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"ASSESSMENT OF PHYSICOCHEMICAL PROPERTIES AND HEAVY METAL OF SOIL IN COAL MINING AREA (KETKI & GYATRI) OF SURAJPUR DISTRICT"

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Abstract:

This study investigates the physicochemical properties and heavy metal concentrations in soil samples from the Ketki and Gaytri coal mining areas in Surajpur District, Chhattisgarh, to assess the environmental impacts of mining activities on soil quality. Soil samples were collected from depths of 0-15 cm and analysed for parameters including pH, electrical conductivity, organic carbon, total nitrogen, phosphorus, and potassium levels. The results show slightly acidic pH levels, indicating potential challenges in nutrient availability and microbial activity. Notably, organic carbon content in sample B is critically low, necessitating organic amendments to enhance soil fertility. Both samples exhibited insufficient nitrogen levels, which could hinder crop productivity. Heavy metal analysis revealed concerning levels of arsenic and copper, along with below-detection levels for zinc in both samples, raising red flags regarding nutrient deficiencies. Furthermore, elevated manganese and chromium concentrations pose risks to plant health and groundwater contamination. The findings highlight the urgent need for targeted reclamation strategies, sustainable land management practices, and responsible mining operations to mitigate environmental impacts, restore soil health, and promote agricultural productivity in mining-affected regions. Continuous monitoring is essential for safeguarding ecosystem integrity and human health in these vulnerable areas.

Keywords: Physico-chemical properties, Heavy Metals, Electric Conductivity.

Introduction:

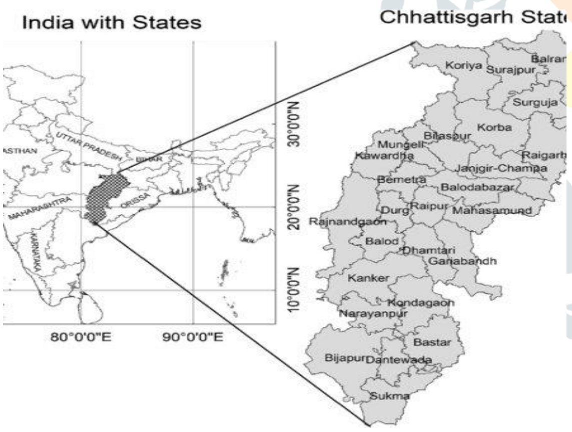
Soil in coal mining areas is a crucial yet often neglected element of the ecosystem, forming the basis for plant life and supporting local biodiversity and agriculture. Unfortunately, coal mining, particularly open-cast operations, severely impacts soil health. The removal of topsoil disrupts the soil's physical structure, leading to nutrient depletion and degradation of its chemical composition. This loss of fertility compromises the soil's ability to retain moisture, disrupting the balance necessary for vegetation growth and exacerbating the risk of erosion.

Moreover, coal mining introduces pollutants like heavy metals and particulate matter into the soil, creating toxic conditions harmful to both plant and animal health. These contaminants can migrate into nearby water bodies, amplifying environmental damage.

To combat these challenges, it is essential to adopt sustainable practices focused on soil reclamation and restoration post-mining. Implementing measures that prioritize soil regeneration and minimize pollution can significantly mitigate the adverse effects of coal mining. By ensuring the resilience of soil as a vital resource, we can help maintain the health of local ecosystems and support agricultural practices, ultimately safeguarding the environment for future generations.

Study area:

Surajpur district, established on August 15, 2011, is situated in the northern part of Chhattisgarh, surrounded by eight newly formed districts. The district's headquarters, Surajpur city, is famous for its vibrant markets and the scenic Tamor Pingla Wildlife Sanctuary, with National Highway 43 facilitating connectivity. Home to a population of 789,043, with a literacy rate of 61%, Surajpur has earned the National Satyan Maitra Literacy Award. The district is notable for its historical temples, such as Bhageheshwari Devi and Patal Bhairav Mandir, and is abundant in natural resources like coal, ordinary stone, and sand.



