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Chemical Composition of Soils of Krishna delta Region in Andhra Pradesh

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ABSTRACT

Horizon-wise soil samples from fourteen pedons representing Krishna delta region of Andhra Pradesh were analyzed for elemental composition. The study revealed that silica and sesquioxides were the dominant fractions contributing to more than 75 per cent followed by calcium and magnesium oxides. The coarse textured pedons registered higher SiO_2 / R_2O_3, SiO_2 / Al_2O_3 and SiO_2 / Fe_2O_3 ratios due to higher silica and lower sesquioxide content than fine textured soils.In much of the study area silica/ alumina and silica/iron oxide ratios increased with depth. The order of other elements was found to be Na>K>Mn>P_2O_5>CuO>ZnOin soils represented by majority of the pedons.

Key words: *Molar concentration, Molar ratios, P_2O_5, K_2O, Na_2O, CaO, MgO, ZnO and CuO.*

Soils are the ultimate products of interplay of various soil forming factors which include climate, organisms, topography, parent material and time. Soil development majorly depends on the active factors like climate and vegetation, which results in variable composition of soils. The nature of parent material whether transported or *in-situ* also decides the composition of soils and in turn the related properties like extent of profile development, drainage and nutrient status of soils. The silica, sesquioxide contents and molar ratios of pedons provide basic information regarding profile development in relation to parent material and degree of weathering. On the other hand, contents of iron and aluminium oxides serve as useful indicators to identify the accumulation of secondary oxides in horizons, stage and degree of soil development. The silica-sesquioxide content and their molar ratios also help in detecting the differences in mineral composition, which are not revealed by x-ray diffraction or the other methods. The content of constituent oxides of soil indicates the total content of different nutrients present in soils.The soils of Krishna delta region were formed on fluvial and coastal sediments occupying an extent of 6240 sq.km. In the present study the soils of the region were characterized for their elemental composition to understand the soil development.

MATERIAL AND METHODS

Geographically the Krishna delta region was located between 15.75^0 to 16.56^0 N latitude and 80.31^0 to 81.33^0 E longitude. Based on the visual interpretation of satellite data and ground truth,fourteen representative pedons were selected in villages Penalmalur, Mudinepalli, Pamarru, Dokiparru, Gollapalli, Chitturpu, Modumudi, Avanigadda, Chodavaram, Talagadadevi, Cherukupalli, Pandurangapuram, Kakumanu and Kondapaturu.Horizon-wise soil samples were collected, processed and analyzed. The acid extract was prepared with nitric acid and perchloric acid mixture and filtered through Whatman no. 41 filter paper and the residue was washed with 0.5M HCl and finally the filtrate volume was made up to 250 mLwith distilled water (Hesse, 1971).The residue left over on the filter paper was washed with warm distilled water until it was free from chlorides. Then the residue along with filter paper was ignited in a muffle furnace, cooled and percentage of silica was calculated from constant weight. The sesquioxides were determined by taking 100 mL of acid extract and the iron and aluminium were precipitated by adding methyl red and (1:1) ammonium hydroxide in the presence of ammonium chloride (1 g). The precipitate was filtrated using Whatman No. 41 and washed with warm distilled water until it was free of chlorides. The residue along with the filter paper was dried, ignited at 800^oC for 4 hours, cooled and weighed to a constant weight. The results are expressed as per cent sesquioxides. Atomic absorption spectrophotometer was used for the estimation of iron in the silica free acid extract and results are expressed as per cent iron oxide. Alumina

content was obtained deducting iron oxide from total sesquioxide content (Hesse, 1971).The molar concentrations of silica, Al_2O_3 and Fe_2O_3 were calculated by dividing content in per cent with their respective molecular weights.Calcium and magnesium were estimated by Versenate method (Kanwar and Chopra, 1976).The total phosphorus content in acid extract was estimated by ascorbic acid blue colour method.Manganese, copper and zinc in the acid extract were determined using atomic absorption spectrophotometer.Potassium and sodium were estimated by aspirating acid extract into the flame photometer (Jackson, 1973).

