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Impact of Opencast Mining on Soil Physico-Chemical Properties – A Case Study from Bansra OCP of Raniganj Coalfield

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ABSTRACT
Coal mining activities affect the soil by causing soil erosion, formation of sinkholes, and leaching chemicals into the soil. The overburden dumps deposited in un-mined areas create mine spoils causing various environmental problems. Present study compared soil physico-chemical properties from an open cast coal mine of Raniganj (Bansra OCP) and a protected forest Ballavpur Wildlife Sanctuary (BWS) to investigate the effects of open cast coal mining on soil quality. Layer wise (0-10, 10-20 and 20-30 cm) soil samples were collected from 0-, 4-, 7- and 26-year old overburden dumps of Bansra OCP and also from BWS. Layer wise, no significant variations were observed in soil properties. ANOVA indicated significant variations in soil properties among overburden dumps and forest. Soil pH, calcium, sodium, magnesium and electrical conductivity were higher in overburden dumps than in the forest. These cations showed 51 to 91% increase in overburden dumps compared to the forest soil. Mining activity altered the soil quality due to decline in organic carbon, available nitrogen, potassium and phosphorus in the young aged overburden dumps. With the increase in the age of overburden dumps, significant recovery in organic carbon, mineral nitrogen and magnesium was observed, while pH, moisture, calcium and sodium declined significantly. No significant increase was observed in soil potassium and phosphorus, while clay and silt contents remained lower in all the overburden dumps.

Key words: Anova, Ballavpur Wildlife Sanctuary, Coal mining, Overburden Dump, Soil physico-chemical properties, Succession.

INTRODUCTION

Soil is the topmost layer of the earth's shell. It is a combination of both living and non-living solid, liquid and gaseous substances like minerals (45%), decomposing organic matter (5%), microbes beside water (25%) and air (25%) contained in pore spaces. Soil helps to regulate the Earth's climate and stores more carbon than all of the world's forests combined. Soil pollution refers to the alteration of soil quality causing land degradation and affects the availability of nutrients, soil structure and water quality of the area, thereby affecting the growth of flora and fauna in various ways. Approximately all cases of soil pollution are anthropogenic in nature. A variety of human activities like accidental spills and industrial accidents, chemical agents of war, landfills and illegal dumping, mining, micro plastic, nuclear waste, coal ash, oil spills, waste disposal, corrosion of underground storage tanks, electronics waste, discharge of sewage and acid rain can cause the contamination of soil (Shaltami et al. 2020). Mining activities can affect the soil by causing soil erosion, the formation of sinkholes, or leaching chemicals of the mining process into the soil (Gyamfi et al. 2019). Coal and allied mining activities render changes in the landscape to a considerable extent resulting in the degradation of the stable ecosystem (Kar 2015). Coal mining is one of the major environmental issues where huge amount of metal dust generates from coal, soil dumping, overburden soil, and transportation in the surrounding regions of mines. The coal mining region is environmentally deteriorated and human health risk amplifies through the food chain, inhalation and direct contact with heavy metals (Shen et al. 2017). Opencast coal mines produce more pollution load to the soil, water and aerial environment (Chakraborty et al. 2021). The overlying soil and the fragmented rock removed during coal mining are heaped in the form of overburden dumps which are devoid of true soil character, nutrient poor and contain elevated concentrations of trace metals. The overburden dumps when deposited in un-mined areas create mine spoils affecting the landscape of the area and cause various environmental problems (Makdoh and Kayang 2015).It is difficult for plants to establish on overburden dumps which raise a number of environmental issues. Consequently, the ecosystem functions are stalled, and requires huge time gap for gaining stability in natural courses. The magnitude of mining is continuously increasing owing to the development activities and the population demand (Wong 2003, Sheoran et al. 2008).

Every year, large areas are continually becoming unfertile due to opencast mining. Every million tonne of coal extracted by surface mining method damages a surface area of about 4 hectares in India (Ghose 2004). This large area of land loses its natural vegetation because of overlying loose dump materials that spread over the surrounding fertile land and plants, and disturb their natural quality and growth of fresh leaves. Dump physico-chemical properties improves with passage of time due to natural plant succession (Malakar and Gupta (Joshi) 2018). In the present study our main objectives are to study the changes in soil physico-chemical properties at different depths among an age sequence of over burden dumps in Bansra OCP of Raniganj coalfield, and to analyse the changes in soil quality caused by coal mining with relation to the forest soil of Ballavpur Wildlife sanctuary.

MATERIALS AND METHODS

Study area description

Bansra OCP

Raniganj coalfield constitutes an important coalfield of India where coal mining started as early as 1774 by British owned companies and private coalmining companies of Bengal. In 1974 all the working mines were regrouped for effective management and exploration strategy and since then this region is known as Eastern Coalfield of Coal India Limited (ECL). Present study was conducted on Bansra Open Cast Project (OCP) situated under Kunustoria area of Raniganj CD block of the Asansol Sadar subdivision in the Paschim Burdwan district of West Bengal, India. The geographical location of Bansra is 23°38'11" N to 20 87°07'41" E and the altitude ranges from 110 to 121 m above the sea level (Fig. 1). Four overburden dumps viz., 0-, 4-, 7- and 26-year dumps were selected (Fig. 2). The climate of Raniganj is dry tropical with sharp summer (mid-March to mid-June), rainy season (mid-June to mid-October) and winter (November to February). Temperature ranges from 8 to 43°C with annual rainfall observed generally 1200 mm to 1500 mm.

Ballavpur Wildlife Sanctuary

Ballavpur Wildlife Sanctuary (BWS) is situated in Bolpur-Sriniketan panchayat Samity of Bolpur subdivision of Birbhum district extending between 23°41' N latitude and 87°40' E longitude (Fig. 1 and 2). It is included under the jurisdiction of Bolpur Range of Birbhum Forest Division of South East circle. This forest was established between 1953 and 1999 and gradually some natural regeneration came up due to succession. As per a technical report from the forest department (Anonymous 2008), this forest holds about 200 ha area and got the status of sanctuary in 1977. BWS harbors a viable population of spotted deer. The area is characterized with red lateritic soil and undulating topography. Average annual rainfall is 1300 mm and temperature ranges from 6-45°C with three distinct seasons - winter, summer and rainy. Tribal people collect leaves and fuelwood for use, eco-tourism also help in their economic development.

Soil sampling and analysis

Layer wise soil samples were collected from the four selected overburden dumps and the forest. Three samples from each site were collected from three different layers i.e., 0-10, 10-20 and 20-30 cm (45 soil samples in total). The samples were properly packed in plastic zipper bags and brought to laboratory for physico-chemical analysis. Each sample was first divided into two parts. One part was used for determination of moisture content in the field moist condition. The other part was air dried, cleaned, and crushed by mortar pestle and finally passed through a 10-mesh (2 mm) sieve, and then used for determination of soil physico-chemical parameters. Soil pH was measured by digital pH meter (Eutech pH tutor) and electrical conductivity (EC) of the soil was measured through conductivity meter (SYSTRONICS 306) using 1:5 soil water suspension. Soil moisture (SM) was determined by gravimetric method (Misra 1968). Water holding capacity (WHC) was determined by keen box method (Keen and Raczkowski 1921). Bulk density (BD) was calculated from dry weight of soil per unit volume inside the keen box. Soil texture was analysed using Bouyoucos soil hydrometer method (Bouyoucos

