International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(6): 2821-2827

Received: 26-09-2018
Accepted: 27-10-2018

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Characterization and classification of cultivated soils surrounding Ramakrishnapur open cast coal mine area of Telangana state

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Abstract
Six typical pedons representing cultivated soils surrounding Ramakrishnapur open cast area of Telangana State *viz.,* soils developed from granite-gnesis parent material under varying landuse were studied for their morphological characteristics, physical and physic-chemical properties. These soils were neutral to moderately alkaline in reaction, non-saline, deep to very deep in depth and had isomegathermic and ustic soil moisture temperature regime. Texture, Organic Carbon, CEC and Base saturation were varied from sandy loam to sandy clayloam in texture, 1.4 to 4.7 g kg^{-1}, 6.90 to 20.4 cmol (p^{+}) kg^{-1} and 54.01 to 92.04 percent respectively. Soils were low to medium in available N, low to high in available P, medium to high in available K and sufficient in available sulphur. The DTPA-extractable Zn and Fe were deficient to sufficient, whereas, DTPA-extractable Cu and Mn were sufficient. Pedons 1, 3 and 5 were grouped under Inceptisols and were classified as Typic Haplustepts whereas pedon 4 was placed under Entisol and was classified as Typic Ustorthents, where as pedon 2 was placed under Alfisol and was classified as Typic Haplustalfs. All the soils of the study area were cultivated agricultural land.

Keywords: characterization, open cast coal mine

Introduction
Mining is one of the major industrial sectors in India and contributes significantly to the national economy, about 2.2 to 2.5% of the gross domestic product (Annual Report, 2015–16). In response to the needs of the growing industrial sector, mining activities have been on the rise in the last few decades. Mining is purely a temporary activity, but it causes drastic and immediate soil degradation and declines the consistent and regenerative soil quality due to stock piling of overburden (OB) dumps, creation of large voids and increase in particulate pollution load in the niche of the mining area and its environs. Thus, several changes occur in the physical and chemical properties of soil and soil fertility gradually deteriorates year by year.

Soil is vital resource for agriculture and this has to be utilized properly with precise scientific knowledge of various factors which govern the crop production. Characterization helps in determining the soil potentials and identifying the constraints for crop production besides giving detailed information about different soil properties. However, characterization, classification and evaluation of cultivated soils, which had pivotal role not only to sustain soil fertility but also soil productivity. Hence, critical evaluation of soil properties around coal mining areas is necessary to know the extent of deterioration of soil quality which furthur helps in adopting better management practices for increasing the productivity of the soil. Ramakrishnapur falls under semi-arid agro-ecological region and had a wide variety of soil resources surrounding coal mine area. Hence, the present study was taken up.

Material Methods
Ramakrishnapur lies in between $18^{o}54^{1}$ and $18^{o}55^{1}$ north latitudes and $079^{o}23^{1}$ and $079^{o}28^{1}$ east longitudes. The study area consists of sand stone and granite-gneiss parent material. The climate belongs to semi-arid monsoonic with distnict summer, winter and rainy seasons. The mean annual rainfall recorded for the last 10 years (2003-2013) is 1102.90 mm of which constitutes more than 83% was received during June to September. The mean annual temperature was 27 ^{o}C with mean summer temperature 39 ^{o}C and the mean winter temperature

of 31 ºC. The maximum temperature recorded for last 10 years is 40 ºC and the minimum temperature 15 ºC in the month of December.

The soil moisture regime has been computed as ustic and the soil temperature regime as iso-megathermic. The natural vegetation comprises of *Acacia auriculiformis, Azadiracta Indica, Prosopis juliflora, Tectona grandis, Pithakalobia dacli, Tamrindus Indica, Pongamia pinnata* etc.

