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Soil Physico-chemical Properties in Coal mining areas of Khliehriat, East Jaintia Hills District, Meghalaya, India

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Abstract

A study was conducted to assess the soil physico-chemical properties of five coal mine spoils in chronosequence and an un-mined site in coal mining areas of Khliehriat, East Jaintia Hills District, Meghalaya, India. The study revealed that the overburden spoils were poor in nutrient content but rich in heavy metals, where higher concentrations were recorded in the summer season than in the dry season. Pearson's correlation coefficients showed a positive correlation between the soil physico-chemical properties at both p<0.05 and p<0.01. Soil moisture content, total nitrogen, available phosphorus and exchangeable potassium were positively correlated whereas, Mn and bulk density were negatively correlated with age of overburden spoils at p<0.05. In analysis of variance, soil pH, SOC, total N, available P, exchangeable K, Cu, Fe and Mn varied significantly at p<0.05 and p<0.01, whereas Zn varied significantly at p<0.05 between all the study sites. Thus the present study clearly revealed that with the passage of time, overburden spoils showed the sign of restoration. It also highlights the physico-chemical properties of soil in coal mining areas of the state which are otherwise scarce.

Keywords: Overburden spoils, chronosequence, Khliehriat, soil nutrients, heavy metals, restoration.

Introduction

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[1]. 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[2]. 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[3]. 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[4] 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.

There are nine significant coal deposits in the Jaintia Hills out of which Bapung and Lakadong are the most important ones. The others are Lumshnong, Malwar Musiang Lamare, Mutang, Sutnga, Jarain Tkentalang, Ioksi and Khliehriat[5]. Coal mining in the region is privately controlled by small-scale ventures and the mining operation depends or varies according to the nature of coal deposits. The exposures of coal are found along rapids, waterfalls, hill slopes and valleys and in some cases in the paddy fields. In the region where coal is seen as an outcrop in the hill slopes, streams, valleys and waterfalls locally it is called 'side cutting'. Whereas in the plain areas where coal beds have to be searched and the overburdens removed, which varies from 10 m to 40 m approximately, it is called 'box cutting'. Though the nature of operation is called by different names but by and large the technique and method is 'rat hole' mining. The entire process of mining is done manually employing small implements. Though this method may be the most economical and suitable to the local populace who own the mines, it is proving to be environmentally degrading. Environmental problems associated with mining have been felt severely in Jaintia Hills such as, large scale denudation of forest cover, scarcity of water, pollution of air, water and soil and degradation of agricultural lands [6].

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[7]. Thus, an attempt has been made in the present study to determine the spoil physical (bulk density and moisture content) and chemical properties (pH, organic carbon, total nitrogen, available phosphorous, exchangeable potassium and heavy metals) in currently mining site, four abandoned coal mine sites (overburden spoils) in chronosequence (2 years, 5 years, 10 years and 15 years abandoned sites) and an un-mined site. The mining site is abbreviated as MS and the un-mined site as UMS, whereas, the 2 years, 5 years, 10 years and 15 years abandoned sites are abbreviated as ABS2, ABS5, ABS10 and ABS15 respectively.

Material and Methods

The study was conducted in Khliehriat, East Jaintia Hills District, Meghalaya, situated in the eastern part of the state and lies between 25°13'N latitudes and 92°17'E longitudes. The physiography of the study sites are presented in table-1. The study was conducted for a period of two years and soil sampling was done seasonally from September 2009 to June 2011 except for bulk density where the experiment was done only once. Soil samples were collected from 0-20cm depth with replicates in each site. In the mining and abandoned sites soil samples were collected from the overburden spoils. The collected samples were kept in a sterilized plastic bag and transported to the laboratory for analysis. The parameters requiring fresh soil samples were determined immediately in the laboratory otherwise air dried and sieved for further use. Soil moisture content, bulk density, soil organic carbon, soil pH, available phosphorus, exchangeable potassium and total nitrogen were analyzed following standard methods[8-10]. For analysis of heavy metal (Zn, Cu, Fe and Mn), 0.1g of crushed, sieved, air dried soil was digested in 2.5 ml of the acid mixture (Hydrofloric acid 2: Perchloric acid 3.5) in a Teflon jar using a hot plate at 70-80°C till dryness. Zn, Cu, Fe and Mn were analyzed by graphite furnace Atomic Absorption Spectroscopy (Vario 6 AAS). Means and standard errors were calculated. The relationships among the various soil physico-chemical properties were analyzed by calculating Pearson's correlation coefficient (*r*) values. The variation of soil physico-chemical properties among the study sites was analyzed statistically using one way analysis of variance (ANOVA).

