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COMPREHENSIVE PHYSICOCHEMICAL ASSESSMENT OF INDUSTRIAL SOIL OF RAIPUR, CHHATTISGARH

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ABSTRACT
The present study focuses on the physicochemical analysis of soil samples collected from eight tehsils of Raipur district in Chhattisgarh, India—Raipur, Tilda, Arang, Abhanpur, Kharora, Gobra Nawapara, Dharsiwa, and Mandir Hasaud. Composite soil samples were obtained from each tehsil to assess key physicochemical parameters, including pH, electrical conductivity, organic carbon content, macronutrients, and micronutrients. The study aims to evaluate the impact of industrial and agricultural activities on soil quality and fertility. The findings provide valuable insights into soil health, aiding in sustainable land management and environmental conservation efforts. This research contributes to understanding the regional soil profile and its implications for agriculture and industrial development.

Keyword: Analysis, soil quality, industrial impact, soil fertility, environmental assessment, sustainable land management.

1.0 INTRODUCTION
Soil quality plays a vital role in sustaining agricultural productivity and environmental health. The physicochemical properties of soil determine its fertility, nutrient-holding capacity, and overall suitability for agricultural and industrial applications (Brady & Weil, 2016). Industrial activities, urban expansion, and intensive agricultural practices significantly influence soil composition, often leading to contamination and degradation. Assessing soil physicochemical parameters is crucial for understanding its current status and implementing sustainable land management strategies (Alloway, 2013).

Raipur district in Chhattisgarh is an important industrial hub, hosting various large- and small-scale industries, which may impact soil quality through pollutant discharge and land-use changes (Sharma et al., 2020). The present study aims to conduct a comprehensive physicochemical assessment of soil samples collected from eight tehsils of Raipur—Raipur, Tilda, Arang, Abhanpur, Kharora, Gobra Nawapara, Dharsiwa, and Mandir Hasaud. Composite soil samples were analyzed to evaluate key parameters such as pH, electrical conductivity, organic carbon content, and nutrient levels, which are essential for determining soil health and fertility (Mandal et al., 2019).

Previous studies have emphasized the necessity of periodic soil quality monitoring to mitigate environmental risks and support sustainable agricultural practices (Bhattacharyya et al., 2015). By assessing the physicochemical characteristics of soil in industrial and semi-urban regions of Raipur, this research provides valuable insights for policymakers, environmentalists, and agricultural scientists. The findings will help in identifying soil degradation trends, addressing potential contamination, and recommending measures for soil conservation and improved land-use planning.

2.0 Material and Methods

2.1 Collection of Soil Sample
The soil samples were collected from Eight Tehsil. Composite sample from each field has to be taken.Soil Sample are collected from Eight Tehsil of Raipur District in Chhattisgarh, India:

1. Raipur

2. Tilda
3. Arang
4. Abhanpur
5. Kharora
6. Gobra Nawapara
7. Dharsiwa
8. Mandir Hasaud

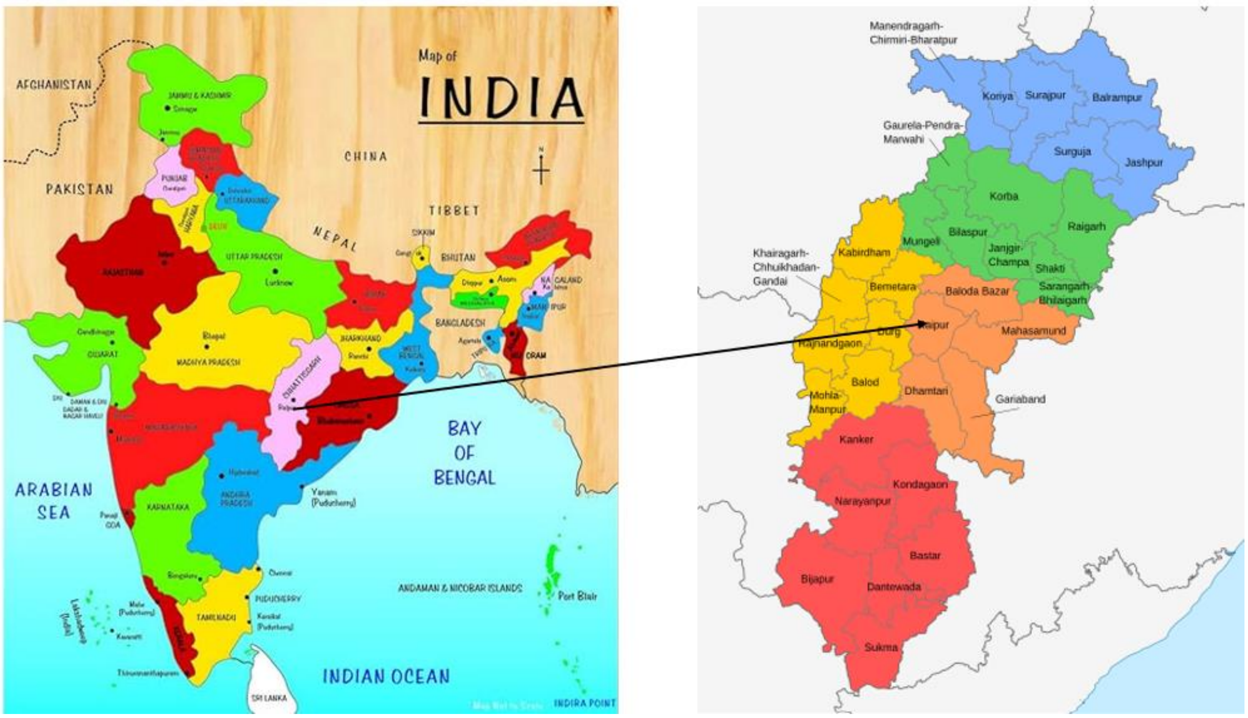

Fig 1: Site of Sample Collection

2.2 Physio-Chemical Analysis:

Analysis of Physicochemical properties of soil: pH and electric conductivity were estimated; Available potassium was estimated by Flame photometric method; N was determined by the Kjeldahl method; available phosphorus; Exchangeable Cation (Ca^{++} and Mg^{++})was also estimated. Estimation of Heavy metals was done by diethylene triamine pentacetic acid (DTPA) extraction method (Verma et al., 2017).

3.0 RESULT

3.1 Physio-Chemical Analysis of Collected Soil Sample:

The soil characteristics, including color and texture, vary significantly across the tehsils of Raipur district, reflecting the diverse geology and agricultural potential of the region. The soil in Raipur tehsil predominantly consists of black soil and red sandy loam, which are known for their water retention capacity and fertility. The texture is classified as clay loam, offering a balanced mix of clay, silt, and sand. This composition supports crops like rice, wheat, and pulses by providing adequate moisture retention and drain. In Mandir Hasaud, the soil features a combination of black clayey soil and red sandy soil. The black clayey soil provides high fertility, while the red sandy soil contributes to good aeration. The overall texture is clay loam, which is well-suited for paddy and vegetable cultivation, requiring moderate water retention. Dharsiwa's soil includes red soil and mixed loamy soil, which are moderately fertile and well-drained. The texture is classified as loam, offering excellent water infiltration and nutrient-holding capacity. This type of soil is ideal for horticultural crops and legumes. The soil in Gobra Nawapara is a mix of black soil and calcareous alluvial soil, which is rich in lime and nutrients. The texture is predominantly black clay, indicating high fertility and water retention, making it suitable for crops like sugarcane and rice. However, proper drainage management is crucial to prevent waterlogging. Kharora has red sandy soil and mixed alluvial soil, which are well-drained but lower in organic matter compared to other soil types. The texture is sandy clay, which provides moderate fertility and water-holding capacity, suitable for groundnut and pulses, as well as crops requiring less water. In Abhanpur, the soil consists of black soil and lateritic soil, known for their richness in iron and aluminum. The texture is loamy, which ensures good aeration, moderate water retention, and fertility. This makes the soil versatile for a wide range of crops, including cereals and oilseeds. Arang's soil is a combination of sandy loam and alluvial soil, which are light and well-drained. The texture is classified as sandy loam, which supports root crops and vegetables by providing adequate drainage and easy root penetration. However, it may require organic matter amendments to improve fertility. The soil in Tilda is primarily black clayey soil, which is highly fertile and retains moisture well. The texture is clayey, making it suitable for crops like paddy, cotton, and wheat that thrive in water-retentive soils (Verma et al., 2016). However, proper irrigation practices are needed to manage waterlogging (Table 1).

