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Effect of opencast mining on soil fertility

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In the process of opencast mining, several changes occur in physical, chemical, and microbiological properties of soil as a result of mining and storage. Inability to preserve topsoil is one of the basic hindrances to restoration of mined land. The acute problem in preserving mine soil is discussed. Every year large areas are continually becoming unfertile in spite of efforts to grow vegetation on the degraded mined land One large opencast coal project of Eastern Coalfields Ltd. (ECL) is investigated to assess the deterioration of soil properties due to stripping and stockpiling. Different age classes of mine soil dumps are identified for the study. Mine soil characteristics of the dumps are compared with those of unmined soil and analyzed critically to evaluate deterioration of soil properties with respect to time of stockpiling. The changes in soil quality were found to be drastic in the first year and continually deteriorating every year, and ultimately the soil became unfertile.

Keywords: Opencast, Topsoil, Stockpile, Preservation, Microbial, Sterile

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Introduction

Mineral extraction process must ensure the return in productivity of the affected land[1]. Every million tonne of coal extracted by surface mining methods damages a surface area of about 4 ha in India[2]. The coal industry alone accounts for rendering biologically unproductive area of about 500 ha during 1994-95, which rose to 1400 ha by 2000 AD[3]. In the process of opencast mining, the area is to be completely stripped of vegetation to remove the overburden covering the coal seam[4]. Several changes occur in the physical, chemical and microbiological properties of soils as a result of storage; some caused by the actual construction of store rather than during course of storage[5]. Topsoil is an essential component in abandoned mines for growth of vegetation and has to be preserved for post-mining land reclamation[6]. The period between initial removal of the topsoil and final laying of the same over the reclamated area might be a long time lapse. So the properties of stockpiled soil deteriorate and become biologically unproductive[7]. The study aims at assessing the effects on soil fertility due to stripping and stockpiling and evaluating the hypothesis of becoming unfertile.

The opencast project under study is the largest project of Eastern Coalfields Limited (ECL), Godda District, Jharkhand[8]. The mining started in 1980. Target production of coal is 10 million t/y. The total volume of overburden has been worked out as 985.15 million m^3. The life of the project is 71 y. The total land requirement for the project has been estimated to be 2177 ha. Land to be affected by direct mining will about 67 per cent (quarry only)[9]. The region was mostly agricultural land (1874 ha) with a small area of wasteland (113 ha), reserved forest and sharb forest (110 ha) the agricultural activities depend on ponds and rains. The major crops cultivated in the region were paddy (*Oryza sativa*), sugar cane (*Sacchurm officimarum*) and gram (*Cicer arietimum*).

Methods

Soil samples were collected from the unmined land in and around the project area. Sub samples were collected from spots, which were distributed at random covering each sampling unit. Each sub sample was taken to a uniform depth and of the same approx. volume. Composite soil samples (12) were stripped and stockpiled separately. The depth of the topsoil varied from 15 to 22cm. Soil samples from six different age classes (1, 3, 4, 6, 9 and 10 y old) of mine soil dumps around the working coal mine, which were not vegetated, were also collected. From each dump[10], eight samples were collected. The sampling location sites were randomized[11] after site facing. The mine soil dumps were having moderate to steep slope

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Table 1—Available and macro and micronutrients and microbial population

