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Evaluation of Soil texture Quality through Physicochemical Parameters in the Industrial Belt of Raipur, Chhattisgarh (India)

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Abstract
This study investigates the physicochemical propertiesand texture of soils from 15 industrial regions of Raipur, Chhattisgarh, India. Soil samples were collected for comprehensive texture analysis for physicochemical parameters such assoil pH, electrical conductivity (EC), organic carbon, total nitrogen, phosphorus, potassium, Ex. calcium, and Ex. magnesium contents etc. by using standard methods. Results revealed that soil pH ranged from acidic to slightly alkaline, with EC levels generally indicating low to moderate salinity. Organic carbon varied widely across sites, influencing nutrient availability. Notably, sites like Sejbahar, Siltara, and Mandhar showed higher nutrient content, whereas Urla exhibited poor soil quality.Soil texture analysis revealed a predominance of loamy soils, which are conducive to agriculture purposes. The findings highlight significant spatial variability in soil quality, underlining the need for continuous monitoring and sustainable management practices to mitigate environmental risks in industrial regions.

Keywords:Soilquality, Physicochemicalparameters, Texture, Industrial belt

Introduction

Soil, a dynamic and intricate component of the earth's biosphere, is constantly evolving due to both natural processes and human-induced disturbances, necessitating continuous assessment of its quality (Abdel*et al.,* 2021). The classical understanding of soil quality emphasizes its capacity to function within the boundaries of both natural and managed ecosystems, encompassing the sustenance of plant and animal productivity, the maintenance, enhancement of air, water quality, the support of human health and habitation (Silva *et al.,* 2011). Evaluating soil quality involves assigning a value to the soil based on its ability to perform a specific function or purpose, with these functions varying depending on soil use and scale (Carter *et al.,* 1997).Soil degradation, driven by factors such as soil fertility decline, biological degradation, increased erodibility, acidity, salinity, and exposure of compact subsoil with poor physicochemical properties, further underscores the importance of soil quality assessment (Saha *et al.*, 2012).The capability of soil to give rise to some products or carry out some functions may reduce with definite land uses. These exhibit changes in soil properties like nutrient content i.e. nitrogen, phosphorus, potassium, calcium, magnesium, sodium and pH, organic matter, cation exchange capacity, structure, etc (Akinrinde and Obigbesan, 2000).

Industrial activities have a substantial impact on soil quality, particularly in regions experiencing rapid industrialization such as Raipur, Chhattisgarh. Such activities frequently lead to the release of a variety of pollutants into the environment, which can drastically change the physicochemical characteristics of the soil and have cascading consequences for both the environment and human health (Verma and Verma, 2018).The introduction of pollutants from industrial sources can cause severe changes to the soil's composition and structure, which can have an influence on its fertility, water-holding capacity, and capacity to support plant life. Evaluating soil quality in industrial belts is therefore not merely an academic exercise but a critical necessity for environmental monitoring, risk assessment, and the development of sustainable industrial practices(Miller and Hutchins, 2017).

Raipur's industrial belt is home to a diverse range of industries, including steel plants, cement factories, and chemical manufacturing units, which collectively discharge a variety of pollutants into the surrounding environment (Mitchell *et al.,* 2016). These pollutants not only affect soil fertility and crop productivity but also pose significant risks to human health through the consumption of contaminated food and water (Xin *et al.,* 2020).The texture and Physicochemical parameters of soil such as pH, electrical conductivity, organic matter content and nutrient serve as key indicators of soil quality.Therefore, this study aims to evaluate soil quality in the industrial belt of Raipur, Chhattisgarh, through the comprehensive analysis of texture and various physicochemicalparameters during study period.

