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Influence of coal mining on the soil physico-chemical properties at Amera Coal mines of Ambikapur, Chhattisgarh

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Abstract
This study was conducted on Amera coal mines which comes under South-Eastern Coal Limited (SECL) to determine the changes in soil's physical, biological, and chemical properties of mined area soil. Five representative samples were obtained and analysed for their: Soil pH, EC, Soil texture Soil bulk density, Soil moisture content, Soil carbon, and Soil nitrogen. Using standard procedures, the physico-chemical parameters, such as pH, bulk density, organic carbon, SOC stock, and N, were examined. It was found that there were no appreciable differences in parameters such as pH, organic carbon, and content between the different mining sites. At each of the site, the values for various parameters are ranges area as follow: pH (4.83-7.08), EC (0.13-0.17 dSm^{-1}) OC (%) 0.15-0.19, Bulk Density (g cm^{-3}) 1.88-2.79, Moisture (%) 6.51-21.66, SOC stock (t ha^{-1}) 2.89-5.73, N (kg ha^{-1}) 38.11-164.56. The texture of soil is sandy to sandy loam in different soil of mining area. The study concluded that soil under mining area was influenced as compared to the natural forest soil.

Keywords: Coal mines, nutrient content, soil quality, soil pollution, soil organic carbon

Introduction

Health of the soil is an indicator of environmental pollution. The long-term interactions between microbes, organic matter, and soil minerals make soil a vitalizing system that affects the physical, chemical, and biological characteristics of terrestrial systems (Ghose, 2004; Maharana *et al.* 2013) [3, 10]. The physical characteristics of land are crucial in assessing its suitability for engineering, environmental, and agricultural purposes and influence chemical and biological properties. Nutrient availability, soil structure, and local water quality are all impacted by soil contamination which affects the growth of vegetation (Makdoh and kayang, 2015) [12]. Wet and dry deposition from the atmosphere, as well as the dumping of industrial/mining and anthropogenic solid wastes, all contribute to soil pollution (Singh and Singh, 2004) [20]. On a global scale about 20% deforestation in developing countries may be attributable to mining (Bahrami *et al.* 2010) [1]. Coal mining plays a crucial role in economy and development of the country. There are two main methods used to mine coal: opencast mining and underground mining. Currently, opencast mines in India produce more than 85% of the country's coal (Poonia *et al.* 2022). Because they often offer an effective strategy for achieving high production, highly mechanised mining techniques are commonly used in surface mining (Shrestha and Lal, 2011) [19]. Opencast mining, a form of surface mining, removes the vegetation, topsoil, and rock (together referred to as overburden materials) above the mineral deposits (Mukherjee and Pahari, 2019) [15], which has an impact on the fertility of the nearby areas (Banerjee and Mistri, 2019) [2]. Land degradation is frequently brought on by coal mining activities, which cause severe changes in their geochemical cycles (Goswami, 2015) [4]. Mining has detrimental effects on the environment, including the worsening of water quality, the loss of forests and wildlife, the destruction of landscapes, the dispersal of spoils into wasteland, noise pollution, and the damage of agricultural lands (Mohanta *et al.* 2021) [13]. Major losses in natural carbon sinks and increased atmospheric CO_2 emissions are also caused by coal mining (Semy *et al.* 2021) [22]. The physical, chemical, and biological components of soil exhibit variations in quality because of the effects of diverse coal mining activities (Masto *et al.* 2015) [11]. In addition to altering the appearance of nearby mining regions, open-cast activities including drilling, blasting, and transporting coal resources have also left inorganic materials and hazardous traces on the soil systems (Rai and Paul, 2011) [17]. Thus, the surface mining causes nutrient deficiency and SOC loss, resulting in a long-lasting dire condition for both plants and soil microbes (Maharana and Patel, 2013) [10]. Mining operations can increase the amount of CO_2 emitted via SOM mineralization caused by soil disturbances and fluxes of C from decomposing biomass (Shrestha and Lal, 2006) [18]. Compared to unmined soils, mining subsided soils have lower levels of organic matter, nitrogen, and potassium, but their bulk densities are higher (Guo *et al.* 2018) [5]. Therefore, the objective of the current study is to ascertain the influence of mining activities on physico-chemical properties of soil.

