Plant Archives Vol. 25, Supplement 2, 2025 pp. 2362-2373 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.supplement-2.299

ASSESSMENT OF SULPHUR, MICRONUTRIENTS AND POLLUTANT ELEMENTS IN SOILS OF PAKUR DISTRICT, JHARKHAND INDIA

A. V. Lakra[1], P. B. Saha[1], D. K. Shahi[1], C. S. Singh[2] and Manas Denre[3]*
[1]Department of Soil Science & Agricultural Chemistry, Birsa Agricultural University, Kanke, Ranchi-834006, Jharkhand, India
[2]Department of Agronomy, Birsa Agricultural University, Kanke, Ranchi-834006, Jharkhand, India
[3]Department of Soil Science & Agricultural Chemistry, Agriculture College Garhwa, Bishunpur, Garhwa-822114, Birsa Agricultural University, Ranchi, Jharkhand, India
*Corresponding author E-mail: dr.manas.denre.711315@gmail.com
(Date of Receiving : 13-04-2025; Date of Acceptance : 20-06-2025)

ABSTRACT

To know the fertility status in soils of Pakur district of Jharkhand, GPS based total two hundred forty-nine soil samples were collected randomly from farmer's fields. Soil of this district is predominantly acidic in nature with 87.98% soil samples established such as, while only 9.23% and 2.82% of the samples recorded in neutral and alkaline pH, respectively. Of the total soil samples analyzed, 24.89, 64.27 and 10.84 percent were observed respectively in high, medium and low categories organic carbon content. The results also indicated that deficiencies of available boron, sulphur, and zinc in soils samples respectively 85.54, 63.45, and 15.67 percent. In contrast, other micronutrients, including iron, manganese, copper and nickel, were found at adequate levels. However, the pollutant elements i.e., Pb, Co and Cd levels in the soils of Pakur district are within safe limits (<MPL) except Pb concentration of few samples were found to exceed the MPL. These findings underscore the urgent need for effective soil management strategies to address nutrient deficiencies and mitigate pollutant risks. Our results also evaluated that if the farmers want to do a profitable crop production should be needed an appropriate management for soil fertility maintain with the supply of adequate manures and balance fertilizers, and also side by side create awareness among the farmers to use these manures and fertilizers in judicious and scientific way, and where soil is strongly acidic condition there should be encouraged to the farmers for lime application for optimum yield potential.
Keywords : Soils, sulphur, micronutrients, pollutant elements, fertility status.

Introduction

Soil is an essential natural asset vital for maintaining the balance of agro-ecosystem and providing crucial benefits to humanity. It acts as a dynamic ecosystem, supporting diverse microorganisms vital for nutrient cycling and ecosystem balance. These microorganisms thrive within the soil, ensuring a steady supply of essential nutrients necessary for sustaining plant life. The fertility of the soil forms the bedrock of agriculture, upon which countless livelihoods depend. Prioritizing the health and vitality of the soil is significant to ensure the seamless functioning of soil processes and maximize agricultural productivity.

Soil fertility, a crucial aspect of the soil-plant relationship, relies heavily on the balance of macro and micronutrients present in the soil. The management practices applied to soil profoundly affects its physical, chemical and biological properties, thereby influencing plant growth and production outcomes. Continuous nutrient extraction by crops without adequate replenishment exacerbates nutrient stress in plants, diminishing their productivity over time. Soil fertility is predominantly influenced by factors such as vegetation type, climate, topography, soil texture, structure, depth, water holding capacity, colour, consistency, porosity, density and the rate of organic matter decomposition. To ensure optimal crop yields, it's imperative to maintain adequate nutrient levels. Higher plants require at least 17 essential mineral elements for growth and development, including macro and microelements.

Micronutrients play a dual role in enhancing crop productivity and sustaining human and animal health. Micronutrient concentrations tend to be highest near the soil surface and diminish with depth. Despite their prevalence in soils, only a fraction of micronutrients is easily accessible to plants. These trace elements, essential in small amounts, play a critical role in preventing significant crop yield losses. Micronutrient deficiencies are more common in regions with humid temperate and tropical climates due to increased leaching from heavy rainfall. Soil pH is a key factor affecting micronutrient availability to plants; generally, nutrient availability decreases with higher pH levels, except for molybdenum, which becomes more available as soil pH increases. Large-scale deforestation and chemical-intensive crop cultivation contribute to soil micronutrient depletion.

Growing high-yielding variants on poor-quality soil and prolonged use of phosphate and nitrogenous fertilizers further aggravate this issue. Intensive cropping accelerates nutrient depletion, which takes time to replenish. Soil moisture, temperature and fertilizer application also influence soil nutrient levels therefore, understanding the status of micronutrients and their correlation to soil characteristics helps us grasp the soil's innate ability to provide these nutrients to plants. Additionally, the pattern of land use plays a significant role in governing soil fertility and nutrient dynamics.

Considering the aforementioned facts, a research endeavor was commenced on topic entitled "*Assessment of Sulphur, Micronutrients and Pollutant elements in soils of Pakur District (Jharkhand)*". Jharkhand, located in northeastern India (21°58'02"–25°18'32" N and 83°19'05"–87°55'03" E), spans 79,714 sq. km, ranking as the 15th largest state. The state comprises 24 districts, each with unique features. Pakur district, renowned for its stone industry, lies in the eastern Rajmahal hills, bordered by Sahibganj, Dumka, Godda and West Bengal. Covering 1,805 sq. km, it has a population of 900,422 (Census 2011), 49% of whom are tribal. It includes one subdivision, Pakur and six blocks: Pakur, Maheshpur, Hiranpur, Amrapara, Littipara and Pakuria (Figure 1).

Pakur's agricultural economy relies on mono-cropping, limited irrigation and small landholdings. Its gross cropped area is 66,488 ha, with 52,721 ha net sown and 12,977 ha irrigated. Predominant soils include fertile Rajmahal basaltic soils, red, tal and alluvial types. The climate is humid to sub-humid, with annual rainfall of 1,399 mm, mainly from the South-West monsoon. Major rivers include Bansloi, Brahamani, and Pagla. Paddy and maize are the main crops, dependent on monsoon rainfall, with a cropping intensity of 126%. Challenges include land degradation, erosion, and soil acidification, reducing nutrient availability and crop productivity. Limited fertilizer use leads to single-crop farming. This study aims to reduce heavy metal toxicity risks, improve vegetable cultivation, and guide policies to mitigate health impacts. Soil testing and fertility mapping are crucial for tailored fertilizer recommendations, enhancing yields, and addressing nutrient deficiencies effectively. Soil testing provides essential data on nutrient levels, helping to recommend the right fertilizers for better crop yields. Fertility maps identify areas that need improvement, allowing farmers and planners to determine the appropriate fertilizers and anticipate future needs based on crop patterns.

