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Effect of Land Subsidence on Distribution of Soil Miconutrients in a Coal Mining Area

Tusarkanta Behera*, Anand Prakash Singh, Jiten Kumar Behera and Sonam Singh

Department of Soil Science and Agricultural Chemistry, I.A.S., B.H.U, Varanasi -221005, India

**Corresponding author*

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A B S T R A C T

Land subsidence accelerated by underground coal extraction has great effect on soil quality. Although many studies have been done with respect to land subsidence effect on different properties of soil still studies on nutrient distribution of soil in subsided land are very few. This paper focuses on effect of land subsidence on distribution of soil micronutrients in a coal mining area. For this study six sites like unaffected sites, crack-1 site, slope-1 site, maximum subsidence site, crack -2 site and slope-2 site were chosen. The variation in content of soil micronutrients like iron(Fe), manganese(Mn),copper(Cu), zinc(Zn) were studied in the six sites. The effect of subsidence was found to be significant on the content of DTPA extractable Mn and Cu in soils of mining area at the depths of 0-15 cm, 15-30 cm and 30-45 cm. The highest DTPA extractable Fe and Mn content was observed in soils of maximum subsidence site at all the three depths. The subsidence had significant effect on the content of DTPA extractable Zn and Fe in soils of mining area at depth of 0-15 cm. Lowest Zn and Cu content was observed in soils of maximum subsidence site at all the three depths.

Introduction

Coal plays an important role in fulfilling the global demand for energy. It is the main energy resource for steel, cement industries and is used in thermal power plants for electricity generation (Ram and Masto, 2010; Mukhopadhyay *et al.*, 2016). Coal mining causes land subsidence by which upper surface of land moves downwards relative to a datum. Due to land subsidence, the equilibrium of ecosystem gets altered. Land subsidence accelerated by underground coal extraction has a vital impact on the soil quality and it causes significant ecological and environmental problems, such as water and soil erosion, land degradation, and declination in soil quality.

After subsidence cracks develop on the land surface which can change the hydrological properties of soil. Impacts of land subsidence on agriculture land have been studied in Illinois, U.S.A (Darmody *et al.*, 2014), United Kingdom (Selman, 1986), China (Donggan *et al.*, 2011), South Africa (Bell *et al.*, 2000), and Australia (Thompson *et al.*, 2010). Although many studies have been carried out to address the issues of mine subsidence in China, Australia, United Kingdom etc., very few of them have been performed in India. Further studies available on impact of mine subsidence on changes in nutrient status with respect to micronutrients content in soil and plants are very few and fragmented. Micronutrients are essential nutrients required in small quantities, but they are as essential as macronutrients.

The micronutrients like iron (Fe), manganese (Mn),copper (Cu),zinc (Zn) play a vital role in growth and development of plants. These micronutrients take part in activating variety of enzymes concerned in cellular oxidation and reduction reactions. From the soil quality point of view the content of micronutrients in soil is very important. Focusing the importance of micronutrients, this study aims to assess the depth wise variations of micronutrients content in soil due to mining subsidence and to evaluate the distribution pattern of micronutrient content of soil in different sites on subsidence curvature.

Materials and Methods

Site information

The study site is located in Anuppur District of Madhya Pradesh, India. It falls under SECL (South Eastern Coalfields Limited) region of CIL (Coal India Limited). It is situated at the latitude in between 23 ^{0}0'N and 23 ^{0}15' N and longitude in between 81^0 45' E and 82^0 05' E. The climate of the region is humid subtropical and divisible in to three distinct seasons, namely rainy (mid-June to October), winter (November to February) and hot summer (March to mid-June). The summers here have a good deal of rainfall, while the winters have very little. Garg *et al.*, (2013) had classified this region into six land-use types using remote sensing technique: water, agriculture, Forest, mining, settlement and waste land.

Soil sampling

Soil samples were collected from Panel-19. Six sites were marked for the said study. These were the unaffected site, crack-1 site, slope-1site, maximum subsidence site, crack-2 site and slope-2 site under panel-19. The samples were collected from 4 sub-spots under each site in a zig zag manner. With the help of spade, khurpi small portions of soil were collected from each sub-spot from 0-15 cm, 15-30 cm and 30-45 cm depth. The bulk soil was reduced to 500g by quartering process. Each sample was labelled with thick paper with proper identification mark. A diagram about site and subsites of mining area is shown in figure-1.

Soil analysis

Collected soil samples were brought in to the laboratory, dried in shade at room temperature and ground on wooden plank with wooden roller and passed through a 2 mm sieve. Thereafter, homogenized soil samples were stored in polythene bags for analysis of DTPA extractable micronutrients content of soil.