Material and Methods

Physio-chemical and Texture analysis of Soil

Soil sample collection

In the present study soil sample was collected from 15 different industrial areas of Raipur district such as Urla, Tendua, Girod, Mandhar, Siltara, Sejbahar, Borjhara, Baktara, Silpahari, Haripur, Amaseoni, Tilda, Bhanpuri, Birgaon, Rawabhata(Fig.1.). It will employ targeted sampling in zones with distinct land uses or potential contamination sources, such as industrial areas, with initial soil sampling from 0-20 cm in the field. All 15 samples were dried at room

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temperature in open air for two days and stored in black polythene bags. The soil samples are ground well into a fine powder by using an agate mortar. The soil samples were oven dried at 60°C for two hours to remove the moisture content. These areas support industries ranging from steel, cement, and manufacturing to small-scale enterprises for soil analysis of different parameters like texture and physicochemical characteristics was analysed (Fig.2).

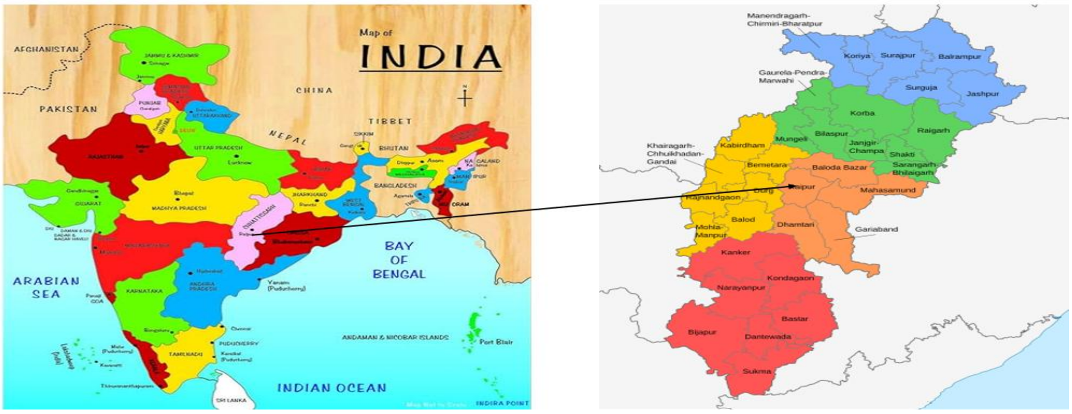

Fig 1: Site of soil Sample Collection from Industrial belt of Chhattisgarh state

Soil analysis will encompass determination of soil pH using standard buffer solution, assessment of soil organic carbon, available potassium, mineralized nitrogen, available phosphorus, (Najdenko*et al.,*2024).

Fig 2: Soil Samples prepared for analysis from 15 no of different Industrial Areas

Results and Discussion

Physicochemical andTextureanalysis of soil

In the present investigation soil, texture and all physiochemical properties like Average N,K,P, Exchangeable Ca, Mg, pH, EC, Organic carbon etc. of different industrial sites of Raipur such as Urla, Tendua, Girod, Mandhar, Siltara, Sejbahar, Borjhara, Baktara, Silpahari, Haripur, Amaseoni, Tilda, Bhanpuri, Birgaon, Rawabhata ofdata represented as in (Table 1).

The soil at Urla is acidic with a pH of 5.55, moderateelectrical conductivity (EC) of 122.85 µS/cm and Organic carbon (OC) is absent, indicating limited nutrient availability and highlighting the need for organic matter supplementation. Low organic carbon levels suggest that the soil may require the addition of organic matter, such as compost or green manure, to improve its fertility and long-term productivity (Yaashikaa *et al.,* 2020). Available average nitrogen is 146.5 kg/ha, reflecting low nitrogen levels andphosphorus is minimal at 3.4 kg/ha, while potassium is also low at 125.9 kg/ha. Exchangeable calcium and magnesium are observed 0.50 and 0.83 meq/100g, indicating poor nutrient reserves with low organic matter. The loamy texture of soil offers decent water retention and drainage, but fertility improvements are necessary.

