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Assessment of heavy metals and Physico-chemical properties of soil near the mining areas of Mayurbhanj district, Odisha

Satya Ranjan Mohanta, Arun Alfred David, Narendra Swaroop, Tarence Thomas and Amreen Hasan

Abstract
The twenty seven soil samples were collected from nine different villages on October 2020 in three different blocks of Mayurbhanj district. The collected soil samples were analyzed for their physico-chemical parameters and presence of heavy metals by using standard laboratory techniques. The result showed that the soils of Bahalda, Kusumi and Rairangpur blocks are from sandy loam to clay loam in soil texture, strongly acidic to moderately acidic in soil reaction, in dry conditions the soil reflected reddish brown to brownish yellow colour and in wet condition, reflected dark reddish brown to brownish yellow colour, medium to high Soil organic carbon content, low to medium in nitrogen content, very low to low in phosphorus content, low to medium in potassium content, moderate amount of Ca, low amount of Mg, deficient in sulphur and in heavy metals; Zn content are deficient where Fe, Cu and Mn are in sufficient range. Because of the mining areas, soil contain higher amount of iron oxides which is dangerous for crop production. The deficient nutrient can be replenished to avoid the crop suffering from the deficiency and optimum utilization of nutrients. Integrated nutrient management can be adopted for sustainable soil fertility management as well as to achieve higher crop production.

Keywords: Physico-chemical parameters, heavy metals, agro climatic zones, mining, Mayurbhanj

Introduction
The word soil represents one of the most active and complex natural systems on the earth's surface. It is essential for the existence of many forms of life and provides medium for plant's growth and also supplies the organisms with most of their nutritional requirements. Soil is a dynamic, natural body that occurs on the earth's surface which supports the growth of plants (Zaware, 2014) [21].

Odisha, situated in the north-eastern part of the Indian peninsula, covers an area of 1,55,707 sq km. It lies between 17° 49' 25" to 22° 32' 23" North latitude; and 81° 22' 17" to 87° 29' 05" East longitudes. Odisha's rich mineral reserves constitute 28% Iron ore, 24% Coal, 59% Bauxite and 98% Chromite of India's total deposits. Mayurbhanj district comes under North Central Plateau Agro Climatic zone of Odisha. Climate of Mayurbhanj district is hot & moist sub-humid and the mean annual rainfall is 1534 mm with 36.6° C and 11.1° C mean maximum summer temperature and mean minimum winter temperature respectively. The main soil groups found in this district are Lateritic, Red and Yellow, Mixed Red and Black.

Mining is the extraction of valuable minerals or other geological materials from the Earth, usually from an ore body, lode, vein, seam, reef or placer deposit. Mining in a wider sense includes extraction of any non-renewable resource such as petroleum, natural gas, or even water. Mining causes negative environmental effects such as degradation of water quality, loss of forest and wildlife, landscape deterioration, spreading of spoils creating wasteland, noise pollution and degradation of agricultural lands.

Physical properties play an important role in determining land suitability for agricultural, environmental and engineering uses. Physical properties also influence the chemical and biological properties.

Chemical attributes of soil health are correlated with the capacity to provide nutrients for plants and/or retaining chemical elements or compounds harmful to the environment and plant growth.

Materials and Methods

Study site: The Mayurbhanj district is the largest among the thirty districts of Odisha and Baripada is the District head quarter, spreading over an area of 10,418 sq.km lies between latitudes 21° 17' North and 22° 34' North and longitudes 85°40' East and 87°10' East. The entire study area was divided into three regions. Three different villages from the district were taken under study, *viz.*, Bahalda (Block I), Kusumi (Block II) and Rairangpur (Block III) with three different sites taken from each village.