Ketki Mining Area	Gyatri Mining Area
The Ketki Underground Coal Mine, located in Ketka village, Surajpur Tehsil of Chhattisgarh, is a key operation managed by South Eastern Coalfields Limited, a subsidiary of Coal India Limited. Covering 548.65 hectares, it has a capacity of 0.42 million metric tonnes per annum and holds approximately 89.594 million metric tonnes of coal resources, with 10.99 million metric	The Gayatri Underground Coal Mine Project, located in Getra village, Ambikapur Tehsil, Surguja District, Chhattisgarh, is operated by South Eastern Coalfields Limited, a subsidiary of Coal India Limited. Spanning 507.472 hectares, the mine specializes in non-coking coal extraction, with a designed capacity of 0.30 million metric tonnes per annum and mineable

tonnes classified as mineable reserves. Securing its environmental clearance on April 15, 2009, the mine adheres to sustainable practices. Its operations are vital for the local economy and India's energy needs, highlighting the critical role of coal in supporting industrial growth.	reserves of approximately 10.899 million tonnes. Since obtaining environmental clearance in 2002, the project has complied with regulations. With 19 coal leases and various quarry leases, the Gayatri Coal Mine is crucial for enhancing Surguja's mineralwealth, fostering local economic activities, and supporting job creation in the region.
	

Review of literature:

Tedi Yunanto *et al.* (2022),They studied reclamation effect the soil properties and plant growth and its diversity.In this study it is concluded that bulk density is affected by diversity and other chemical property are affected by pH.Guowang Wang *et al.* (2021) they study of the change of physiochemical property of waste dump of the open pit mining area. They particle size analyser (Beckman Coulter) is used to determine mechanical composition of soil.It is concluded that Open cast coal mining dumb area the soil quality is gradually poor.KhikeyaSemy*et al.* (2021) In this article focus on Changki forest coal mine area of soil quality and polluted of soil by coal area and weighted soil quality indexOver all they concluded that soil deterioration rate is higher in coal. Mining activity like : loss of organic carbon , reduction of Nutrient and rejuvenating process is slow down the forest soil.Uttam Kumar Mandal *et al.* (2021) In this article is based on analysis of Soil physical and chemical property of natural resources.Study concluded that soil property are affected by the human activity.Q. Li *et al.*(2020)This study is focused on heavy metal accumulation in coal mining area will effect the soil wheat system and health risk. They analyse soil pH organic matter and concentration of Cu , Zn , Cd, Pb, Cr, Ni these are heavy metals.Ranhong Liu *et al.* (2020) This study is focused on the variation of vegetation Restoration and reconstruction along the slope position gradient to affect the physical chemical properties of soil.Dewi Wulandari *et al.* (2020), This study is based on chemical property of soil which effect the plant growth in soil from natural forest which effect of opencast coal mining area. Study concluded that Reclamation played improved soil nutrition is stoichiometry then land.Caiyao Xu *et al.* (2018) In this study mainly focused on reclamation effectin soil . In this study TOC, TN , TP and C:N:P Stoichiometry in bulk soil are affected in reclamation of coal mining area.

Methodology:

The study on the physico-chemical properties and heavy metals in the Ketki and Gayatri coal mining areas of Surajpur District, Chhattisgarh, utilized a systematic approach. This involved soil sampling, comprehensive laboratory analysis, and detailed data interpretation to assess the environmental impact of mining activities on soil quality.

Soil sampling:

Site Selection- Collecting soil samples from the Ketki and Gayatri coal mining areas to ensure a comprehensive and representative analysis of the soil properties. This strategic approach aimed to capture variations across the mining sites, contributing to a better understanding of the environmental implications of mining activities.

Sample Depth - Carefully selected sites facilitated the collection of samples from depths of 15-30 cm, capturing both surface and subsurface soil properties.

Sample Collection - Utilizing a soil auger, approximately 1 kg of soil was retrieved from each designated point. To prevent contamination, samples were securely stored in clean, labeled polyethylene bags, ensuring the integrity of the samples for subsequent laboratory analysis and evaluation of physico-chemical properties and heavy metals.

