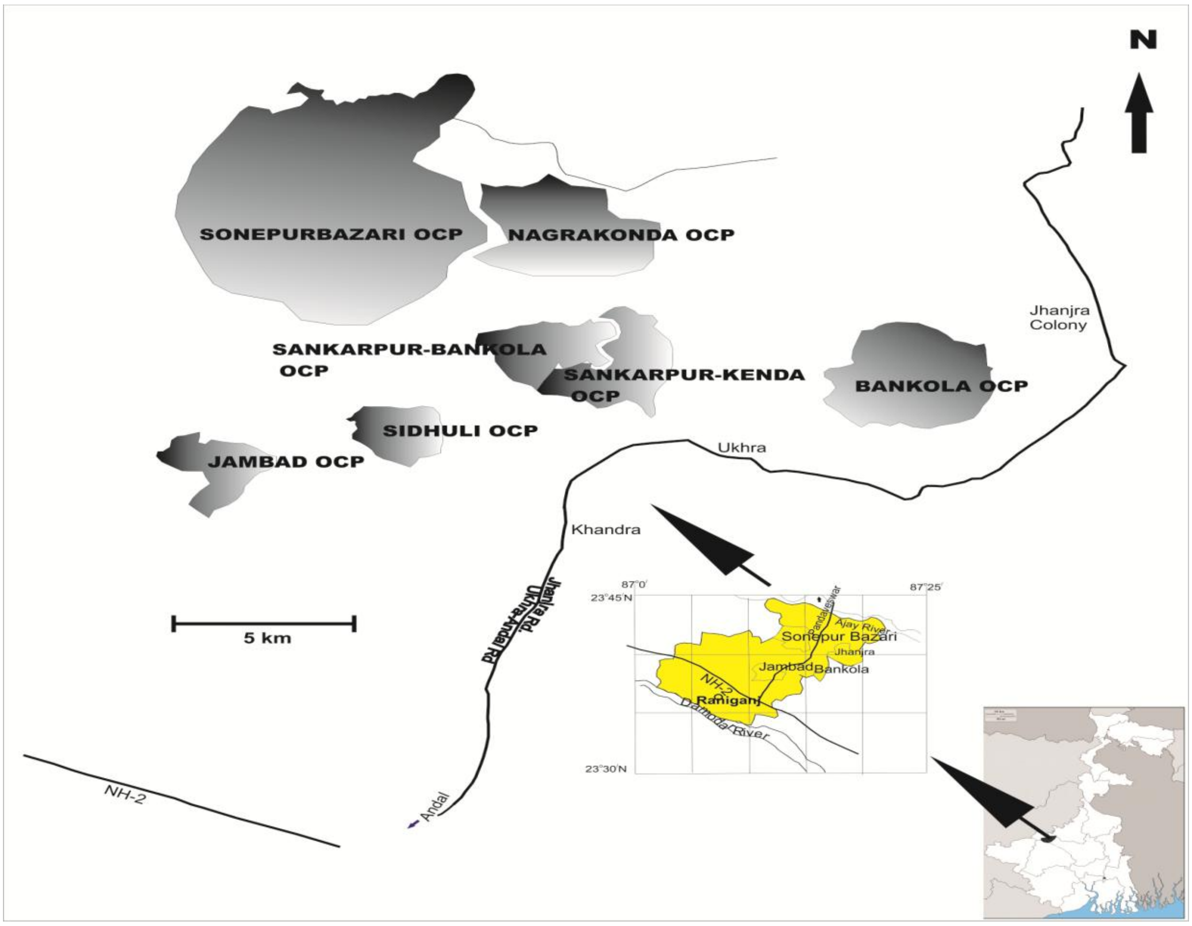
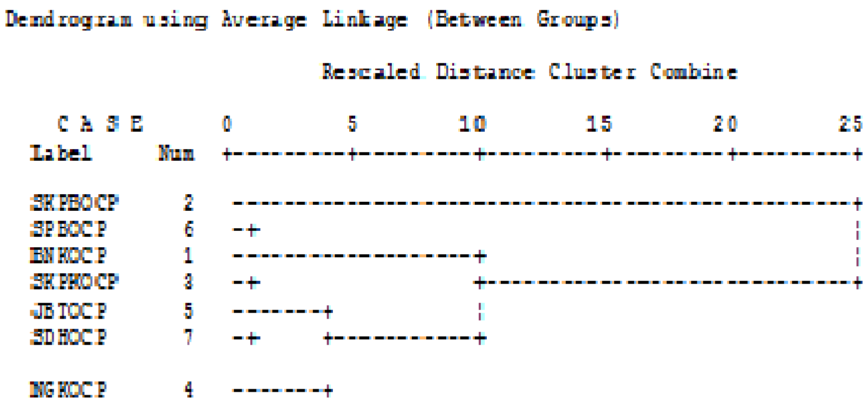