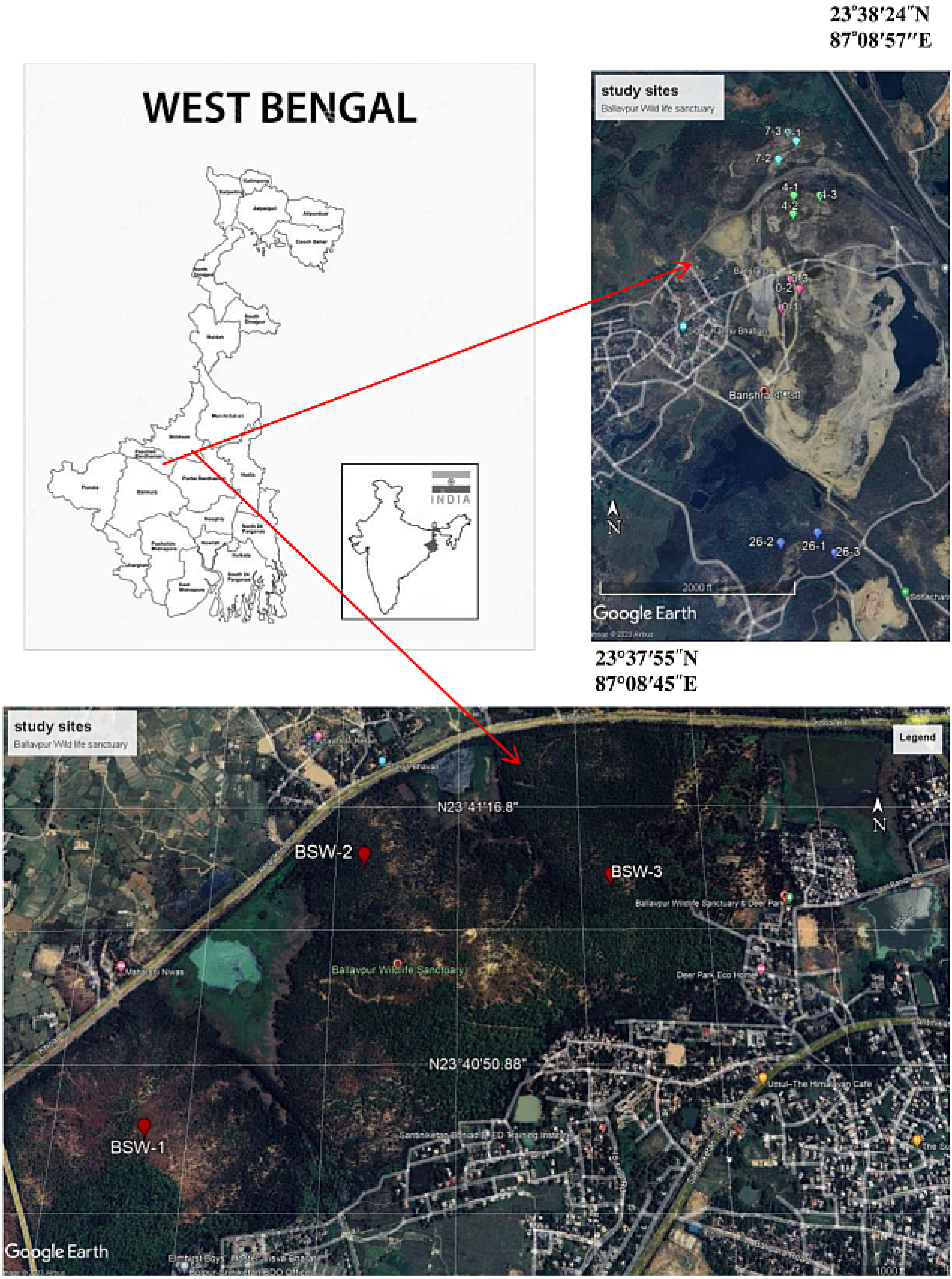

Figure 1. Map of the study area showing sampling sites (Source: ©Google Earth 2023)

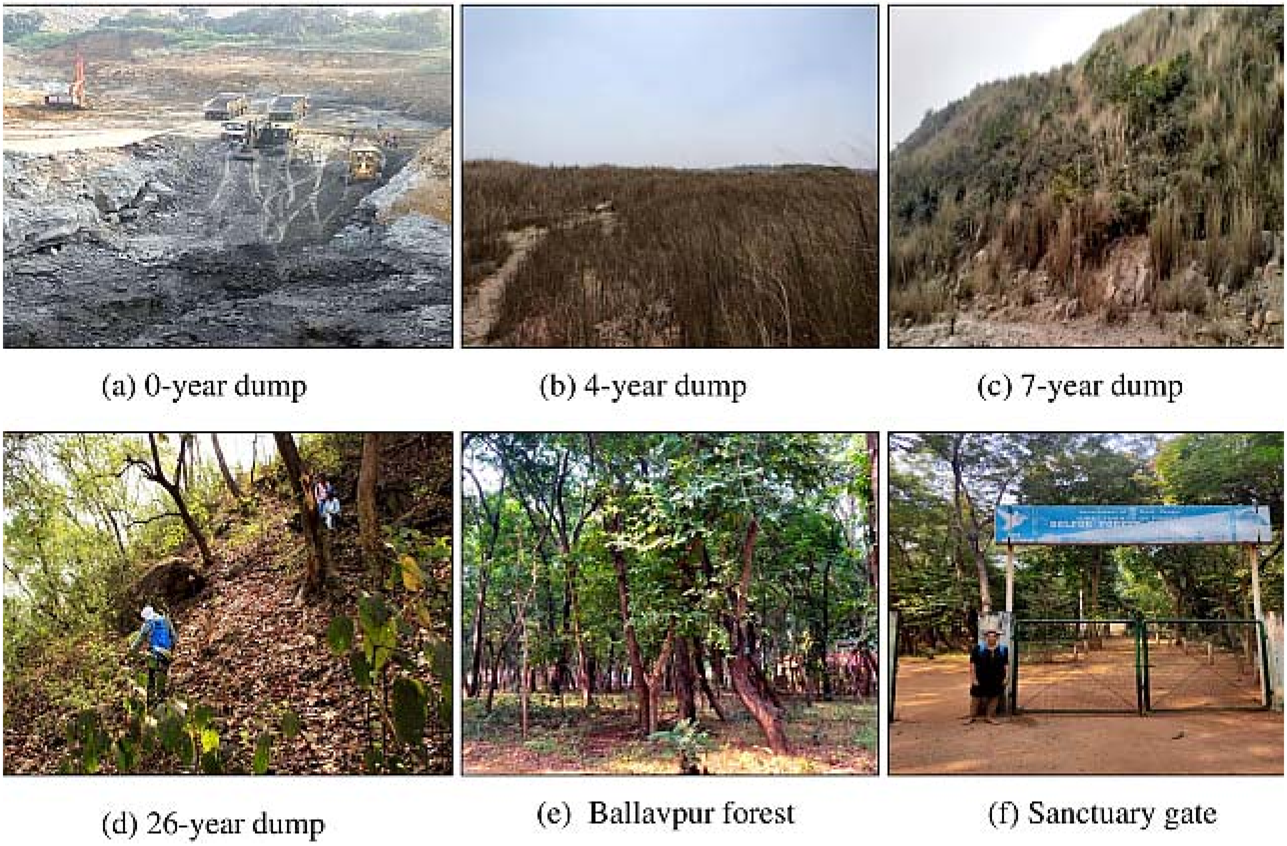

Figure 2. Landscape view of different overburden dumps in Bansra OCP and forest inside Ballavpur Wildlife Sanctuary

1927).

Organic carbon (OC) was determined by $K_2Cr_2O_7$ wet oxidation method (Walkley and Black 1934). Available sodium (Na) and potassium (K) were determined by flame photometer (SYSTRONICS 130). Exchangeable calcium (Ca) and magnesium (Mg) were determined using EDTA method of Trivedy and Goel (1986). Available phosphorus (P) was determined following Olsen's method (Olsen 1954) using spectrophotometer (SYSTRONICS UV-VIS 118) at 660 nm wavelength. Mineral nitrogen (NH_4^+-N and NO_3^--N) was estimated by alkaline-$KMnO_4$ method (Kjeldhal distillation) following Sahrawat and Burford (1982) using Foss Kjeltech™ 8100/8200 distillation unit.

Statistical analysis

Results of physico-chemical parameters were expressed as mean and standard error using Microsoft Excel. Normality test was done to analyse the data distribution. Non-parametric Spearman's Rank correlation analysis was performed to analyse relationships among soil parameters. Correlation was also tested between the dump age and dump parameters. Univariate ANOVA on log transformed data was done to test significant differences due to site and depth, followed by Tukey Post hoc test (á<0.5). The statistical tests were performed in the SPSS statistical software.