Results and Discussion

Moisture content was lowest in MS where in September 2009, June 2010 and June 2011it showed an increasing trend with age of abandonment of the overburden spoils. Lowest moisture content was recorded in March and highest in June throughout the sampling period. Bulk density on the other hand showed a decreasing trend where highest value was recorded in MS (1.39 g/cm^3) and lowest in ABS15 (0.78 g/cm^3). Bulk density of mine spoils was comparatively higher as compared to the un-mined soil. Soil pH was acidic in all the study sites where MS has the lowest value and it did not show any trend of variation with age of abandonment of the overburden spoils (table-2). Soil organic carbon, total nitrogen, available phosphorus and exchangeable K content were found to be lowest in MS and highest in ABS15 except in September 2010 for total N and September 2009 for available P (table-3) and showed an increasing trend with increasing age of abandonment of overburden spoils during most of the sampling months. Higher concentrations were also recorded in June and September when compared to December and March.

Table-1
Physiography of the study sites

Study sites	Latitude	Longitude	Altitude (m)
MS	25°21.953'N	092°20.554'E	1195
ABS2	25°21.508'N	092°20.743'E	1189
ABS5	25°21.609'N	092°20.394'E	1184
ABS10	25°22.744'N	092°20.437'E	1203
ABS15	25°21.497'N	092°20.628'E	1189
UMS	25°18.154'N	092°22.388'E	1175

MS: mining site, ABS2: 2 years abandoned site, ABS5: 5 years abandoned site, ABS10: 10 years abandoned site, ABS15: 15 years abandoned site and UMS: un-mined site.

Highest concentration of heavy metals (Cu, Zn, Fe and Mn) was recorded in MS during the whole study period (table-4). Higher Cu and Zn concentrations were recorded during the monsoon sampling period (June and September) when compared to the dry sampling period (December and March). They were undetected in some overburden spoils and the highest concentration was recorded in MS (2.23 mg/kg Cu and 0.528 mg/kg Zn). Cu concentration showed a decreasing trend with increasing age of abandonment of the overburden spoils during September 2009, June 2010 and June 2011. Mn concentration ranged from 0.28-1.03 mg/kg and showed a decreasing trend with age of overburden spoils except in March, September and December 2010. The concentration of Fe was found to be higher than all the other three studied heavy metals (22.82-27.7 mg/kg) but there was no clear trend of variation during the sampling periods.

Table-2
Soil physical properties measured in the study sites

Parameters	**Sampling period**	**Sampling sites**					
		MS	**ABS 2**	**ABS 5**	**ABS 10**	**ABS 15**	**UMS**
Soil pH	Sep, 2009	2.7±0.02	3.9±0.01	4.2±0.02	4.6±0.01	4.6±0.04	5.7±0.10
	Dec, 2009	2.5±0.01	3.6±0.02	4.6±0.05	3.9±0.01	4.3±0.03	5.0±0.00
	Mar, 2010	3.1±0.04	4.1±0.02	4.7±0.01	4.0±0.03	4.6±0.13	4.9±0.02
	Jun, 2010	3.5±0.00	4.0±0.02	5.0±0.01	4.2±0.03	4.8±0.03	5.5±0.04
	Sep, 2010	3.9±0.02	3.8±0.03	5.2±0.07	4.3±0.03	4.6±0.02	5.1±0.03
	Dec, 2010	3.6±0.04	3.7±0.01	5.1±0.03	3.8±0.03	4.2±0.03	5.4±0.06
	Mar, 2011	3.6±0.05	3.8±0.05	5.5±0.19	3.7±0.03	3.4±0.11	5.5±0.06
	Jun, 2011	4.3±0.06	4.4±0.03	4.9±0.02	4.7±0.05	4.1±0.03	5.4±0.03
Soil moisture content (%)	Sep, 2009	28.4±0.10	28.6±0.07	30.1±0.23	31.9±0.06	32.4±0.12	33.7±0.03
	Dec, 2009	16.4±0.07	20.2±0.07	21.5±0.13	17.3±0.10	17.5±0.09	20.5±0.03
	Mar, 2010	13.4±0.15	17.5±0.15	16.9±0.09	15.4±0.12	16.5±0.07	16.5±0.09
	Jun, 2010	31.0±0.09	33.7±0.13	33.8±0.13	36.0±0.12	38.90.15±	40.1±0.19
	Sep, 2010	25.5±0.17	25.8±0.03	25.3±0.15	34.1±0.12	37.5±0.09	39.8±0.32
	Dec, 2010	17.4±0.09	20.7±0.12	18.8±0.18	19.0±0.09	18.8±0.18	22±0.10
	Mar, 2011	13.2±0.12	14.1±0.13	16.7±0.09	16.7±0.10	17.1±0.15	19.4±0.12
	Jun, 2011	29.4±0.15	30.6±0.03	31.6±0.09	36.4±0.15	38±0.15	38.7±0.23
Bulk density (gm/cm^3)	-	1.39	1.24	1.2	1.1	0.78	0.77