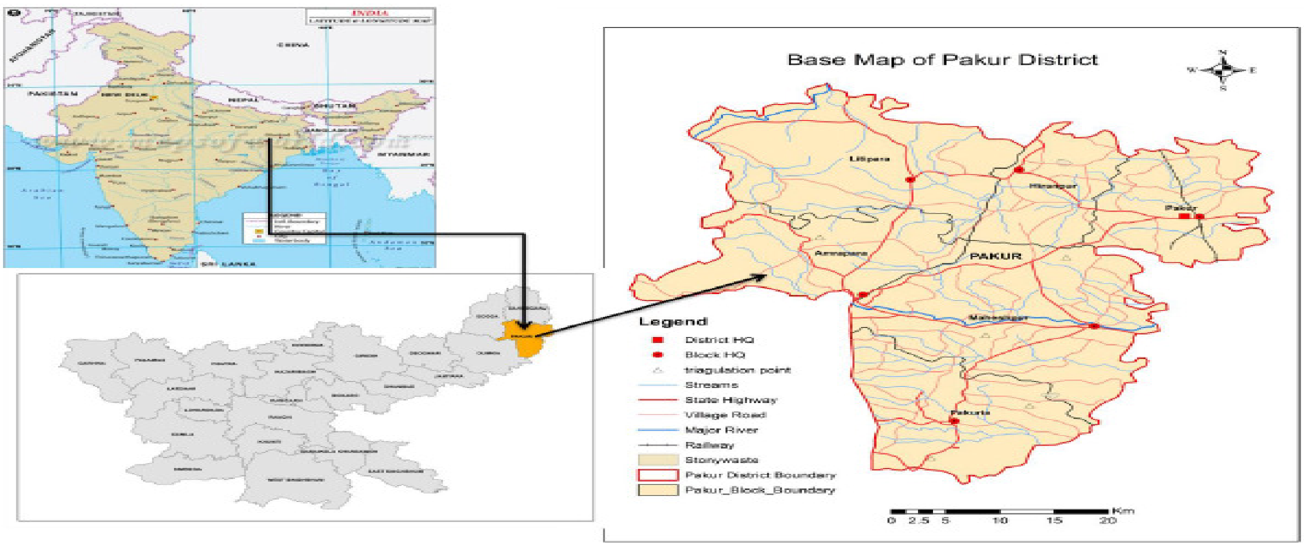

Fig. 1 : Location map of Pakur District

Materials and Methods

The Global Positioning System (GPS) based 249 surface (0.0-15.0 cm) soils were collected from six blocks (Pakur, Maheshpur, Pakuria, Hiranpur, Littipara and Amrapara) of Pakur district (Latitude (24°18´0.18´´ - 24°47´0.27´´ N) and longitude (87°35´0.27´´ - 87°53´0.27´´ E) with the variation of altitude from 10 to 121 m) during December 2023 to February 2024 under the delineation programme of "All India Coordinated Research Project on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants (ICAR)", Ranchi Centre (Table 1). Collected soil samples were air dried, ground in wooden pestle and mortar and passed through 0.5 and 2.0 mm sieve, stored in properly labeled cloth's bags for analysis. Processed soil samples were analyzed for pH, electrical conductivity (EC) by employing the method (1:2.5:: soil:water) as outline by Jackson (1973), organic carbon (potassium dichromate and sulfuric acid method) by Walkley and Black (1934). The DTPA extractable Zn, Cu, Fe, Mn, Pb, Ni, Co and Cd was extracted with di-ethelene tri-amine penta-acetic acid (DTPA) solution (Lindsay and Norvell, 1978). Hot water solution boron of soils was estimated as per method outlined by Gupta (1967) using Azomethine-H through UV-spectrophotometer at 420 nm. Sulphur was analyzed by employing the method (0.15 % $CaCl_2$ as the extractant) of Williams and Steinbergs (1959). Descriptive statistical and simple correlation coefficients were analyzed with the help of statistical software (Microsoft XL 2007).

Table 1: GPS data for collected soil samples from different blocks of Pakur district.

Sl. No.	Name of Block	No. of Soil samples	Latitude	Longitude	Altitude (m)
01.	Pakur	41	N24°38´0.05´´– 24°47´0.21´´	E87°48´0.11´´– E87°53´0.21´´	11–42
02.	Maheshpur	42	N24°29´0.08´´– 24°25´0.19´´	E87°40´0.18´´– E87°48´0.16´´	29–60
03.	Pakuria	42	N24°18´0.18´´– 24°19´0.26´´	E87°45´0.006´´– E87°39´0.025´´	37–64
04.	Hiranpur	41	N24°36´0.06´´– 24°45´0.26´´	E87°41´0.24´´– E87°44´0.05´´	10–112
05.	Littipara	42	N24°42´0.27´´–24°39´0.08´´	E 87°37´0.04´´– E87°41´0.12´´	28–89
06.	Amrapara	42	N24°37´0.24´´–24°33´0.50´´	E 87°35´0.27´´– E87°31´0.04´´	49–121
Overall		**249**	**N24°18´0.18´´–24°47´0.21´´**	**E 87°35´0.27´´– E87°53´0.21´´**	**10–121**

Results and Discussions

Cropping System

Field observations and discussions with farmers during the delineation program in Pakur district indicated that the primary cropping system was Rice–Fallow. Secondary cropping systems, such as Mustard, Wheat and Vegetables, were also prevalent. Additionally, the cultivation of rabi vegetables, including potato, tomato, chili, brinjal, cauliflower, broccoli, cabbage and green peas, was common and largely depended on the availability of irrigation water (Table 2).

Table 2 : Block wise predominant cropping systems (Primary and secondary) in Pakur district of Jharkhand.

Sl. No.	Name of Block	Primary Cropping system	Secondary Cropping systems
1	Pakur	Rice–fallow	Potato-Jute–Mustard
2	Maheshpur	Rice–fallow	Wheat-Vegetables–Lentil
3	Pakuria	Rice–fallow	Wheat-Mustard–Vegetables
4	Hiranpur	Rice–fallow	Wheat-Mustard-Lentil– Vegetables
5	Littipara	Rice–fallow	Mustard-Pigeonpea–Vegetables
6	Amrapara	Rice–fallow	Lentil–Vegetables

Variation in Ph, Electrical Conductivity and Organic Carbon in Soils

Table 3 highlights the variations in pH, EC and OC across different land types in Pakur district. The soil pH in Pakur ranged from 4.27 to 7.40, with a mean value of 5.87. Up land soils had a slightly lower pH (5.15) compared to medium land (5.90), low land (6.12) and bari land (6.53). These findings highlight the need for pH adjustments, particularly in upland areas, to enhance nutrient availability and crop productivity. Understanding pH dynamics aids in crop selection and implementing appropriate fertilization strategies to improve yields.

The electrical conductivity (EC) of soil samples varied between 0.01 and 0.35 dS m^{-1}, with an average of 0.07 dS m^{-1}, indicating low salinity across the district. Up land and low land soils both recorded an EC of 0.07 dS m^{-1}, reflecting limited water retention in up lands and runoff effects in low lands. Medium land soils had a slightly higher EC (0.08 dS m^{-1}) due to moderate water retention, while bari lands, often used for vegetable cultivation, showed the highest EC (0.09 dS m^{-1}), attributed to intensive fertilizer and organic input application. These consistently low EC levels confirm minimal salinity risks.