RESULTS AND DISCUSSION

Soil physical properties

The mean values of various physical parameters in the overburden dumps and forest soil are shown in the Table 1. Soil pH is a measure of the acidity or alkalinity of soil and plays a significant role in nutrient availability. In Bansra OCP pH was more or less neutral in the 0-year dump (7.01-7.13) and 4-year dump (7.13-7.22). The 7-year dump soil was slightly acidic (6.55-6.68) and 26-year dump soil was moderately acidic (5.95-6.02) in nature. In all the dumps soil pH was slightly acidic to neutral in upper layer and became more acidic with depth. Increasing soil acidity with increasing depth was also noticed by Mohapatra and Goswami (2012) in Ib river

Table 1. Soil physical properties (mean ± standard deviation) of different sites at different layers

Sites	Depth (cm)	pH	EC (µs cm^{-1})	Moisture (%)	WHC (%)	BD (gm cm^{-3})	Clay (%)	Silt (%)	Sand (%)	Soil texture
0-year dump	0 to 10	7.01±0.14	13.09±0.46	10.18±1.22	39.74±0.31	1.20 ±0.02	22.66	10.10	67.25	Loamy sand
	10 to 20	7.05±0.11	11.68±1.46	14.36±1.75	41.55±1.31	1.14±0.03	23.07	10.56	66.37	Loamy sand
	20 to 30	7.13±0.20	8.65±2.29	14.11±1.45	41.55±2.05	1.17±0.04	22.62	12.50	64.89	Loamy sand
4-year dump	0 to 10	7.13±0.07	14.91±1.57	8.38±2.28	33.84±3.38	1.26±0.10	18.85	8.26	72.89	Loamy sand
	10 to 20	7.20±0.14	14.60±0.33	8.53±2.49	35.07±2.97	1.21±0.05	17.88	10.05	72.07	Loamy sand
	20 to 30	7.22±0.24	13.66±1.08	8.93±2.06	35.48±2.57	1.24±0.02	11.91	9.16	78.93	Sandy loam
7-year dump	0 to 10	6.68±0.11	15.17±3.08	13.85±6.02	35.09±0.09	1.25±0.03	23.60	8.39	68.01	Sandy clay loam
	10 to 20	6.55±0.11	13.20±1.59	7.24±0.13	37.03±1.41	1.20±0.02	23.16	9.08	67.77	Sandy clay loam
	20 to 30	6.67±0.18	14.74±1.13	8.72±0.98	35.89±2.64	1.24±0.06	20.06	10.93	69.01	Loamy sand
26-year dump	0 to 10	5.95±0.10	12.26±1.24	7.46±0.00	45.27±0.83	1.11±0.03	15.33	11.91	72.77	Sandy clay loam
	10 to 20	6.02±0.08	11.77±1.57	7.46±0.00	37.89±2.77	1.18±0.03	18.09	9.01	72.9	Loamy sand
	20 to 30	5.96±0.04	7.76±2.91	7.46 ±0.00	37.61±2.59	1.18±0.02	19.51	8.12	72.37	Loamy sand
BWS	0 to 10	5.96±0.51	6.36±1.67	6.09±0.50	41.04±3.28	1.20±0.04	31.37	17.68	50.96	Clay loam
	10 to 20	5.78±0.40	5.74±1.04	7.09±0.83	39.71±1.15	1.25±0.06	36.73	14.27	49.00	Clay loam
	20 to 30	5.76±0.35	6.67±1.10	8.40±0.76	38.98±1.02	1.26±0.03	37.12	17.16	45.72	Clay loam

EC= Electrical conductivity, WHC= Water holding capacity, BD= Bulk density

coalfield, Orissa. Soil pH also decreased with increasing dump age. Soil tends to acidify over time (Semy et al. 2021). The BWS forest soil was moderately acidic in nature (5.76-5.96). Percent increase in soil pH due to coal mining decreased from 17.55% in the active dump to 2.5% in the 26-year dump (Fig. 3). Increase in the soil pH in the coal mining area has been reported (Ahirwal and Maiti 2017, Malakar and Gupta (Joshi) 2018), when compared with soil of natural Sal forests having low pH. Other studies reported acidic nature of soils around coal mine [pH 4.97 to 6.83 by Rahman et al. (2017), 2.9 to 4.1 by Semy et al. (2021)] and held oxidation of pyrites in the coal spoils responsible for decreasing pH value.

Electrical conductivity (EC) is the common measure of dump materials' salinity and is determined by the rock composition. In 0-year dump, EC decreased from 13.09 ìs cm^{-1} at 0-10 cm depth to 8.65 µs cm^{-1} at 20-30 cm. In 4-year and 7-year dumps, EC didn't differ much depth wise. In 26-year dump, EC declined from 12.26 to 7.76 µs cm^{-1} upto 20-30 cm depth. EC increased slightly with age upto 7-year dump and again declined in the 26-year dump. The EC values in Ballavpur forest soil decreased slightly upto10-20 cm and again increased in the lowermost depth, and were lower than the EC values in overburden dumps. The EC values were 43.5 to 57.4% higher in the overburden dumps at Bansra OCP than in the forest soil (Fig. 3). Malakar et al. (2015) reported higher electrical conductivity in overburden dumps than in natural forest.

Soil moisture (SM) is very important for hydrological, biological and biogeochemical process. It is a key variable in controlling the exchange of water and heat energy between the land surface and the atmosphere through evaporation and plant transpiration. SM increased depth wise in 0-year dump (10.18 to 14.11%) and 4-year dump (8.38 to 8.93%), while decreased depth wise (13.85 to 8.72%) in7-year dump. In 26-year dump, average SM content in all the depths was 7.46%. SM plays a vibrant role in the ecosystem functioning and depends on the sampling time, dump height, texture, OC, vegetation cover and width of litter layer (Huang

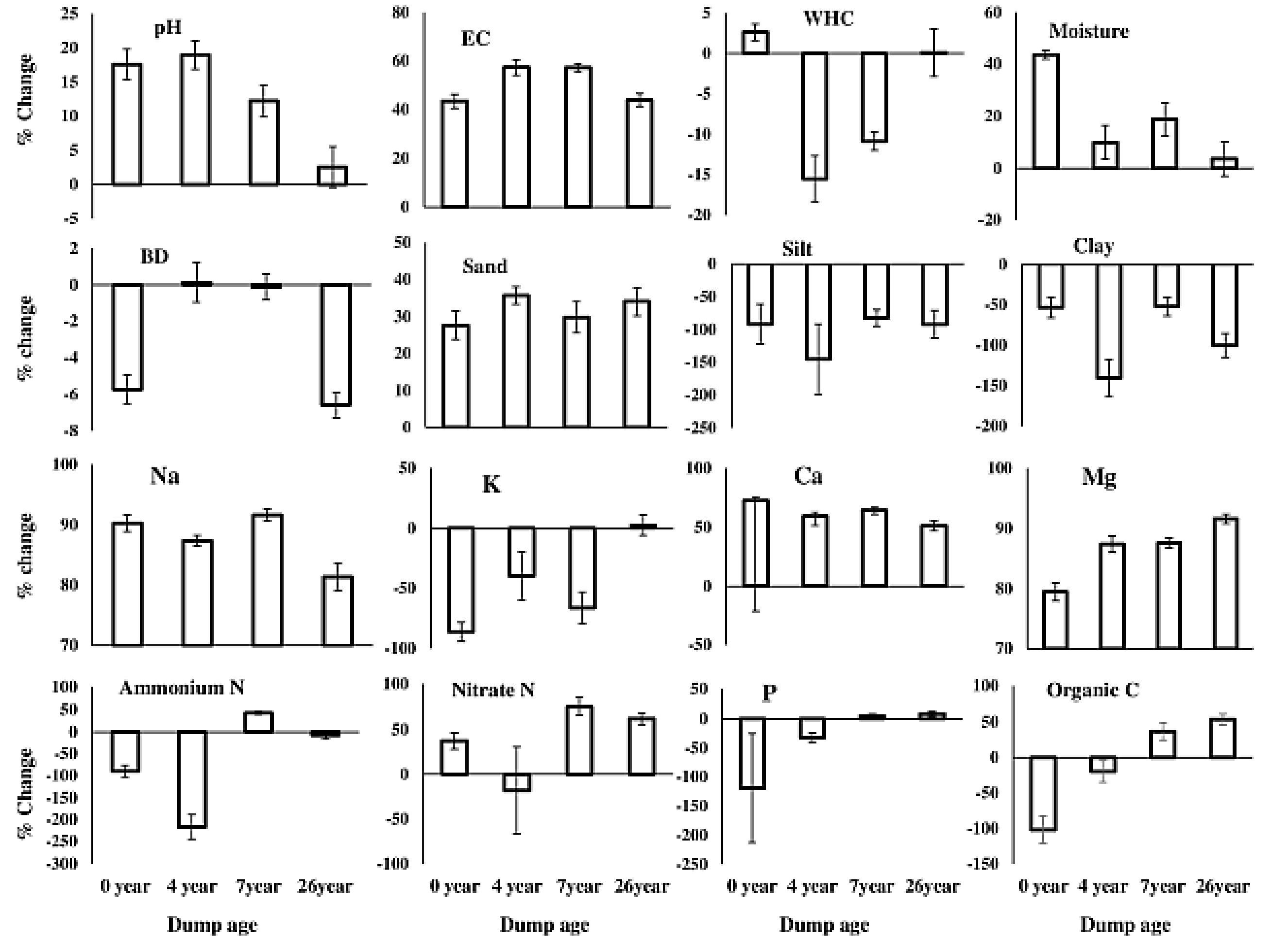

Figure 3. Change (%) in different physico-chemical parameters of overburden dumps in comparison with the Ballavpur forest soil. EC= Electrical conductivity, WHC= Water holding capacity, BD= Bulk density, Na= sodium, K= potassium, Ca= calcium, Mg= magnesium, N= nitrogen, P= phosphorus, C= carbon

et al. 2016, Mukhopadhyay et al. 2013). Venkatesh et al. (2011) also recorded an increase in moisture content with the soil depth in Western Ghats. In the forest soil, average SM content increased from 6.69% at 0-10 cm depth to 8.40% at 20-30 cm depth. Average SM content in overburden dumps (7.2 to 14.3%) was higher than that in the forest soil (6.1 to 8.4%). Previous studies have reported higher SM content in overburden dumps (Malakar et al. 2015) and reclaimed coal mine soil (Ahirwal and Maiti 2017) than in natural Sal forest. The 0-year active dump had 43% more SM compared to forest soil, which might be due to dumping of freshly excavated soil from lower depths. SM content declined with increasing dump age and after 26 years, it was almost similar to that of the forest soil.