±= Standard error, MS: mining site, ABS2: 2 years abandoned site, ABS5: 5 years abandoned site, ABS10: 10 years abandoned site, ABS15: 15 years abandoned site and UMS: un-mined site.

Table-3
Soil chemical properties measured in the study sites

Parameters	Sampling period	Sampling sites					
		MS	ABS2	ABS5	ABS10	ABS15	UMS
Total Nitrogen (%)	Sep, 2009	0.075±0.01	0.177±0.02	0.168±0.01	0.280±0.02	0.308±0.00	0.439±0.02
	Dec, 2009	0.047±0.01	0.112±0.01	0.14±0.01	0.149±0.01	0.224±0.02	0.336±0.03
	Mar, 2010	0.065±0.02	0.168±0.01	0.168±0.00	0.289±0.02	0.373±0.02	0.401±0.02
	Jun, 2010	0.103±0.02	0.177±0.01	0.205±0.02	0.355±0.02	0.392±0.02	0.485±0.01
	Sep, 2010	0.065±0.01	0.159±0.02	0.187±0.02	0.317±0.02	0.261±0.01	0.448±0.02
	Dec, 2010	0.047±0.01	0.131±0.01	0.149±0.02	0.233±0.01	0.233±0.01	0.420±0.02
	Mar, 2011	0.056±0.00	0.14±0.016	0.159±0.02	0.205±0.02	0.327±0.02	0.439±0.02
	Jun, 2011	0.093±0.01	0.196±0.03	0.196±0.02	0.299±0.01	0.373±0.02	0.457±0.02
Available Phosphorus (%)	Sep, 2009	0.002±0.00	0.004±0.00	0.004±0.00	0.004±0.00	0.004±0.00	0.004±0.00
	Dec, 2009	0.001±0.00	0.001±0.00	0.002±0.00	0.002±0.00	0.003±0.00	0.003±0.00
	Mar, 2010	0.002±0.00	0.002±0.00	0.003±0.00	0.003±0.00	0.003±0.00	0.004±0.00
	Jun, 2010	0.002±0.00	0.004±0.00	0.005±0.00	0.005±0.00	0.005±0.00	0.006±0.00
	Sep, 2010	0.002±0.00	0.003±0.00	0.004±0.00	0.004±0.00	0.004±0.00	0.004±0.00
	Dec, 2010	0.002±0.00	0.002±0.00	0.001±0.00	0.002±0.00	0.003±0.00	0.004±0.00
	Mar, 2011	0.002±0.00	0.002±0.00	0.002±0.00	0.003±0.00	0.004±0.00	0.003±0.00
	Jun, 2011	0.003±0.00	0.004±0.00	0.005±0.00	0.006±0.00	0.006±0.00	0.006±0.00
Exchangeable Potassium (%)	Sep, 2009	0.0020±0.00	0.029±0.00	0.037±0.01	0.047±0.00	0.074±0.00	0.149±0.00
	Dec, 2009	0.0033±0.00	0.020±0.00	0.031±0.00	0.030±0.00	0.056±0.00	0.110±0.01
	Mar, 2010	0.002±0.00	0.026±0.00	0.031±0.00	0.036±0.01	0.062±0.00	0.120±0.01
	Jun, 2010	0.0050±0.00	0.037±0.00	0.042±0.00	0.051±0.01	0.075±0.00	0.170±0.00
	Sep, 2010	0.0025±0.00	0.023±0.00	0.032±0.00	0.045±0.00	0.056±0.00	0.120±0.00
	Dec, 2010	0.0025±0.00	0.014±0.00	0.023±0.00	0.026±0.00	0.025±0.00	0.113±0.00
	Mar, 2011	0.0018±0.00	0.020±0.00	0.034±0.01	0.031±0.01	0.040±0.00	0.118±0.00
	Jun, 2011	0.0028±0.00	0.030±0.00	0.037±0.00	0.049±0.01	0.058±0.00	0.150±0.00
Soil Organic Carbon (%)	Sep, 2009	0.91±0.027	1.62±0.027	2.08±0.009	2.16±0.036	2.16±0.025	2.24±0.044
	Dec, 2009	0.48±0.009	1.48±0.020	1.75±0.002	2.07±0.012	2.09±0.009	2.12±0.016