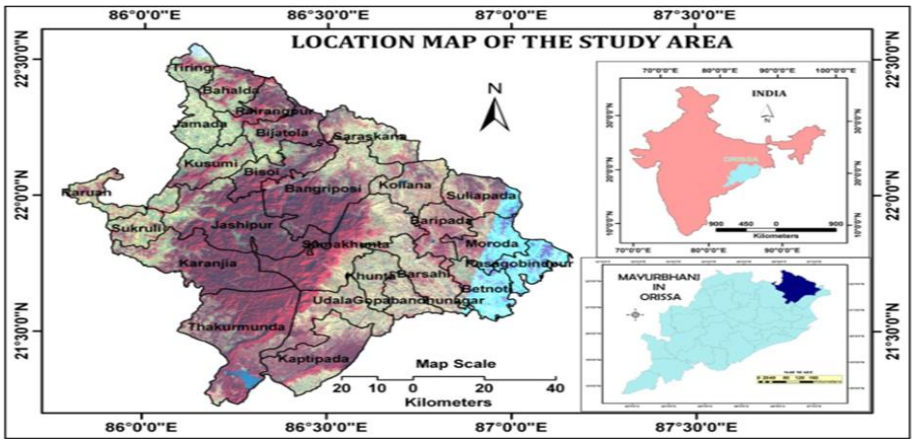

Fig 1: Location map of Mayurbhanj**,** Odisha

Analysis of Physico-Chemical and Heavy Metals Parameters

Total twenty seven soil samples were collected at different depths of 0-15, 15-30 and 30-45 cm, from three different blocks and three villages from each block of Mayurbhanj district, Odisha. With the help of spade/garden hoe and khurpi soils were collected from crop fields by following v-shaped method. Samples were dried in shade and large clods were broken using wooden mallet. Using 2 mm sieve the powdered soils were sieved and were collected in a polythene bag and was labeled properly for laboratory analysis.

The collected samples were analysed for physical-chemical and heavy metals parameters. Soils were analyzed for its textural class by Bouyoucos hydrometer method (Bouyoucos, 1927) [1], soil colour by using Munsell soil colour chart (Albert H. Munsell, 1954) [13], bulk density and particle density was determined by graduated measuring cylinder method (Muthuvel *et al.*,1992) [14], pH was determined by pH meter by making 1:2 soil water suspension (Jackson, 1958) [7], where as EC was measured by digital EC meter (Wilcox, 1950) [20], organic carbon was determined by wet-oxidation method (Walkley,1947) [19], available nitrogen was determined by alkaline potassium permanganate method by 800ml kjeldhal flask (Subbiah and Asija, 1956) [17], available phosphorous was determined by colorimetric method by using spectrophotometer (Olson *et al.*, 1954) [15], available potassium was determined by flame photometer using neutral ammonium acetate solution (Toth and Prince, 1949) [18], exchangeable calcium and magnesium were estimated by versanate titration method (Gupta, 1999) [6], available sulphur was determined by using spectrophotometer (Chesnin and Yien, 1950) [3], available heavy metals of Fe, Cu, Zn, and Mn were determined by using DTPA extraction by using AAS (Lindsay and Norvell, 1978) [9].

Results and Discussion

Most of the soils of Mayurbhanj district in dry condition, reflected reddish brown (5YR 4/4) to brownish yellow (10YR 6/8) colour and in wet condition, reflected dark reddish brown (5YR 3/3) to brownish yellow (10YR 6/8) colour. Soil texture of soil samples from Mayurbhanj district varied from sandy loam to clay loam. The bulk density in soils from different villages varied from 1.11 to 1.33 g cm^{-3}. Soil bulk density showed positive relationships with sand content and clayey soils tend to have lower bulk densities (Chaudhari *et al.* 2013) [2]. Particle density of soils varied from 2.22 to 3.33 g cm^{-3}. Particle density of soil was found to be in the range of medium to dense. Particle density varies accordingly to the mineral content of the soil particles.

Soil reaction

Soil pH (1:2) of Mayurbhanj district of different villages were found to varied between 4.02 to 6.45 i.e. strongly acidic to moderately acidic with a mean value of 5.23, thus the pH indicates that the availability of micro nutrients should be high in the soil. The range of pH with mean value of all the villages are given in Table: 2. Hence, the soil acidity appears to be a major crop production constraint in the study area. Similar findings have also been reported earlier by Mishra *et al.* (2017) [10], Digal *et al.* (2018) [5].

Table 1: Assessment of physical properties of soils of Mayurbhanj District, Odisha

