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A STUDY OF PHYSICO-CHEMICAL CHARACTERISTICS OF OVERBURDEN DUMP MATERIALS FROM SELECTED COAL MINING AREAS OF RANIGANJ COAL FIELDS JHARKHAND INDIA

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A Study of Physico-Chemical Characteristics of Overburden Dump Materials from Selected Coal Mining Areas of Raniganj Coal Fields, Jharkhand, India

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Abstract - Most of the coal production in India comes from open cast mines contributing over 81% of the total production. A large number of open cast mines of over 10 million tons per annum capacity are in operation. Mining activities particularly opencast mining in huge forest areas results into loss of biodiversity, loss of nutrient qualities and microbial activities of the soil system. Opencast mining releases huge amount of mining wastes to the upper part of the land surface as overburden dump materials. In this study, the site selected for the experiment was overburden dump at different mining areas under Raniganj coalfields (RCF). The overburden (OB) samples were collected during the months of February and May 2010. Physico chemical characteristics such as Bulk density, Grain size distribution, pH, Electrical conductivity, Organic carbon, Organic matter, Nitrogen and Available phosphorus were determined in the Geoenvironment Division Lab, CIMFR Dhanbad. The objective of the present investigation was to characterization of overburden materials for revegetation or plantation purposes on the top surface of the overburden dump materials. This base line data can be used for reclamation of degraded opencast mines in Raniganj coalfield, in Dhanbad Jharkhand and Raniganj Coal field West Bengal. The positive co-relation coefficient was observed between particle density and bulk density, particle density and total porosity, Particle density and maximum water holding capacity, total porosity and bulk density, bulk density and maximum water holding capacity, total porosity and maximum water holding capacity, pH and conductivity, organic matter and pH, organic carbon and pH, organic carbon and conductivity, organic matter and electric conductivity, and organic carbon and organic matter. The one way analysis of variance confirms that spatial variation has less significant effect on concentration of chemical factors.

Keywords : Coal, Opencast mines, Overburden materials, Bulk density, Organic carbon.

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I. Introduction

Coal is the most abundant fossil fuel resource present in India. Coal mining in India dates back to the 18th century. Coal has a relatively high importance for the economical growth of a country. An estimated 55% of India installed capacity of 124,287 MW of power generation is through coal based thermal power plants. India is the 3 rd largest producer of coal in the world and India has the 4th largest reserves of coal in the world (approx. 197 billion tonnes). There are 44 major coalfields located in the Indian peninsular, in addition to 17 in the north-eastern region. The geological reserves of coal have been estimated at 24 123 Mt of coking coal and 162 914 Mt of noncoking coal, up to a depth of 600 m. The average stripping ratio (overburden to coal) during the last three decades was 1.97m:3 /t (Chaulya *et al.,* 2009). These overburden dumps change the natural land topography, affect the drainage system and prevent natural succession of plant growth (Bradshaw and Chadwick 1980; Wali, 1987) resulting in acute problems of soil erosion and environmental pollution (Singh *et al.,* 1994;Singh *et al.,* 1996). Selection of plant species for revegetation of overburden (OB) dumps depends on various parameters such as physical and chemical properties of dump materials (Singh and Jha, 1992).

In India two types of mining operated as opencast and underground mining. Opencast mining is a developmental activity, which is bound to damage the natural ecosystem by several mining activities. During opencast mining, the overlying soil is removed and the fragmented rock is heaped in the form of overburden dumps (Ghosh, 2002). Dump materials are left over the land in the form of overburden dumps. These occupy large amount of land, which loses its original use and generally gets soil qualities degraded (Barpanda *et al.,* 2001). As the dump materials are generally loose, fine particles from it become highly prone to blowing by wind. These get spread over the surrounding fertile land, plant, disturb their natural quality, and growth of fresh leaves. It has been found that overburden dump top materials are usually deficient in major nutrients. Hence, most of the overburden dumps do not support plantation. The physico chemical properties of overburden dump materials are site specific and differ from one dump to another dump due to different geological deposit of rocks (Lovesan *et al.,* 1998). The side view of overburden dump materials is shown in figure 1