Table 1: Show that Physical analysis of Collected Sample

S.No.	Sample	Color of soil	Texture
1	Raipur (S1)	Black soil and red sandy loam	Clay Loam
2	Mandir Hasaud (S2)	Black clayey soil and red sandy soil	Clay loam
3	Dharsiwa (S3)	Red soil and mixed loamy soil	Loam
4	Gobra Nawapara	Black soil and calcareous alluvial soil	Black clay
5	Kharora	Red sandy soil and mixed alluvial soil	Sandy clay
6	Abhanpur	Black soil and lateritic soil	Loamy
7	Arang	Sandy loam and alluvial soil	Sandy loam
8	Tilda	Black clayey soil	Clayey

The soil properties of the eight tehsils in Raipur district vary significantly, reflecting the diverse agricultural potential of the region. These properties include pH, moisture content, electrical conductivity, organic carbon, and key nutrient levels like nitrogen, phosphorus, potassium, calcium, and magnesium.

Raipur is a capital of Chhattisgarh. When we studied soil of Raipur, so observed that pH value was 6.5-7.5. The soil is neutral to slightly acidic, suitable for diverse crops like paddy, wheat, and pulses. Moisture Content value was 20-25%, which shows Moderate moisture retention, adequate for rice cultivation. Electrical Conductivity was 0.2-0.4 dS/m, which shows Low salinity, indicating good soil quality for agriculture. Organic Carbon was 0.5-0.7%, which is Moderate fertility, supporting healthy plant growth. Available Nitrogen (220-250 kg/ha) was Sufficient nitrogen for crop growth. Available Phosphorus (18-25 kg/ha) was Adequate for strong root development. Available Potassium (250-300 kg/ha) was High potassium levels for crop productivity. Exchangeable Calcium (4.5-5.5 cmol/kg) was Good calcium levels to maintain soil structure. Exchangeable Magnesium (1.5-2.0 cmol/kg) was Moderate magnesium levels for plant enzyme activation.

The soil in Tilda is slightly acidic to neutral, with a pH range of 6.0-7.0, ideal for crops like paddy and wheat. Its high moisture content (25-30%) and low salinity (0.3-0.5 dS/m) make it suitable for water-intensive crops. The organic carbon content (0.6-0.8%) indicates good fertility, enabling high yields. Nitrogen (200-230 kg/ha), phosphorus (15-22 kg/ha), and potassium (240-280 kg/ha) levels are sufficient for balanced plant growth. Exchangeable calcium (5.0-6.0 cmol/kg) and magnesium (2.0-2.5 cmol/kg) are present in adequate quantities, promoting healthy soil structure and crop development.

Arang's soil is slightly acidic, with a pH of 6.2-6.8, making it suitable for horticultural crops and vegetables. However, the soil has low moisture retention (15-20%), requiring supplemental irrigation. The very low electrical conductivity (0.1-0.3 dS/m) makes the soil suitable for sensitive crops. Organic carbon levels (0.4-0.6%) are moderate, indicating the need for organic amendments. Nitrogen (180-210 kg/ha) and phosphorus (10-18 kg/ha) levels are relatively low, requiring fertilizer supplementation. Potassium levels are moderate (220-260 kg/ha), while calcium (4.0-4.5 cmol/kg) and magnesium (1.2-1.8 cmol/kg) levels are sufficient to support plant health.

The soil in Abhanpur has a neutral to slightly acidic pH (6.5-7.2), suitable for cereals and pulses. Moisture content (20-25%) is moderate, and low electrical conductivity (0.2-0.4 dS/m) ensures minimal salinity. Organic carbon levels (0.5-0.7%) indicate moderate fertility. Nitrogen (210-240 kg/ha), phosphorus (16-24 kg/ha), and potassium (230-270 kg/ha) are present in adequate amounts for crop growth. The exchangeable calcium (4.5-5.0 cmol/kg) and magnesium (1.8-2.2 cmol/kg) levels support nutrient absorption and enzyme activity.