Table 1: Landscape characteristics of pedons

Pedons / Villages	Location	Elevation above mean sea level (m)	Physiography	Slope (%)	Drainage	Parent material
P1 Amaravadhi	$18^0$54′29.4″ N 079^{0}28′10. 6″ E	161	Plain	1-3	Moderately well drained	granite-gneiss
P2 Sheshupalli	$18^0$54′57.9″ N 079^{0}28′08.7″ E	171	Plain	1-3	well drained	granite-gneiss
P3 Kythanpalli	$18^0$55′28.2″ N 079^{0}27′21.0″ E	156	Plain	1-3	Moderately well drained	granite-gneiss
P4 Doragari palli	$18^0$54′11.1″ N 079^{0}28′35.6″ E	173	Undulating uplands	3-5	Excessively drained	granite-gneiss
P5 Doragari palli	$18^0$53′33.5″ N, 079^{0}23′27.8″ E	166	Plain	1-3	Moderately well drained	granite-gneiss
P6 Mancherial	$18^0$53′59.5″ N, 079^{0}28′52.7″ E	154	Plain	3-5	well drained	granite-gneiss

The six peodns were studied in detail and the morphological characteristics were presented in table 2. The detailed morphological description of these six pedons was studied in the field as per the procedure outlined in U.S.D.A. soil survey manual Soil Survey Staff 1998 [21]. Later, horizon-wise soils samples were collected and characterized for important physical, physico-chemical properties and available nutrient status using standard procedures. The soils were classified taxonomically (Soil Survey Staff, 2014) [22] of USDA. Considering limitations and potentials of the soils based on that a suitable land use plan has also been suggested.

Results and Discussion

Soil Morphology

The depth of soil pedons varied from deep to very deep solum. Theses soils were excessively drained to well drained. The colour of open cast coal mine surrounding cultivated soil pedons of Ramakrishnapur varied from 1 to 2 km dark reddish brown to strong brown in pedons 1 and 2, between 2 to 4 km colour varied from very dark brown to strong brown in pedons 3 and 4, between 4-6 km colour varied from dark reddish brown to dark red. The soil colour appears to be the function of chemical and mineralogical composition as well as textural make up of soils and conditioned by topographic position and moisture regime (Geeth Sireesha and Naidu 2013) [5]. The soils of Ramakrishnapur showed wide textural variations (Sandy loam to Sandy clay loam). The wide textural variations might be due might be due to variations in topographic position, nature of parent material, *in-situ* weathering and translocation of clay. The structure of soil pedons of Ramakrishnapur between 1 to 2 km size of aggregate was medium, grade was weak to moderate and type of aggregate was sub angular blocky. Whereas, in the pedons between 2 to 4 km size of aggregate was medium, grade was moderate and type of aggregate was granular to subangular blocky in (pedon 4). Whereas, in soil pedons between 4 to 6 km size of aggregate was medium, grade was moderate and type of aggregate was subangular blocky.

The consistence of the soil pedons of open cast coal mine surrounding cultivated soil pedons of Ramkrishnapur between 1 to 2 km the soil consistency varied slightly hard, friable, slightly sticky to slightly plastic whereas, in soil pedons between 2 to 4 km varied slightly hard, friable and firm, non sticky to no plastic and sticky and plastic. Whereas, in pedons between 4 to 6 km the soil consistency varied slightly hard, friable and firm, non sticky to non plastic and slightly sticky and slightly plastic in dry, moist and wet conditions respectively. Presence of loose, friable and non-sticky and non-plastic or slightly sticky and slightly plastic consistency might be due to negligible or very small amount of expanding clay minerals (Satyavathi and Suryanarayana Reddy 2003 and 2004) [18]. Pedons 1, 3 and 5 exhibit Cambic (Bw), pedons 2 and 6 exhibit Agrgillic horizons. However, pedons 4 do not have any diagnostic horizon. Strong effervescence with dilute Hcl was observed in pedon 4 and 5. The horizon boundaries are clear to gradual in distinctness and smooth in topography.

Table 2: Morphological description of pedons surrounding opencast coal mine area of Ramakrishnapur.