II. Study Area

The Raniganj Coalfield lies in West Bengal and partly in Jharkhand states at the Eastern most part of the Damodar valley coalfield. Raniganj Coalfield is situated about 185 Km North-West of Kolkata. Asansol is the most important town located in the central part of the Coalfield. Asansol and Raniganj are the major railway station in this region. It is located at 23°37′N-87°08′ E / 23.62°N- 87.13°E. The Raniganj Coalfield is the birth place of coal mining in the India. In the 1850's this coalfield were the major coal producer, constituting over 90% of the total country's coal production. Presently, in this area coal are produce by underground as opencast mining methods by the Eastern Coalfield Ltd. (E.C.L), a subsidiary of Coal India Ltd. In addition, a small part of the coalfield area cover about 1530 Km , spreading over Burdwan, Birbhum and Purulia districts in West Bengal and Dhanbad district in Jharkand. The major part of Raniganj coalfield is in Burdwan district and smaller portion in Birbhum, Purulia, Bankura and Dhanbad district. The Kolkata-Delhi National Highway (NH-2) as Howrah –Delhi railway line of Eastern Railway passes through this coalfield area. A network of roads and railway branch link the surrounding areas.

III. Material and Methods

a) Overburden (OB) sampling

In general, coal is a sedimentary formation, so the overburden materials are include shale, sandstone and other impurities is generally heaped at the mining site, during the time of opencast mining. The overburden samples were collected by a manually operated split tube coring tool (depth 20 cm). The samples were properly packed and brought carefully to Laboratory, CIMFR, Dhanbad for physical and chemical analysis. The overburden samples were air dried, cleaned, crushed in mortar and pestle and passed through 2 mm mesh sieves and then analyzed.

b) Overburden Analysis

Bulk density was determined by gravimetric method. The Grain size distribution was determined by gravimetric method by taking the weight of the fraction passed through the following sieve, 4.75 mm, 2.00 mm, 1mm, 0.425 micron, 0.212 micron, 150 micron, and 75 micron, divided by the total weight of the sample (Ranjan & Rao, 2000). pH and Electrical conductivity was determined in (soil/water1:2.5) suspension with a pH meter and Conductivity meter respectively. Organic Matter of the overburden dump materials was determined by using the Walkley and Blake Method (Nelson and Summers, 1982) after first determining the organic carbon by using a conversion factor of 1.724. Available Nitrogen was determined by the alkaline potassium permagnate Method (Keeney and Bremer, 1966). Available phosphorus content was determined by Olsen's Method (Bray and Kurtz, 1966). The brief details of the sampling sites of overburden samples are given in Table 1.

c) Statistical Analysis

The data collected were subjected to Pearson's correlation matrix to study the significant level at 0.05 and 0.01 (2 tailed) to note the positive and negative correlation among the physico-chemical factors. Similarly, one way analysis of variance was applied to chemical factors to measure the distance or similarity in relation to spatial variations. The SPSS Ver. 16.0 Statistical Program was used for all statistical analysis throughout this research.

IV. Results and Discussions

The results of physico chemical analysis of overburden samples are presented in Table1-3. Bulk density of overburden materials is the mass of the overburden materials per unit volume. Bulk density in all the samples varied from 1.15 gm/cc to1.3 gm/cc. The minimum value (1.15gm/cc) of bulk density was observed at site IV Mandaman Colliery. This may be due to high organic matter content present in the dump samples (Leelavathi *et al.,* 2009). The maximum value (1.3 gm/cc) of bulk density was found in Site II site Gopinathpur Colliery (OCP). The high bulk density values in site are due to the presence of movements of heavy earth moving machineries (HEMMs), big dumpers, water tankers and less amount of grass cover on dump materials. The OB sample having high bulk density value cannot be used as vegetation as well as plantation growth.