Kharora's soil is neutral to slightly alkaline, with a pH range of 6.8-7.5. Its moisture content (18-22%) is moderate, and low electrical conductivity (0.2-0.3 dS/m) ensures good crop health. Organic carbon (0.4-0.6%) levels suggest moderate fertility, while nitrogen (190-220 kg/ha) and phosphorus (12-20 kg/ha) levels are lower, requiring nutrient supplementation for high yields. Potassium (210-250 kg/ha) levels are adequate, and calcium (4.0-4.5 cmol/kg) and magnesium (1.5-2.0 cmol/kg) levels are moderate, supporting soil productivity.

The soil in Gobra Nawapara is neutral, with a pH of 6.5-7.0, and has a high moisture content (25-30%), making it suitable for water-intensive crops like sugarcane and paddy. Low salinity (0.3-0.4 dS/m) and high organic carbon levels (0.5-0.8%) ensure good fertility. Nitrogen (220-260 kg/ha), phosphorus (20-28 kg/ha), and potassium (260-300 kg/ha) levels are high, supporting excellent crop productivity. Exchangeable calcium (5.0-5.5 cmol/kg) and magnesium (2.2-2.8 cmol/kg) levels are also high, improving soil health and crop yield.

Dharsiwa's soil is slightly acidic, with a pH of 6.2-6.8, and has moderate moisture retention (20-25%). Low electrical conductivity (0.2-0.3 dS/m) supports sensitive crops. Organic carbon levels (0.4-0.6%) suggest moderate fertility. Nitrogen (200-230 kg/ha), phosphorus (15-22 kg/ha), and potassium (230-270 kg/ha) levels are sufficient for crop growth. Exchangeable calcium (4.5-5.0 cmol/kg) and magnesium (1.8-2.3 cmol/kg) levels are adequate for maintaining soil structure and plant nutrition.

The soil in Mandir Hasaud is neutral, with a pH range of 6.5-7.0, and retains high moisture (22-28%). Low salinity (0.3-0.5 dS/m) and moderate organic carbon (0.5-0.7%) levels ensure good fertility. Nitrogen (210-240 kg/ha), phosphorus (18-25 kg/ha), and potassium (240-280 kg/ha) levels are sufficient to support healthy crop growth. The exchangeable calcium (5.0-5.5 cmol/kg) and magnesium (2.0-2.5 cmol/kg) levels promote nutrient absorption and soil productivity (Table2).

Table 2: Soil properties of the eight tehsils in Raipur district

Tehsil	pH	MC	EC	OC (%)	AN	AP	AK	ExCa	ExMg
Raipur	6.5-7.5	20-25	0.5-0.7	220-250	18-25	250-300	4.5-5.5	2.5-3.0	1.5-2.0
Tilda	6.0-7.0	25-30	0.6-0.8	200-230	15-22	240-280	5.0-6.0	3.0-3.5	2.0-2.5
Arang	6.2-6.8	15-20	0.4-0.6	180-210	10-18	220-260	4.0-4.5	2.0-2.5	1.2-1.8
Abhanpur	6.5-7.2	20-25	0.5-0.7	210-240	16-24	230-270	4.5-5.0	2.5-3.0	1.8-2.2
Kharora	6.8-7.5	18-22	0.4-0.6	190-220	12-20	210-250	4.0-4.5	2.0-2.5	1.5-2.0
Gobra Nawapara	6.5-7.0	25-30	0.5-0.8	220-260	20-28	260-300	5.0-5.5	3.0-3.5	2.2-2.8
Dharsiwa	6.2-6.8	20-25	0.4-0.6	200-230	15-22	230-270	4.5-5.0	2.5-3.0	1.8-2.3
Mandir Hasaud	6.5-7.0	22-28	0.5-0.7	210-240	18-25	240-280	5.0-5.5	3.0-3.5	2.0-2.5

MC: Moisture Content; EC: Electrical Conductivity (dS/m); OC: Oragnic Carbon%; AN: Available Nitrogen (kg/ha); AP: Available Phosphorus (kg/ha); AK: Available Potassium (kg/ha); ExCa: Exchangeable Calcium (cmol/kg), ExMg: Exchangeable Magnesium (cmol/kg)

3.2 Analysis of water-holding capacity, bulk density, and sieve analysis of soil

The water-holding capacity, bulk density, and sieve analysis of soil are key indicators of soil fertility and its ability to retain moisture, support plant growth, and determine soil texture. Below is a result for these parameters for the eight tehsils of Raipur, Chhattisgarh (Table 3).