Available micronutrients (Fe, Cu, Mn, Zn) were extracted with the help of DTPA extracting solution (0.005 M DTPA+ 0.01 M $CaCl_2$ + 0.1 M TEA), pH adjusted to 7.3 as per the procedure described by Lindsay and Norvell (1978). The extracted amounts were measured by using atomic absorption spectrophotometer(AAS). After analysis of DTPA extractable micronutrients, the value of individual DTPA extractable micronutrient present in four sub spots under each site were averaged out.

Results and Discussion

A critical perusal of data related to depth wise distribution of micronutrient content of soil presented in table-1 and fig- 2,3,4. The data also showed that the highest DTPA extractable Fe content was observed in soils of maximum subsidence site, the respective values being 54.9 ppm, 52.8 ppm and 50.5 ppm at the depth of 0-15 cm,15-30 cm and 30-45 cm. The lowest availability of iron was observed in soils of crack-2 site (38.15ppm), slope-1 site (30.1 ppm) and unaffected site (41.3ppm) at depth of 0-15 cm, 15-30 cm and 30-45 cm, respectively. The data showed that the highest DTPA extractable Mn content was observed in soils of maximum subsidence site and the respective values were 73.7 ppm, 57.20 ppm and 69.53ppm at all the depths of 0-15 cm,15-30 cm and 30-45 cm.

The lowest availability of DTPA extractable Mn i.e., 46.57 ppm was observed in soils of slope-2 site at the depth of 0-15 cm, whereas the lowest value in crack-2 site and crack-1 site were 48.82 ppm and 44.82 ppm at the depth of 15-30 cm and 30-45 cm, respectively. The low content of Fe and Mn at slope and crack site might be due to leaching of the nutrient through percolation of water due to heavy precipitation.

The contents may also be affected by soil types, topography and climates (Hamilton, 1998; Maitima *et al.,* 2009; Zhang *et al.*, 2011). The effect of subsidence was found to be significant on the content of DTPA extractable Fe in soils of mining area at the depth of 0-15 cm and 15-30 cm, whereas there was insignificant difference in Fe content of soils in mining area at the depth of 30-45 cm. The DTPA extractable Fe content of soils showed an increase from crack-2 site to maximum subsidence site through slope-2 site at the depth of 0-15 cm, whereas the same trend was not followed in soils at the depth of 15-30 cm and 30-45 cm. There was no obvious pattern in increment of Fe content of soils in mining area from crack-I site to maximum subsidence site at the depth of 0-15 cm, 15-30 cm and 30-45 cm.

The formation of insoluble hydroxide starts as soon as the pH of the solution is raised to 6 and above. So, the solubility and bioavailability of iron increases below pH 6. As the pH of maximum subsidence site was below 6 and maximum concentration of iron was found at this site. The DTPA extractable Mn content of soils increased from crack-2 site to maximum subsidence site through slope-2 site at the depth of 15-30 cm, whereas the same trend was not followed in soils of depth of 0-15 cm and 30-45 cm.

The DTPA extractable Mn content of soils also increased from crack-1 site to maximum subsidence site through slope-1 site at the depth of 0-15 cm and 30-45 cm, whereas the same pattern was not followed in soils at depth of 15-30 cm. Data presented in table-1 revealed that effect of subsidence was found to be significant on the content of DTPA extractable Mn in soils of mining area at the depths of 0-15 cm, 15-30 cm and 30-45 cm. It is evident from the data presented in table-1 and fig.-2,3,4 that the DTPA extractable Zn content of soils decreased from crack-2 site to maximum subsidence site through slope-2 site at the depths of 0-15 cm, 15-30 cm and 30-45 cm.

The DTPA extractable Zn content of soils was also decreased from crack-1 site to maximum subsidence site through slope-1 site at all the three depths i.e., 0-15 cm, 15-30 cm, 30-45 cm. The data showed that the lowest DTPA extractable Zn content was observed in soils of maximum subsidence site, the values being

0.46ppm, 0.49ppm and 0.31 ppm at the depths of 0-15 cm,15-30 cm and 30-45 cm respectively. The highest availability of Zn i.e., 1.19 ppm was observed in soils of crack-2 site, whereas the highest DTPA extractable Zn content was found in soils of unaffected site and crack-1 site, the values being 0.75 ppm and 0.64 ppm at depth of 15-30 cm and 30-45 cm respectively.

Data presented in table-1 revealed that the subsidence had significant effect on the content of DTPA extractable Zn in soils of mining area at depth of 0-15 cm. whereas there was insignificant difference in DTPA extractable Zn content of soils in mining area at depth of 15-30 cm and 30-45 cm. It is obvious from the data presented in table-1 and fig.- 2,3,4 that underground coal mining activities had remarkable impact on DTPA extractable Cu content in soil. The significant difference was found in DTPA extractable Cu content of soils in all sampling sites of mining area at the depths of 0-15 cm, 15-30 cm, 30-45 cm.