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The Tendua soil has a slightly acidic pH of 6.11 and moderate EC at 289.97 µS/cm, indicating tolerable salinity levels. This pH level is considered optimal for most crops, as it facilitates better nutrient availability, particularly for macronutrients like nitrogen, phosphorus, and potassium (Six *et al.,*2002). Organic carbon is low at 0.188%, while average nitrogen availability is moderate at 232.7 kg/ha but phosphorus and potassium levels are present at 13.9 and 270.5 kg/ha, which are satisfactory for crop cultivation.Exchangeable Calcium (4.73 meq/100g) and magnesium (2.60 meq/100g) are adequate, supporting soil fertility. The silty loam texture provides balanced water retention and aeration, making it suitable for crop cultivation. The texture of soil sandy ensures good drainage and fertility, making it productive for agriculture. Same results observed in industrial belt soil (Akanxhise *et al.,*2020).

The Girod soil has pH (6.28) also indicates slightly acidicin nature withEC of307.47 µS/cm, Organic carbon is 0.59%, moderate average nitrogenat 360.8 kg/ha., average phosphorous 19.4 kg/ha, potassium 435.4 kg/ha with low Exchangeable calcium (4.90 meq/100g) and magnesium (3.63 meq/100g) respectively. The texture of soil represents sandy loam in this particular region (Sumithra*et al.,*2013)

The soil in Mandhar has a slightly acidic pH of 6.38, with moderate EC at 325.8 µS/cm. Organic carbon is 0.659%, and nitrogen availability is high at 389.2 kg/ha. Average phosphorus (21.5 kg/ha) and potassium (552.4 kg/ha) levels are significantly high, supporting nutrient-rich soil. Exchangeable Calcium (7.43 meq/100g) and magnesium (4.30 meq/100g) are also abundant. The clay loam texture enhances nutrient retention and water-holding capacity, making it excellent for agriculture.

With a nearly neutral pH of 6.87, Siltara soil is moderately saline (EC of 354 µS/cm). Organic carbon is 0.719%, and nitrogen availability is high at 393.1 kg/ha. Average phosphorus (23.8 kg/ha) and potassium (614.6 kg/ha) levels are notably high. Exchangeable Calcium (8.73 meq/100g) and magnesium (4.53 meq/100g) are abundant. The silty clay texture offers high nutrient-holding capacity but may require management for optimal aeration (Tihonova *et al.,*2019).

Sejbahar soil is slightly alkaline with a pH of 7.43 and high EC at 438.5 µS/cm, reflecting salinity concerns. Organic carbon is 0.963%, with very high nitrogen (504.3 kg/ha), phosphorus (31.7 kg/ha), and potassium (881.7 kg/ha) levels. Exchangeable Calcium is exceptionally high at 26.27 meq/100g, and magnesium is 4.77 meq/100g. The loamy sand texture ensures excellent drainage but may require organic matter to retain nutrients effectively.

Neutral soil in Borjhara has a pH of 7.20 and low EC of 200 µS/cm. Organic carbon is 0.7%, with moderate nitrogen (230 kg/ha) and phosphorus (15 kg/ha) levels. Average Potassium is relatively low at 210 kg/ha. Calcium (4.5 meq/100g) and magnesium (2.8 meq/100g) are adequate. The sandy clay texture provides moderate fertility and water retention.

Baktara soil has a pH of 6.80, with low EC of 190 µS/cm. Organic carbon is moderate at 0.9%. AverageNitrogen hasrecorded as 270 kg/ha, phosphorus is 20 kg/ha, and potassium is 250 kg/ha respectively, all indicating moderate fertility. Exchangeable Calcium and magnesium levels are 4.0 and 2.6 meq/100g, respectively. The silty clay loam texture offers good nutrient and water retention properties (Guan *et al.,*2014).

The soil in Silpahari is slightly alkaline with a pH of 7.50 and low EC of 170 µS/cm. Organic carbon is 1.1%, indicating good organic matter. Average Nitrogen (290 kg/ha), phosphorus (25 kg/ha), and potassium (270 kg/ha) levels are moderate. Calcium (3.9 meq/100g) and magnesium (2.3 meq/100g) are adequate. The sandy texture ensures excellent drainage but may require nutrient management.