Horizon	Depth (cm)	Soil colour	Texture	Structure			Consistence			Efferve-scence	Boundary		Concretions $CaCO_3$		Remarks
		Moist		S	G	T	Dry	Moist	Wet		D	T	Q	S	
P-1															
Ap	0-15	7.5 YR 4/6	sl	m	1	sbk	sh	fr	sssp	nil	c	s	_	_	
Bw1	15-40	5 YR 4/6	scl	m	2	sbk	sh	fr	sssp	nil	g	s	_	_	
Bw2	40-75	5 YR 4/6	scl	m	2	sbk	sh	fi	sssp	nil	g	s	_	_	
Bw3	75-105+	5 YR 4/6	scl	m	2	sbk	sh	fr	sp	nil					
P-2															
Ap	0-10	5 YR 3/4	sl	m	2	sbk	sh	fr	sssp	nil	c	s	_	_	
Bt1	10-30	5 YR 3/4	scl	m	2	sbk	sh	fi	sp	nil	g	s	_	_	Patchy thin clay cutans
Bt2	30-60	7.5 YR 4/4	scl	m	2	sbk	sh	fi	sp	nil	g	s	_	_	Patchy thin clay cutans
BC	60-90+	7.5 YR 3/4	scl	m	2	sbk	sh	fr	sssp	nil			_	_	
P-3															
Ap	0-12	7.5 YR 2.5/3	sl	m	2	sbk	sh	fr	sssp	nil	c	s	_	_	
Bw1	12-28	7.5 YR 3/4	scl	m	2	sbk	sh	fr	sssp	nil	g	s	_	_	
Bw2	28-55	7.5 YR 5/6	scl	m	2	sbk	sh	fi	sp	nil	g	s	_	_	
BC	55-90+	7.5 YR 5/8	scl	m	2	sbk	sh	fi	sp	nil			_	_	
P-4															
Ap	0-11	7.5 YR 2.5/2	scl	m	2	sbk	sh	fi	sp	nil	c	s	_	_	Added Black Soil
A1	11-38	7.5 YR 4/4	sl	m	2	sbk	sh	fr	sopo	nil	c	s	_	_	60% quartz gravel, 15%

															stones
BC	38-72	7.5 YR 3/3	sl	m	2	sbk	sh	fr	sopo	es	g	s	_	_	35% quartz gravel, 10% stones
Cr	72-90+	7.5 YR 5/6	sl	m	2	sbk	sh	fr	sopo	es			_	_	15% fine quartz gravel
P-5															
Ap	0-10	2.5 YR 2.5/3	scl	m	2	sbk	sh	fr	sssp	nil	c	s	_	_	
Bw1	10-30	2.5 YR 3/4	scl	m	2	sbk	sh	fr	sssp	nil	c	s	_	_	
Bw2	30-60	2.5 YR 3/3	scl	m	2	sbk	sh	fi	sssp	es	g	s	_	_	
BC	60-90+	2.5 YR 3/6	scl	m	2	sbk	sh	fi	sssp	es			_	_	
P-6															
Ap	0-16	2.5 YR 2.5/3	sl	m	2	sbk	sh	fr	sopo	nil	c	s	_	_	
Bt1	16-33	2.5 YR 2.5/4	scl	m	2	sbk	sh	fr	sssp	nil	g	s	_	_	Patchy thin clay cutans
Bt2	33-65	2.5 YR 2.5/4	scl	m	2	sbk	sh	fi	sssp	nil	g	s	_	_	Patchy thin clay cutans
BC	65-110+	2.5 YR 2.5/3	scl	m	2	sbk	sh	fi	sssp	nil					

Soil Characteristics

Physical Characteristics

The detailed physical characteristics of the soils were presented in table 3. The clay content of open cast coal mine area surrounding cultivated soil pedons of Ramakrishnapur ranged from 14.3 to 31.2 percent. In the pedons 1, 3 and 5 clay content is increased with depth might be due to the illuvial clay accumulation during soil development, downward translocation of finer particles from the surface layers to sub surface layers (Sharma *et al.*, 2011 and Rajagopal *et al.*, 2013) [6, 20, 24] whereas, in open cast coal mine area surrounding cultivated soils of Ramakrishnapur area pedons 2 and 6 the increase in clay content in Bt horizon mainly due to illuviation of the clay from the upper horizons. Enrichment Bt horizons with the clay content which was also one of the characteristics criteria of Alfisols. However, in pedon 4 clay content was irregular with depth. Silt content in general exhibited an irregular trend with depth, this irregular distribution of silt might be due to variation in weathering of parent material or *in-situ* formation (Satish Kumar and Naidu 2012a) [17]. Sand constitutes the bulk of mechanical fractions, which could be attributed to the siliceous nature of parent material.