It is clear from the data shown in table-1 that lowest DTPA extractable Cu content was found in soils of maximum subsidence site at all the three depths, viz. 0-15 cm, 15-30 cm and 30-45 cm the respective values being 2.58 ppm, 2.65 ppm and 2.30 ppm.

Table.1 Mean values of micronutrient distribution in mining subsided land at different depth range

Sampling	Fe(ppm)	Mn(ppm)	Zn(ppm)	Cu(ppm)
Sites		**0-15cm**		
Unaffected	39.55	55.38	0.50	5.60
crack 1	40.35	48.55	0.76	3.50
slope 1	38.2	49.44	0.71	3.70
max sub	54.9	73.70	0.46	2.58
slope 2	40.85	46.57	0.70	2.80
crack 2	38.15	47.22	1.19	2.83
SE(m±)	**3.279**	**2.76**	**0.133**	**0.419**
CD ($P_{0.05}$)	**9.189**	**8.263**	**0.397**	**1.255**
		15-30cm		
Unaffected	44.95	59.52	0.75	5.50
crack 1	44.75	61.28	0.65	3.50
slope 1	30.1	53.78	0.51	3.75
max sub	52.8	57.20	0.49	2.65
slope 2	37.2	48.82	0.55	3.25
crack 2	38.25	47.30	0.61	3.40
SE(m±)	**2.634**	**2.319**	**0.117**	**0.311**
CD ($P_{0.05}$)	**7.886**	**6.943**	**NS**	**0.932**
		30-45cm		
Unaffected	41.3	55.57	0.40	4.75
crack 1	44.2	44.82	0.64	3.45
slope 1	43.35	61.25	0.51	3.30
max sub	50.5	69.53	0.31	2.30
slope 2	42.85	49.67	0.54	2.70
crack 2	44	59.80	0.55	2.85
SE(m±)	**3.376**	**4.195**	**0.087**	**0.199**
CD ($P_{0.05}$)	**NS**	**12.56**	**NS**	**0.596**

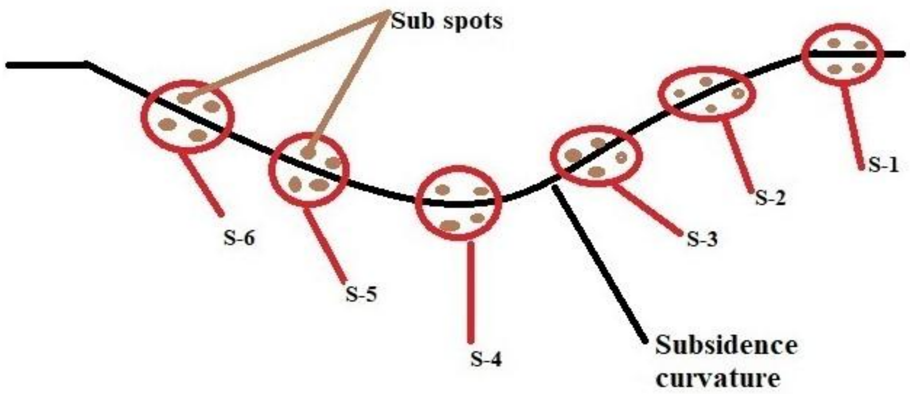

Fig.1 Soil sampling sites and sub spots where S-1= unaffected site; S-2= crack-1 site; S-3= slope-1 site, S-4= maximum subsidence site; S-5= slope-1 site; S-6= crack-2 site