Organic carbon (OC) content ranged from 2.70 to 12.58 g kg^{-1}, with a mean of 6.87 g kg^{-1}. Up land soils exhibited the lowest mean OC (5.66 g kg^{-1}), likely due to erosion, rapid decomposition, and limited moisture availability. Medium land soils had slightly higher OC levels (6.91 g kg^{-1}) because of better moisture retention. Low land soils, benefiting from waterlogged conditions, demonstrated further improvement, while bari lands recorded the highest mean OC (7.73 g kg^{-1}), owing to frequent applications of organic inputs such as compost and kitchen waste.

Table 3: Variation of soil pH, EC and OC under different land situation in Pakur district, Jharkhand.

Land Situation	No. of samples	pH		EC (dS m^{-1})		OC (g kg^{-1})	
		Range	Mean	Range	Mean	Range	Mean
Up land	26	4.27-6.40	5.15	0.02-0.16	0.06	2.70-7.25	5.66
Medium land	187	5.34-6.75	5.90	0.01-0.35	0.08	4.58-8.70	6.91
Low land	22	5.60-6.94	6.12	0.03-0.12	0.07	5.62-10.20	7.42
Bari land	14	5.78-7.40	6.53	0.04-0.22	0.09	6.49-12.58	7.73
Overall	**249**	**4.27-7.40**	**5.87**	**0.01-0.35**	**0.07**	**2.70- 12.58**	**6.87**

The strongly acidic soils in Pakur are due to excessive leaching of basic cations caused by heavy rainfall on undulating cultivated lands. The district soils fall under the low EC category, as sandy and gravelly soils, prevalent here, exhibit lower conductivity compared to clay-rich soils. Organic carbon levels vary across land types: fertile medium land, bari land and low lands benefit from higher organic inputs and vegetation, whereas up lands experience OC loss due to erosion and intensive farming. These factors explain the variations in pH, EC and OC across land types, aligning with findings by Saha *et al.* (2024) in Deoghar and Kumar *et al.* (2019) in Chatra and Giridih. The results also support Minz (2022), who reported strongly acidic to slightly alkaline soil pH (5.5-7.3) and medium to high organic matter levels (5.6-9.6 g kg^{-1}) in Pakur blocks.

Our results also clearly showed that the soil reaction in Pakur district is predominantly acidic, with 87.98% of samples classified as such, indicating significant challenges for crop growth since many plants prefer neutral to slightly acidic conditions. Only 9.23% of the samples showed neutral pH and a mere 2.82% were alkaline, highlighting the scarcity of favorable soil conditions for agriculture (Table 4). The predominance of acidic pH levels in Pakur district soils points to a need for targeted soil management practices. Acidic soils often lead to nutrient deficiencies, particularly of essential nutrients like calcium, magnesium and potassium, which can negatively impact crop yields. Farmers may need to consider practices such as liming to raise soil pH, improve nutrient availability and enhance overall soil health (Fig. 2).

Table 4 showed that details block-wise analysis of soil pH in Pakur district is showing significant variation, with Maheshpur block having all its soil sample falling within acidic range. To address this, immediate actions such as applying lime and organic amendments are needed. In contrast, Hiranpur and Amrapara have more favorable soils with neutral and slightly alkaline pH, offering opportunities to optimize cropping and fertilization strategies. A block-specific soil management approach is crucial for enhancing productivity and ensuring sustainable agriculture throughout the district (Fig. 3).

Table 4: Block wise variation in soil pH in Pakur district.

Denomination	pH	Pakur	Maheshpur	Pakuria	Hiranpur	Littipara	Amrapara	
Ultra acidic	3.5	-	-	-	-	-	-	**Acidic**
Extremely acidic	3.5–4.5	2.44	30.00	11.90	7.34	7.14	2.10	
Very strongly acidic	4.5–5.0	12.19	50.00	16.67	19.51	26.19	4.60	
Strongly acidic	5.0–5.5	31.70	15.00	11.91	26.82	16.66	22.10	
Moderately acidic	5.5–6.0	36.58	5.00	28.57	21.95	33.35	25.00	
Slightly acidic	6.0–6.5	12.19	-	26.19	17.07	11.90	32.50	

Neutral	6.5–7.3	4.87	-	4.76	7.31	4.76	4.60	**Neutral**
Slightly alkaline	7.3–7.8	-	-	-	-	-	9.10	**Alkaline**
Moderately alkaline	7.8-8.4	-	-	-	-	-	-	
Strongly alkaline	8.4-9.0	-	-	-	-	-	-	
Very strongly alkaline	9.0	-	-	-	-	-	-	

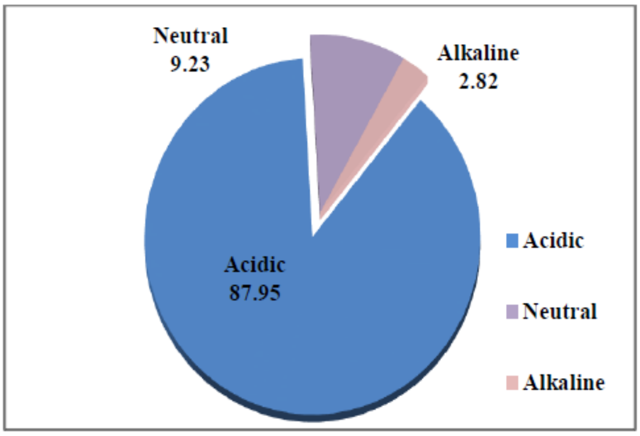

Fig. 2: Overall soil pH of Pakur district.

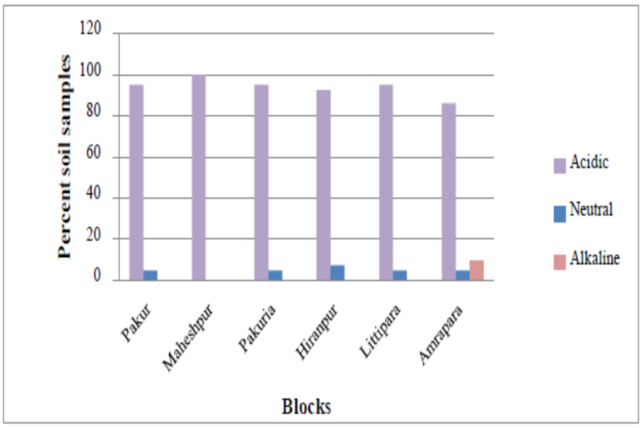

Fig. 3: Block wise variation of pH in Pakur district.

Table 5 provides an overview of organic carbon (OC) levels in the soils of Pakur district (Figure 4). Of the total soil samples analyzed, 24.89% showed high OC content, 64.27% had medium OC content and 10.84% had low OC content. Among all the blocks, Pakuria recorded the highest proportion of samples with high OC content (74.00%), followed by Hiranpur (61.87%), Maheshpur (47.50%), Pakur (24.39%), Littipara (21.40%) and Amrapara (18.62%). On the other hand, Amrapara accounted for the largest share of samples with medium OC content (69.76%), closely followed by Littipara (64.30%).

Table 5: Block wise variation in soil organic carbon in Pakur district.