Village	Soil Texture	Soil Colour		Bulk Density		Particle Density	
		Range (Dry)	Range (Wet)	Range	Mean	Range	Mean
Gunduria	Sandy Loam	Reddish Brown- Yellowish Red	Dark Reddish Brown- Reddish Brown	1.11-1.25	1.18	2.86-3.33	3.17
Tikhia	Sandy Clay Loam	Strong Brown- Reddish Yellow	Reddish Yellow- Brownish Yellow	1.11-1.18	1.15	2.86-2.50	2.62
Pandarsila	Sandy Clay Loam	Strong Brown- Reddish Yellow	Reddish Yellow- Brownish Yellow	1.18-1.33	1.25	2.22-2.50	2.31
Ukam	Clay Loam	Reddish Yellow- Brownish Yellow	Dark Brown- Yellowish Brown	1.11-1.18	1.15	2.86-3.33	3.17
Kumudasol	Sandy Clay	Reddish Yellow- Brownish Yellow	Brown- Reddish Yellow	1.25-1.33	1.27	2.21-2.22	2.22
Joypur	Clay Loam	Strong Brown– Yellowish Brown	Yellowish Brown- Brownish Yellow	1.11-1.18	1.15	2.50-2.86	2.62
Badada	Sandy Clay	Yellowish Brown- Brownish Yellow	Dark Brown- Yellowish Brown	1.18-1.25	1.20	2.86-3.33	3.17
Dubulabeda	Sandy Clay Loam	Yellowish Brown- Brownish Yellow	Dark Brown- Yellowish Brown	1.11-1.25	1.18	2.22-2.86	2.52
Badgan	Sandy Loam	Brown- Reddish Yellow	Yellowish Brown- Brownish Yellow	1.18-1.25	1.20	2.22-2.86	2.52

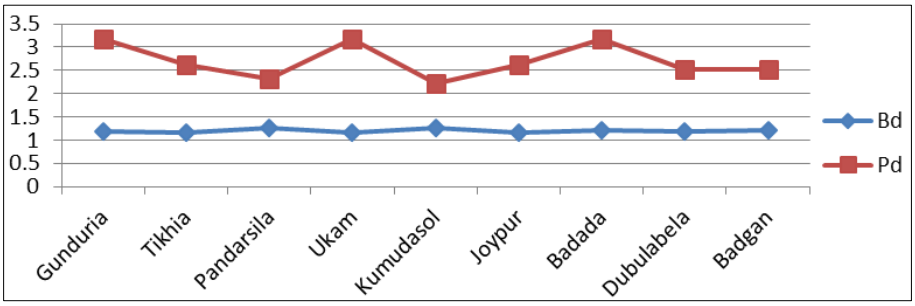

Fig 2: Show the Gunduria and badgan

Electrical conductivity

Electrical Conductivity (1:2) of surface soil samples of the entire study area was found to be less than 1dS m^{-1} (Table 2). Hence, all the soils under the study area are safe for all types of crop production with respect to the soluble salt content. Similar findings have also been reported earlier by Mishra *et al.* (2017) [10], Digal *et al.* (2018) [5].

Organic carbon

The soil organic carbon of different villages were found to vary between 0.36 to 1.3%. The range of organic carbon with mean value of all the villages are given in Table: 2. Soil organic carbon status was found to be medium to high which enables the soil for higher crop production. Similar findings have also been reported earlier by Dash *et al.* (2016) [4].

Table 2: Evaluation of chemical properties of soils of Mayurbhanj District, Odisha

Village	pH (1:2)		EC (1:2) (dS m^{-1})		OC (%)	
	Range	Mean	Range	Mean	Range	Mean
Gunduria	4.92-5.15	5.04	0.08-0.09	0.086	0.61-0.99	0.78
Tikhia	6.35-6.45	6.41	0.08-0.10	0.09	0.39-0.68	0.52
Pandarsila	5.45-5.51	5.47	0.05-0.06	0.053	0.63-1.14	0.89
Ukam	5.27-5.90	5.52	0.04-0.07	0.056	0.42-0.99	0.65
Kumudasol	4.35-4.70	4.50	0.06-0.09	0.076	0.61-1.30	0.98
Joypur	5.15-5.49	5.23	0.05-0.08	0.063	0.72-1.14	0.91
Badada	5.99-6.12	6.04	0.03-0.06	0.043	0.55-0.99	0.77
Dubulabela	4.02-4.49	4.24	0.07-0.09	0.08	0.36-1.14	0.72
Badgan	5.75-6.30	5.97	0.09-0.17	0.12	0.68-1.30	0.99

Available nitrogen: The available nitrogen content of soil samples range from 135.17 to 257.77 kg ha^{-1} with a mean value of 194.78, standard deviation of 19.79. Based on the limits suggested by Muhr *et al.*, the soil samples of the villages were found to be low to medium in nitrogen content. The reason may be attributed to the fact that nitrogen content is positively correlated with organic matter content which decreases with depth. Similar findings have also been reported earlier by Mishra *et al.* (2017) [10], Digal *et al.* (2018) [5], Mohapatra *et al.* (2020) [11].