RESULTS AND DISCUSSION

Silica, Sesquioxides and their Molar Ratios

Silica and sesquioxide contents

The results of analyzed data reported that total silica content (Table 1) varied from 37.98 to 98.62 per cent. The silica content in fine textured pedons (1, 2, 3, 4, 5, 6, 7, 8, 10, 13 and 14) varied between 37.98 and 69.29 per cent while, coarse textured pedons (11 and 12) recorded silica content of 53.76 to 98.62 per cent. Pedon 9 with variable texture recorded 54.18 to 73.7 per cent silica, which followed an increasing trend with depth. The surface horizons of all fine textured pedons reported higher silica content than sub-surface horizons, it could be due to increase in clay content with depth. All the fine textured pedons more or less showed a decreasing trend with depth due to high clay content and low sand content in deeper layers. The silica content showed highly significant positive correlation with sand (r = +0.771**). Silica content was comparatively higher in coarse textured soils than in fine textured soils.

Sesquioxide (R_2O_3) content of the pedons ranged from 1.48 to 29.20 per cent.Fine textured pedons(1, 2, 3, 4, 5, 6, 7, 8, 10, 13 and 14) recorded higher sesquioxidescontent (16.00 to 29.20 %) as compared to coarse textured pedons11 and 12(1.48 to 7.03 %). The sesquioxide content in variable textured pedon 9 ranged from 7.72 to 17.00 per cent.The sesquioxide content increased with clay content. This can be evidenced by highly significant positive correlation (r = +0.894**) between clay and sesquioxides.

The pattern of distribution of alumina followed the same trend as that of sesquioxides down the profile. Contribution of alumina to the seaquioxide content was major. Similar findings were reported by Singh *et al*. (1998) in TypicHaplusterts of Sone river basin of Bihar. The aluminum oxide content varied from 0.34to 22.31 per cent.The fine textured pedons (1, 2, 3, 4, 5, 6, 7, 8, 10, 13 and 14) recorded higher amount of aluminum oxide content ranging from 7.70 to 22.31 per cent as compared to coarse textured pedons (11 and 12), which varied from 0.34 to 5.21 per cent.

The iron oxide content in pedons of Krishna delta soils ranged from 0.82 to 11.60 per cent.Pedons 3, 6 and 10 exhibited almost an increasing trend with depth while, pedons 4 and 7 showed an increasing trend up to 120 and 75 cm, respectively and later decreased with depth. However, remaining pedons did not show any specific depth function.The increase iniron oxide content with soil depth, revealed the translocation of free iron oxide along with clay.

Molar concentration

The molar concentration of silica, sesquioxide, Al_2O_3 and Fe_2O_3 in Krishna delta soils (Table 2) ranged from 0.633 to 1.644, 0.011 to 0.255, 0.003 to 0.219 and 0.005 to 0.073, respectively. The silica concentration nearly decreased with depth except in pedons 2, 9, 11 and 12, which indicate poor drainage condition and clay content increases with depth. Coarse textured pedons recorded higher concentration of silica than fine textured pedons.The highest sesquioxide concentration was observed in horizon Bss1 of pedon 2 (0.255) whereas, the lowest sesquioxide concentration was reported in pedon 12 (0.011) in 2C1 and 2C2 horizons.

The highest value of $Al_2O_3$was observed in Ap horizon of pedon 1 whereas, the lowest value was reported in 2C1 horizon of pedon 12. The highest value $Fe_2O_3$was observed in Bss2 horizon of pedon 7 whereas, the lowest value was reported in 2C3 horizon of pedon 12.

Molar ratios

The silica / sesquioxide values (Table 2) in Krishna delta soils ranged from 3.13 to 148.30 with the highest and lowest values recorded in 2C1 and 2C2 horizons in pedon 12 and Bss2 of pedon 8, respectively. The ratio of silica to sesquioxide was

Table 1. Chemical composition of the soils (silica and sesquioxides).