Block	**No of samples**	**Organic C (g kg^{-1})**		**Low (<5.0)**	**Medium (5.0-7.5)**	**High (>7.5)**
		Range	**Mean**			
Pakur	41	4.58-10.24	6.78	12.20	63.41	24.39
Maheshpur	40	4.10-8.26	6.93	20.00	32.50	47.50
Pakuria	42	4.15-8.65	7.28	7.00	19.00	74.00
Hiranpur	41	4.25-8.37	6.77	9.65	28.48	61.87
Littipara	42	4.60-12.58	6.84	14.30	64.30	21.40
Amrapara	43	2.70-9.52	6.62	11.62	69.76	18.62
Overall	**249**	**2.70-12.58**	**6.87**	**10.84**	**64.27**	**24.89**

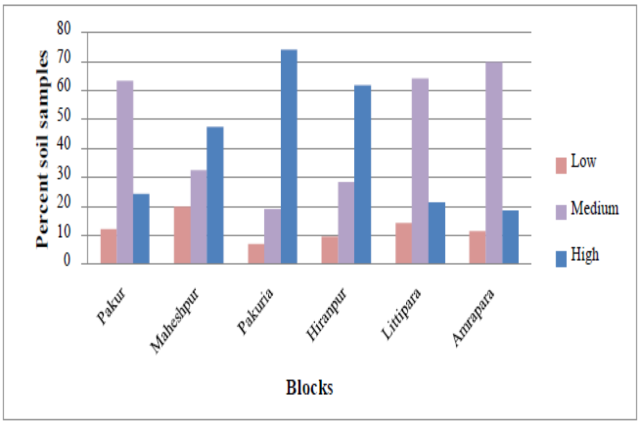

Fig. 4: Block wise status of soil organic carbon in Pakur district.

Variation of available B and S in soils of Pakur district

The availability of Boron (B) and Sulphur (S) across different land types (Up land, Medium land, Low land, and Bari land) based on 249 soil samples. Boron levels show slight variation: 0.30 mg kg^{-1} in upland, 0.37 mg kg^{-1} in medium land, 0.28 mg kg^{-1} in low land, and 0.42 mg kg^{-1} in bari land (Table 6). Sulphur content varies more significantly, with the highest in bari land (14.98 mg kg^{-1}), followed by medium land (13.22 mg kg^{-1}), low land (12.44 mg kg^{-1}), and the lowest in upland (9.01 mg kg^{-1}) (Table 6).

Table 6: Variation of B and S content in soil of different land situations in Pakur district.

Land Situation	No. of Samples	B (mg kg^{-1})		S (mg kg^{-1})	
		Range	Mean	Range	Mean
Up land	26	0.06-0.67	0.30	2.16-47.45	9.01
Medium land	187	0.13-0.94	0.37	2.43-55.16	13.22
Lowland	22	0.21-0.43	0.28	3.57-32.48	12.44
Bari land	14	0.33-0.76	0.42	5.30-58.95	14.98
Overall	**249**	**0.06-0.94**	**0.36**	**2.16-58.95**	**12.80**

The moderate levels of these micronutrients in upland soils are linked to leaching, intensive farming, and limited organic matter retention. In contrast, medium and bari lands have higher levels due to better organic matter content and moisture retention. In low land areas, prolonged flooding reduces boron solubility and converts sulphate into unavailable forms, highlighting the need for proper drainage. This study emphasizes the importance of land type, hydrology, and soil management in optimizing nutrient availability for soil fertility and crop health.

In contrast, block wise variation of available boron (B) content in the soils of Pakur district ranged from 0.06 to 0.94 mg kg^{-1}, with an average of 0.36 mg kg^{-1} (Table 7). Among the blocks, Pakuria and Littipara had the highest mean B content (0.39 mg kg^{-1}), while Maheshpur recorded the lowest (0.32 mg kg^{-1}). Given the critical limit of 0.5 mg kg^{-1} for boron in soils, approximately 85.54% of the soils in the district were found to be deficient in boron, with Amrapara and Maheshpur blocks exhibiting the highest deficiencies (Figure 5).

Table 7: Block wise variation of available B content in soils.

Block	No. of samples	B (mg kg^{-1})		Deficient (%)	Marginal (%)	Adequate (%)
		Range	Mean			
Pakur	41	0.21-0.94	0.38	82.94	12.19	4.87
Maheshpur	40	0.18-0.76	0.32	95.00	2.5	2.5
Pakuria	42	0.21-0.82	0.39	83.34	11.90	4.76
Hiranpur	41	0.20-0.64	0.35	90.24	9.76	---
Littipara	42	0.21-0.94	0.39	71.44	26.19	2.37
Amrapara	43	0.06-0.87	0.34	95.34	2.32	2.34
Overall	**249**	**0.06-0.94**	**0.36**	**85.54**	**12.04**	**2.42**

Rating: Deficient: <0.50 mg kg^{-1}; Marginal: (0.50-0.75) mg kg^{-1}; Adequate: >0.75 mg kg^{-1}

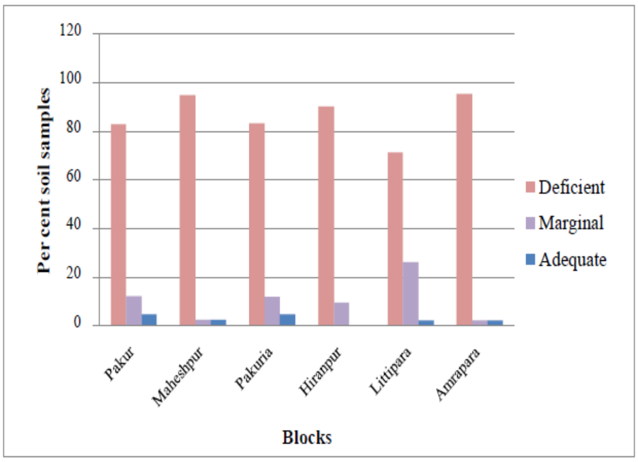

Fig. 5: Block wise status of Available B-content in soil.

These findings align with Kumar *et al.* (2018), who reported 66.93% boron deficiency in Khunti district, and Kumar *et al.* (2019), who found 94.03% deficiency in Chatra district. Agarwal *et al.* (2013) also noted that 63.3% of soils in Jharkhand were deficient in boron, with levels ranging from 0.01 to 4.2 mg kg^{-1}. Boron deficiency is often caused by factors such as leaching in coarse-textured soils, high precipitation, and sorption by iron and aluminum oxides in acidic soils.In comparison, Saha *et al.* (2024) observed a wider range of boron content in Deoghar district, from 0.01 to 6.35 mg kg^{-1}, with an average of 0.88 mg kg^{-1}.

While sulphur availability in Pakur district soils varied widely, ranging from 2.16 to 58.95 mg kg^{-1}, with an average of 12.80 mg kg^{-1} (Table 8). The lowest mean S content was found in Hiranpur block, while the highest was in Pakur block. Based on categorization, 63.45% of samples were classified as low (<10 mg kg^{-1}), 16.07% as medium (10-20 mg kg^{-1}), and 20.48% as high (>20 mg kg^{-1}) (Figure 6).

Kumar *et al.* (2019) reported widespread sulphur deficiencies in Chatra and Giridih districts, with 99.72% of Chatra samples and all samples in Giridih showing deficiencies. Similarly, Saha *et al.* (2024) observed significant variation in sulphur content in Deoghar district, ranging from 0.66 to 62.83 mg kg^{-1}, with an average of 13.44 mg kg^{-1}, further emphasizing the variability in sulphur availability across Jharkhand.