Grain size distribution plays an important role in plant establishment of the overburden dump materials. It plays an important role for the maintenance of bulk density of the overburden dump materials. In all the sampling sites percentage of sand fraction was found to be higher. The sand content was found 96% at site I, 73.16 % at SITE II 80.32% at SITE III 84.48 % at, SITE IV, 86.48 % at SITE V indicating poor quality for plant growth. In dump materials sand fraction comes from breakdown of sandstone. Due to higher amount of sand particles in the overburden samples allowing water to move into the dump materials by infiltration process (Ghosh, 2002). Silt is intermediate in size between sand and clay, but silt is easily detached and easily transported. Clay minerals are hydrous aluminosilicates with other metallic ions. Their particles are very small in size, very flaky in shape and considerable surface area (Ranjan and Rao, 2000). Percentage of silt and clay fraction was found to be in low range. The silt and clay content of overburden samples ranges from 1.56 % at Site V to 5.08 % at Site IV and 6.44 % at Site I to 24.92 % at Site II respectively. The low content of clay and silt was found due to presence of rock forming minerals at the sampling sites. Several researchers are of opinion that lesser amount of clay materials has many microspores through which water passes very slowly into the dump materials. Hu *et al,* (1992) are of opinion that soil with more than 50% stoniness should be rated to be poor quality. The results of grain size distribution of overburden samples are given in Table 2. The pH of soil or more precisely the pH of the soil solution is very important because soil solution carries in it nutrients such as nitrogen, potassium, and phosphorus that plants need in specific amounts to grow, thrive, and fight off diseases. The samples having pH less than 7 were found to be weakly acidic in nature in nature (Brady, 2002). pH of these overburden samples was found to be low, ranging from 6.25 to 6.85 (Figure 5). The slightly acidic natures of all dump materials are due to the geology of the rock composition which will be a problem for plant growth. Brady, 2002, found that a pH range of 6.5 to 7.5 is optimal for plant nutrient availability. If the soil solution is too acidic plants cannot utilize N, P, K and other nutrients they need. In acidic soils, plants are more likely to take up toxic metals and some plants eventually die of toxicity. The results of pH are shown in Figure 5.

Electrical conductivity (EC) is the common measure of dump materials salinity and is indicative of the ability of an aqueous solution to carry an electric current. The rock composition determines the chemistry of the dump materials and ultimately affects electrical conductivity. For example, limestone leads to higher EC because of the dissolution of carbonate minerals in the dump particles. For mine soil, Saxena (1989), proposed that while EC < 4 dS/m may be considered to be good for plant growth. EC values within the range of 7 to 8 dS/m may be accepted as fair and soil/spoil with an EC value 8dS/m should be considered to be of poor quality. During study period, EC was found to be ranged 3.715dSm^{-1} to 4.075 dSm^{-1} in selected areas of Raniganj coalfield. The higher valued were due to upward migration of different salts with partially combustion of coal particles at Site II. The lower valued were due to lower amount of salts present in the dump samples at Site V and Organic carbon is an index of dump materials productivity and the amount of carbon broken down from plants and animals that stored in soil (Dekka *et al.,* 2008). Organic carbon levels greater than 0.8% is rated as good quality of soil or dump and less than 0.4% is rated as low quality of dump (Ghosh *et al.,* 1983).The present study showed percentage of organic carbon ranging from 1.42 % to 8.53% indicating presence of high organic carbon hence medium productive value of the dump samples. Similar observation was made by (Rai *et al.,* 2009) in soils of Jharia Coal Field. The increase in organic carbon at site IV was due to the accumulation of leaf litter and their decomposition to form humus and vice versa.

Organic matter (SOM) is the organic matter component of dump materials. It can be divided into three general pools: living biomass of microorganisms, fresh and partially decomposed residues, and humus, the well decomposed organic matter and highly stable organic material. Surface litter is generally not included as part of soil organic matter (Juma, 1999). As the amount of organic matter present in a soil increase, the number of stable aggregates also increases. These results in increased permeability, increased infiltration, and consequently, decreased runoff and erosion. In brief the present study showed percentage of organic matter ranging from 2.4 % to 14.75 % in all the samples, indicating good accumulation of humus matter in the dump samples.