Available phosphorus

The phosphorus content of soil samples were ranged from 3.56 to 23.82 kg ha-1 with a mean of 10.03, standard deviation of 4.51. Available phosphorus status was found to be very low to low which enables the soil for higher crop production. Low content of phosphorus is due to higher amount of iron present in soil. Similar findings have also been reported earlier by Mishra *et al.* (2017) [10], Mohapatra *et al.* (2020) [11].

Table 3: Primary nutrients status of Mayurbhanj District, Odisha

Village	N (Kg ha^{-1})		P (Kg ha^{-1})		K (Kg ha^{-1})	
	Range	Mean	Range	Mean	Range	Mean
Gunduria	188.61-235.77	209.57	8.90-13.34	11.75	48.37-78.59	61.03
Tikhia	160.32-223.19	160.32	16.83-23.82	20.13	101.04-138.48	120.94
Pandarsila	166.61-235.77	203.28	8.63-12.01	10.63	56.13-78.59	66.34
Ukam	147.75-216.91	184.42	7.15-9.34	8.33	67.54-101.04	86.13
Kumudasol	135.17-179.18	157.17	8.62-12.34	10.28	44.90-83.51	69
Joypur	194.90-257.77	228.43	6.31-10.97	8.56	44.90-78.59	62.60
Badada	169.75-229.48	202.23	5.03-6.63	5.97	56.13-78.59	67.36
Dubulabela	176.04-213.76	193.85	8.34-12.56	10.59	33.68-44.90	39.33
Badgan	160.32-204.33	184.42	3.56-4.52	3.56	64.32-89.81	77.57

Available potassium

The Potassium content of soil samples ranges from 33.68 to 138.48 kg ha-1 with a mean value of 72.25. The available potassium status in the entire study area was found to be low to medium. The highest K content observed in the surface horizon and showed more or less decreasing trend with depth. This might be attribute to more intense weathering and release of liable K from organic residues. Similar findings have also been reported by Mishra *et al.*, (2017) [10] and Digal *et al.*, (2018) [5].

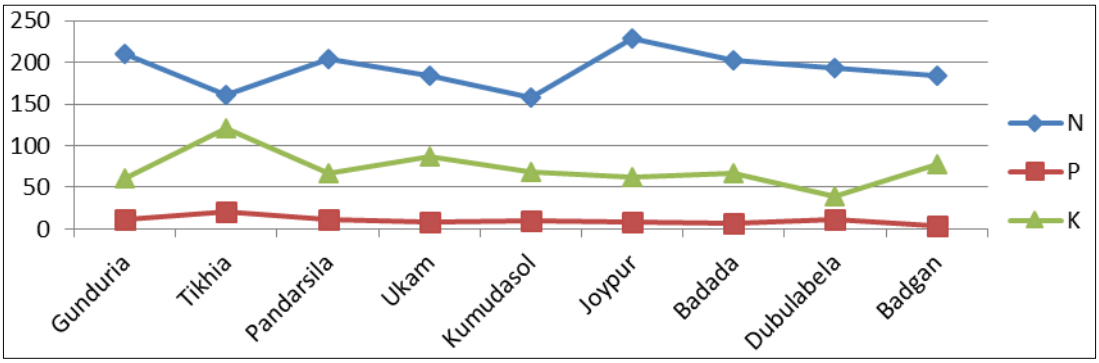

Fig 3: Show the kumudasol and dubulabela

Exchangeable Ca and Mg

The exchangeable Ca and Mg of soil samples ranges from 0.8 to 8.4 [cmol (p+) kg^{-1}] and 0.5 to 5.3 [cmol (p+) kg^{-1}] with a mean value of 4.68 and 3.11, respectively. It signifies moderate amount of Ca present in the soil due to moderate amount of rainfall. The amount of Mg found in low range due to the rainfall. Similar findings have also been reported earlier by Mohapatra *et al.* (2020) [11].

Available sulphur

The available sulphur content of soil samples ranges from 0.37 to 3.93 ppm with a mean value of 2.47. The range signifies that sulphur is deficient in the soil. The available sulphur is found below critical limit in most of the studied areas. Similar findings have also been reported earlier by Mohapatra *et al.* (2020) [11].