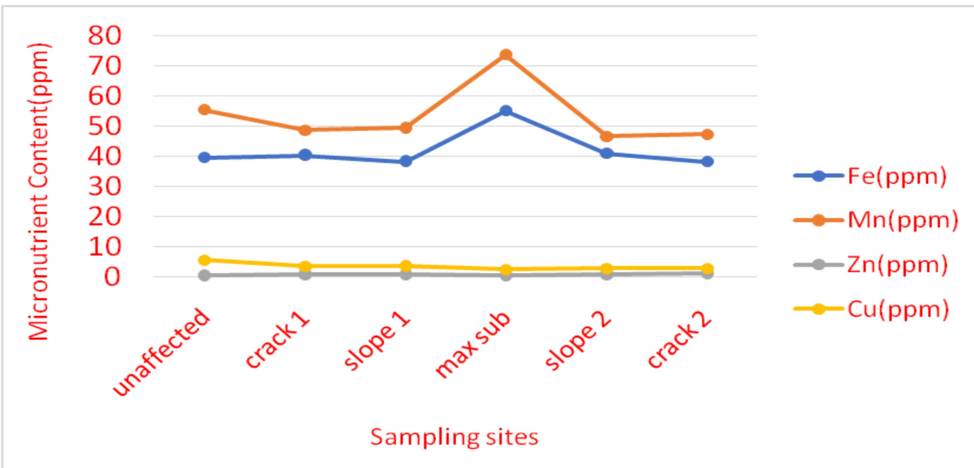

Fig.2 Micronutrient distribution in mining subsided land at 0-15 cm. depth

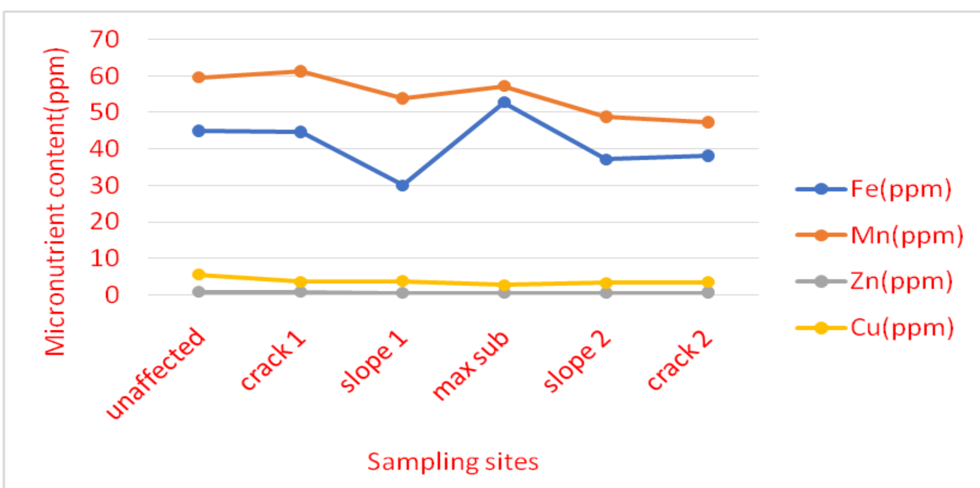

Fig.3 micronutrient distribution in mining subsided land at 15-30 cm. depth

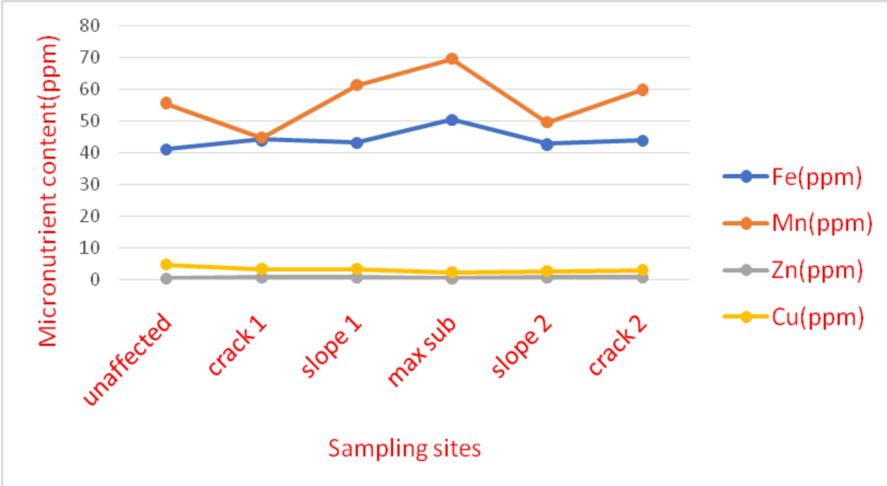

Fig.4 Micronutrient distribution in mining subsided land at 30-45 cm. depth

The DTPA extractable Cu content of soils decreased from crack-2 site to maximum subsidence site through slope -2 site at depths of 0-15 cm, 15-30 cm, 30-45cm. There was no specific pattern shown by DTPA extractable Cu content of soils from crack-1 site to maximum subsidence site through slope-1 site in any depth i.e., 0-15 cm, 15-30 cm, 30-45 cm.

Soil organic matter contains several reactive functional groups and multivalent cations (Cu^{2+}, Zn^{2+}, Mn^{2+}, Fe^{2+}) which have the potential for forming coordinating linkages with those functional groups. Amongst the highly stable complexes, stability sequence for some selective divalent cation is as: Cu^{2+}> Ni^{2+}> Co^{2+}> Zn^{2+}> Fe^{2+}> Mn^{2+}. DTPA extractable Cu might have complexed with organic matter, resulting in lesser availability of Cu.

This study showed that the land subsidence resulted from coal mining altered the micronutrients content ofthe soil. Although the macro nutrients have a major effect on plant growth and metabolism, the importance of micronutrientson maintenance of soil quality is same as macronutrients. The phenomenon of subsidence resulted in high Fe and Mn content in maximum subsidence site and low amount of Zn and Cu at that site. On the basis of the value of micronutrients content, soils of subsidence area could be diverted towards cultivation of crops by managing the land properly.

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