Table 8: Block wise variation of available S content in soils.

Block	No. of samples	S (mg kg^{-1})		Deficient (%)	Marginal (%)	Adequate (%)
		Range	Mean			
Pakur	41	2.45-55.61	21.62	41.46	9.76	48.78
Maheshpur	40	2.16-42.74	8.92	77.50	12.50	10.00
Pakuria	42	2.43-58.95	12.48	71.42	11.90	16.68
Hiranpur	41	2.43-36.50	6.14	90.24	7.31	2.45
Littipara	42	2.61-48.70	9.49	71.42	21.44	7.14
Amrapara	43	3.57-43.65	19.38	30.23	32.56	37.21
Overall	**249**	**2.16-58.95**	**12.80**	**63.45**	**16.07**	**20.48**

Rating: Deficient: <10 mg kg^{-1}; Marginal: (10–20) mg kg^{-1}; Adequate: >20 mg kg^{-1}

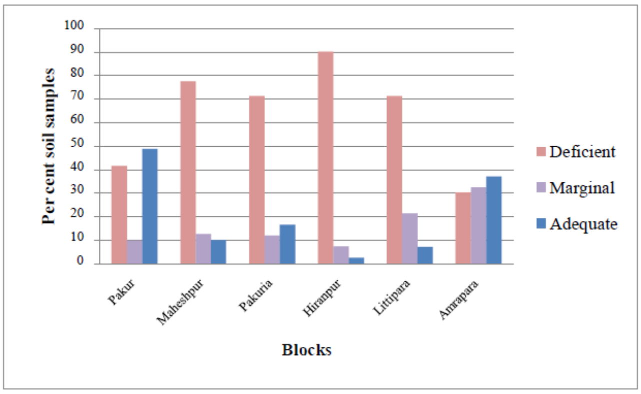

Fig. 6: Block wise status of Available S content in soil.

Variation of Zn, Fe, Mn, Cu and Ni content in soils of Pakur district

Table 9 and 10 showed the variability of micronutrient levels (Zn, Fe, Mn, Cu and Ni) across different land types in Pakur district. Zinc (Zn) concentrations were highest in bari land (1.50 mg kg^{-1}) and lowest in lowland soils (0.87 mg kg^{-1}), with upland and medium land showing intermediate levels. This suggests that better drainage and organic matter content in higher lands support zinc availability, while lowland soils may experience nutrient leaching and flooding, reducing zinc levels.

Iron (Fe) levels were generally consistent across land types, but medium land exhibited a wide range (21.25–225.00 mg kg^{-1}), indicating variability in iron availability, likely influenced by soil conditions such as organic matter content and acidity.

Manganese (Mn) concentrations were highest in upland soils (121.64 mg kg^{-1}) and lowest in lowland soils (107.52 mg kg^{-1}), reflecting the impact of drainage and aeration on manganese availability.

Copper (Cu) was most abundant in medium land (7.63 mg kg^{-1}) and least in bari land (5.79 mg kg^{-1}), likely due to differences in soil texture and moisture retention.

Nickel (Ni) was highest in bari land (1.98 mg kg^{-1}), followed by medium land (1.56 mg kg^{-1}), indicating that mineral composition and organic content influence nickel levels.

These findings emphasize the role of soil properties, such as drainage, texture, and organic matter, in determining micronutrient availability and highlight the importance of land-specific soil management to optimize nutrient levels for sustainable agriculture.

Table 9: Variation of Zn and Fe content in soil under different land situations in Pakur district, Jharkhand.

Land Situation	No. of samples	Zn (mg kg^{-1})		Fe (mg kg^{-1})	
		Range	Mean	Range	Mean
Up land	26	0.26- 3.16	1.33	11.50- 282.00	103.04
Medium land	187	0.32-7.42	1.24	21.25- 225.00	104.23
Low land	22	0.47-2.24	0.87	34.50-176.21	98.25
Bari land	14	0.62-3.82	1.50	31.50- 184.75	99.12
Overall	**249**	**0.26-7.42**	**1.22**	**11.50- 282.00**	**103.28**

Table 10: Variation of Mn, Cu and Ni content in soil under different land situations in Pakur district, Jharkhand.

Land Situation	No. of samples	Mn ($mg\ kg^{-1}$)		Cu ($mg\ kg^{-1}$)		Ni ($mg\ kg^{-1}$)	
		Range	Mean	Range	Mean	Range	Mean
Up land	26	33.25- 319.00	121.64	3.00- 12.38	7.51	0.31- 3.34	1.42
Medium land	187	35.75- 245.25	109.89	2.28- 11.94	7.63	0.26- 3.78	1.56
Low land	22	38.14-221.05	107.52	1.42-11.31	6.11	0.56-2.58	1.42
Bari land	14	42.00- 216.53	110.02	2.46- 9.22	5.79	0.42- 3.41	1.98
Overall	**249**	**33.25- 319.00**	**108.46**	**1.42- 12.38**	**7.47**	**0.26- 3.78**	**1.55**

In contrast, block wise variation of available zinc (Zn) content in the soils of Pakur district showed significant variation, ranging from 0.26 to 7.42 mg kg-1, with an average of 1.22 mg kg^{-1} (Table 11). Pakur block recorded the highest mean Zn content at 1.63 mg kg^{-1}, while Pakuria block had the lowest at 1.00 mg kg^{-1}. Based on the critical threshold of 0.6 mg kg^{-1} for Zn, 15.67% of soil samples were found deficient, 43.37% were marginal, and 40.96% were adequate (Figure 7). The most severe deficiency was observed in Hiranpur and Pakuria blocks. This deficiency is attributed to factors such as the continuous cultivation of high-yielding rice varieties, imbalanced nutrient management, and insufficient use of zinc-containing fertilizers, particularly in lowland areas. These findings are consistent with Tiu *et al.* (2018), who reported a 47% Zn deficiency in Sahibganj district, and Saha *et al.* (2024), who observed a 35% deficiency in Deoghar district, with Zn content ranging from 0.04 to 12.62 mg kg^{-1} and an average of 1.35 mg kg^{-1}.

The available iron (Fe) content in the soils of Pakur district (Table 11) ranged from 11.50 to 282.00 mg kg^{-1}, with a mean of 103.28 mg kg^{-1}. The lowest mean Fe content was observed in Hiranpur block (82.51 mg kg^{-1}), while the highest was in Maheshpur block (150.62 mg kg^{-1}). All soil samples were well above the critical limit of 4.5 mg kg^{-1}, indicating sufficient Fe availability across the district (Figure 8). These findings are consistent with Kumar *et al.* (2018), who reported adequate Fe levels in Khunti district, and Saha *et al.* (2024), who found Fe content ranging from 4.27 to 743.66 mg kg^{-1}, with an average of 72.54 mg kg^{-1} in Deoghar district, where 99.44% of soil samples met the critical Fe threshold.

Table 11: Block wise variation of available Zn and Fe content in soils.