Physico-chemical properties-

a. **pH-** Soil pH in coal mining areas typically ranges from 4.0 to 7.0, but mining activities can lower it, impacting ecosystems, soil health, and agriculture. Monitoring is vital for effective rehabilitation.pH was determined using a pH meter in a 1:2.5 soil-water suspension for accurate measurement.
b. **Electrical Conductivity -** In coal mining areas, soil electrical conductivity is affected by minerals and contaminants. Increased conductivity indicates dissolved ions, impacting soil health and ecosystems; thus, monitoring is essential for sustainable land use.Electrical conductivity was measured using a conductivity meter in a 1:2 soil-water extract for accurate assessment of soil salinity.
c. **Organic Carbon** - The percentage of carbon in soil from coal mining areas typically varies due to contamination and mineral composition, often ranging from low values around 1% to higher levels, depending on reclamation efforts.Organic carbon content was determined using the Walkley-Black method, oxidizing organic matter with potassium dichromate and sulfuric acid for accurate measurement.
d. **Total nitrogen** Total nitrogen levels in coal mining-affected soils vary due to disturbances, erosion, and degradation, but reclamation can enhance nitrogen through cover crops and soil amendments, improving overall soil health. The Kjeldahl method is used to measured total nitrogen content.

e. **Total Phosphorus** - Total phosphorus levels in coal mining soils generally range from 50 to 200 mg/kg, affected by mining activities, soil type, and surrounding vegetation, influencing nutrient availability and ecosystem health. Total Phosphorus was determined by using the Olsen method.

f. **Total Potassium -** Total potassium levels in soils of coal mining areas typically range from 100 to 400 mg/kg. These levels can be influenced by soil composition, mining practices, and vegetation cover. Total Potassium was determined by using the Flame Photometer method.

Heavy metal:

Arsenic, a toxic element found in coal, can leach into soil and water during mining, posing severe health risks, including cancer and cardiovascular diseases. Copper and zinc are essential trace elements but can reach toxic levels due to mining, harming soil microorganisms and disrupting nutrient cycling. Elevated manganese levels can impair plant growth, while hexavalent Chromium (Cr(VI)) poses significant carcinogenic risks, contaminating soil and persisting in the environment. These pollutants threaten both ecological systems and human health significantly.

❖ Heavy Metals was determine by using instrument

a) The Atomic Absorption Spectrophotometry (iCE 3000 Model, ThermoFisher).

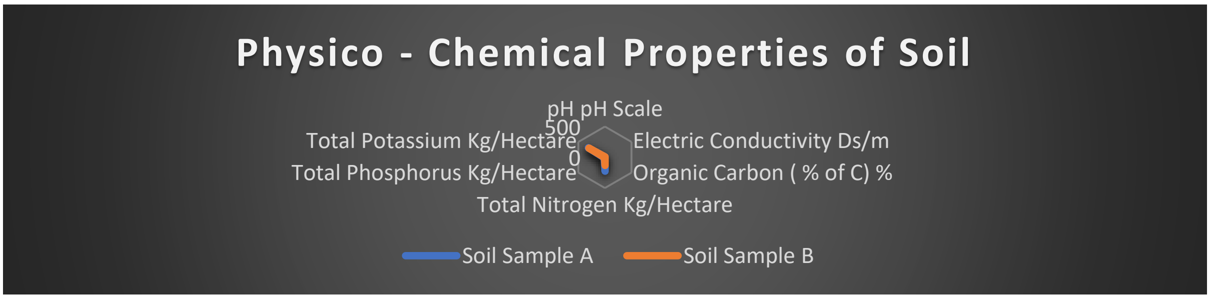
b) Microwave Acid Digestion System (Mars 6, CEM)