Parameters	Unmined soil	Age classes (y) 1	3	4	6	9	10
N (Kg/ ha)	(173.5-266.1) 221.0	(142.5-159.3) 151.7	(121.2-134.6) 129.4	(128.2-139.1) 132.9	(111.4-127.5) 119.2	(105.3-118.7) 110.0	(106.7-124.3) 112.5
P (Kg/ha)	(6.7-10.6) 8.4	(6.1-7.0) 6.5	(5.7-6.8) 6.2	(5.4-6.1) 6.1	(5.2-5.9) 5.8	(4.9-6.0) 5.6	(106.7-124.3) 5.5
K (Kg/ ha)	(198.5-254.1) 223.6	(143.6-181.3) 162.0	(131.6-162.3) 145.7	(142.1-161.6) 151.2	(128.1-131.7) 137.5	(118.8-131.7) 123.1	(116.4-129.1) 121.2
Fe (Kg /ha)	(26.5-31.3) 28.9	(19.4-21.8) 20.5	(23.1-24.6) 23.7	(22.8-23.8) 23.3	(26.1-27.5) 26.6	(32.6-34.1) 32.2	(29.7-33.8) 31.6
Mn (Kg/ ha)	(16.7-20.8) 18.6	(15.7-16.5) 16.1	(14.8-15.9) 15.4	(17.1-18.6) 17.8	(18.2-19.3) 18.7	(22.0-23.5) 22.8	(22.8-24.1) 23.4
Cu (Kg/ ha)	(0.63-0.87) 0.71	(0.48-0.57) 0.52	(0.41-0.53) 0.47	(0.49-0.62) 0.56	(0.57-0.66) 0.61	(0.48-0.59) 0.53	(0.51-0.63) 0.57
Zn (Kg/ ha)	(0.41-0.66) 0.53	(0.27-0.34) 0.31	(0.35-0.46) 0.40	(0.34-0.44) 0.38	(0.31-0.43) 0.39	(0.28-0.37) 0.32	(0.31-0.40) 0.36
Bacteria ($\times10^{5-1}$ g)	(640-920) 775	(81-106) 92.2	(74-92) 83.0	(78-94) 85.3	(55-79) 67.6	(50-72) 58.3	(48-71) 57.8
Actinoaycetes ($\times10^{5-1}$ g)	(470-610) 536	(52-87) 73.4	(57-75) 66.1	(49-67) 57.7	(40-63) 52.5	(35-51) 42.3	(31-48) 40.6
Fungi ($\times10^{5-1}$ g)	(200-330) 272	(42-65) 53.8	(33-51) 42.5	(29-45) 36.5	(27-40) 32.4	(20-31) 23.8	(18-27) 24.3

Values in parenthesis represent range

(7-8 m high). Soil samples were air dried at room temperature and lightly crushed with mortar pastels and passed through 2 mm sieve for analysis[12]. Infiltration rates[13], and field capacity and bulk density[14] were measured. Water holding capacity (WHC) and moisture content of soils was measured[15]. Soil pH, electrical conductivity (EC), organic carbon (OC), available nitrogen, phosphorous and potassium were determined[16]. The wilting coefficient was measured by plant method [13]; cation exchange capacity (CEC) and exchangeable cations were also determined by neutral normal ammonium acetate method[15]. Available micronutrient cations, Fe^+, Mn^+, Cu^+ and Zn^+, were extracted with diethylene triamine penta acetic acid /calcium chloride (DTPA-Cl_2) solution and analyzed by atomic absorption spectroscopy[17].

Results and Discussion

Average value for the particle size distribution was: sand, 61.2; silt, 27.7; and clay, 11.1%. The bulk density of unmined soil was 1.39 g/m^3. The bulk densities of soil dumps gradually increased from 1.66-mg/m^3 (1 y-old) to 1.72-mg/m^3 (10 y-old). The cation exchange capacity of the unmined soil was found to have a mean value of [11.8 cmol (P^+)/ kg]. In the soil dumps, this value decreased gradually from 9.61 to 7.41 cmol (P^+)/ kg with the increase of age. The OC content in unmined soil (0.72%), which was very poor and varying (0.26-0.38%) in soil dumps, decreased markedly with storage of dumps: 1 y-old dumps, 47; 1-6 y-old dumps, 23; and 6-10 y old dumps, 6% decrease

The mean values (Table 1) of available nutrients in unmined soils were: N, 221.0; P, 8.4; and K, 223.6 hg/ ha. NPK values were found to decrease with increasing age of the soil dumps: N, 151.7-112.5; P, 6.5-5.5; and K, 162.0-121.2 kg/ ha. Available N was found to decrease rapidly in dumps: 1 y-old dumps, 31; 1-6 y-old dumps, 27; and 6-10 y old dumps, 5% decrease. A similarly decreasing trend was also observed for the available P and K (respectively): 1 y-old dumps, 23, 28; 1-6 y-old dumps, 11, 18; and 6-10 y old dumps, 6, 11% decrease.

The microbial population in soil dumps decreased sharply in comparison to unmined soil. In the 1 y-old dump, the population of microbial population was found to be 5 to 8 times lower. There was a gradual decrease in microbial population from 1-10 y-old dumps, and at the tenth year, these were: bacteria, 44; actimycetes, 60; and fungi, 76%. The decrease was statistically significant. The clay content and the field moisture content showed strong and significant positive correlation with field capacity, WHC and wilting coefficient at 1-per cent level. Very high positive correlation coefficient was also observed among organic, available N and available P, while available K did not show strong correlation with other parameters. Changes in microbial numbers due to the increased age of soil dumps showed a continuous decrease every year and at the end of the sixth year, the number decreased to a minimum level[18]. By statistical analysis (student test for two means for p=0.05), the decrease of microbial number was significant up to the sixth year and insignificant in the ninth and tenth year as compared to sixth year.