Nitrogen is a major soil limiting nutrient elements and influence plant productivity. The nitrogen used by plants on dump materials comes from organic matter, fertilizer application and legumes plants (Maiti *et al.,* 2002). Soils fertility exhibits the status of different soils with regard to the amount and availability of nutrients essential for plant growth. It has been observed that nitrogen content was found to be maximum in surface horizons and decreased regularly with depth which is due to decreasing trend of organic carbon with depth and because cultivation of crops is mainly confined to the surface horizon only at regular intervals the depleted nitrogen content is supplemented by the external addition of fertilizers during crop cultivation (Prasuna rani *et al.,* 1992). In the present study, available nitrogen was found to be ranged from 64.44 kg/ha to 89.24 kg/ha in selected areas of Ranigang coalfield. However, available nitrogen content was found to be maximum (89.24 kg/ha), at the Site IV due to higher amount of mineralizable matter present in the samples, and lower values (64.44 kg/ha) was recorded at Site I due to lower rates of mineralization in the dump samples.

Phosphorus of overburden samples was determined in the form of phosphorus pentaoxide. In the present investigtion avaialble phosphorus content of the dump materials was recorded in low amount in the range of 0.765 kg/ha to 9.405kg/ha. The present observation was also agreed with (Tripathy *et al.,* 1998) in soils of Jharia coalfield. The available phosphorus of the overburden samples were recorded in low amount at Site IV. This might be due to slightly acidic nature of samples which restricted the microbial action activities resulting in very poor mineralization and organic decomposition process in the overburden samples. The available phosphorus of the overburden samples were recorded in high amount at Site III due to higher organic decomposition process in the samples.

V. Conclusions

From the above study, it can be concluded that the overburden samples collected from the coal mining areas are poor in organic carbon, available nitrogen and available phosphorus due to lower amount of microbial activities in the overburden samples. In addition to bulk densities of all the overburden samples are in medium range, which is not suitable for plantation purposes without addition of fertilizers. pH of all the sampling sites is slightly acidic in nature, under these (acidic) conditions of dump materials growth of plants severely affected in various ways. The data reveals that dump materials are deficient in N, P, & K which requires addition of extra fertilizer and manures to make the dump suitable for any purpose. The dump material at all the sampling sites was not found suitable for plant growth.

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Table 1 : Brief details of sampling sites in RCF

S. No.	Site Description	Sample Code	Mining Area
01.	SITE I	RS3	Chapapur Colliery U/G
02.	SITE II	RS4	Gopinathpur Colliery (OCP)
03.	SITE III	RS8	Lakhimata Colliery GT Road
04.	SITE IV	RS9	Mandman Colliery
05.	SITE V	RS16	Gourandih OCP Abundant Mine

Table 2 : Texture distribution of overburden samples

Site Description	Sample Code	Sand%	Silt%	Clay %	Soil classification
SITE I	RS3	96.08	1.96	6.44	Sand
SITE II	RS4	73.16	1.92	24.92	Sandy Clay Loam
SITE III	RS8	80.32	3.36	16.32	Loamy Sand
SITE IV	RS9	84.48	5.08	10.44	Loamy Sand
SITE V	RS16	86.84	1.56	11.6	Loamy Sand

Table 3 : Variation in Chemical Properties of the Soil Samples of Study Area during the study period.

Sites	pH	EC	Sulphide	Chloride	OC	OM	AVB'P	Ca	Mg	Na	K
		μS/cm	ppm	ppm	%	%	kg/hect	mg/g	mg/g	mg/g	mg/g
RS3	6.3	126.5	20	71	8.03	13.84	0.99	0.038	0.048	0.058	0.036
RS4	6.3	517.0	28	71	2.23	3.84	1.52	0.109	0.102	0.114	0.027
RS8	6.2	263.0	28	36	1.89	3.26	10.30	0.078	0.048	0.079	0.050
RS9	6.3	512.0	16	36	6.11	10.53	0.90	0.047	0.096	0.055	0.041
RS16	6.2	169.4	24	71	8.04	13.86	5.20	0.029	0.043	0.079	0.040

Table 4 : Pearson's correlation coefficients of physical factors of Raniganj coalfields (February and May 2010)