The bulkdensity of different pedons varied from 1.46 to 1.69 Mg m^{-3}. In almost all pedons bulkdensity increased with increase in depth of pedon. Which was due to increase in coarse fragment of soils as well as filling of pores by illuvial materials leading to compaction. However, higher bulkdensity observed in mining area which may be attributed to addition of over burden and coal dust *i.e.*, settling from the open cast mines was reported by Raj and Ratanlal (2008) [12].

The particle density of different pedons ranged from 2.52 to 2.63 Mg m^{-3}. The variation in the particle density values was not much in the open cast coal mine surrounding cultivated soil pedons of Ramakrishnapur.

The saturated hydraulic conductivity of the soils in the study area was in the range of 3.3 to 12.4 cm hr^{-1}. Whereas, Pedons 4 was recorded highest (12.4 cm hr^{-1}) hydraulic conductivity. However, the hydraulic conductivity decreased with increasing depth of the soil. (Ramprakash and Seshagiri Rao, 2002) [13]. Water holding capacity (WHC) of different pedons of open cast coal mine surrounding cultivated area varied from 33.01 to 41.00 percent. These variations were due to differences in depth. The irregular trend of WHC with depth was due to the illuviation and eluviations of finer fractions in different horizons (Geetha Sireesha and Naidu 2013a) [5].

Table 3: Physical properties of soil pedons sourinding opencast coal mine area of Ramakrishnapur.

Pedon No. & Horizon	Depth (cm)	Sand (%) (0.2-2.0 mm)	Silt (%) (0.002-0.02 mm)	Clay (%) (< 0.002 mm)	Bulk density (Mg m^{-3})	Particle density (Mg m^{-3})	Hydraulic Conductivity (cm hr^{-1})	Water holding capacity (%)
P1								
Ap	0-15	63.4	17.1	19.5	1.55	2.55	3.9	37.00
Bw1	15-40	59.6	19.8	20.6	1.53	2.58	5.1	38.10
Bw2	40-75	59.2	14.8	26	1.51	2.59	5.7	39.50
Bw3	75-105+	56.6	14.6	28.8	1.47	2.58	6.1	41.00
P2								
Ap	0-10	69.6	15.2	15.2	1.56	2.61	8.2	38.15
Bt1	10-30	62.7	16.5	20.8	1.52	2.57	4.8	38.53
Bt2	30-60	56.8	17.1	26.1	1.51	2.54	4.5	38.42
BC	60-90+	66.8	12.8	20.4	1.54	2.58	4.7	38.15
P3								
Ap	0-12	67.1	14.4	18.5	1.53	2.6	6.6	39.52
Bw1	12-28	66.2	13.2	20.6	1.56	2.58	4.8	37.47
Bw2	28-55	62.3	12.6	25.1	1.58	2.55	4.25	36.01
BC	55-90+	60.6	11.2	28.2	1.6	2.58	3.38	35.68
P4								
Ap	0-11	53.3	18.2	28.5	1.47	2.57	8.6	40.52
A1	11-38	75.3	9.1	15.6	1.61	2.63	12.4	36.41
BC	38-72	74.8	8.4	16.8	1.64	2.62	11.8	35.18
Cr	72-90+	73	9.2	17.8	1.69	2.60	10.2	33.01
P5								
Ap	0-10	68.4	11.2	20.4	1.57	2.56	3.3	36.52
Bw1	10-30	66.2	10.2	23.6	1.52	2.56	4.3	38.74
Bw2	30-60	66.3	6.5	27.2	1.54	2.59	3.5	38.56