Table 4: Secondary nutrients status of Mayurbhanj District, Odisha

Village	Ex. Ca [cmol (p+) Kg^{-1}]		Ex. Mg [cmol (p+) Kg^{-1}]		S (ppm)	
	Range	Mean	Range	Mean	Range	Mean
Gunduria	5.7-7.4	6.63	1.8-4.4	3.1	2.89-3.93	3.51
Tikhia	3.6-4.7	4.26	1.5-2.6	2.03	1.38-2.58	1.87
Pandarsila	0.9-4.2	2.46	1.2-4.9	2.96	2.22-3.34	2.75
Ukam	3.8-8.4	5.96	0.9-5.1	3.1	2.59-3.53	3.03
Kumudasol	1.3-4.1	2.86	2.9-5.3	4.3	2.59-2.81	2.72
Joypur	3.5-7.8	5.8	1.8-4.6	3.03	2.87-3.90	3.32
Badada	4.1-8.0	6.43	1.8-4.4	3.26	1.69-2.32	2.00
Dubulabela	0.8-3.4	2.26	0.5-2.1	1.33	0.37-0.92	0.62
Badgan	3.5-7.8	5.53	4.0-5.7	4.93	1.94-2.96	2.43

Available Heavy Metals

DTPA extractable Heavy Metals content, Zn ranges from 0.45 to 1.5 ppm, Cu ranges from 0.9 to 3.94 ppm, Mn ranges from 12.4 to 57 ppm and Fe ranges from 212 to 3200 ppm, with the mean value of 0.93, 1.81, 22.07 and 1446.07, respectively. The range signifies deficiency of Zn in soil. The Zn is found below critical limit in most of the studied areas. The range signifies low to high amount of Cu in the soil. Low Cu levels attributed due to high organic matter content while high values due to lower pH of the soil. The range signifies higher amount of Mn in the soil. The higher amount of Mn is due to the low pH of the studied area. The range signifies very high amount of Fe which is due to the mining areas as well as the lower pH of the soil. Similar findings have also been reported earlier by K Laxminarayana *et al.* (2020) [8], Patnaik *et al.* (2013) [16].

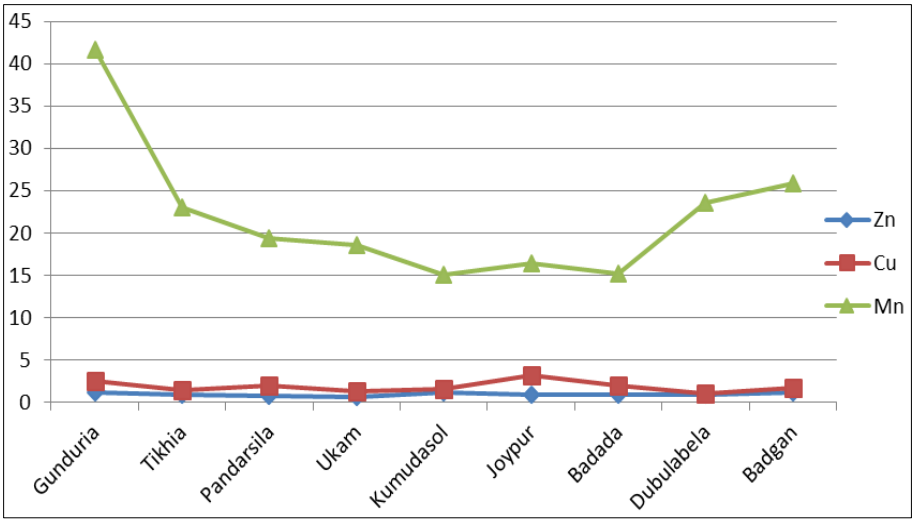

Fig 4: Show the Zn Cu Mn

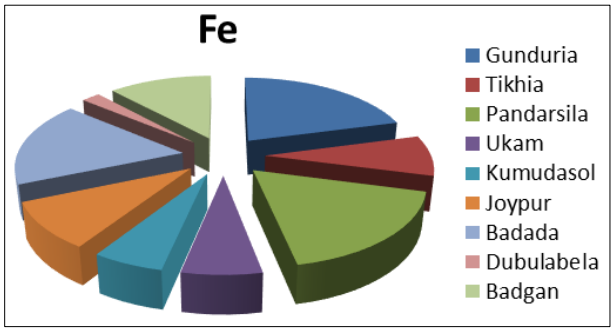

Fig 5: Show the gunduria and tikhia Fe

Table 5: Assessment of available Heavy Metals status of Mayurbhanj District, Odisha