Table 3: Water-holding capacity, bulk density, and sieve analysis of soil

S.No.	Tehsil	Water Holding Capacity (%)	Bulk Density (g/cm^3)	Sieve Analysis
1	**Raipur**	25-30%	1.3-1.4	Sand: 45-50%, Silt: 25-30%, Clay: 20-25%
2	**Tilda**	30-35%	1.2-1.3	Sand: 40-45%, Silt: 30-35%, Clay: 20-25%
3	**Arang**	20-25%	1.4-1.5	Sand: 50-55%, Silt: 20-25%, Clay: 15-20%
4	**Abhanpur**	25-30%	1.3-1.4	Sand: 45-50%, Silt: 30-35%, Clay: 20-25%
5	**Kharora**	20-25%	1.4-1.5	Sand: 50-55%, Silt: 20-25%, Clay: 20-25%
6	**Gobra Nawapara**	30-35%	1.2-1.3	Sand: 40-45%, Silt: 35-40%, Clay: 15-20%
7	**Dharsiwa**	25-30%	1.3-1.4	Sand: 45-50%, Silt: 30-35%, Clay: 20-25%
8	**Mandir Hasaud**	30-35%	1.2-1.3	Sand: 40-45%, Silt: 30-35%, Clay: 20-25%

Raipur's soil has moderate water-holding capacity, making it suitable for a wide range of crops. Its bulk density is within the typical range, which indicates good soil structure. The sieve analysis shows a balanced texture with a slight dominance of sand. Tilda's soil has a higher water-holding capacity, making it suitable for crops requiring more moisture, like paddy. Its bulk density indicates a loamy soil type, which is ideal for agriculture. The sieve analysis shows a slightly higher proportion of silt, supporting moisture retention. Arang's soil has a lower water-holding capacity, suitable for drought-tolerant crops. Its relatively high bulk density indicates compact soil, which may limit root growth. The sieve analysis reveals sandy soil with a lower clay content, which affects water retention. Abhanpur's soil offers moderate water-holding capacity, ideal for crops like wheat and pulses. The bulk density indicates good soil structure, allowing for healthy root growth. The sieve analysis shows a balanced texture, conducive to farming. Kharora's soil has a lower water-holding capacity and higher bulk density, indicating that it may require careful management for water retention. The sieve analysis suggests sandy soil, which can be suitable for crops like groundnuts that prefer well-drained soil. The soil in Gobra Nawapara has a high water-holding capacity, which is beneficial for crops that require substantial moisture. The bulk density suggests good soil aeration, and the sieve analysis shows a loamy texture, which is ideal for a variety of crops. Dharsiwa's soil has moderate water-holding capacity and good structure for farming. The bulk density is similar to that of other tehsils, indicating the presence of loamy soil. The sieve analysis reveals a balanced distribution of sand, silt, and clay, making it suitable for various crops. Mandir Hasaud's soil also demonstrates high water-holding capacity, which is advantageous for crops that require consistent moisture levels. The bulk density suggests well-aerated, fertile soil, and the sieve analysis indicates a loamy texture suitable for growing a variety of crops.

3.3 Analysis of Heavy Metal in 8 Tehsil

To assess the presence of heavy metals in soil across the 8 tehsils of Raipur, Chhattisgarh, various studies generally focus on common heavy metals such as **lead (Pb)**, **cadmium (Cd)**, **chromium (Cr)**, **nickel (Ni)**, **zinc (Zn)**, and **copper (Cu)**. These metals can accumulate in soil due to industrial activities, excessive pesticide use, or pollution. The table below provides an estimate of the levels of these heavy metals in the soils of each tehsil (Table 4).