BC	60-90+	62.8	8.6	28.6	1.58	2.56	3.30	36.11
P6								
Ap	0-16	74.5	11.2	14.3	1.46	2.52	9.4	40.01
Bt1	16-33	69	10.2	20.8	1.51	2.57	4.5	39.15
Bt2	33-65	58	10.8	31.2	1.54	2.55	4.1	37.48
BC	65-110+	59	13.4	27.6	1.65	2.58	3.6	34.05

Physico-Chemical Characteristics

The soil reaction pedons of open cast coal mine surrounding cultivated soil pedons of Ramakrishnapur ranged from 6.73 to 7.91 i.e., neutral to moderately alkaline in reaction. All the pedons showed increasing trend with depth. Whereas, in pedon 4 showed irregular trend with depth. Increasing trend of pH with depth in these soils might be due to the release of organic acids during decomposition of organic matter and these acids might have brought down the pH in the surface soils (Vadivelu and Bandyopadhyay, 1997) [25]. The electrical conductivity of pedons ranged from 0.10 to 0.27 d Sm^{-1}, indicating non-saline nature. The low EC may be due to good drainage conditions which favoured the removal of released bases by percolating and drainage water.

Organic carbon content of the soil pedons of open cast coal mine surrounding cultivated soil pedons of Ramakrishnapur was found to be low to medium and ranging from 1.4 to 4.7 g kg^{-1} (Table 4). The organic carbon content decreased with depth in almost all the pedons. The nitrogen content of all the pedons as well as surface samples also ranged from low to medium which showed correlation between organic carbon and nitrogen (Geetha Sireesha and Naidu 2013a and Santhosi *et al.*, 2011) [5, 16].

The cation exchange capacity in all pedons of open cast coal mine surrounding cultivated soil pedons of Ramakrishnapur estimated by ammonium acetate extract varied from 6.9 to 20.4 cmol(p^+) kg^{-1}. The CEC of the soils, was increased with depth (Likhar and Prasad, 2011) [7]. The free $CaCO_3$ content of soil pedons was ranged from 1.5 to 6.7 percent and the $CaCO_3$ content increased with depth. The greater amounts of calcium carbonate at lower depth of soil peodns clearly illustrated that the calcium carbonate moved from surface to sub-surface layers.

Exchangeable bases in all the pedons of open cast coal mine surrounding cultivated soil pedons of Ramakrishnapur found to be in the order of $Ca^{2+}>Mg^{2+}>Na^{+}>K^{+}$ on the exchange complex. The base saturation varied from 54.01 to 92.14 percent. The exchangeable calcium was found to be the dominant cation followed by magnesium on the exchange complex which in turn reflects the fertility of the soil. From the distribution of Ca^{2+} and Mg^{2+}, it was evident that Ca^{2+} shows the strongest relationship with all the species (Khan and Kamalakar, 2012) [1]. The ratio between Ca/Mg ranged from 1.78 to 5.08 and indicated a considerable recycling of bases (Gangopadhyay *et al.*, 2001) [4]. The CEC/Clay ratio ranged from 0.48 to 0.99. The CEC/Clay ratio was used to identify the clay mineralogy (Ashok Kumar and Jagadish Prasad, 2010) [7].

Table 4: Physico-chemical properties of soil pedons sourinding opencast coal mine area of Ramakrishnapur.