	A	B	C	D	E	F	G
A	+1						
B	+.759	+1					
C	+.837	+.992**	+1				
D	+.790	+.999**	+.997**	1			
E	+.810	+.997**	.999**	.999**	1		
F	+.104	-.515	-.413	-.478	-.451	1	
G	-.582	-.523	-.555	-.536	-.545	.272	1

*** Correlation is significant at the 0.01 level (2-tailed).*

A = Moisture content (%), B = Bulk density, C = Particle density (gm/cm^3), D = Total porosity (%), E = Max. Water holding capacity (%), F = Water in air dry soil (%), G = Volume Expansion

Table 5 : Pearson's correlation coefficients of Chemical factors of Raniganj coalfields (February and May 2010)

	A	B	C	D	E	F
A	+1					
B	+.992**	+1				
C	+.999**	+.997**	+1			
D	+.997**	+.999**	+.999**	+1		
E	-.515	-.413	-.478	-.451	+1	
F	-.523	-.555	-.536	-.545	+.272	+1

**. Correlation is significant at the 0.01 level (2-tailed)

A = pH, B = Conductivity, C = Organic carbon, D = Organic matter, E = Available phosphorus, F = Available nitrogen

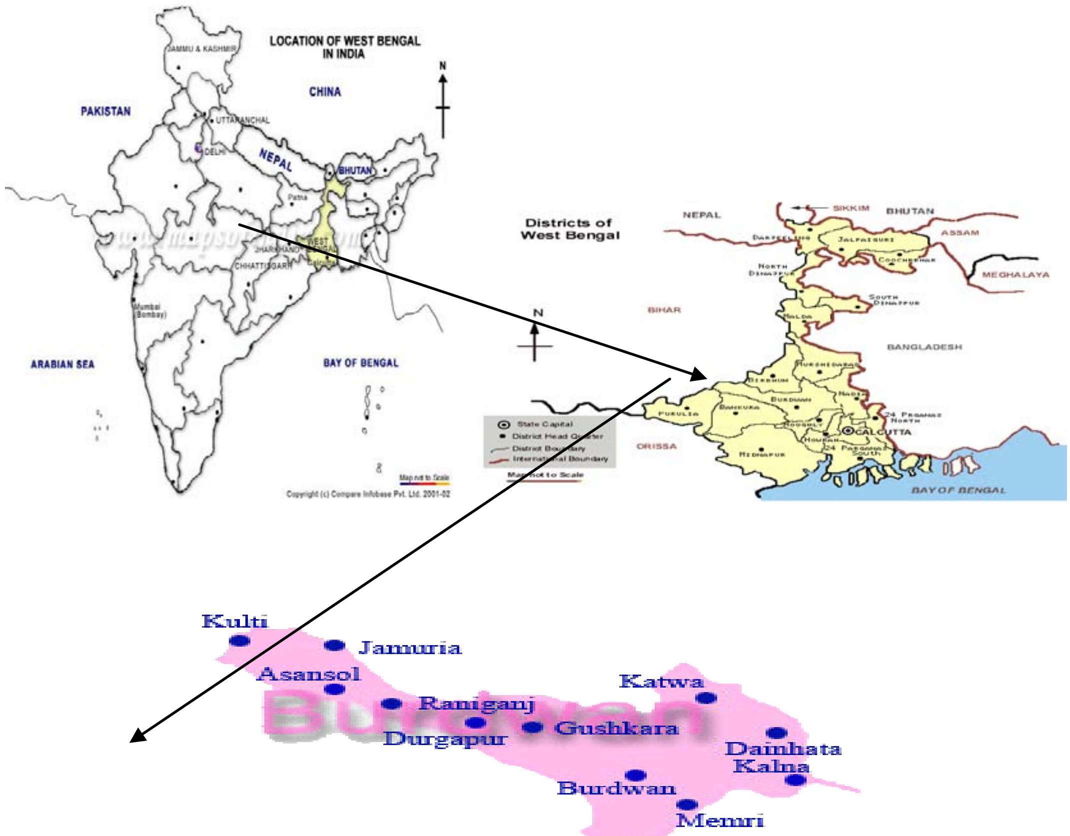

Figure 1 : Map of study area, (not to scale)

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