Results of the soil samples were compared with samples collected from stockpiles. Component size analysis revealed that sand particles increased, silt and clay particles decreased, with respect to unmined soil. This trend may be because of increased erosion. Dominance of sand particles indicated low stability of aggregates and consequently a high rate of infiltration. The average infiltration rate was found to be intermediate in nature[19]. The infiltration rate or water intake rate is initially high, but decreases with time[12]. Infiltration rates also decreased, approaching to a steady infiltration rate with time. The high bulk density of the dumps was evidently influenced by the use of machinery. This has serious implication for subsequent change of soil properties because gaseous diffusion is made more difficult. Such high bulk density would pose restrictions on the growth of deep-rooted plants and may be one of the reasons of cessation of plant growth at the shrub stage. The porosity was found to be less than that found in unmined soil due to compaction during excavation and, as a result, plants cannot grow smoothly. For good plant growth, bulk density should be below 1.4-g/ cm^3 for clays and 1.6g/cm^3 for sand[17]. The most useful water parameters of the soil relating to plant growth, are moisture content, field capacity, WHC and the wilting coefficient that were found to be lower in the soil dump samples than those of unmined soil and decreased slightly with age due to the decrease in OC[20]. A decrease in soil WHC as a result of storage[21] is also reported. Greater value of wilting coefficient indicates the deficiencies of plant growth materials.

The *p*H of soil dumps was acidic due to leaching of basic cations. Under such acidic conditions, H-ion toxicity, high availability of A1 and Mn and unavailability of Mo are the principal deterrents of plant growth[22]. For plant nutrient availability[23], optimum *p*H is 6.5 to 7.5. Electrical conductivity decreased with increasing age of soil dump but was higher than the surrounding unmined soils. A mixing of lower surface horizons may cause this. The cation exchange capacity of soil dumps was lower than unmined soils and decreased with increasing age of the soil dumps[23]. Again the mixing of the lower soil horizons may cause this. Similar trends were also observed for exchangeable Ca, Mg, Na, and K.

OC gradually decreased with increase in age of soil dumps, probably due to low humification by the lake of soil micro flora. It appeared that after 6 years OC reached a steady state condition. The available P was lower than the available N and K, because most of the P present in the soil is not readily available to plants. The deficiency in nutrients was probably caused by the reduction in soil microbes induced by stockpiling and excessive leaching (Table 1). Available macronutrients (NPK) decreased considerably in comparison to unmined soil and also decreased with increase in age of soil dumps (Table 1). This may be due to reduction in soil microbes[21] caused by stockpiling and excessive leaching. In 1-6 y old dumps, the available Fe was not found toxic to plants, but in 9-10 y old dumps, Fe was found toxic.

Stockpiled soil became biologically unproductive after sixth year. OC and NPK values came to a stagnant condition and microbiological activity decreased to a minimum level (Table 1). The period up to sixth year may be considered as the shelf period of the soil in that particular area. The shelf life of topsoil indicates the period over which the mine soil maintains its sustainability for suitable plant growth without major biological reclamation (growing plantation or vegetation). Biological reclamation must be adopted to preserve the topsoil if the storage period exceeds the shelf life period. If the shelf life period of topsoil in a particular area is ascertained, then the mining authority can decide whether it is essential to choose biological reclamation for the preservation of topsoil or whether they can preserve the soil by technical reclamation only[23] (maintaining proper height and slope). A prior knowledge of topsoil shelf life would enable mine planners to draw up an appropriate strategy for topsoil excavation vis-a-vis mine scheduling. An appropriate concurrent and post-mining reclamation strategy can also be determined. This will save time and money.

NPK nutrients and soil amendments in the amounts determined by soil tests should be applied to the redistributed surface soil layer, so that it supports the approved post-mining land use and meets the revegetation requirements. A detailed chemical analysis of the soil is essential to the planning of a revegetation program. Analysis is needed to determine elements essential for plant growth and to determine soluble elements that may be toxic to plants. Once the composition of the soil has been established, amendments may be selected to modify soil media so that adopted plant species can be used.

Conclusions

The biological reclamation, if not done within the shelf life (period up to which the soil will maintain its fertility status to support plant growth), the nutrients released by microbiological activity are lost continually due to leaching and erosion, the nutrient cycle is broken down, and the soil ultimately becomes unproductive. It should be stockpiled only when it is not feasible to promptly redistribute on regraded areas. However, if storage is unavoidable, stockpiled topsoil should be reclaimed biologically when the redistribution of such materials over the regraded areas requires beyond the shelf life period. The methodology adopted may be useful for such studies on industrial scale for various sites.