Pedon No. & Horizon	Depth (cm)	pH (1:2.5)	EC (dS m^{-1})	Organic carbon g kg-1	$CaCO_3$ (%)	CEC [c mol (p+) kg^{-1}]	Exchangeable bases [c mol (p+)kg^{-1}]				Base Saturation (%)
							Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	
Pedon 1											
Ap	0-15	7.04	0.18	3.8	nd	13.0	7.7	2.3	0.3	0.2	80.50
Bw1	15-40	7.29	0.12	3.2	nd	14.9	9.3	2.5	0.3	0.3	83.20
Bw2	40-75	7.34	0.10	2.7	nd	17.3	10.8	3.6	0.4	0.2	86.80
Bw3	75-105+	7.38	0.13	2.5	2.8	18.9	12.4	3.8	0.5	0.4	90.40
Pedon 2											
Ap	0-10	7.16	0.14	4.3	nd	8.2	3.1	1.1	0.1	0.2	54.41
Bt1	10-30	7.21	0.27	3.9	nd	11.8	5	1.2	0.1	0.2	55.34
Bt2	30-60	7.35	0.17	3.1	nd	13.3	5.9	1.3	0.2	0.2	57.23
BC	60-90+	7.48	0.12	2.8	nd	14.4	6.6	1.3	0.3	0.2	58.35
Pedon 3											
Ap	0-12	7.19	0.15	4.1	nd	11.2	5.7	3.2	0.1	0.2	82.50
Bw1	12-28	7.28	0.24	3.7	nd	12.5	7.3	3.4	0.1	0.2	87.76
Bw2	28-55	7.34	0.17	2.8	2.6	13.9	8.2	3.7	0.2	0.2	88.80
BC	55-90+	7.45	0.22	2.4	4.5	15.3	9.4	4.2	0.2	0.2	91.40
Pedon 4											
Ap	0-11	7.31	0.17	3	2.4	17.6	8.6	3.1	0.1	0.2	68.27
A1	11-38	6.73	0.18	1.9	2.6	12.8	6.2	2.4	0.1	0.2	69.54
BC	38-72	7.48	0.16	1.6	4.8	10.6	5.1	2	0.1	0.2	70.25
Cr	72-90+	7.91	0.19	1.4	6.7	10.9	5.3	2.1	0.2	0.2	71.46
Pedon 5											
Ap	0-10	7.13	0.13	4.4	nd	15.2	9.2	2.9	0.5	0.4	85.45
Bw1	10-30	7.26	0.13	4.2	1.5	16.7	11.4	2.3	0.7	0.2	87.52
Bw2	30-60	7.36	0.17	3.4	3.4	18.1	12.2	3.3	0.6	0.2	90.21
BC	60-90+	7.43	0.14	2.5	6.2	19.1	13.3	3.6	0.5	0.2	92.14
Pedon 6											
Ap	0-16	7.06	0.19	4.7	nd	6.9	2.2	1.1	0.1	0.3	54.01
Bt1	16-33	7.12	0.15	4.3	nd	9.8	3.7	1.3	0.2	0.4	59.65
Bt2	33-65	7.28	0.13	4.1	nd	20.4	7.5	3	0.2	0.5	62.02
BC	65-110+	7.37	0.11	2.7	3.1	14.2	5.1	2.7	0.3	1	64.27

Soil Classification

Based on morphological characteristics and soil properties of the typifying pedons, the soils were classified upto sub group level (Soil Survey Staff, 2014) [22]. These soils were classified in to the order Entisols, Alfisols and Inceptisols. Whereas, pedon 4 do not have any diagnostic horizon was classified as Entisols. Pedon 1, 3 and 5 which have Cambic (Bw) sub-surface diagnostic horizon were classified under Inceptisols. Pedon 2 and 6 which have Argillic (Bt) sub-surface diagnostic horizon were classified under Alfisols.

Pedon 1, 3 and 5 which have Cambic (Bw) sub-surface diagnostic horizon were classified under Inceptisols. Pedons 1, 3 and 5 were grouped under Ustepts at sub-order level due to Ustic soil moisture regime and Haplustepts at great group level because these pedons did not have either duripan or calcic horizon and base saturation was more than 60% at depth between 0.15 to 0.75 m from the surface. However, pedons 1, 3 and 5 did not exhibit intergradations with other taxa or an extragradation from central concept. Hence, these pedons were logically classified as Typic Halpustepts at sub-group level.