Materials and Methods

Study Site

The investigation was carried out in Chhattisgarh's Surguja district at the Amera Coal Mine. The SECL is in charge of the Amera coalfields. The mines are located between the longitudes of 83.04769° E and 23.058423° N in latitude. It is an open-pit coal mining with a 668.184-hectare mining area. On February 22, 2005, it received environmental approval for a production capacity of one million tonnes annually. In the current study, an effort was undertaken to evaluate the soil samples that were taken from four various blocks of coal stock within the coal mine. The Department of Forestry, Wildlife and Environmental Sciences at Guru Ghasidas Central University in Bilaspur, Chhattisgarh, gave its approval to the study.

Analysis of physico-chemical properties of soil

Twenty soil samples in total, at a depth of 0–15 cm, were collected from five different locations of coal stock in the Amera Coal Mines, Surguja, Chhattisgarh, for the analysis of soil physico-chemical properties. The soil samples were brought to laboratory and dried in oven for 48 hrs and crushed to pass through 2 mm sieve. The sieved soil samples were placed into polythene bags and labelled properly for laboratory analysis.

The soil pH is the most important characteristic of soil gives us an idea whether the soil is acidic, neutral, or alkaline. Using a digital pH metre, the pH of the soil was measured (1:2.5 soil to water ratio) (Jackson, 1973) [6]. The relative amounts of sand, silt, and clay in a soil are referred to as its texture. The determination of soil texture was done by touch and feel method by assessing the texture of soil samples through tactile examination, specifically by rubbing the soil between the thumb and fingers. Soil organic carbon percentage was calculated by (Walkley, 1947) [23].

Soil Carbon stock (t ha $^{-1}$) = [soil bulk density (g cm $^{-3}$)] x soil depth (cm) x soil carbon (%). The soil bulk density was estimated using a core sampler after pebbles were removed. Bulk density: Weight of dry soil (g)/ Volume of soil (cm)Alkaline potassium permanganate method was used to measure the amount of available nitrogen (Subbiah and Asija, 1956) [21]. The moisture content of soil samples was calculated by proposed method by (Poonia *et al.* 2020) [16].

For statistical analysis “Analysis of variance” technique was applied to the data recorded for each character. Overall differences were tested by “F” test of significance at 5% level of significance as suggested by (Cochran and Cox, 1957). Critical differences at 5% level of probability were worked out for comparing treatments.

$$\text{C.D. at 5\%} \sqrt{\frac{2\,ErrormeanSquare}{N}} \times' T'value\ at\ 5\ \%$$

Fig 1: Map of the selected experimental site.

Fig 2: Soil sampling locations selected coal mines area.

Here, S_1= Coal stock 5 (Actively used), S_2= Coal stock 3& 4 (Actively used), S_3= Coal 1&2 (Not in used), S_4= (Plantation area), S_5= Forest soil.

Results and discussion

Soil Texture

The data presented in table1 is an indicative of soil texture. The study concluded that the soil found in coal stock area 3, 4 and 5, being actively used had sandy soil, whereas that in coal stock area 1 and 2 had silt clay while that in the plantation area had loam soil. Soil texture is good’ if the length of the extruded soil ribbon’s size is more than 5 medium, if the length of the extruded soil ribbon’s size is between 2.5-5 cm ‘poor’ if the length of the extruded soil ribbon’s size is less than 2.5 cm. in mining areas Land subsidence-induced dense surface cracks can result in a rise in the percentage of sand in the soil, the loss of silt and clay, and a tendency toward desertification (Ma *et al.* 2019). Land subsidence increases the soil's capability for erosion and infiltration because the large surface cracks caused by coal seam extraction degrade the soil's structure and increase its overall porosity (Yang *et al.* 2019).