Block	No. of samples	Zn ($mg\ kg^{-1}$)		Fe ($mg\ kg^{-1}$)	
		Range	Mean	Range	Mean
Pakur	41	0.32- 7.42	1.63	49.50-222.00	104.29
Maheshpur	40	0.32- 3.16	1.39	21.25-225.01	150.62
Pakuria	42	0.48- 2.62	1.00	22.25-179.50	92.20
Hiranpur	41	0.26- 3.82	1.22	11.50-216.00	82.51
Littipara	42	0.34- 4.48	1.08	29.50-184.25	91.60
Amrapara	43	0.32- 1.64	1.06	51.00-282.00	103.90
Overall	**249**	**0.26- 7.42**	**1.22**	**11.50-282.00**	**103.28**

Table 12: Block wise variation of available Mn, Cu and Ni content in soils.

Block	No. of samples	Mn ($mg\ kg^{-1}$)		Cu ($mg\ kg^{-1}$)		Ni ($mg\ kg^{-1}$)	
		Range	Mean	Range	Mean	Range	Mean
Pakur	41	35.75-222.15	108.99	1.92-10.82	5.86	0.34-1.74	1.02
Maheshpur	40	64.00-319.00	134.43	2.76-10.12	6.68	0.86-3.34	1.56
Pakuria	42	35.73-214.51	94.81	2.28-11.92	8.43	0.60-3.34	1.87
Hiranpur	41	54.00-296.23	119.53	2.28-11.22	6.68	1.04-3.22	1.93
Littipara	42	37.00-183.50	103.10	2.46-12.00	7.75	0.32-3.78	2.32
Amrapara	43	33.25-245.26	101.36	1.42-12.38	8.76	0.26-2.68	0.70
Overall	**249**	**33.25-319.00**	**108.46**	**1.42-12.38**	**7.47**	**0.26-3.78**	**1.55**

The available manganese (Mn) content in Pakur district soils (Table 12) ranged from 33.25 to 319.00 mg kg^{-1}, with an overall mean of 108.46 mg kg^{-1}. All blocks in the district had Mn levels above the critical threshold of 2.0 mg kg^{-1}, indicating sufficient Mn availability (Figure 9). While, earlier Mishra *et al.* (2006) and Bhuyan *et al.* (2014) also reported almost similar trend of Mn availability in acidic soil of Jharkhand, Odisha and Assam, respectively.

The soil analysis presented in Tables 12 highlights the available copper (Cu) and nickel (Ni) levels in Pakur district. Cu levels ranged from 1.42 to 12.38 mg kg^{-1}, with a mean of 7.47 mg kg^{-1}, showing the highest concentration in Amrapara block (8.76 mg kg^{-1}) and the lowest in Pakur block (5.86 mg kg^{-1}). Ni levels ranged from 0.26 to 3.78 mg kg^{-1}, with an average of 1.55 mg kg^{-1}. All samples were found to be above the critical limit of 0.2 mg kg^{-1} for both Cu and Ni, indicating sufficient levels across the district (Figure 10 & 11). These results align with findings from Kumar *et al.* (2018) in Khunti, where only 10% of samples were Cu deficient, and Saha *et al.* (2024) in Deoghar, where 85% of samples had sufficient Cu. Similar trends of nutrient sufficiency have been reported in other Jharkhand districts, including Sahibganj, Ranchi, and Dumka.

The elevated copper levels in Pakur district are likely influenced by anthropogenic activities, particularly mining. The district is known for its coal and stone mining industries, which can contribute to the release of heavy metals, including copper, into the environment. Additionally, the use of copper-based chemicals in agriculture may also play a role in the increased copper concentrations in the soil. On the other hand, the presence of adequate nickel levels in Pakur district soils can primarily be attributed to geogenic factors. Nickel is naturally found in the Earth's crust, and the district's geological composition, including mineral deposits such as coal, likely contributes to its presence in the soil. The weathering of rocks and soil parent material in the region may release nickel, ensuring its adequate concentration.

The favorable Cu and Ni levels in Pakur district suggest healthy soil conditions for plant growth, reducing the risk of micronutrient-related issues. However, proper soil management is essential to maintain these nutrient levels over time.

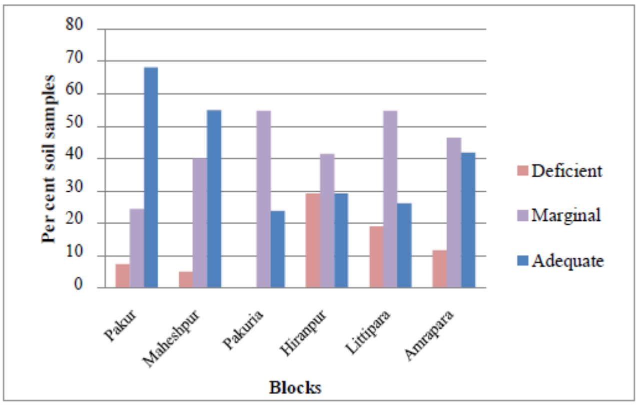

Fig. 7: Block wise status of available Zn content in soil.

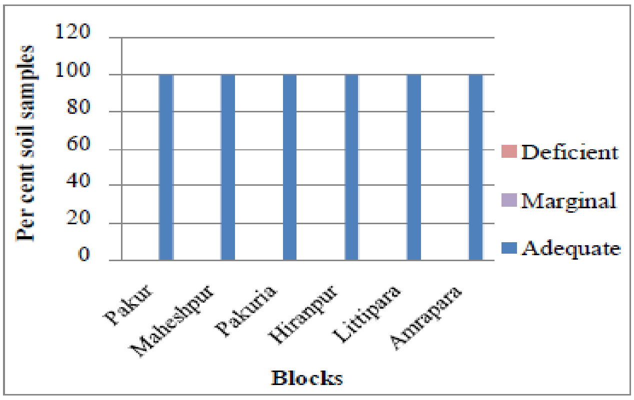

Fig. 8: Block wise status of available Fe content in soil.

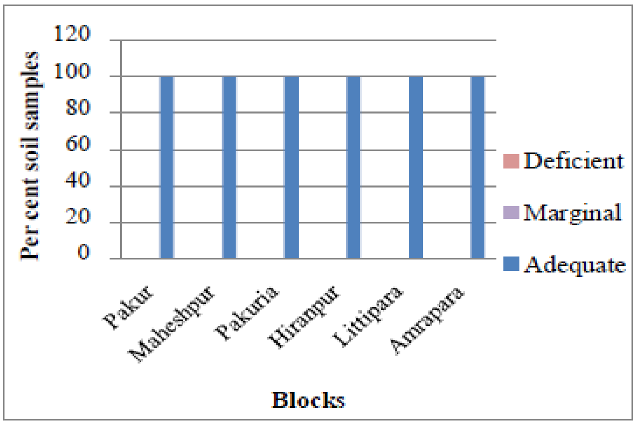

Fig. 9: Block wise status of available Mn content in soil.

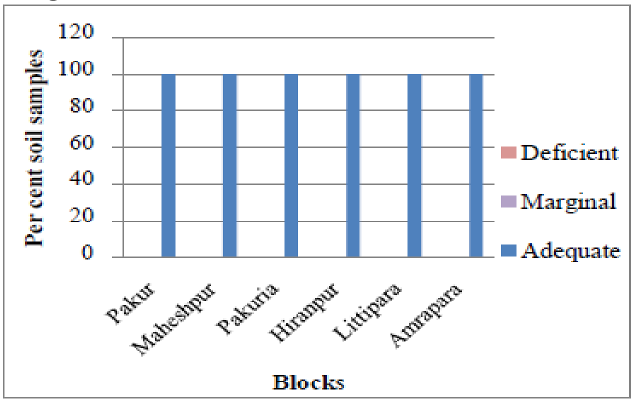

Fig. 10: Block wise status of available Cu content in soil.