DATA COLLECTION & ANALYSIS

Tabal1 :Physico Chemical Properties of Soil

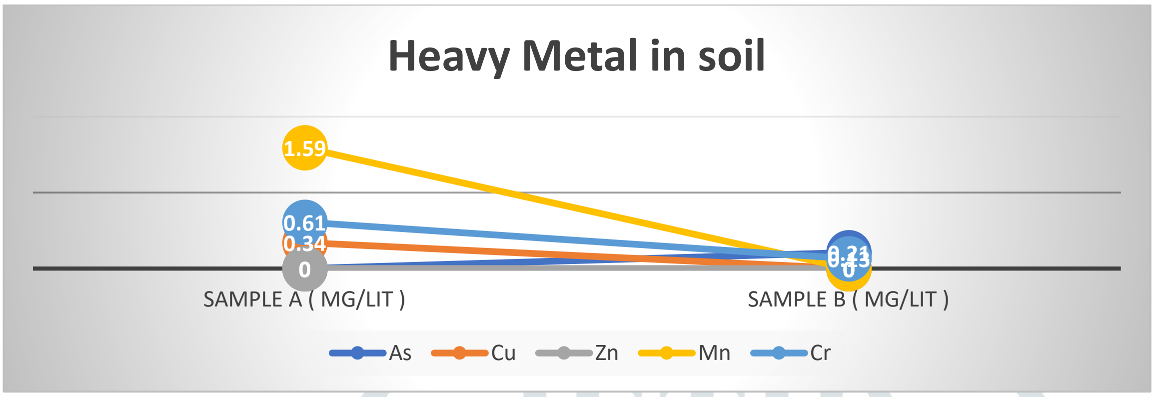
S.No	Physico-Chemical Properties	Unit	Sample A	Sample B	Level Description / Critical Level
1	pH	pH Scale	6.40	5.92	5.5 to 6.5 Medium Acidic Range
2	Electric Conductivity	dS/m	0.55	0.45	< 1.0 Normal Range
3	Organic Carbon (% of C)	%	0.61	0.29	< 0.50 Below Range; 0.50–0.75 Medium Range
4	Total Nitrogen	Kg/Hectare	230.00	135.00	< 280 Below Range
5	Total Phosphorus	Kg/Hectare	18.00	12.60	12–24 Medium Range
6	Total Potassium	Kg/Hectare	308.00	297.00	135–335 Medium Range

Sample A – Ketki Coal Mining Area, Sample B – Gyatri Coal Mining Area



Tabal2 : Heavy Metal in Soil

Heavy Metal	Sample A (mg/L)	Sample B (mg/L)	Notes
As	BDL	0.21	BDL – Below Detection Level
Cu	0.34	BDL	BDL – Below Detection Level
Zn	BDL	BDL	BDL – Below Detection Level
Mn	1.59	BDL	BDL – Below Detection Level
Cr	0.61	0.13	



Result and discussion:

The physicochemical properties analysis of soil samples from the Ketki and Gaytri coal mining areas in Surajpur District, Chhattisgarh, revealed critical information. Soil samples collected at a depth of 15-30 cm were evaluated against standard critical levels to determine soil quality, highlighting potential environmental impacts from mining activities.

pH-value-Soil sample A has a pH of 6.40, while sample B is 5.92, indicating slightly acidic conditions. Neutral pH is optimal for crop growth, enhancing nutrient availability and microbial activity.

Electrical Conductivity (EC)- The electrical conductivity of soil samples A (0.55 ds/m) and B (0.45 ds/m) indicates low salinity levels, characteristic of normal soils. These low EC values suggest minimal soluble salts, making the soil suitable for a diverse range of crops.

Organic Carbon (C)- Soil sample A has a carbon content of 0.61%, categorized as medium, while sample B at 0.29% is below the critical level of 0.50%. This indicates low organic matter in sample B, potentially impacting soil fertility and structure. Enhancing organic matter with compost or green manure could improve conditions.

Total Nitrogen- Soil sample A contains 230.00 kg/ha of total nitrogen, while sample B has 135.00 kg/ha, both below normal levels. Nitrogen deficiency can significantly impact crop productivity and health, leading to inhibited cell division, stunted leaf growth, and reduced thickness in longitudinal shoots, ultimately hindering overall plant growth.