Parameters	Sampling period	Sampling sites					
		MS	ABS2	ABS5	ABS10	ABS15	UMS
	Mar, 2010	0.80±0.000	1.41±0.028	1.92±0.000	2.12±0.027	2.12±0.016	2.18±0.005
	Jun, 2010	1.03±0.016	2.09±0.027	2.14±0.005	2.23±0.028	2.36±0.020	2.42±0.059
	Sep, 2010	1.03±0.018	1.27±0.012	2.10±0.024	2.16±0.009	2.19±0.027	2.18±0.049
	Dec, 2010	0.45±0.021	1.06±0.027	1.85±0.014	2.14±0.027	2.14±0.036	2.18±0.039
	Mar, 2011	0.66±0.014	1.17±0.009	1.99±0.028	2.15±0.016	2.15±0.020	2.18±0.014
	Jun, 2011	1.18±0.020	1.25±0.032	2.17±0.009	2.25±0.020	2.25±0.020	2.41±0.061

±= Standard error, MS: mining site, ABS2: 2 years abandoned site, ABS5: 5 years abandoned site, ABS10: 10 years abandoned site, ABS15: 15 years abandoned site and UMS: un-mined site.

Pearson's correlation coefficients showed a positive correlation between the soil physico-chemical properties at both $p<0.05$ and $p<0.01$. SMC was found to be positively correlated with Zn in MS and ABS10; with Cu in ABS2, ABS5 and ABS10; with P in ABS2 and ABS10; with K in ABS10 and with Fe in ABS15. Soil pH was positively correlated with total N in ABS2 and with P in ABS10. SOC was found to be positively correlated with Total N in ABS15; Available P with total N in ABS2 and ABS5; with SOC in ABS5 and ABS10 and with K in ABS10; A positive correlation was observed between SOC and Mn in ABS10, Total N and Mn in MS and ABS15, Total N and Zn in ABS15; between Available P, Cu and Zn in ABS2, ABS5, ABS10 and ABS15; Available P and Mn in ABS5, ABS10 and ABS15 and between Available P and Fe in ABS15. A positive correlation was also observed between Cu, Zn and Mn in ABS15, between Zn and Mn in MS, ABS5, ABS10 and ABS15 and between Fe and Mn in ABS15.

At $p<0.05$, SMC, total nitrogen, available phosphorus and exchangeable potassium were positively correlated whereas, Mn and bulk density were negatively correlated with age of overburden spoils. At $p<0.01$, SMC and total nitrogen were positively correlated whereas; bulk density was negatively correlated with age of overburden spoils. In analysis of variance, soil pH, SOC, total N, available P, exchangeable K, Cu, Fe and Mn varied significantly at $p<0.05$ and $p<0.01$, whereas Zn varied significantly at $p<0.05$ between all the study sites. However, for soil moisture content, no significant variation was observed between the study sites throughout the study period.

The moisture content showed an increasing trend with the increase in age of abandoned overburden spoils, i.e. highest in 15 years abandoned site. This may be due to the positive influence of the vegetation on the abandoned site mine spoils, which prevented the loss of soil water through evaporation, by not allowing direct exposure of soil surface to the incoming radiation. The low moisture content in mine spoil is due to lack of soil structure, higher stone content, and lack of organic matter [11]. Soil moisture content was also lower in the overburden spoils than in the un-mined soil. It is evident that moisture content in soil is more in the rainy season as the soil capillaries (porosity) retain a lot of water from the run off[12]. Moisture content in dump is a fluctuating parameter which is influenced by the time of sampling, height of dump, stone content, amount of organic carbon, and the texture and thickness of litter layers on the dump surface[13].