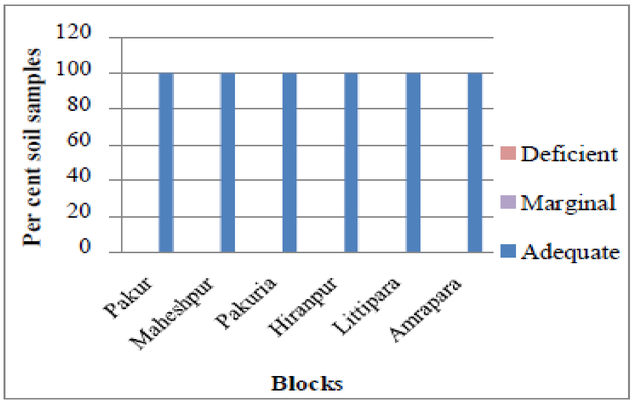

Fig. 11: Block wise status of available Ni content in soil.

Variation of Pb, Co and Cd content in soils

Table 13 showed that while the mean Pb content (10.33 mg kg^{-1}) is within the safe limit of 20.00 mg kg-1 (Kabata-Pendias, 2011), elevated levels in some Medium and Low land soils raise concerns about crop toxicity and bioaccumulation, requiring targeted interventions. Cobalt (Co) levels, with a mean of 1.41 mg kg^{-1}, and cadmium (Cd) levels, averaging 0.71 mg kg^{-1}, are generally within safe limits. However, areas with elevated Cd levels need continuous monitoring and remediation to prevent risks to crops and human health.

Table 13: Variation of Pb, Co and Cd content in soil as per land situations in Pakur district.

Land Situation	No. of Samples	Pb (mg kg^{-1})		Co (mg kg^{-1})		Cd (mg kg^{-1})	
		Range	Mean	Range	Mean	Range	Mean
Up land	26	2.32-21.83	9.32	0.12-3.36	1.55	0.06-3.20	0.80
Medium land	187	1.82-59.88	10.23	0.10-4.00	1.43	0.08-1.58	0.75
Low land	22	2.10-67.24	11.84	0.32-3.16	1.22	0.10-1.52	0.80
Bari land	14	6.26-31.48	10.75	0.26-3.24	1.24	0.12-1.48	0.87
Overall	**249**	**1.82-67.24**	**10.21**	**0.10-4.00**	**1.41**	**0.06-3.20**	**0.71**

While, block wise variation of DTPA-extractable cobalt (Co) and cadmium (Cd) levels in the soils of Pakur district are within safe limits, as the Co levels are below the maximum permissible limit (MPL) of 10.00 mg kg^{-1}, and the Cd levels are below the MPL of 5.00 mg kg^{-1} (Tables 14 and 15). However, lead (Pb) concentrations were found to exceed the MPL of 20.00 mg kg^{-1} in 3.22% of the soil samples (Figure 12, 13 and 14).

Table 14: Block wise variation of available Pb, Co and Cd content in soils.

Block	No. of samples	Pb (mg kg^{-1})		Co (mg kg^{-1})		Cd (mg kg^{-1})	
		Range	Mean	Range	Mean	Range	Mean
Pakur	41	2.10-11.42	9.31	1.02-2.80	1.62	1.22-1.44	1.33
Maheshpur	40	7.46-11.36	9.33	1.02-3.54	1.87	1.40-1.54	1.47
Pakuria	42	5.56- 12.04	9.57	0.16-2.80	1.20	0.08-1.58	1.02
Hiranpur	41	1.82- 10.74	7.98	0.10-0.80	0.31	0.06-0.22	0.13
Littipara	42	6.78- 31.48	10.15	0.22-2.72	0.75	0.10-0.50	0.37
Amrapara	43	5.06- 67.24	15.38	1.40-4.00	2.75	0.08-3.20	0.36
Overall	**249**	**1.82- 67.24**	**10.33**	**0.10-4.00**	**1.41**	**0.06-3.20**	**0.71**

Table 15: Block wise status of pollutant elements in soils.

Block	No. of samples	Pb		Co		Cd	
		Under safe limit* (%)	Above safe limit (%)	Under safe limit* (%)	Above safe limit (%)	Under safe limit* (%)	Above safe limit (%)
Pakur	41	100.0	-	100.0	-	100.0	-
Maheshpur	40	100.0	-	100.0	-	100.0	-
Pakuria	42	100.0	-	100.0	-	100.0	-
Hiranpur	41	100.0	-	100.0	-	100.0	-
Littipara	42	94.20	5.80	100.0	-	100.0	-
Amrapara	43	83.70	16.30	100.0	-	100.0	-
Overall	**249**	**96.78**	**3.22**	**100.0**		**100.0**	**-**
Safe limit		≤20.00 mg kg^{-1}		≤20.00 mg kg^{-1}		≤5.00 mg kg^{-1}	

Source: Kabata Pendias, 2011

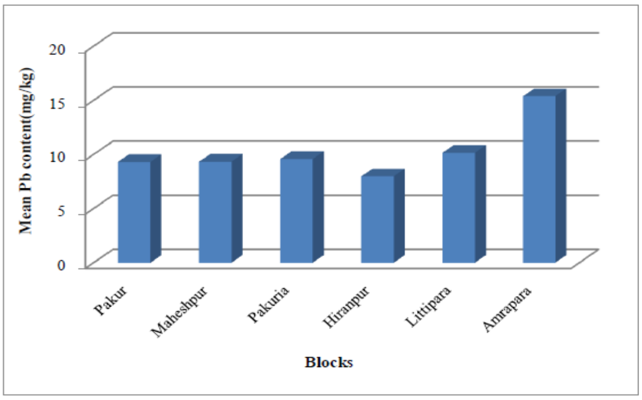

Fig. 12: Block wise status of Pb in soil.

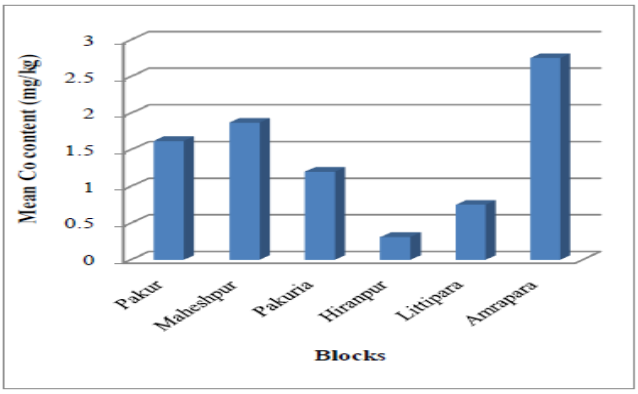

Fig. 13: Block wise status of Co in soil.