The water holding capacity (WHC) of soil is an important characteristic and rises when soil texture moves from sandy to clayey. In overburden dumps, WHC ranged from 33.84 to 45.27% at different depths and years. In 0-, 4- and 7-year dumps, WHC was lowest at 0-10 cm depth while in 26-year dump, it decreased with depth. WHC declined with age upto7-year dumps, but again increased in 26-year dump. Malakar et al. (2015) also reported interrupted increase in WHC with increasing dump age. WHC values in BWS forest soil decreased with depth from 41.04% at 0-10 cm depth to 38.98% at 20-30 cm depth. WHC showed slight (2.6%) increase in the 0-year dump but declined by 15% in the 4-year dump and by 10.8% in the 7-year dump as compared to the forest soil (Fig. 3). Higher clay and silt content in the forest soil is responsible for higher WHC. Javed and Khan (2012) also reported lower soil moisture (9.85%) in degraded soils of Singrauli industrial belt, Madhya Pradesh compared to undisturbed forest soil (23.95%), along with reduction in soil WHC, organic matter and plant growth.

Bulk density (BD) is the dry weight of soil per unit volume. It is an indicator of suitability of soil for root proliferation, nutrient availability and water holding capacity, and hence an important parameter for coal mined land (Masto et al. 2015). BD varied only slightly among different overburden dumps and soil depths ranging from 1.11 to 1.26 gm cm^{-3}. It was higher in the 4-year and 7-year dumps than in 26-year dump. In the forest soil BD value slightly increased with depth. Mining process increased BD value due to soil compaction (Ahirwal and Maiti 2017), but we found 5.9 to 6.6% decreased BD values in 0-year and 26-year dumps in comparison to forest soil. The overburden dumps possess site specific physico-chemical properties due to different geological deposits of rocks (Lovesan et al. 1998). In Bansra OCP soil texture was sandy loam, sand and loamy sand in almost all the dumps. Depth wise only slight variations were noticed. Clay and silt were low and sand remained the dominant particle even after 26 years of succession. Ekka and Behera (2011) and Maiti (2007) noticed increase in clay content in overburden dumps with age resulting from development of vegetation on the dumps. In BWS forest soil texture was clay loam with high clay. Clay, silt and sand particles showed 52 to 140% reduction, 82 to 145% reduction and 27 to 35% increase, respectively, in over burden dumps in comparison to the forest soil. Malakar and Gupta Joshi (2018) also noticed higher clay content in natural forest than in the over burden dumps. Ahirwal and Maiti (2017) have reported relatively higher silt content in the mine face topsoil compared to a Sal forest.

Soil chemical properties

The mean values of various chemical parameters in the overburden dumps and forest soil are shown in the Table 2. Organic carbon (OC) is an index of dump materials productivity and the amount

Table 2. Soil chemical properties (mean ± standard deviation) of different sites at different layers

Sites	Depth (cm)	Organic C (%)	Na (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	P (ppm)	Ammonium N (ppm)	Nitrate N (ppm)
0–year dump	0 to 10	0.37±0.04	5.22±0.99	6.67±0.67	306.85±13.70	137.26±27.98	1.02±0.04	14.93±4.94	7.93±0.93
	10 to 20	0.31±0.05	5.78±0.91	6.67±0.67	316.44±25.11	52.60±4.58	0.84±0.31	13.07±1.87	2.33±0.93
	20 to 30	0.37±0.02	5.56±0.48	7.33±2.40	278.08±40.71	80.55±18.14	0.76±0.33	11.20v0.00	9.80±1.62
4-year dump	0 to 10	0.58±0.08	3.78±0.87	12.67±6.67	217.81±57.73	92.05±14.33	0.75±0.15	6.53±2.47	4.76±2.24
	10 to 20	0.73±0.13	4.22±1.39	8.67±2.67	238.36±50.50	84.66±21.13	0.72±0.11	9.33±3.73	5.13±0.93
	20 to 30	0.85±0.17	4.67±1.26	18.00±10.26	189.04±70.74	87.12±5.39	0.85±0.08	9.33±1.87	6.07±3.37
7-year dump	0 to 10	1.12±0.02	6.45±1.35	8.67±2.91	224.66±57.94	79.73±9.26	1.04±0.04	50.40±3.23	29.40±6.47
	10 to 20	1.02±0.08	6.33±1.35	8.00±2.00	234.25±25.11	101.92±29.05	1.05±0.14	37.33±6.73	21.93±4.94
	20 to 30	1.11±0.05	6.11±0.87	22.00±3.06	232.88±45.29	84.66±4.58	1.05±0.10	37.33±6.73	14.47±6.73
26-year dump	0 to 10	1.94±0.07	2.44±0.29	11.33±2.40	175.34±30.23	119.18±20.74	1.06±0.02	37.33±8.14	12.60±1.62
	10 to 20	1.18±0.04	3.22±0.55	9.33±1.33	184.93±78.30	137.26±27.98	1.14±0.11	37.33±9.47	7.00±0.00
	20 to 30	1.25±0.05	2.89±0.59	13.28±2.90	191.78±42.73	136.44±16.00	1.06±0.03	17.73±4.67	7.93±0.93
BWS	0 to10	0.70±0.17	0.54±0.16	13.17±0.78	75.34±23.04	16.44±5.39	0.91±0.02	25.20±9.00	5.13±2.47
	10 to 20	0.86±0.23	0.54±0.27	11.22±1.70	89.04±26.24	8.22±1.64	1.16±0.20	24.27±6.73	2.33±0.93
	20 to 30	0.67±0.37	0.63±0.24	11.22±2.08	93.15±25.37	9.86±1.42	0.93±0.04	24.27±1.87	4.20±1.62

of carbon broken down from plants and animals stored in soil (Deka et al. 2008). Soil or dump with OC > 0.8% is rated as good quality and < 0.4% is rated as low quality (Ghosh et al. 1983). In this study, OC increased with the age of the dumps, ranging from 0.3 to 0.37% in the 0-year dump, and from 1.18 to 1.94% in the 26-year dump. Depth wise slight changes were observed in OC but no uniform pattern of increase or decrease was observed. Rai and Paul (2011) also recorded poor OC (0.39 to 0.57%) in Jharia coalfield stating lack of microbes, low humification rate and lack of weeds in the sampling sites as probable reasons. In contrast, Tapadar and Jha (2015) reported high OC in Ledo colliery at Tinsukia district of Assam. Masto et al. (2015) recorded higher OC in opencast coal mine compared to underground mine in Raniganj and attributed deposition of fine coal on the soil surface for this observation. In BWS forest soil OC from different depths was in medium to high range (0.67-0.86%). There was 102% reduction of OC in the 0-year dump, followed by 19% reduction in the 4-year dump compared to the forest soil (Fig. 4). Ahirwal and Maiti (2017) also reported significant decline in OC in reclaimed dump soil. Further natural succession increased the OC to 37 and 54% more in the 7-year and 26-year dumps, respectively, in comparison to the forest soil. Plants help in binding of soil particles to roots and deliver protection of soil which increases organic matter over time (Banerjee et al. 2000, Roy 2015). Previous studies from Raniganj reported increased OC during succession but remained lower than native forest soil (Kumar et al. 2015, Malakar and Gupta (Joshi) 2018).

Sodium (Na) closes the soil pores and makes water infiltration difficult causing permeability problems. Na concentration at different depths was highest in the 7-year dump (6.11-6.45 ppm), followed by 0-year dump (5.22-5.78 ppm), 4-year dump (3.78-4.67 ppm), and the lowest in 26-year dump (2.44-3.22 ppm). So, there was slight decrease in the Na concentration with increasing dump age. It was very low in the BWS forest soil ranging from 0.54 to 0.63 ppm at different depths. Mining caused 81 to 91% increase in the Na level in various overburden dumps compared to the forest soil.