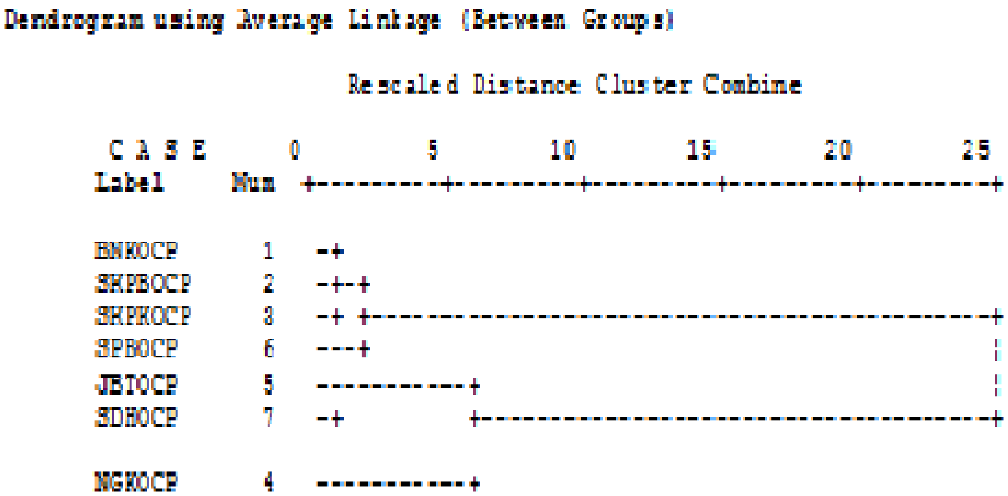
Fig. 1: Location of Selected Study Areas in Raniganj Coal Field, West Bengal, India

Fig. 2: Hierarchical Cluster Analysis of The Pit Lakes (1 To 7) Under The Study Area Depending on Physicochemical Conditions of Consecutive Three Different Seasons (Pre Monsoon, Monsoon and Post Monsoon)

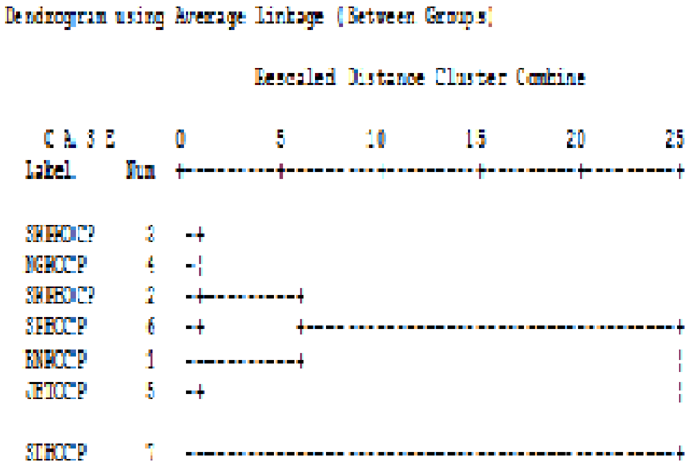
Pre monsoon



Monsoon



Post monsoon



5. Conclusion

The present study revealed that the coalmine overburden spoils were both physically and chemically poor. Nutrient content is very poor in overburden spoil in all the mining sites. A clear seasonal variation found in physico chemical parameters. Factor analysis explain the parameters like pH, conductivity, particle density, soil porosity, organic carbon, available nitrogen, available sodium and available phosphate phosphorous which are found most important factors responsible for soil quality changes. Thus, the study clearly revealed the effect of open cast mining on the soil physico-chemical properties.

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