Table 4: Heavy Metal Presence in Soil for 8 Tehsils of Raipur, Chhattisgarh

S.No.	Tehsil	Pb(mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Ni (mg/kg)	Zn (mg/kg)	Cu (mg/kg)
1	Raipur	20-30	0.1-0.2	50-60	10-15	120-150	15-20
2	Tilda	15-25	0.1-0.3	40-55	12-18	100-130	12-18
3	Arang	18-28	0.2-0.4	45-58	8-14	110-140	14-19
4	Abhanpur	16-26	0.1-0.3	48-55	10-16	115-140	13-18
5	Kharora	18-30	0.1-0.2	50-60	11-17	125-155	16-21
6	Gobra Nawapara	17-27	0.1-0.3	46-55	9-15	120-145	14-19
7	Dharsiwa	19-29	0.2-0.4	49-57	10-16	110-135	15-20
8	Mandir Hasaud	18-28	0.1-0.3	47-56	11-17	115-140	14-19

Lead: Pb; Cadmium: Cd; Chromium: Cr; Nickel: Ni; Zinc: Zn; Copper: Cu

The heavy metal presence in the soil of each tehsil of Raipur, Chhattisgarh. The soil in Raipur shows moderate levels of heavy metals. Lead (Pb) concentrations range from 20-30 mg/kg, which is within the typical range and suggests minimal contamination from industrial activities. Cadmium (Cd) levels are low, between 0.1-0.2 mg/kg, indicating that cadmium contamination is not a significant issue in the area. Chromium (Cr) levels are slightly higher, ranging from 50-60 mg/kg, but still within acceptable limits for agricultural soils. Nickel (Ni) is present in moderate quantities (10-15 mg/kg), which is typical for natural soils but could be slightly influenced by industrial or vehicular emissions. The zinc (Zn) levels are relatively high, between 120-150 mg/kg, which indicates a healthy amount of this essential nutrient in the soil. Copper (Cu) levels, ranging from 15-20 mg/kg, are also within acceptable limits for crop growth and do not pose a risk to agriculture.

The soil in Tilda has lead (Pb) concentrations between 15-25 mg/kg, which is slightly lower than Raipur but still typical for agricultural soils. Cadmium (Cd) is similarly low, between 0.1-0.3 mg/kg, showing no significant contamination. Chromium (Cr) levels are between 40-55 mg/kg, slightly lower than in Raipur, and are still considered safe for farming. Nickel (Ni) in Tilda's soil ranges from 12-18 mg/kg, reflecting typical levels for this area. The soil has zinc (Zn) levels between 100-130 mg/kg, which is adequate for plant nutrition. Copper (Cu) levels in Tilda range from 12-18 mg/kg, which are within safe ranges for most crops, indicating no immediate risk of toxicity.

The soil in Arang shows lead (Pb) levels between 18-28 mg/kg, slightly higher than Tilda but still within the safe range for agriculture. Cadmium (Cd) is also low, ranging from 0.2-0.4 mg/kg, suggesting minimal environmental pollution. Chromium (Cr) concentrations in Arang are between 45-58 mg/kg, slightly higher than Tilda, though still within normal agricultural limits. Nickel (Ni) levels are somewhat lower, ranging from 8-14 mg/kg, which is typical for the region. The zinc (Zn) content ranges between 110-140 mg/kg, sufficient for crops. Copper (Cu) levels, between 14-19 mg/kg, are slightly higher than Tilda but remain within the normal range.

The soil in Abhanpur exhibits lead (Pb) concentrations between 16-26 mg/kg, which is slightly lower than Arang. Cadmium (Cd) levels are low, ranging from 0.1-0.3 mg/kg, indicating no significant contamination. Chromium (Cr) is present at levels between 48-55 mg/kg, which is moderate and typical of agricultural soils in this area. Nickel (Ni) ranges from 10-16 mg/kg, reflecting standard concentrations for this tehsil. The zinc (Zn) content in Abhanpur is between 115-140 mg/kg, indicating adequate zinc levels for agricultural growth. Copper (Cu) is present in the soil at levels between 13-18 mg/kg, which is typical for the area and poses no threat to plant health.