Potassium (K) is one of the essential elements for plant growth. Deficiency of soluble K can stunt growth and cause other symptomatic issue. In the overburden dumps of Bansra OCP, K content increased with the increase in dump age ranging from 6.67 to 7.33 ppm in the 0-year dump to 9.33 to 13.28 ppm in the 26-year dump. Depth wise, all the dumps had the highest value at 20-30 cm depths. K content was higher in the BWS forest soil than in the overburden dumps and varied slightly at different depths. K content decreased by 86, 39 and 66% in the 0-, 4- and 7-year dumps, respectively, and slightly increased (2.5%) in 26-year dump, as compared to the forest soil. Similar results were reported by Ahirwal and Maiti (2017) where K concentration was 66, 42 and 50% lower in reclaimed coal mine soil at different depths compared to a Sal forest soil. On the contrary in Barapukuria coal mine of Bangladesh, higher K and organic matter, and lower pH and N than the standard reference value indicated degraded soil quality (Rahman et al. 2017).

Presence of too much calcium (Ca) in soil could kill the plants by raising the soil pH levels that most plants cannot tolerate. Ca content in overburden dumps decreased with increase in dump age and ranged from the lowest (191.78 ppm) at 20-30cm depth in the 26-year dump to the highest (316.44 ppm) at 10-20 cm depth in the 0-year dump. In the BWS forest soil Ca content at different depths ranged from 75.34 to 93.15 ppm. Increase in soil Ca due to mining was 72% in the current dump compared to the forest soil and decreased to 51% in the 26-year dump. Ahirwal and Maiti (2017) and Malakar and Gupta (Joshi) (2018) also reported high calcium content in coal mine soil compared to natural forest soil. Contrary to this, Tapadar and Jha (2015) reported low Ca (160.72 ppm) in disturbed soil compared to undisturbed forest soil (424.81 ppm) that might be due to excavation and weathering of calcium rich rocks.

Presence of too much magnesium (Mg) in soil inhibits the uptake of calcium (Ca), and the plant displays general symptoms of an excess of salts; stunted growth, and dark-coloured vegetation. In the Bansra OCP Mg content increased with increasing dump age. Depth wise no uniform pattern of increase or decrease was seen. Both the highest and lowest values were recorded from the 0-year dump at 0-10 cm (137.26 ppm) and 10-20 cm (52.6 ppm) depths, respectively. Comparatively very less (8.22-16.44

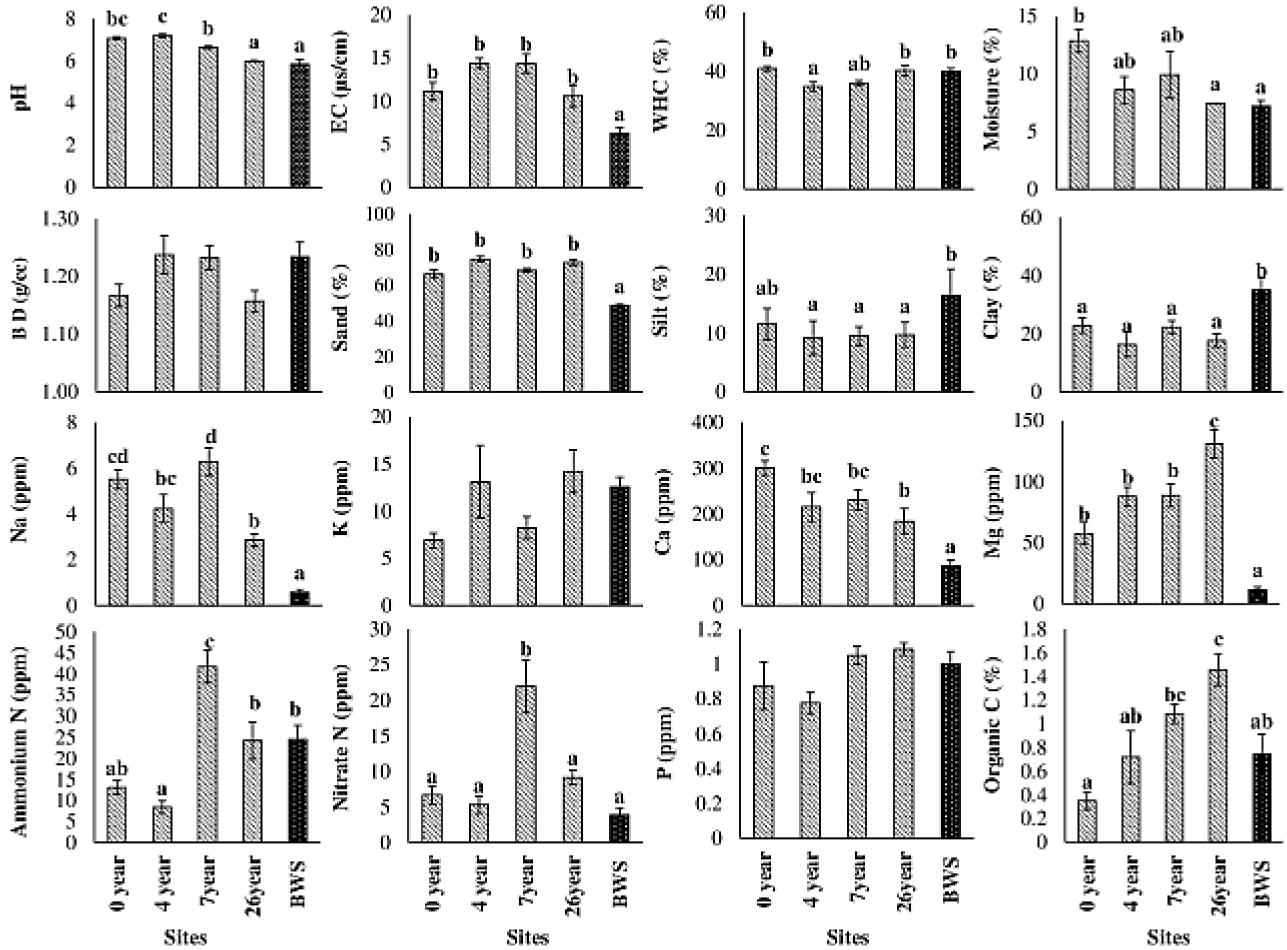

Figure 4. Mean values of soil physico-chemical parameters across different sites. Small alphabets above error bars represent significant differences after Tukey s post hoc test (á=0.05). EC= Electrical conductivity, WHC= Water holding capacity, BD= Bulk density, Na= sodium, K= potassium, Ca= calcium, Mg= magnesium, N= nitrogen, P= phosphorus, C= carbon

ppm) Mg content was found in the BWS forest soil. Mining caused 79 to 91% increase in the Mg content in overburden dumps compared to the forest soil. High concentration of Mg^{2+} and Ca^{2+} were found in reclaimed coal mine soils of India. Ahirwal and Maiti (2017) noticed very high Mg content in coal mine dump and argued that dolomite content of the subsurface soil (Ciarkowska et al. 2016) probably increased Mg content due to mining activity. However, Rao et al. (2023) reported lower Mg and Ca in Talabira mining area of Odisha than in a Sal forest. The pattern of successional change in soil cations in this study slightly differed from a previous work in Raniganj. Malakar and Gupta (Joshi) (2018) reported increase in Ca and K content and decrease in Na and Mg content during succession, but in the present study Ca and Na decreased while Mg and K increased with increase in dump age.

Phosphorus (P) is very important nutrient for plant growth. Very low soil P was present in all the sites. In overburden dumps, P content showed a slight increase with increasing dump age ranging from 0.72 ppm (4-year dump at 10-20 cm depth) to 1.14 ppm (26-year dump at 10-20 cm depth). The BWS forest soil had higher P than 0- and 4-year dumps but lower than 7- and 26-year dumps. Depth wise P content was higher in 10-20 cm depth in 7- and 26-year dumps and forest soil. The dispersal of P may vary with the depth mostly due to the substrate richness, abiotic condition and root action (Jobbagy and Jackson 2001). Mining caused 119 and 32% reduction in P in 0- and 4-year dumps, respectively, but slight increase (5-8%) was noticed in 7- and 26-year dumps in comparison to the forest soil in the present study (Fig. 4). Low amount of P was also noticed in open cast coal mine dump of Odissa by Mohapatra and Goswami (2012). Another study reported 60% reduction in P content in reclaimed mine soil compared to a Sal forest (Ahirwal and Maiti 2017).