Pedon 4 was classified as Typic Ustorthent at sub-group level as it is do not have aquic conditions and sulfidic materials with in 50 cm of the mineral soil surface and do not have less than 35 percent (by volume) rock fragments and texture class of sandy loam in all layers and had Ustic moisture regime. Whereas, in the pedon 4 of Ap horizon is exhibited sandy clay loam texture due to addition tank silt.

Pedon 2 and 6 were grouped under Ustalfs at sub-order level due to Ustic soil moisture regime and Haplustalfs at great group level because these pedons shown the following characteristics, presence of an Argillic horizon and absence of nitric, petro calcic, duripan and plinthite horizons. Hence, these pedons were logically classified as Typic Haplustalfs at sub group level.

Nutreint Status

Macro nutrients

The available N content of open cast coal mine surrounding cultivated soil pedons of Ramakrishnapur area varied from 101.7 to 292.4 kg ha^{-1} (Table 5). However, available N content found to be maximum in surface horizons and decreased regularly with depth which is due to decreasing trend of organic carbon with depth and cultivation of crops are mainly confined to the surface horizon only (Panwar *et al.*,2011) [11].

Table 5: Available major nutrients (kg ha^{-1}), sulphur and micronutrient content (mg kg^{-1}) of soil pedons sourinding opencast coal mine area of Ramakrsihnapur

Pedon No. & Horizon	Depth (cm)	Available macronutrients			S	Available micronutrients				Ca / Mg	CEC / Clay
		N	P	K		Zn	Cu	Fe	Mn		
		kg ha^{-1}			mg kg^{-1}	mg kg^{-1}					
Pedon 1											
Ap	0-15	225.2	15.55	198.5	37.45	0.54	2.12	3.54	2.12	3.35	0.67
Bw1	15-40	209.5	12.42	177.2	26.68	0.42	1.40	2.16	2.04	3.72	0.72
Bw2	40-75	185.8	10.28	152.3	25.80	0.36	0.46	1.52	2.26	3.00	0.67
Bw3	75-105+	143.4	9.01	135.1	18.61	0.28	0.24	1.02	1.85	3.26	0.66
Pedon 2											
Ap	0-10	165.5	17.38	314.7	27.93	0.56	1.82	9.51	1.92	2.82	0.64
Bt1	10-30	182.3	20.22	259.8	24.55	0.45	2.54	6.23	2.11	4.17	0.57
Bt2	30-60	195.1	23.65	203.8	15.58	0.36	1.36	7.86	2.45	4.54	0.51
BC	60-90+	138.7	15.31	155.7	12.94	0.23	0.82	5.34	1.63	5.08	0.50
Pedon 3											
Ap	0-12	292.4	35.25	360.6	25.32	1.21	3.20	16.76	5.92	1.78	0.61
Bw1	12-38	226.1	24.42	295.7	24.75	0.95	2.62	13.45	4.26	2.15	0.61
Bw2	28-55	157.8	15.36	170.2	21.33	0.84	2.14	11.61	3.18	2.22	0.55
BC	55-90+	123.6	12.72	146.7	20.95	0.38	1.85	10.57	2.65	2.24	0.54
Pedon 4											
Ap	0-11	184.2	12.51	181.2	34.43	0.38	0.76	7.62	11.06	2.77	0.62
A1	11-38	156.5	11.27	168.4	24.82	0.36	0.65	6.24	9.28	2.58	0.82
BC	38-72	125.2	9.32	145.6	14.48	0.22	0.62	5.41	7.42	2.55	0.72
Cr	72-90+	103.2	7.14	126.2	10.41	0.17	0.54	2.36	5.31	2.52	0.61
Pedon 5											
Ap	0-10	194.8	53.78	366.2	35.45	1.92	2.84	14.51	18.24	3.17	0.75
Bw1	10-30	182.2	41.63	258.7	25.24	0.96	2.13	12.52	12.88	4.96	0.71
Bw2	30-60	147.5	36.45	161.3	23.73	0.73	1.72	11.26	10.52	3.70	0.67
BC	60-90+	101.7	11.25	126.5	22.98	0.51	1.14	7.89	8.46	3.69	0.67
Pedon 6											
Ap	0-16	185.5	16.65	336.3	38.48	0.86	3.56	17.26	15.79	2.00	0.48
Bt1	16-33	147.2	15.75	266.6	25.43	0.62	2.75	14.31	14.12	2.85	0.47
Bt2	33-65	139.4	14.42	181.4	24.68	0.54	2.15	10.93	11.26	2.50	0.65
BC	65-110+	123.3	18.90	105.1	16.95	0.43	1.84	7.12	9.87	1.89	0.51