Hirapur soil hasa neutral pH of 7.00 and very low EC of 7.1 µS/cm, organic carbon is 0.8%, with moderate average nitrogen (260 kg/ha), phosphorus (19 kg/ha), potassium (230 kg/ha),Exchangeable Calcium and magnesium levels are 3.7 and 2.5 meq/100g, respectively. The loamy texture is ideal for balanced water retention and aeration (Joshi and Kumar, 2011).

The soil in Amaseoni is slightly acidic with a pH of 6.90 and low EC at 6.7 µS/cm., organic carbon is relatively high at 1.2%, enhancing soil fertility. The presence of adequate organic carbon is often associated with higher microbial activity and improved nutrient cycling, making it essential for sustainable agriculture (Six *et al.,* 2002). Average Nitrogen availability is 300 kg/ha, phosphorus is 28 kg/ha, and potassium is 280 kg/ha, all of which indicate moderate fertility. Exchangeable Calcium (3.5 meq/100g) and magnesium (2.5 meq/100g) are present in adequate amounts. The silty loam texture supports good water retention and nutrient availability, making the soil suitable for crop cultivation.

Tilda soil is slightly acidic with a pH of 6.50 and a low EC of 130 µS/cm., Organic carbon is high at 1.3%, Nitrogen (310 kg/ha), phosphorus (30 kg/ha), and potassium (290 kg/ha) respectively are moderately abundant, suggesting good

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organic matter content.pH is a principal parameter for determining, it assist in certify the availability of plant nutrients, which can also help in maintaining the soil fertility. ExchangeableCalcium (3.3 meq/100g) and magnesium (2.0 meq/100g) levels are slightly lower compared to other regions. The sandy loam texture ensures good drainage, though additional organic inputs may enhance water retention and nutrient availability. (Akinrinde and Obigbesan ,2000).

The soil in Bhanpuri is slightly alkaline with a pH of 7.40 and moderate EC at 195 µS/cm., Organic carbon is 0.7%, reflecting low organic matter content.Average Nitrogen is 255 kg/ha, phosphorus is 16 kg/ha, and potassium is 245 kg/ha, indicating moderate nutrient levels. Calcium (4.4 meq/100g) and magnesium (2.6 meq/100g) levels are sufficient. The clay loam texture enhances water retention and nutrient availability, making the soil moderately fertile for agricultural purposes.

Birgaon soil has a slightly acidic pH of 6.60 and low EC of 145 µS/cm. Organic carbon is 1.1%, which is beneficial for fertility. Average Nitrogen is 295 kg/ha, phosphorus is 24 kg/ha, and potassium is 275 kg/ha, indicating moderate fertility. Exchangeable Calcium and magnesium levels are 3.4 and 2.2 meq/100g, respectively. The silty clay texture offers excellent water retention, though proper aeration and drainage management may be required (Solanki and Chavda, 2012).

The soil at Rawabhata is neutral with a pH of 7.00 and moderate EC of 175 µS/cm. Organic carbon is 0.9%, signifying moderate organic matter. Soils with a pH in the range of 5.5 to 7.0 are ideal for crop cultivation, as they enhance the availability of essential nutrients without causing toxicities (Singh *et al*.,2019).Organic carbon is a key indicator of soil fertility as it contributes to nutrient retention, improves soil structure, and enhances microbial activity. Average Nitrogen availability is 265 kg/ha, phosphorus is 21 kg/ha, and potassium is 255 kg/ha, all within moderate ranges. Exchangeable Calcium and magnesium levels are 4.0 and 2.5 meq/100g, respectively. The loamy sand texture ensures good drainage but may require organic inputs to improve water and nutrient retention for better agricultural output (Devi and Premkumar ,2012).Thus, to protect the deterioration soil quality, control of such industrial pollution assumes greater significance which can be assured by planned industrialization.Maintenance or enhancement of soil quality is a more important criterion for analysis and sustainability of soil ecosystems (Saroj and Billore, 2014).