Total Phosphorus- Soil sample A contains 18.00 kg/ha of total phosphorus, and sample B has 12.60 kg/ha, both within normal levels. However, excess phosphorus may hinder plants' absorption of critical micronutrients like iron and zinc, leading to deficiencies despite adequate soil tests indicating sufficient nutrient levels for plant growth.

Total Potassium- Soil sample A contains 308.00 kg/ha of potassium, while sample B has 297.00 kg/ha. Potassium plays a crucial role in water and nutrient movement, enzyme activation, and ATP production, which regulates photosynthesis. Excess potassium enables forage grasses and alfalfa to absorb far beyond the normal amounts needed for growth.

Heavy Metal: Arsenic (As) - Soil sample A has arsenic below detection, while sample B contains 0.21 mg/lit. Arsenic can weaken roots, wilt leaves, reduce photosynthetic pigments, and diminish chlorophyll, impacting plant metabolism.

Copper (Cu): Soil sample A contains 0.34 mg/lit of copper, while sample B is below detection level. Toxic copper concentrations can hinder seed germination, root development, and overall plant Vigor. Conversely, copper deficiency can also negatively impact plant metabolism and development, leading to stunted growth and impaired physiological functions.

Zinc (Zn): Both soil sample A and sample B show zinc levels below detection. Zinc deficiency can cause stunted growth and reduced yields, as it is essential for plant metabolism, enzyme activity, and ion transport. Insufficient zinc availability in soil critically affects plant nutrition, leading to significant losses in production and nutrient content.

Manganese (Mn): Soil sample A contains 1.59 mg/lit of manganese, while sample B is below detection level. Manganese deficiency can result in poor plant growth and development. Conversely, manganese toxicity may arise in acidic, poorly drained soils, leading to symptoms like leaf curling, interveinal chlorosis, and blackened veins on older leaves.

Chromium (Cr) : Sample A contains 0.61 mg/lit of chromium, while sample B has 0.13 mg/lit. Chromium is a hazardous ion that contaminates groundwater and impacts plant growth by disrupting metabolic processes. Wetting and drying of soils can enhance its solubility, although organic matter can mitigate Cr levels in soils.

Conclusion:

The comprehensive examination of physicochemical and heavy metal characteristics of soil samples from the Ketki and Gaytri coal mining areas in Surajpur District, Chhattisgarh, reveals critical insights into the environmental consequences of mining activities on soil quality. The analyses indicate slightly acidic pH levels across both samples, potentially impairing nutrient availability and microbial activity vital for healthy crop growth. While electrical conductivity readings are within acceptable limits, organic carbon content, particularly in sample B, is alarmingly low, indicating a pressing need for organic matter amendments to enhance soil fertility and structure.

Both soil samples exhibit nitrogen levels below optimal thresholds, suggesting that nitrogen deficiency could hinder crop productivity and negatively influence plant health. Although phosphorus and potassium concentrations are considered adequate, the risk of excess phosphorus leading to micronutrient imbalances is concerning, emphasizing the complexity of nutrient management in mining-affected soils.

Furthermore, the assessment of heavy metal concentrations uncovers additional risks. While arsenic levels in sample B may pose risks even at low concentrations, copper presence in sample A demonstrates the delicate balance necessary for essential trace elements, where both deficiency and toxicity can impair plant functions. The absence of zinc in both samples raises alarms about potential nutrient deficiencies that could significantly impact agricultural yield. Manganese levels in sample A suggest possible toxicity under certain conditions, while elevated chromium levels raise serious concerns regarding groundwater contamination and disruptions to plant metabolic processes.

To address these multifaceted challenges, it is crucial to implement targeted reclamation strategies, such as the integration of organic amendments and nitrogen-fixing cover crops. Continuous soil monitoring and sustainable land management practices are vital for enhancing soil quality and agricultural resilience in mining-impacted regions. The findings underscore an urgent need for responsible mining practices, along with effective rehabilitation strategies, to safeguard ecosystem health and human well-being, ensuring the landscape can support sustainable agricultural productivity for the future.

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