Village	Zn (ppm)		Cu (ppm)		Mn (ppm)		Fe (ppm)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Gunduria	0.70-1.11	1.10	1.44-3.50	2.54	25.9-57.0	41.63	2276-3200	2710
Tikhia	0.81-0.98	0.91	1.12-1.71	1.37	22.1-23.9	23.06	972-1200	1075
Pandarsila	0.62-0.85	0.76	1.40-2.23	1.91	17.0-22.0	19.36	1605-2845	2316.66
Ukam	0.45-0.68	0.57	0.89-1.71	1.26	17.5-20.0	18.56	758-926	842.33
Kumudasol	0.84-1.41	1.19	1.41-1.59	1.50	14.1-15.9	15	702-800	754.66
Joypur	0.87-0.97	0.91	2.32-3.94	3.18	15.3-18.0	16.46	989-1435	1232
Badada	0.90-0.98	0.94	1.83-2.10	1.98	13.3-17.0	15.2	2000-2556	2263.33
Dubulabela	0.80-0.96	0.88	0.97-1.11	0.99	12.4-31.0	23.53	212-342	276
Badgan	0.99-1.19	1.11	1.32-1.98	1.63	22.2-29.3	25.83	1400-1724	1544.66

Table 6: Correlation between different soil properties of Mayurbhanj District, Odisha

	Bd	Pd	pH	EC	OC	N	P	K	Ca	Mg	S	Zn	Cu	Mn	Fe
Bd	1														
Pd	-0.56916	1													
pH	-0.31551	0.295175	1												
EC	-0.07495	-0.28335	0.057568	1											
OC	0.643326	-0.4711	-0.31849	0.150271	1										
N	-0.27002	0.327385	-0.10149	-0.35369	0.226439	1									
P	-0.21756	-0.13633	0.095111	0.056285	-0.66174	-0.38449	1								
K	-0.29492	0.069876	0.763323	0.195592	-0.49628	-0.56391	0.520007	1							
Ca	-0.53463	0.816882	0.470682	-0.01629	-0.09733	0.384636	-0.31616	0.189298	1						
Mg	0.458713	-0.11445	0.170926	0.287403	0.730546	-0.14039	-0.61039	0.066949	0.307286	1					
S	0.023874	0.234572	0.110657	-0.12225	0.343079	0.31154	-0.15703	0.121901	0.52142	0.525304	1				
Zn	0.411225	-0.28579	-0.18361	0.563969	0.515189	-0.19191	-0.07678	-0.1464	0.019531	0.477935	0.050533	1			
Cu	-0.14001	0.185188	0.061031	-0.19194	0.373697	0.752525	-0.16953	-0.20393	0.509875	0.194608	0.67605	0.207168	1		
Mn	-0.22354	0.330337	-0.06939	0.523262	-0.14153	0.167476	0.193293	-0.0823	0.287368	-0.07885	0.185432	0.304049	0.15376	1	
Fe	0.183729	0.375266	0.372484	-0.16193	0.181043	0.464164	-0.14836	-0.04373	0.455431	0.261968	0.491269	0.159642	0.555968	0.426262	1

Correlation Matrix between Physico-Chemical and Heavy Metals Parameters of soil in Mayurbhanj District, Odisha