Bulk density was found to be negatively correlated with age of overburden spoils as reported by Sadhu *et al*[14]. It decreases with the increase in age of overburden spoils. This is due to accumulation of organic matter in the dump samples[15]. A decline in bulk density, with age of mine spoil, can be interpreted as a reduction in soil compactness, because of the development of soil micro-pore space[7]. The absence of vegetation on dump materials may also contribute to high bulk density in the mining site.

The mine spoils from mining site showed the maximum acidic value and exhibited gradual improvement with the age of spoils. Low pH in coal mine overburdens was reported by several workers in India [16-18]. Acidification in the mine spoil is due to the geology of the rock composition[19] and different mineral deposits in the mine spoil[20]. The acidic pH of the fresh overburden spoil in the mining site may also be due to the leaching of basic cations[3]. Improvement of pH value is due to both passive and active reclamation, either by natural succession or by the plantation strategy on coal mine overburden spoil [20, 21]. Promotion of organic matter decomposition on degraded soil has been reported to lower soil acidity [22].

Table-4
Heavy metals content measured in the study sites

Parameters	Sampling period	Sampling sites					
		MS	ABS2	ABS5	ABS10	ABS15	UMS
Cu (mg/kg)	Sep, 2009	1.35±0.1	0.93±0.01	0.6±0.08	0.55±0.07	0.25±0.04	0.24±0.09
	Dec, 2009	0.32±0.02	0.23±0.08	0.25±0.01	0.23±0.06	0.22±0.01	0.11±0.06
	Mar, 2010	0.41±0.07	0.32±0.02	0.25±0.07	0.14±0.06	0.17±0.01	0.13±0.04
	Jun, 2010	1.39±0.03	1.24±0.02	1.00±0.01	0.68±0.01	0.60±0.01	0.26±0.05
	Sep, 2010	2.23±0.04	0.40±0.08	0.31±0.05	0.26±0.08	0.20±0.01	0.23±0.05
	Dec, 2010	1.08±0.1	0.53±0.03	0.28±0.01	0.22±0.01	-	-
	Mar, 2011	0.53±0.02	-	-	-	0.31±0.01	0.14±0.03
	Jun, 2011	2.12±0.02	1.14±0.03	1.02±0.01	0.69±0.01	0.55±0.1	0.30±0.01
Fe (mg/kg)	Sep, 2009	26.12±0.09	25.04±0.11	25.71±0.99	26.64±0.31	25.96±0.52	22.08±0.12
	Dec, 2009	26.46±0.14	25.09±0.61	25.8±0.63	23.47±0.06	24.03±0.01	22.36±0.42
	Mar, 2010	26.88±0.51	26.12±0.12	22.82±0.19	24.26±0.94	25.24±0.71	17.83±0.3
	Jun, 2010	27.7±0.13	26.99±0.13	26.66±0.1	26.32±0.09	26.52±0.14	26.02±0.09
	Sep, 2010	26.9±0.21	26±0.14	25.42±0.12	26.78±0.05	26.06±0.01	22.82±0.4
	Dec, 2010	27.23±0.08	26.05±0.7	25.39±0.66	24.81±0.04	24.26±0.04	23.1±0.03
	Mar, 2011	25.99±0.81	26±0.24	26.29±0.01	26.78±0.2	24.39±0.19	19.12±0.12
	Jun, 2011	27.04±0.1	26.73±0.31	26.58±0.1	26.73±0.15	26.94±0.55	25.79±0.32
Zn (mg/kg)	Sep, 2009	0.196±0.03	0.103±0.01	0.036±0.0	0.037±0.0	0.013±0.0	0.003±0.0
	Dec, 2009	0.019±0.0	0.009±0.0	0.005±0.0	0.004±0.0	0.004±0.0	-
	Mar, 2010	0.02±0.0	0.019±0.0	0.013±0.0	0.013±0.0	0.01±0.0	-
	Jun, 2010	0.528±0.02	0.293±0.03	0.192±0.02	0.193±0.02	0.166±0.01	0.015±0.0
	Sep, 2010	0.442±0.01	0.192±0.0	0.179±0.01	0.179±0.02	-	-
	Dec, 2010	0.137±0.01	0.089±0.01	-	-	-	-
	Mar, 2011	0.119±0.02	0.074±0.01	0.012±0.0	-	-	-
	Jun, 2011	0.446±0.02	0.445±0.01	0.218±0.03	0.239±0.02	0.183±0.02	0.159±0.01
Mn (mg/kg)	Sep, 2009	0.85±0.03	0.76±0.02	0.43±0.04	0.42±0.03	0.36±0.02	0.28±0.02
	Dec, 2009	0.79±0.01	0.66±0.04	0.41±0.02	0.39±0.04	0.34±0.02	0.12±0.01
	Mar, 2010	0.79±0.03	0.72±0.05	0.50±0.03	0.40±0.03	0.43±0.04	0.37±0.02
	Jun, 2010	1.03±0.01	0.82±0.05	0.76±0.04	0.69±0.04	0.60±0.02	0.51±0.03
	Sep, 2010	0.80±0.02	0.53±0.04	0.58±0.03	0.45±0.02	0.44±0.02	0.38±0.04
	Dec, 2010	0.68±0.03	0.36±0.05	0.29±0.01	0.37±0.05	0.28±0.03	0.24±0.03
	Mar, 2011	0.87±0.02	0.65±0.02	0.44±0.04	0.44±0.04	0.33±0.0	0.23±0.01
	Jun, 2011	0.97±0.03	0.91±0.04	0.85±0.03	0.76±0.0	0.57±0.03	0.49±0.02