Ammonium ($NH4^{+}$) and nitrate ($NO3^{-}$) are the predominant inorganic forms of nitrogen in soils. Ammonium N was higher than nitrate N in all the overburden dumps and the forest soil. Both these forms increased in the dump soil with increase in the dump age but the highest values were noticed in the 7-year dump. Ammonium N ranged from 6.5 ppm in the 4-year dump at 0-10 cm depth to 50.4 ppm in the 7-year dump at 0-10 cm depth, and nitrate N ranged from 2.3 ppm in the 0-year dump at 10-20 cm depth to 29.4 ppm in the 7-year dump at 0-10 cm depth. Depth wise no uniform pattern was observed. The BWS forest soil had higher ammonium N than in the 0- and 4-year dumps but nitrate N was lower than in the overburden dumps. Mining activity caused 89 and 216% reduction in ammonium N in the 0- and 4-year dumps, respectively, in comparison to the forest soil. The 26-year dump showed 7.5% increase in ammonium N and 6.1% increase in nitrate N compared to the forest soil. Earlier Kumar et al. (2015) and Malakar and Gupta (Joshi) (2018) reported increase in available nitrogen during succession in Raniganj, but the value didn't exceed that of native forest. The influence of coal mining activity on soil nitrogen was also calculated by Singh et al. (2012), Shrestha and Lal (2011) and Ahirwal and Maiti (2017), where they reported 52, 61 and 79% deterioration in soil nitrogen, respectively.

Comparing the results of this study with published works reveals that decline in soil OC and NPK was more or less uniformly reported in various coal mining impacted regions of India, but impact on soil pH, EC and cations were more site specific. Many studies have reported decline in soil OC and nutrients like NPK from different coal mined regions of India: Biswas et al. (2013) in Raniganj coal field of West Bengal; Talukdar et al. (2016) in Simsung river basin soil of a coal mine of Meghalaya; Kumar and Patel (2013) in the Basundhara coal mine, Orissa; Tapadar and Jha (2015) reported low NPK in Ledo colliery of Assam; Yaseen et al. (2012) in Raniganj coal field of Jharkhand; Ralte (2017) at Nokrek Biosphere Reserve of Meghalaya; Mohapatra and Goswami (2011) in Ib river coalfield, Orissa; and Rai and Paul (2011) in Jharia coalfield, Jharkhand. Decrease in organic matter is held responsible for decreased nitrogen in mined soil. Talukdar et al. (2016) also argued that low nitrogen might result due to loss of OC which comprises the N fixing microorganisms in soil and low phosphorous content may be due to its presence in insoluble state or absence of organic matter in soil. Dominant influence of leaching process in lateritic soil removing P (Malakar and Gupta (Joshi) 2018) and poor mineralization process in acidic soil due to restricted microbial activities (Rai and Paul 2011) were also reasoned for low P in coalfield soils. Opposite trend of soil P was reported from Bulianta mine area, China by Wu et al. (2021). They recorded decreased OC, N and K, and increased moisture, pH, BD and soil P immediately after mining activity; during the course of succession moisture, BD and soil P decreased, pH remain unchanged to slightly increased, and OC, N and K increased.

Relationship among various parameters

Almost all the sixteen soil parameters displayed pattern of increase or decrease with dump age, but only four parameters – pH, moisture, Ca and Na showed significant negative correlation with dump age, and five parameters – OC, Mg, K, ammonium and nitrate N were significantly positively correlated with dump age (Table 3). All the soil physico-chemical parameters except P displayed significant correlations among themselves. Such correlations indicate increase or decrease in availability of nutrient parameters with changes in physical parameters. For instance, soil pH was positively correlated with EC, moisture content, Ca and Na while negatively with OC and ammonium N. Electrical conductivity also showed positive correlation with cations like Na, Ca and Mg and also with sand, and negative with clay. Sand remained as the dominant particle in all the dumps and showed strong negative correlation with clay, silt and WHC and positive correlation with Ca, Mg and EC. Hence increase in basic cations coincides with increased EC and decreased pH with increasing dump age. OC had strong positive correlation with ammonium N, nitrate N, K, WHC and negative with BD and Ca.

Successional increase in OC on dumps was accompanied by increase in nutrients like N and K. Among cations positive correlation of Ca were seen with Na and Mg while negative with K.

Except BD, P and silt, all other parameters varied significantly among different dumps and forest soil as indicated by the F-value and its significance (Table 4). Depth wise no parameter significantly varied. Post-hoc test clearly distinguished the BWS forest soil in terms of Na, Ca, Mg, clay and electrical conductivity from all the overburden dumps of Bansra OCP (Fig. 4). The basic cations and electrical conductivity were significantly higher and clay was significantly lower in all the dumps. Additionally, the active dump (0-year) also differed from the forest soil with respect to pH, moisture, OC and ammonium N. Intense leaching of base cations decrease soil pH in Sal forest (Islam and Weil, 2000). A recent study on impact of surface coal mining on soil properties in Talabira mining area, Sambalpur, Odisha, also recorded increase in soil pH, EC and BD, and decrease in OC and soil nutrients in mining region compared to a natural Sal forest (Rao et al. 2023). Similarly, the 26-year dump was significantly different from all other dumps in terms of OC, ammonium-N and Mg and differed particularly from 0-year dump with respect to pH, moisture, Ca and Na also. The dump quality improved with increase in OC and N and decrease in cations and pH after 26 years. Comparing the 26-year dump with the forest soil separate them in two distinct groups for significant differences in their EC, clay, silt, sand, OC, Na, Mg and Ca. A period of 26 years was not enough to improve the soil texture and lower the cations and conductivity. According to Ghosh (1996, 2004) top soil is an essential component for vegetation growth in abandoned mines and has to be preserved for post

Table 3. Spearman's rank correlation coefficients among different soil properties and dump age

	Dump age	pH	EC	Moisture	OC	Na	K	Ca	P	WHC	BD	NitrateN	AmmN	Clay	Sand	Silt
pH	**-.819****															
EC	-.028	**.464****														
Moisture	**-.469****	**.376***	-.024													
OC	**.716****	**-.448****	.024	-.046												
Na	**-.387***	**.549****	**.535****	**.419****	-.046											
K	**.410***	-.219	-.079	-.098	**.525****	**-.361***										
Ca	**-.455****	**.528****	**.472****	.123	**-.403****	**.607****	**-.547****									
P	.268	-.134	.034	.136	.147	.062	.076	.163								
WHC	-.016	-.180	-.237	**.335***	**.294***	-.038	**.410****	-.264	.131							
BD	-.038	.089	.032	-.243	**-.383****	-.082	**-.300***	.063	-.225	**-.768****						
NitrateN	**.360***	-.120	.240	.111	**.517****	**.370***	.022	.080	.118	.148	-.213					
AmmN	**.536****	**-.561****	-.072	-.058	**.616****	-.010	**.318***	**-.307***	.274	.256	-.145	**.542****				
Clay	-.091	-.120	**-.318***	.283	-.136	-.044	.080	-.255	-.062	.168	.084	-.098	.164			
Sand	.179	.158	**.390****	-.275	.022	.112	-.241	**.354***	.020	**-.380***	.119	.141	-.190	**-.852****		
Silt	-.081	-.157	-.269	.141	.193	-.192	**.481****	**-.426****	.012	**.483****	-.249	-.192	.197	.283	**-.686****	
Mg	**.645****	.025	**.368***	-.230	.209	**.298***	-.125	**.309***	.166	-.068	-.201	**.382****	-.068	**-.365***	**.460****	**-.478****

**=Correlation is significant at the 0.01 level. *=Correlation is significant at the 0.05 level. Bold numbers indicate significant correlation coefficient. EC= Electrical conductivity, WHC= Water holding capacity, BD= Bulk density, Na= sodium, K= potassium, Ca= calcium, Mg= magnesium, N= nitrogen, AmmN= ammonium nitrogen, P= phosphorus, OC= organic carbon mining reclamation that should be accomplished within a period up to which the soil maintains its fertility. Soil properties deteriorate and become biologically unproductive when there is a long time interval between initial removal of the topsoil and final putting of the same over the reclaimed area (Singh and Singh 2004, Das 2003, Aswathanarayana 2003, Chakraborty 2000, Kundu and Ghose 1997a, b). On the other hand, the 7-year dump can be identified from other dumps as well as from the forest soil by its exceptionally high mineral N. Organic C was also significantly lower in the BWS forest soil than in 7-year and 26-year dumps. Here it is worthwhile to mention that Ballavpur is nearly 82 km from Raniganj, and is an artificially planted forest on wastelands with dominance of fast-growing species. Hence the BWS forest soil is physico-chemically different and nutritionally poor in comparison to soil from other natural Sal forests of India.