Table 1: Soil texture from various sampling units

Sample Number	Area Description	Balls/Ribbons formed (YES or NO)	Size of the Ribbon	Soil Texture
S_1	Coal Stock Area No. 5 (Actively Used)	Neither ball nor ribbon formed	N.A.	Sandy
S_2	Coal Stock Area No. 3 & 4 (Actively Used)	Yes	Less than 2.5 cm	Sandy
S_3	Coal Stock Area No. 1 & 2 (Not in Use)	Yes	Less than 2.5 cm	Silt Clay
S_4	Plantation Area	Yes	Between 2.5 to 5 cm	Loam
S5	Forest soil	Yes	Between 2.5 to 5 cm	Loam

Soil pH

The pH of the soil solution is crucial because it affects nutrients like Nitrogen (N), Potassium (K), and Phosphorus (P), which plants require in precise amounts to grow. Based on the experimental findings, data indicates that the highest pH (7.08) was found in S_4, while the lowest (4.83) in S_1. The data also showed that the pH recorded in S_2 was found to be 5.27 and that of S_3 was 5.71 while the pH value of natural forest was recorded 5.79 (Fig. 2). The acidic pH of mining area soil may be due to the leaching of basic cations [3]. The similar result was also found by the Mohanta *et al.,* (2021) [13] conducted at mayurbhanj and found that the pH of soil in mining area was acidic (4.02-6.45). Similar findings were made by [19], who discovered low pH in the mining site soil. Juwarkar *et al.,* (2010) [7] also reported a similar observation of an increase in soil pH during reclamation, from a nearly neutral value 6.9 to a slightly basic condition of 7.5.

Bulk Density

Bulk density (g/cm³) is determined by dividing the dry soil weight (g) by the soil volume (cm³). Bulk density also depends on the soil's texture, soil structures, and level of organic matter [11]. The bulk density ranges between 1.88 g cm $^{-3}$ to 2.79 g cm $^{-3}$ and the bulk density of natural forest soil was recorded 1.88 g cm $^{-3}$ (Fig. 2). The bulk density in mining areas may be higher due to the absence of vegetation on mining site. Rai and Paul, (2011) [17] find similar result and reported that the soil in mining area has high bulk density due to less amount of organic matter present in soil system. The findings of Shrestha and Lal (2011) [19] also similar to the finding of study.

Electrical conductivity

An integrated measure of soil physical and chemical characteristics, soil EC is closely linked to both crop yield and soil health. The result showed that maximum EC was 0.16 DSM $^{-1}$found under S_2 followed by S_5 (0.16 DSM $^{-1}$), whereas the minimum was 0.13 DSM $^{-1}$ observed in S_3. The variation in EC might be attributed to the upward movement of various salts resulting from extraction and burning of coal particles in and around the study sites. Study conducted by Rai and Paul, (2011) [17] found that variation in EC ranged between 0.12 to 0.88 mmhos/cm. Similar finding was also reported by the Mohanta *et al.* (2021), Semy *et al.* (2021) [13, 22].

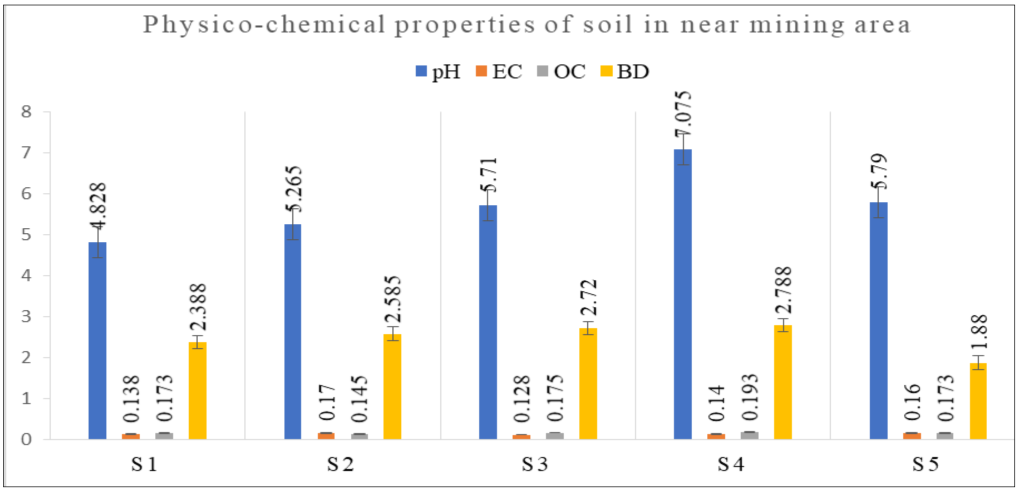

Fig 3: Physico-chemical properties of soil near mining area.