±= Standard error, - = undetected, MS: mining site, ABS2: 2 years abandoned site, ABS5: 5 years abandoned site, ABS10: 10 years abandoned site, ABS15: 15 years abandoned site and UMS: un-mined site.

Low SOC, NPK content was recorded in all the overburden dump materials which were in agreement with earlier findings[18,20,23]. The increasing trend of organic carbon content showed gradual accumulation of organic carbon in the abandoned spoils[24]. Organic carbon deposition in abandoned mine spoils is due to accumulation of litter and its decomposition which happens due to activity of soil organisms which develop with the increase in age of the dump. Low organic carbon content in mining site is because of burning out of organic matter, low rate of humification and lack of microbes in top soil. On the other hand un-mined site has highest soil organic carbon content because of favourable conditions for microbial activity in the process of organic matter decomposition[25].

Lower values of total N in mining site was due to lower rates of mineralization in the dump samples and also due to loss of organic carbon which contains nitrogen and nitrogen fixing microorganisms[17]. Higher values of total N in abandoned overburden spoils in comparison to fresh mine spoil is due to the organic matter accumulation in soil by roots and leaching of N from the vegetation of the area[20]. Low available phosphorus content in the overburden dump materials is due to acidic nature of the samples which restricted the microbial activities resulting in very poor mineralization and organic decomposition process in the overburden samples [19]. Exchangeable K content is lowest in mining site which indicates low fertility status [26]. On the other hand, higher SOC, NPK content were recorded in the un-mined site when compared to that in the overburden spoils, which is due to higher amount of mineralizable matter present in the soil[19]. SMC, total nitrogen, available phosphorus and exchangeable potassium were positively correlated with age of overburden spoils. Thus, it clearly revealed that with the passage of time, overburden spoils showed the sign of restoration, accumulating NPK to support the vegetational and soil biodiversity.

Significantly higher concentrations of heavy metals were observed in mine overburdens and showed decreasing trend with the increase in the age of overburden spoils which may be due to sorption and desorption characteristics of soil and substantial amount of organic matter[27]. Among the heavy metals, Fe had the highest concentration in all the study sites throughout the study period which is in agreement with the findings of Pradhan *et al* [28]. Positive correlation between heavy metals suggests that these heavy metals have a common source or a similar geochemical behavior[29].

Conclusion

The present study revealed that the coalmine overburden spoils were both physically and chemically poor. The mining site overburden spoil has the lowest nutrient content but highest heavy metal concentration and with age of abandonment, the physico-chemical properties of the overburden spoils improve. However, the physico-chemical properties of the overburden spoils were very poor in comparison to that of the un-mined site. Thus, the study clearly revealed the effect of 'rat hole' mining on the soil physico-chemical properties. Future research covering larger areas in other parts of the state is required to assess the status of soil in coal mining areas for reclamation strategies.

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