CONCLUSIONS

Present study compared the physico-chemical properties of overburden dumps in Bansra OCP of Raniganj coalfield with the forest soil in Ballavpur Wildlife Sanctuary, Santiniketan. Overburden dumps had mostly neutral pH whereas the BWS forest soil was slightly acidic. Sodium, calcium and magnesium along with EC in overburden dumps were much higher while OC was lower than in the forest soil, resulting in lower growth of plants in the overburden dumps. Organic C improved significantly in the overburden dumps with age and exceeded that in the forest soil. Nitrogen also showed drastic increase upto 7-years of succession, probably due to presence of leguminous herbs, but declined in the 26-year dump dominated by trees. Successional changes are not always ordered and sometimes may show stagnation. The other important nutrients, phosphorus and potassium, were low both in the overburden dumps and the forest soil, and didn't improve significantly during succession. This mine degraded land should be restored properly for maintaining the ecosystem. Use of grass and legume mixture along with organic amendments during plantation can boost the overall quality of the soils and may help to achieve the ecosystem as it was prior to the mining.

Table 4. Results of Anova showing F value and significance among different sites and soil depths

Parameter	Source	F	Significance
pH	Site	**21.278**	**.000**
	Depth	.019	.981
EC	Site	**8.299**	**.000**
	Depth	1.493	.241
Moisture	Site	**5.155**	**.003**
	Depth	.413	.665
WHC	Site	**5.082**	**.003**
	Depth	.237	.790
BD	Site	2.405	.072
	Depth	.371	.693
OC	Site	**6.363**	**.001**
	Depth	.029	.971
Na	Site	**47.919**	**.000**
	Depth	.191	.827
K	Site	**3.004**	**.034**
	Depth	.562	.576
P	Site	1.641	.190
	Depth	.243	.786
Ca	Site	**10.016**	**.000**
	Depth	.043	.958
Mg	Site	**63.535**	**.000**
	Depth	.478	.624
AmmN	Site	**17.526**	**.000**
	Depth	.430	.655
NitrateN	Site	**6.474**	**.001**
	Depth	1.015	.375
Clay	Site	**4.162**	**.008**
	Depth	.132	.877
Silt	Site	2.445	.068
	Depth	.012	.988
Sand	Site	**8.937**	**.000**
	Depth	.037	.963

Bold numbers indicate significant F values. EC= Electrical conductivity, WHC= Water holding capacity, BD= Bulk density, Na= sodium, K= potassium, Ca= calcium, Mg= magnesium, N= nitrogen, AmmN= ammonium nitrogen, P= phosphorus, OC= organic carbon

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REFERENCES

Ahirwal, J. and Maiti, S.K. 2017. Assessment of carbon sequestration potential of revegetated coal mine overburden dumps: A chronosequence study from dry tropical climate. Journal of Environmental Management, 201, 369-377, https://doi.org/10.1016/j.jenvman.2017.07.003.

Anonymous. 2008. Ballavpur Wildlife Sanctuary, Technical Report, Ballavpur Forest Range, Department of Forests, Government of West Bengal, Kolkata.

Aswathanarayana, U. 2003. Natural Resources and Environment. Geological Society of India, Bangalore, India. 106 pages.

Banerjee, S.K., Das, P.K. and Mishra, T.K. 2000.Microbial and nutritional characteristics of coal mine overburden spoils in relation to vegetation development. Journal of the Indian Society of Soil Science, 48(1), 63-66.

Biswas, C.K., Mukherjee, A. and Mishra, S.P. 2013. Physico-chemical properties of overburden dumps of different ages at Sonepur Bazari coalmine area, Raniganj, West Bengal (India). The Ecoscan, 7(1&2), 57-60.

Bouyoucos, G.J. 1927. The hydrometer as a new method for the mechanical analysis of soils. Soil Science, 23(5), 343-354. https://journals.lww.com/soilsci/Citation/1927/05000/THE_HYDROMETER_AS_A_NEW_METHOD_FOR_THE_MECHANICAL.2.aspx

Chakraborty, B., Bera, B., Roy, S., Adhikary, P.P., Sengupta, D. and Shit, P.K. 2021. Assessment of non-carcinogenic health risk of heavy metal pollution: Evidences from coal mining region of eastern India. Environmental Science and Pollution Research, 28(34), 47275-47293, https://doi.org/10.1007/s11356-021-14012-3 .

Chakraborty, P.K. 2000. Environment in Underground Coal Mines (mine gases, climate, dust, noise). 2nd Edn. CMPDI Ltd., Ranchi, India. 107 pages.

Ciarkowska, K., Gargiulo, L. and Mele, G. 2016. Natural restoration of soils on mine heaps with similar technogenic parent material: A case study of long-term soil evolution in Silesian-Krakow Upland Poland. Geoderma, 261, 141-150, https://doi.org/10.1016/j.geoderma.2015.07.018.

Das, D.K. 2003. Introductory Soil Science. Kalyani Publishers, Ludhiana, India.

Deka, R.M., Baruah, B.K. and Kalita, J. 2008. Physico-chemical characteristics of soil of Kapla Beel, A freshwater wetland in Barpeta district, Assam. Pollution Research, 27(4), 695-698.

Ekka, N.J. and Behera, N. 2011. Species composition and diversity of vegetation developing on an age series of coalmine spoil in an opencast coalfield in Orissa, India. Tropical Ecology, 52(3), 337-343.

Ghose, M.K. 1996. Damage of land due to coal mining and conservation of topsoil for land reclamation. Environment and Ecology, 14, 466-468.

Ghose, M.K. 2004. Effect of opencast mining on soil fertility. Journal of Scientific & Industrial Research, 63, 1006-1009, http://nopr.niscpr.res.in/handle/123456789/5511.

Ghosh, A.B., Bajaj, J.C., Hasan, R. and Singh, D. 1983. Soil and Water Testing Methods: A Laboratory Manual. IARI, New Delhi.

Gyamfi, E., Appiah-Adjei, E.K. and Adjei, K.A. 2019. Potential heavy metal pollution of soil and water resources from artisanal mining in Kokoteasua, Ghana. Groundwater for Sustainable Development, 8, 450-456, https://doi.org/10.1016/j.gsd.2019.01.007.

Huang, X., Shi, Z.H., Zhu, H.D., Zhang, H.Y., Ai, L., Yin, W., 2016. Soil moisture dynamics within soil profiles and associated environmental controls. Catena, 136, 189-196, https://doi.org/10.1016/j.catena.2015.01.014.

Islam, K.R. and Weil, R.R. 2000. Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. Agriculture, Ecosystems & Environment, 79(1), 9-16, https://doi.org/10.1016/S0167-8809(99)00145-0.

Javed, A. and Khan, I. 2012. Land use/land cover change due to mining activities in singrauli industrial belt, Madhya Pradesh using remote sensing and GIS. Journal of Environmental Research and Development. 6(3a), 834-843.

Jobbagy, E.G. and Jackson, R.B. 2001. The distribution of soil nutrients with depth: global patterns and the imprint of plants. Biogeochemistry, 53, 51-77, https://doi.org/10.1023/A:1010760720215.

Kar, D. 2015. Phytoremediation of selected wastelands in colliery belt of Raniganj West Bengal India. Ph.D. Thesis, University of Burdwan, West Bengal, India.

Keen, B.A. and Raczkowski, H. 1921. The relation between the clay content and certain physical properties of a soil. The Journal of Agricultural Science, 11(4), 441-449. https://doi.org/10.1017/S0021859600004469

Kumar, J.M. and Patel, A.K. 2013. Characterization and mine soil genesis in age series coal mine overburden spoil in chronosequence in a dry tropical Environment. Journal of Phylogenetics and Evolutionary Biology, 1, 101. https://doi.org/10.4172/2329-9002.1000101.

Kumar, S., Maiti, S.K. and Chaudhuri, S. 2015. Soil development in 2–21 years old coalmine reclaimed spoil with trees: A case study from Sonepur-Bazari opencast project, Raniganj Coalfield, India. Ecological Engineering, 84, 311-324. https://doi.org/10.1016/j.ecoleng.2015.09.043.

Kundu, N.K. and Ghose, M.K. 1994. Studies on the topsoil of an opencast coal mine. Environmental Conservation, 21(2), 126-132. https://doi.org/10.1017/S0376892900024553.

Kundu, N.K. and Ghose, M.K. 1997a. Shelf life of stock-piled topsoil of an opencast coal mine, Environmental Conservation, 24, 24-30. https://www.jstor.org/stable/4451923.