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References

1 Ghose M K, Land reclamation and protection of environment from the effect of coal mining operation, *Minetech*, **10** (5) (1989) 35-39.

2 Ghosh A K, Mining in 2000 AD – Challenges for India, J *Inst Eng. (India)*, **39** (1990) 1 – 11.

3 Chari K S R., Banerjee S P, Sengupta S R, Luthm K L, Babu C R, Mishra B C, Vijaykumar S & Namdeo R K, *Report of the expert committee on restoration of abandoned coal mines*, **No. J**. **11015/13/88-1A** (Department of Environment and Wildlife, New Delhi) (1989).

4 Kundu N K & Ghose M K, Status of soil quality in the subsided areas caused by underground coal mining. *Indian J Environ Protect*, **25** (1998) 110-113.

5 Sendlein V A, Lyle Y H & Carison L C, *Surface mining reclamation handbook*,(Elsevier Science Publishing Co. Inc) 1983, 290.

6 Kundu N K & Ghose M K, Studies on the topsoil of an opencast coal mine, *Environ Conserv*, **21** (1994) 126-132.

7 Kundu N K & Ghose M K, Shelf life of stock-piled topsoil of an opencast coal mine, *Environ Conserv*, **24** (1997) 24-30.

8 Ghose M.K, Damage of land due to coal mining and conservation of topsoil for land reclamation, *Environ Ecol*, **14** (1996) 466 – 468.

9 Kundu N K & Ghose M K, Impact of coal mining on land use and its reclamation –A case study, *Trans MGMI*, **93** (1997) 97-104.

10 Riley C V, Chemical alternations of strip mine spoil by furrow grading – Revegetation success, presented in *Ecology and reclamation of devastated lands* edited by R J Hatnik & G Davis (Gordon and Breach, London) 1978, pp 315-331.

11 Jackson M L, *Soil chemical analysis*, (Prentice Hall of India Pvt. Ltd, New Delhi) 1973, pp 498

12 Ghose M.K & Kundu, N.K, Soil profile studies as a part of environmental management, *Indian J Environ Protect*, **11** (1991) 413-417.

13 Dakshinamurti C & Gupta, R.P, *Practicals in soil physics* (Indian Agricultural Research Institute, New Delhi) 1968, pp1-16.

14 Black C A, *Methods of soil analysis*, (Am Soc Agron Inc. Madison, Wisconsin, USA) 1965.

15 Trivedy R K, Goel P K & Trisal C L, in *Practical methods in ecology and environmental science* (Environmental Publications, Karad) 1987, pp 115-137.

16 Ghose A B, Bajaj J C, Hassan R. & Singh D, *Soil and water testing methods* (Indian Agricultural Research Institute, New Delhi) 1983, pp11-22.

17 Lindsay W L & Norvell W A, *Development of DTPA test for Fe, Mn, Cu, and Zn* (Soil Sci Soc, Am) **42** (1978) pp 421-428.

18 Kundu N K& Ghose M K, Microbiological studies of soil in coal mining areas, *Indian J Soil Water Conserv*, **25** (1997) 110-113.

19 Donhue R L, Miller R W & Shickleena J G, *Soils – An introduction to soils and plant growth*, (Prentice –Hall of India Pvt. Ltd. New Delhi) 1990, pp 57-58 & 187-188.

20 Biswas T.D & Mukherjee S K, *Test book of soil science* (Tata McGraw Hill Publishing Co. Ltd., New Delhi), 2nd reprint, 1989, pp156.

21 Miller R M & Cameron R E, Some effects on soil microbiota of topsoil storage during surface mining, *Fourth Symp Surf Min Reclam*, NCA/BCR, Coal Conference and Expo III, October 1976, Louisville, Kentucky (National Coal Association, Washington, USA) 1976, pp 131-139.

22 Foy C.D, Effects of aluminum on plant growth, in *The Plant Root and its Environment*, edited by E W Carson (University Place of Virginia, Charlottesville) 1974, 601-642.

23 Braddy N C, *The nature and properties of soils* (Macmillan Publishing Co. Inc.USA) 1988, pp207.

24 Kundu N K & Ghose M K, Studies on the existing plant communities in Eastern Coalfield areas with a view to reclamation of mined out lands, *J Soil Biol*, **19** (1998) 83-89.