The data on correlation matrix between physico-chemical and heavy metals properties of soil of different villages in Mayurbhanj district, Odisha is given in Table:-6. The bulk density of the soil is negatively significantly correlated with particle density (r = -0.56916), pH (r = -0.31551), EC (r = -0.07495), nitrogen (r = -0.27002), phosphorus (r = -0.21756), potassium (r = -0.29492), calcium (r = -0.53463), copper (r = -0.14001), manganese (r = -0.22354) and positively significantly correlated with organic carbon (r = 0.643326), sulphur (r = 0.023874), zinc (r = 0.411225), iron(r = 0.183729), positively non-significantly correlated with magnesium (r = 0.458713). The particle density of the soil is negatively significantly correlated with EC (r = -0.28335), organic carbon (r = -0.4711), phosphorus (r = -0.13633), zinc (r = -0.28579), negatively non-significantly correlated with magnesium (r = -0.11445) and positively significantly correlated with pH (r = 0.295175), nitrogen (r = 0.327385), potassium (r = 0.069876), calcium (r = 0.816882), sulphur (r = 0.234572), copper (r = 0.185188), manganese (r = 0.330337), iron (r = 0.375266). The pH of the soil is negatively significantly correlated with organic carbon (r = -0.31849), nitrogen (r = -0.10149), zinc (r = -0.18361), manganese (r = -0.06939) and positively significantly correlated with EC (r = 0.057568), phosphorus (r = 0.095111), potassium (r = 0.763323), calcium (r = 0.470682), sulphur (r = 0.110657), copper (r = 0.061031), iron (r = 0.372484), positively non-significantly correlated with magnesium (r = 0.170926). The EC of the soil is negatively significantly correlated with nitrogen (r = -0.35369), calcium (r = -0.01629), sulphur (r = -0.12225), copper (r = -0.19194), iron (r = -0.16193) and positively significantly correlated with organic carbon (r = 0.150271), phosphorus (r = 0.056285), potassium (r = 0.195592), zinc (r = 0.563969), manganese (r = 0.523262), positively non-significantly correlated with magnesium (r = 0.287403). The organic carbon of the soil is negatively significantly correlated with phosphorus (r = -0.66174), potassium (r = -0.49628), calcium (r = -0.09733), manganese (r = -0.14153) and positively significantly correlated with nitrogen (r = 0.226439), calcium (r = -0.09733), zinc (r = 0.515189), copper (r = 0.373697), iron (r =

0.181043), positively non-significantly correlated with magnesium (r = 0.730546). The nitrogen of the soil is negatively significantly correlated with phosphorus (r = -0.38449), potassium (r = -0.56391), zinc (r = -0.19191), negatively non-significantly correlated with magnesium (r = -0.14039) and positively significantly correlated with calcium (r = 0.384636), sulphur (r = 0.31154), copper (r = 0.752525), iron (r = 0.464164), manganese (r = 0.167476). The phosphorus of the soil is negatively significantly correlated with zinc (r = -0.07678), calcium (r = -0.31616), sulphur (r = -0.15703), copper (r = -0.16953), iron (r = -0.14836), negatively non-significantly correlated with magnesium (r = -0.61039) and positively significantly correlated with potassium (r = 0.520007), manganese (r = 0.193293). The potassium of the soil is negatively significantly correlated with zinc (r = -0.1464), copper (r = -0.20393), manganese (r = -0.0823), iron (r = -0.04373) and positively significantly correlated with calcium (r = 0.189298), sulphur (r = 0.121901), positively non-significantly correlated with magnesium (r = 0.066949). The calcium of the soil is positively significantly correlated with copper (r = 0.509875), zinc (r = 0.019531), manganese (r = 0.287368), iron (r = 0.455431), sulphur (r = 0.52142) and positively non-significantly correlated with magnesium (r = 0.307286). The magnesium of the soil is negatively significantly correlated with manganese (r = -0.07885) and positively significantly correlated with copper (r = 0.194608), zinc (r = 0.477935), iron (r = 0.261968), sulphur (r = 0.525304). The sulphur of the soil is positively significantly correlated with copper (r = 0.67605), zinc (r = 0.050533), manganese (r = 0.185432), iron (r = 0.491269). The zinc of the soil is positively significantly correlated with copper (r = 0.207168), manganese (r = 0.304049), iron (r = 0.159642). The copper of the soil is positively significantly correlated with manganese (r = 0.15376), iron (r = 0.555968). The manganese of the soil is positively significantly correlated with iron (r = 0.426262).

Conclusion

It can be concluded that the soils of Mayurbhanj district have a good physical condition which favors the cultivation of most of crops. Soil texture showed high clay percentage, strongly acidic to moderately acidic in soil reaction, medium to high soil organic carbon content, low to medium in nitrogen content, very low to low in phosphorus content, low to medium in potassium content, moderate amount of Ca, low amount of Mg, deficient in sulphur, the heavy metals; Zn content is deficient where as Fe, Cu and Mn are sufficient. The deficient nutrient can be replenished to avoid the crop suffering from the deficiency and optimum utilization of nutrients. Integrated nutrient management can be adopted for sustainable soil fertility management as well as to achieve higher crop production. The correlation showed that the negatively significantly, non-significantly and positively significantly, non-significantly varies among the soil parameters.

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Conflict of Interest

As a Corresponding Author, I Satya Ranjan Mohanta, confirm that none of the others have any conflicts of interest associated with this publication.

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