Kundu, N.K. and Ghose, M.K. 1997b. Impact of coal mining on land use and its reclamation – a case study. Transactions, 93(20), 97-104.

Lovesan, V.J., Kumar, N. and Singh, T.N. 1998. Effect of the bulk density on the growth and biomass of the selected grasses over overburden dumps around coal mining areas. Pp. 182-185. In: Proceedings of the 7th National Symposium on Environment, Dhanbad, Jharkhand, India.

Lowry, O., Rosebrough, N., Farr, A.L. and Randall, R. 1951. Protein measurement with the Folin phenol reagent. Journal of Biological Chemistry, 193(1), 265-275. https://doi.org/10.1016/S0021-9258(19)52451-6

Maiti, S.K. 2007. Bioreclamation of coalmine overburden dumps with special emphasis on micronutrients and heavy metals accumulation in tree species. Environmental Monitoring and Assessment, 125, 111-122, https://doi.org/10.1007/s10661-006-9244-3.

Makdoh, K., and Kayang, H. 2015. Soil physico-chemical properties in coal mining areas of Khliehriat, East Jaintia Hills district, Meghalaya, India. International Research Journal of Environment Sciences, 4 (10), 1-10.

Malakar, S. and Gupta (Joshi), H. 2018. Successional changes in some physicochemical properties on an age series of overburden dumps in Raniganj Coalfields, West Bengal, India. Pp. 101-112, In: Dasgupta R. (Ed.) Advances in Growth Curve and Structural Equation Modeling. Springer Nature, Singapore. https://doi.org/10.1007/978-981-13-1843-6_6.

Malakar, S. and Gupta (Joshi), H. 2019. Composition and diversity of tree saplings in Raniganj coalfield of West Bengal. International Journal of Research and Analytical Reviews, 6(1), 667- 672.

Malakar, S., Gupta (Joshi), H. and Kumar, M.L. 2015. Species composition and some physico-chemical properties of an age series of overburden dumps in Raniganj coalfields, WestBengal, India. International Journal of Scientific Research in Environmental Sciences, 3(7), 239, http://dx.doi.org/10.12983.

Masto, R.E., Sheik, S., Nehru, G., Selvi, V.A., George, J. and Ram, L.C. 2015.Assessment of environmental soil quality around Sonepur Bazari mine of Raniganj coalfield, India. Solid Earth, 6(3), 811-821, https://doi.org/10.5194/se-6-811-2015.

Misra, R. 1968. Ecology Work Book. Oxford and IBH Publishing Company. New Delhi.

Mohapatra, H. and Goswami, S. 2012. Impact of coal mining on soil characteristics around Ib river coalfield, Orissa, India. Journal of Environmental Biology, 33(4), 751. http://jeb.co.in./journal_issues/201207_jul12/paper_13.pdf

Mukhopadhyay, S., Maiti, S.K. and Masto, R.E. 2013. Use of Reclaimed mine soil index (RMSI) for screening of tree species for reclamation of coal mine degraded land. Ecological Engineering, 57, 133-142, https://doi.org/10.1016/j.ecoleng.2013.04.017.

Olsen, S.R. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate (No. 939). US Department of Agriculture.

Rahman, M.M., Howladar, M.F. and Faruque, M.O. 2017. Assessment of soil quality for agricultural purposes around the Barapukuria coal mining industrial area, Bangladesh: insights from chemical and multivariate statistical analysis. Environmental Systems Research, 6(1), 1-13, https://doi.org/10.1186/s40068-017-0101-x.

Rai, A.K. and Paul, B. 2011. Degradation of soil quality parameters due to coal mining operations in Jharia coalfield, Jharkhand, India. Journal of Advanced Laboratory Research in Biology, 2(2), 51-56.

Ralte, V. 2017. Effect of coal mining on soil physico-chemical properties of Nokrek Biosphere Reserve of Meghalaya, northeastern India. Science Vision, 17(4), 228-237, https://doi.org/10.33493/scivis.17.04.07.

Rao, T.M., Ahmed, S.N., Sahu, A.K., Shroff, S., Behera, A.K. and Baitharu, I. 2023. Impact of surface coal mining on soil properties of the region at Talabira mining area, Sambalpur, Odisha. Ecology Environment and Conservation Journal, 29, 229-240. http://doi.org/10.53550/EEC.2023.v29i01.037.

Roy, R. 2015. Ecofloristic and micribiological studies on the overburdens in Raniganj coalfiled area West Bengal. Ph.D. Thesis, University of Burdwan, West Bengal, India, 204 pages.

Sahrawat, K.L. and Burford, J. R. 1982. Modificaion of the alkaline permanganate method for assessing the availability of soil nitrogen in upland soils. Soil Science, 133, 53-57. http://journals.lww.com/soilsci/pages/articleviewer.aspx?year=1982&issue=01000&article=00009&type=abstract

Semy, K., Singh, M.R. and Vats, N. 2021. Evaluation of soil quality of a coalmine affected forest at Changki, Nagaland, India. Journal of Environmental Engineering and Landscape Management, 29 (4), 381-390. https://doi.org/10.3846/jeelm.2021.15848.

Shaltami, O.R., Fares, F.F., El-Shari, S.M., Oshebi, F.M., Salloum, F.M., Favaloro, R.R., Alshelmani, N., Al-Maqrif, A. and Moftah, S.A. 2020. Assessment of drinking water quality and sanitation in Ajdabiya city, NE Libya. The Iraqi Geological Journal, 53(1B), 102-107. https://doi.org/10.46717/igj.53.1b.7rz-2020-03.03

Shen, Z.J., Chen, Y.S. and Zhang, Z. 2017. Heavy metals translocation and accumulation from the rhizosphere soils to the edible parts of the medicinal plant Fengdan (Paeonia ostii) grown on a metal mining area, China. Ecotoxicology and Environmental Safety, 143, 19-27, https://doi.org/10.1016/j.ecoenv.2017.04.042.

Sheoran, A.S., Sheoran, V. and Poonia, P. 2008. Rehabilitation of mine degraded land by metallophytes. Mining Engineers Journal, 10(3), 11-16.

Shrestha, R.K. and Lal, R. 2011. Changes in physical and chemical properties of soil after surface mining and reclamation. Geoderma, 161(3-4), 168-176, https://doi.org/10.1016/j.geoderma.2010.12.015.

Singh, R.S., Tripathi, N. and Chaulya, S.K. 2012. Ecological study of revegetated coalmine spoil of an Indian dry tropical ecosystem along an age gradient. Biodegradation, 23(6), 837-849, https://doi.org/10.1007/s10532-012-9573-6.

Singh, V. and Singh, T.N. 2004. Environmental impact due to surface mining in India. Minetech, 25(1), 3-7.

Talukdar, B., Kalita, H.K., Basumatary, S. and Sarma, D. 2016. Impact of coal mining on soil characteristics of Simsang river, Meghalaya India. Journal of Fundamentals of Renewable Energy and applications, 6, art 6. https://doi.org/10.4172/2090-4541.1000219

Tapadar, S.A. and Jha, D.K. 2015. Influence of open cast mining on the soil properties of Ledo Colliery of Tinsukia district of Assam, India. International Journal of Scientific and Research Publications. 5(3), 365- 369.

Trivedy, R.K. and Goel, P.K. 1984. Chemical and Biological Methods for Water Pollution Studies. Environmental Publications, Jaipur.

Venkatesh, B., Lakshman, N., Purandara, B.K., Reddy, V.B., 2011. Analysis of observed soil moisture patterns under different land covers in Western Ghats. India. Journal of Hydrology, 397(3-4), 281-294. https://doi.org/10.1016/j.jhydrol.2010.12.006.

Walkley, A. and Black, I.A. 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Science, 37(1), 29-38. https://doi.org/10.1097/00010694-193401000-00003.

Wong, M.H. 2003. Ecological restoration of mine degraded soils, with emphasis on metal contaminated soils. Chemosphere, 50(6), 775-780. https://doi.org/10.1016/S0045-6535(02)00232-1.

Wu, Y., Gao, X., Zhou, D. and Zhou, R., 2022. Changes in Soil Physical and Chemical Properties after a Coal Mine Subsidence Event in a Semi-Arid Climate Region. Polish Journal of Environmental Studies, 31, 3. https://doi.org/10.15244/pjoes/143274

Yaseen, A.P., Singh, S. and Dar, I.Y. 2012. A Study of physico-chemical characteristics of overburden dump materials from selected Coal mining areas of Raniganj Coal Fields, Jharkhand, India. Global Journal of Science Frontier Research, 12(1H), 7-8.

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