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Table1: Physicochemicaland Texture analysis of Soil from15 no of different Industrial areas during study period

S.No.	Soil sample collection site	pH	EC (µS/cm)	OC (%)	Av. N (kg/ ha)	Av. P (kg/ ha)	Av. K (kg/ ha)	Ex. Ca (meq/100g)	Ex. Mg (meq/100g)	Soil Texture
1	Urla	5.55	122.85	0.00	146.5	3.4	125.9	0.50	0.83	Loamy
2	Tendua	6.11	289.97	0.18	232.7	13.9	270.5	4.73	2.60	Silty Loam
3	Girod	6.28	307.47	0.59	360.8	19.4	435.4	4.90	3.63	Sandy Loam
4	Mandhar	6.38	325.8	0.65	389.2	21.5	552.4	7.43	4.30	Clay Loam
5	Siltara	6.87	354	0.71	393.1	23.8	614.6	8.73	4.53	Silty Clay
6	Sejbahar	7.43	438.5	0.96	504.3	31.7	881.7	26.27	4.77	Loamy Sand
7	Borjhara	7.2	200	0.7	230	15	210	4.5	2.8	Sandy Clay
8	Baktara	6.8	190	0.9	270	20	250	4.0	2.6	Silty Clay Loam
9	Silpahari	7.5	170	1.1	290	25	270	3.9	2.3	Sandy
10	Hirapur	7.0	7.1	1.50	0.8	260	19	230	3.7	Loamy
11	Amaseoni	6.9	6.7	1.40	1.2	300	28	280	3.5	Silty Loam
12	Tilda	6.5	130	1.3	310	30	290	3.3	2.0	Sandy Loam
13	Bhanpuri	7.4	195	0.7	255	16	245	4.4	2.6	Clay Loam
14	Birgaon	6.6	145	1.1	295	24	275	3.4	2.2	Silty Clay
15	Rawabhata	7.0	175	0.9	265	21	255	4.0	2.5	Loamy Sand

EC=Electrical Conductivity,OC=Organic Carbon,Av. N=Average Nitrogen,Av. P=Average phosphorous, Av. K = Average Potassium, Ex. Ca= Exchangeable Calcium,Ex. Mg= Exchangeablemagnesium,meq/100g=Milliequivalents per 100gms of soil,µS/cm=Micro Siemens per centimeter,kg/ha=Kilogram per hectare

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Conclusion

Chhattisgarh, a state in central India, has experienced rapid industrial growth in recent decades, particularly in and around its capital city, Raipur. This industrial expansion has brought economic benefits, but it has also raised concerns about the environmental impact of industrial activities, especially on soil quality.Fertility status of soils of Raipur district of industrial areas indicated that soils are low to medium in available N and available K and low in available P. Available Sulphur remained low in soils of some studied regions. Among the exchangeable bases, exchangeable calcium was found to be high in most soils, followed by magnesium. Results revealed that soil pH ranged from acidic to slightly alkaline, with EC levels generally indicating low to moderate salinity. Organic carbon varied widely across sites, influencing nutrient availability. The organic carbon content ranges from (00-1.50 kg/ha), low content suggests that the soil's fertility could be improved by incorporating organic particles such as compost or green manure, to enhance nutrient retention, microbial activity, and overall soil structure.The electrical conductivity values were within acceptable limits, suggesting the absence of severe salinity. Notably, Sejbahar, Siltara, and Mandhar showed higher nutrient content, whereas Urlaregion exhibited poor soil quality.

The findings highlight significant spatial variability in soil texture quality andPhysicochemical parameters**,**underlining the need for continuous monitoring and sustainable management practices to mitigate environmental risks in industrial regions. Soil texture analysis revealed a predominance of loamy soils, which are conducive to agriculture. Overall, the study highlights the variability in soil quality across different locations within Raipur districts and provides insights for sustainable land management practices.

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