Moisture Content

The moisture content of the samples selected ranged from 6.51 % to 21.66 % (Table 2). Based on the study conducted, the results showed that the highest moisture content was recorded in S_5 (21.66 %), while the lowest in S_3 (6.51 %). The data also indicated that the S_2 and S_4 had a similar moisture content of 11.80 and 12.61% respectively. The low moisture content was found in the study site which may be due to the disturbed soil structure, higher stone, lack of organic matter and less vegetation. In a similar study Makdoh and Kayang (2015) [12] found that in mining area has low moisture content which is influence by site conditions. Similar result was also reported by (Mohapatra and Goswami, 2012) [14].

Soil Organic Carbon and SOC stock

One of the important parameters of soil is organic carbon as it improves both, physical and chemical properties along with providing several beneficial effects to the agricultural soil quality. It is an important attribute for improving soil structure, enhancing aeration, water penetration, and increasing water-holding capacity of the soil. It even supplies nutrients for growing plants. The soil organic carbon is an envisage of soil texture, climate, vegetation, and historical and current land use/management. Soil organic carbon is affected by soil texture because of the stabilizing properties of clay on organic matter (Rai and Paul, 2011) [17]. The maximum soil organic carbon was (0.19%) found in S_4, followed by S_3, whereas the lowest (0.15 %) was found in S_2 (fig. 1). Decreased mineralization rates in the dump samples and the loss of organic carbon, which contains nitrogen and nitrogen-fixing microbes, were the causes of the decreased total N values in the mining site (Rai and Paul, 2011) [17]. Similar trend of results was also reported by (Yaseen *et al.* 2012) [25]. Analysis of variance showed that S_4 had the maximum SOC stock (5.73 t ha $^{-1}$) significantly higher SOC stock values over the remaining. The lowest value of soil organic carbon stock was found (2.89 t ha $^{-1}$) in S_5 (table 2).

Nitrogen

Nitrogen in the soil is the most important element for plant development. In their above-ground tissues, healthy plants have a nitrogen content of 3% to 4%[19]. In the current study, the available nitrogen in the different soil sample was ranged between 38.11 kg ha $^{-1}$ to 164.56 kg ha $^{-1}$. The nitrogen level in in the collected S_1, S_2, S_3, and S_4 was 54.28, 38.11, 45.42 and 49.22 respectively, while the highest nitrogen content was 164.56 kg ha $^{-1}$ found in S_5 (table 2). Kumar and Kumar (2013) [8] found low concentration of nitrogen in the coal mine dump soil. The lower value of nitrogen may be due to lower rate of mineralization in that mining site and due to lower organic carbon, which contains nitrogen and nitrogen fixing microorganism (Makdoh and Kayang, 2015) [12].

Table 2: The data presented shows mean + SE of soil characteristics of soil near mining area as compared to forest soil

Sampling site	SOC stock (t ha $^{-1}$)	N (kg ha $^{-1}$)	MC (%)
S_1	5.08±0.17	54.28±11.81	17.24±0.47
S_2	4.63±0.11	38.11±1.76	11.80±0.69
S_3	4.80±0.17	45.42±2.12	6.51±0.42
S_4	5.73±0.18	49.22±1.16	12.61±1.18
S_5	2.89±0.27	164.56±3.50	21.66±1.16
C.D.	0.51	15.50	2.29

Conclusion

In conclusion, this study provides valuable insights into the soil characteristics and nutrient dynamics within the Amera coal mine area. The findings shed light on the impact of mining activities on soil moisture content, organic carbon content, and nitrogen levels. The results indicate that all four soils examined in the study are predominantly sandy in texture, which can have implications for water retention and nutrient availability. The acidic soil pH suggests the need for soil amendment and pH adjustment to create more favorable conditions for plant growth and nutrient uptake. The measured bulk density falls within the range of 2.82, indicating the compactness of the soils. These findings highlight the heterogeneous nature of soil moisture distribution within the coal mine area. In conclusion, the findings highlight the importance of implementing soil management strategies tailored to the specific soil characteristics and challenges present in the Amera coal mine area. Measures such as soil amendment, pH adjustment, water management, organic matter addition, and nitrogen supplementation should be considered to improve soil health, enhance nutrient availability, and support ecosystem recovery. Continued monitoring and research efforts are necessary to assess the effectiveness of these interventions and ensure the long-term sustainability of the coal mine area.

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