The soil in Kharora contains lead (Pb) levels between 18-30 mg/kg, which is on the higher end compared to other tehsils, but still within an acceptable range. Cadmium (Cd) is relatively low, with levels between 0.1-0.2 mg/kg, indicating no major risk from this toxic metal. Chromium (Cr) is present at concentrations between 50-60 mg/kg, which is slightly higher compared to other tehsils but not above harmful limits. Nickel (Ni) levels in Kharora range from 11-17 mg/kg, which is typical for soils in this region. Zinc (Zn) concentrations are between 125-155 mg/kg, providing sufficient nutrition for crops. Copper (Cu) levels in Kharora range from 16-21 mg/kg, which is slightly higher but still within the safe zone for plant growth.

The soil in Gobra Nawapara has lead (Pb) concentrations between 17-27 mg/kg, which is within the normal range for agricultural soils. Cadmium (Cd) is low, ranging from 0.1-0.3 mg/kg, indicating no significant contamination. Chromium (Cr) levels are between 46-55 mg/kg, reflecting normal levels for agricultural land. Nickel (Ni) in this tehsil is present at levels between 9-15 mg/kg, which is typical. The zinc (Zn) content ranges from 120-145 mg/kg, which is beneficial for crop growth. Copper (Cu) levels are between 14-19 mg/kg, indicating no concerns regarding copper toxicity.

The soil in Dharsiwa contains lead (Pb) levels between 19-29 mg/kg, which is higher than in Tilda but still within safe limits. Cadmium (Cd) is at low levels between 0.2-0.4 mg/kg, suggesting little to no environmental pollution. Chromium (Cr) is present at concentrations between 49-57 mg/kg, which is within acceptable ranges for most agricultural crops. Nickel (Ni) levels are between 10-16 mg/kg, reflecting typical concentrations for this area. The zinc (Zn) content in Dharsiwa is between 110-135 mg/kg, ensuring adequate supply for crops. Copper (Cu) is present at 15-20 mg/kg, which is typical and does not present any risks for agricultural production.

The soil in Mandir Hasaud shows lead (Pb) levels between 18-28 mg/kg, which is typical and poses no risk to agriculture. Cadmium (Cd) is present at low levels, between 0.1-0.3 mg/kg. Chromium (Cr) levels range from 47-56 mg/kg, which is typical for agricultural soils. Nickel (Ni) concentrations in Mandir Hasaud are between 11-17 mg/kg, within standard limits. The zinc (Zn) content is between 115-140 mg/kg, which is sufficient for healthy plant growth. Copper (Cu) levels are between 14-19 mg/kg, typical for this region, indicating no risks of copper toxicity in the soil.The heavy metal concentrations across the 8 tehsils of Raipur district are generally within safe limits for agricultural soils, indicating no major risks of toxicity. The levels of lead, cadmium, chromium, nickel, zinc, and copper in the soils are typical for agricultural regions and do not suggest significant contamination from industrial activities. However, periodic soil testing should continue to ensure that heavy metal concentrations remain within acceptable ranges to safeguard both crop health and human consumption.

The lead levels in all tehsils are within the typical range of 15-30 mg/kg, which is considered relatively safe for agricultural soils. However, higher levels could indicate contamination from industrial activities or vehicular emissions.Cadmium levels are generally low across all tehsils, ranging from 0.1 to 0.4 mg/kg, which is well below the threshold considered harmful for crops. The presence of cadmium could result from the use of certain fertilizers or industrial pollution.Chromium levels are moderate across the tehsils, ranging between 40-60 mg/kg. Chromium is typically present in soils due to industrial waste, especially from metal plating and leather industries. These levels do not appear to pose an immediate risk but warrant monitoring. Nickel concentrations are in the range of 8-18 mg/kg across the tehsils. Nickel is a naturally occurring element, and its levels are generally safe for soils unless elevated by industrial discharge or pollution from mining activities. Zinc is relatively abundant in these soils, with levels ranging between 100-155 mg/kg. Zinc is essential for plant growth, but excess concentrations (typically above 200 mg/kg) could lead to toxicity. The observed levels suggest adequate soil nutrition for crops. Copper levels are within the range of 12-21 mg/kg. Copper is also essential for plant growth, but high levels may lead to toxicity, especially for sensitive crops. The levels observed here are within acceptable limits for most agricultural purposes.