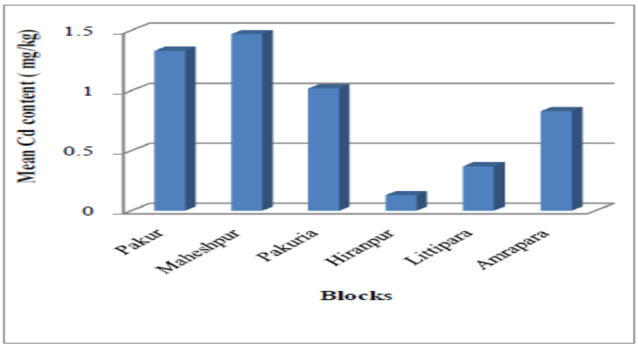

Fig. 14: Block wise status of Cd in soil.

The levels of heavy metals reported by Saha *et al.* (2024) indicate that lead (Pb) ranged from 0.22 to 25.10 mg kg^{-1}, cobalt (Co) ranged from 0.00 to 3.54 mg kg^{-1} and cadmium (Cd) ranged from 0.00 to 3.43 mg kg^{-1}. The mean values for these metals were 5.03 mg kg^{-1} for Pb, 1.42 mg kg^{-1} for Co and 1.64 mg kg^{-1} for Cd. When compared to the established safe limits 20 mg kg^{-1} for Pb, 20 mg kg^{-1} for Co, and 5 mg kg^{-1} for Cd all measured levels were below these thresholds. This indicates that there is no risk to agricultural land or sustainable crop production in the region. The findings of Saha *et al.* (2024) confirm that heavy metal concentrations in the soils of Deoghar district are within safe limits, affirming the land's suitability for cultivation. Similarly, my research aligns with the conclusions of *Saha et al.* (2024), Kumar *et al.* (2018) and Tiu and Kumar (2018), further validating the safety of the soil for agricultural use.

Lead (Pb) accumulation in Pakur soils is primarily due to industrial activities like coal and stone mining, along with lead-based products and vehicular emissions. Cobalt (Co) levels are elevated due to natural geological factors and mining activities, which release Co into the environment. Cadmium (Cd) accumulation is driven by metal mining, smelting, and the use of phosphate fertilizers containing cadmium, as well as industrial effluents and waste disposal. These factors contribute to the accumulation of heavy metals, posing potential risks to soil health and agriculture in the region. Sustainable management practices are essential to mitigate the impact of these contaminants.

Conclusion

Soil fertility is the main factors for quantitative and qualitative food productions. Therefore for knowing the status of soil health, we analyzed the several physiochemical parameters in soils of Pakur district, Jharkhand. Analyzed soil samples of this district revealed that 87.98% soil acidic in nature and 24.89 % soil low content of organic carbon with high deficiency of available boron (85.54%) and sulphur (63.45%), and light deficiency (15.67%) of zinc. In contrast, other essential nutrients, including iron, manganese, copper and nickel, were found at adequate levels. On the other hand, the pollutant elements i.e., Pb, Co and Cd levels in the soils were within safe limits (<MPL) except Pb concentration in few samples (3.22%) were found to exceed the MPL. Apart from these findings it is evaluated that if the farmers want to do a profitable crop production should be needed an appropriate management for soil fertility maintain with the supply of adequate manures and balance fertilizers, and also side by side create awareness among the farmers to use these manures and fertilizers in judicious and scientific way, and where soil is strongly acidic condition there should be encouraged to the farmers for lime application for optimum yield potential.

Conflict of Interests

The authors have declared that no conflict of interests exists.

Acknowledgements

We are grateful to the Indian Council of Agricultural Research, New Delhi for providing necessary financial assistance to this research programme. The first author is a M. Sc. (Agriculture) student; this research work is done under the supervision of the second author who was Chairman of first author and Project In-charge of All India Coordinated Research Project on Micro and Secondary Nutrients & Pollutant Elements in Soils and Plants, at Ranchi Centre. Third, fourth and fifth authors of this research paper also help in research works and preparation of manuscript.

References

Agarwal, B. K., Sahoo, A. K., Kumar, A., Shahi, D. K., Kumar, R. and Karmakar, S. (2013). Macro and Micronutrients Status Including Soil Acidity in Western Plateau Zone of Jharkhand. *Journal of Research (BAU)*, **25**, 16-23.

Bhuyan, N., Barua, N. G., Borah, D. K., Bhattacharyya, D. and Basumatari, A. (2014). Georeferenced Micronutrient Status in Soils of Lakhimpur District of Assam. *Journal of the Indian Society of Soil Science*, **62**, 102-107.

Gupta, U. C. (1967). A simplified method for the determination of hot water soluble B from podzol soils. *Soil Science*, **103**, 424-427.

Jackson, M. L. (1973). Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi.

Kabata-Pendias, A. (2011). Trace elements in soils and plants, 4th ed. Taylor & Francis Group, Boca Raton London New York.

Kumar, A., Denre, M. and Prasad, R. (2018). Assessing the Status of Available Micro, Secondary and Pollutant Elements in Soil of Khunti District, Jharkhand, India. *International Journal of Ecology and Environmental Sciences*, **44(1)**, 59-66.

Kumar, A., Kachhap, S. and Prasad, R. (2019). Micro and Secondary Nutrients and Pollutant Elements Research in Jharkhand. Ranchi Centre Annual Report 2018-2019, AICRP on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants, BAU, Ranchi, pp. 1-48.

Kumar, J. P., Agarwal, B. K., Kumar, A., Shahi, D. K. and Denre, M. (2018). Assessing the Status of Available Micro, Secondary and Pollutant Elements in soil of Dumka District, Jharkhand, India. *International Journal of* Current *Microbiology and Applied Sciences*, **Special Issue-7**, 561-568.

Lindsay, W. L. and Norwell, W. A. (1978). Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America Journal*, **42**, 421-428.

Minj, A. A. (2022). Soil and Rainfall characterization for suitable crop planning of Pakur District. Diss. Birsa Agricultural University, Ranchi, 2022.

Mishra, G. N., Rout, R. K., and Sahu, S. K. (2006). Nutrient status of soil of Orissa. In: Mishra GN, ed. Nutrient Management of crops in Soil of Orissa. Orissa: G. N. Mishra, p. 19-44.

Saha, P. B., Shahi, D. K., Kumar, J. P. and Denre, M. (2024). Fertility status in geo-referenced soils of Deoghar District, Jharkhand. *International Journal of Advanced Biochemistry Research*, **8(5)**, 209-218.

Tiu, S. P. and Kumar, A. (2018). Assessment of Trace Elements in Soil and Plant Samples Under Intensive Cropped Area of Sahibganj Block (Jharkhand), M. Sc. (Ag.) Thesis, B. A. U. Kanke (Jharkhand), p. 72-74.

Tiu, S. P., Kumar, A. & Denre, M. (2018). Evaluation of Soil Fertility Status in Various Land Situations in Sahibganj. *Multilogic in Science*, Vol. **VIII**, Issue Special(E), 111-114.

Walkley, A. J. & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science*, **37**, 29-38.

Williams, C. H. & Steinbergs, A. (1959). Soil sulphur fractions as chemical indices of available sulphur in some Australian soils. *Australian Journal of Agricultural Research*, **10**, 340- 352.