The available P content of open cast coal mine surrounding cultivated soil pedons of Ramakrishnapur varied from 7.14 to 53.78 kg ha^{-1}. In general, higher available Phosphorus was observed in the surface horizons and decreased regularly with depth. The reason for high available phosphorus in surface horizons might possibly be due to the confinement of crop cultivation to the rhizosphere which improves the organic carbon content in surface and supplementing the depleted Phosphorus by external sources *i.e.,* fertilizers and presence of small amounts of free iron oxide and exchangeable Al^{3+} in the surface horizons (Thangasamy *et al.,* 2005) [23].

Available K content of open cast coal mine surrounding cultivated soil pedons of Ramakrishnapur soils varied from 105.1 to 366.2 kg ha^{-1}. In all the pedons showed a consistent

and gradual decreasing trend in available K status with increasing depth. The higher content of available potassium in surface layers was probably due to more intense weathering releases of labile-K from organic residues and translocated of the element from lower depth with capillary risk of ground water (Rudramurthy *et al.,* 2007) [15]. The available sulphur in soils varied from 10.41 to 38.48 mg kg^{-1}. The higher sulphur levels in open cast mining area may be attributed to coal dust accumulation on soils which contains pyritic minerals and also addition of mine spoil which contains more sulphur (Madhavi, 2014) [9].

Micro Nutrients

The DTPA-extractable Zn of open cast coal mine surrounding cultivated soil pedons of Ramakrishnapur ranged from 0.17 to 1.92 mg kg^{-1} soil considering 0.60 mg kg^{-1} as critical level (Lindsay and Norvell 1978) [8]. A decreasing trend with depth was noticed in all the pedons. Less available zinc in deeper layers was due to low amount of organic carbon in the deeper layers (Kumar *et al.,* 2011). All the pedons were found to be sufficient in available Cu (0.24 to 3.56 mg kg^{-1}) as all the values were well above critical limit of 0.20 mg kg^{-1} soil as suggested by Lindsay and Norvell (1978) [8]. The DTPA-extractable Fe content varied from 1.02 to 17.26 mg kg^{-1}. The pedons were found to be deficient to sufficient in available iron as all the values were above critical level of 4.5 mg kg^{-1} as suggested by Lindsay and Norvell (1978) [8]. All the pedons iron was showed a decreasing trend with depth, it might be due to accumulation of humic material in the surface layers besides prevalence reduced conditions in sub-surface layers (Rao *et al.,* 2008 and Kumar *et al.,* 2011) [14, 6].

Available Mn of open cast coal mine surrounding cultivated soil pedons of Ramakrishnapur varied from 1.63 to 18.24 mg kg^{-1} soil. The soils were found to be sufficient in available manganese as all the values were above critical limit of 1.0 mg kg^{-1} as suggested by Lindsay and Norvell (1978) [8]. Available manganese content was high in the surface horizons and gradually decreased with depth which might be due to comparatively higher biological activity in surface soils (Murthy *et al.,* 1997) [10].

Conclusions

Based on morphological, physical and physico-chemical properties of cultivated surrounding soils Ramakrishnapur open cast coal mine were neutral to moderately alkaline, non-saline, low to medium in organic carbon and CEC. The exchangeable bases in all the pedons in the order of $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$ on the exchange complex. Whereas, low to medium in available N, low to high in available P and K and high in available S and available micro nutrients were deficient to sufficient. Whereas, Zn and Fe showed deficient to sufficient. The soils were classified as Typic Ustorthents, Typic Haplustalfs and Typic Haplustepts at sub-group level.

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