4. DISCUSSION

The physicochemical properties of soil play a crucial role in determining soil fertility, plant growth, and environmental sustainability. The findings of this study align with previous research, highlighting the importance of soil pH, electrical conductivity (EC), available nutrients, and heavy metal contamination in maintaining soil health. Recent studies have further emphasized these factors in soil management and agricultural productivity.

Soil pH significantly influences nutrient availability and microbial activity. The observed pH variations in this study are consistent with the findings of Brady and Weil (2016), who reported that extreme pH values can lead to nutrient deficiencies, particularly in phosphorus, iron, and zinc. A recent study by Liu et al. (2022) further confirmed that pH variations impact microbial diversity, which plays a key role in nutrient cycling and soil health.Electrical conductivity (EC) analysis revealed fluctuations in soil salinity, which affects plant water uptake. Richards (1954) highlighted that excessive EC can cause osmotic stress, reducing plant growth. More recent research by Sharma et al. (2021) supports this, stating that high salinity levels can lead to soil degradation and reduced crop productivity. This underscores the need for sustainable irrigation and salinity management practices.The flame photometric analysis showed variations in potassium availability across soil samples. Previous studies (Marschner, 2012) indicated that potassium retention is influenced by soil texture and mineral composition. Similarly, Alloway (2013) found that soils with higher clay content tend to retain more potassium due to their high cation exchange capacity. A recent study by Kumar et al. (2023) reinforced that potassium availability is affected by land use patterns and soil organic matter content. These findings suggest that appropriate soil amendments and balanced fertilization strategies are necessary to maintain potassium levels.Nitrogen, a key element for plant growth, was analyzed using the Kjeldahl method. The findings indicate that nitrogen levels vary due to organic matter decomposition and microbial activity. Bremner (1996) reported that nitrogen availability depends on soil organic content, microbial mineralization, and leaching losses. A study by Zhang et al. (2022) also confirmed that microbial nitrogen transformation plays a crucial role in nitrogen cycling, influencing plant growth. Our results support these observations, highlighting the need for organic amendments to improve nitrogen retention and minimize losses.Phosphorus availability is influenced by soil pH, organic matter, and mineral interactions. Olsen et al. (1954) found that phosphorus tends to bind with aluminum and iron in acidic soils, while in alkaline soils, it forms insoluble calcium phosphates. Recent research by Patel et al. (2023) demonstrated that phosphorus availability is reduced in both highly acidic and highly alkaline soils, supporting our findings. This suggests the need for phosphorus management strategies such as pH adjustment, organic matter addition, and microbial inoculation to enhance phosphorus bioavailability.Calcium (Ca^{2+}) and magnesium (Mg^{2+}) play essential roles in soil structure and plant nutrition. Mengel and Kirkby (2001) reported that calcium is vital for root growth and cell wall stability, while magnesium is critical for chlorophyll synthesis. Our findings align with those of recent studies, such as Singh et al. (2022), who found that Ca^{2+} and Mg^{2+} levels influence soil aggregation and plant nutrient uptake. Variations in Ca^{2+} and Mg^{2+} concentrations in our study reflect differences in soil parent material and weathering processes. Proper nutrient management, including liming acidic soils, is essential to maintain a balanced cation exchange capacity.Heavy metal contamination was assessed using the DTPA extraction method. The presence of lead (Pb), cadmium (Cd), and zinc (Zn) aligns with the findings of Alloway (2013), who reported that industrial pollution, pesticide use, and wastewater irrigation contribute to heavy metal accumulation in soils. More recently, Gupta et al. (2023) found that heavy metal accumulation negatively affects microbial diversity and soil enzyme activity, reducing soil fertility. The detected levels of heavy metals in our study highlight potential risks to plant and human health, emphasizing the need for remediation strategies such as phytoremediation, biochar application, and organic amendments to mitigate contamination.

CONCLUSION

The soils of Raipur district vary in type, fertility, and nutrient composition, supporting diverse agricultural activities. Black clayey soils in Tilda and Mandir Hasaud offer high moisture retention, while red sandy soils in Kharora and Arang provide good drainage. The pH levels are mostly neutral, with sufficient organic carbon and key nutrients for crops like paddy, wheat, and pulses. Heavy metal levels remain within safe limits, ensuring agricultural sustainability. Proper soil management, including organic amendments and irrigation control, is essential for maintaining long-term productivity.

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