Profile No.& horizon	Depth (m)	SiO_2(%)	R_2O_3 (%)	Fe_2O_3 (%)	Al_2O_3 (%)
Pedon 1					
Ap	0-15	67.16	27.98	5.66	22.31
AB	15-40	69.29	26.28	7.94	18.33
Bw1	40-60	67.37	27.20	8.77	18.43
Bw2	60-90	59.33	27.52	8.30	19.22
Bw3	90-130	56.56	28.10	7.89	20.21
Pedon 2					
Ap	0-18	58.95	25.15	9.34	15.81
Bw	18-43	61.53	22.58	9.23	13.35
Bss1	43-72	58.87	29.20	8.84	20.36
Bss2	72-90+	57.04	28.08	9.04	19.04
Pedon 3					
Ap	0 -20	66.09	17.90	8.78	9.12
Bw	20-40	62.87	21.00	9.19	11.81
Bss1	40-55	58.70	21.65	9.19	12.46
Bss2	55-74	56.15	22.55	10.33	12.22
Bss3	74-100	56.17	23.87	10.72	13.16
Bss4	100-140	58.52	25.83	10.79	15.04
Pedon 4					
Ap	0-15	58.07	17.88	8.89	8.98
Bw1	15-40	60.15	17.75	9.90	7.85
Bw2	40-60	58.07	17.88	10.19	7.68
Bss1	60-90	57.02	19.72	10.58	9.15
Bss2	90-120	55.81	24.07	11.06	13.01
Bss3	120-150	46.46	24.80	10.79	14.01
Pedon 5					
Ap	0-15	67.96	16.00	8.30	7.70
AB	15-35	66.56	16.40	9.01	7.39
Bw1	35-60	63.25	18.30	8.48	9.82
Bw2	60-80	61.85	17.88	9.11	8.77
Bw3	80-100	68.34	17.13	11.15	5.97
Bw4	100-120	61.53	18.45	9.56	8.89
Pedon 6					
Ap	0-20	68.05	18.75	8.70	10.05
AB	20-35	57.25	18.08	8.97	9.11
Bss1	35-63	56.91	16.97	9.24	7.74
Bss2	63-90	58.90	18.50	9.20	9.30
Bss3	90-110	55.46	19.40	9.40	10.00
Pedon 7					
Ap	0-15	59.06	18.28	10.52	7.75
AB	15-36	56.50	22.78	11.00	11.77
Bss1	36-56	54.30	22.50	11.12	11.38
Bss2	56-75	59.54	21.85	11.60	10.25

Table 1. cont...

Profile No. & horizon	Depth (m)	SiO_2 (%)	R_2O_3 (%)	Fe_2O_3 (%)	Al_2O_3 (%)
Pedon 8					
Ap	0-20	61.72	20.42	9.86	10.71
AB1	20-40	55.93	20.58	10.15	10.27
AB2	40-60	47.80	21.82	9.80	12.02
Bw1	60-80	41.80	22.27	10.18	12.09
Bw2	80-115	42.44	22.90	10.05	12.85
Bss	115-150	37.98	24.38	10.47	13.91
Pedon 9					
Ap	0-10	54.18	17.00	7.68	9.32
A2	10-22	70.04	9.53	6.73	2.80
AC1	22-40	70.04	8.70	5.26	3.44
AC2	40-60	72.99	11.38	6.52	4.85
AC3	60-90+	73.70	7.72	5.85	1.87
Pedon 10					
Ap	0-15	59.9	20.90	8.83	12.07
AB1	15-35	58.64	20.42	9.15	11.27
AB2	35-50	58.08	23.27	9.65	13.62
Bw1	50-70	55.10	24.18	10.14	14.03
Bw2	70-100	49.13	24.30	10.01	14.29
Pedon 11					
^Ap	0-15	53.76	7.03	1.82	5.21
AC	15-40	72.60	2.25	1.73	0.52
2C1	40-65	75.75	2.00	0.94	1.06
2C2	65-85	85.54	2.35	1.50	0.85
2C3	85-110	83.73	1.88	1.43	0.44
Pedon 12					
^Ap	0-15	88.90	2.63	1.09	1.53
AC	15-38	87.75	1.67	1.17	0.51
2C1	38-60	95.74	1.53	1.18	0.34
2C2	60-75	97.54	1.48	0.99	0.49
2C3	75-90	98.62	2.90	0.82	2.08
Pedon 13					
Ap	0-15	53.39	19.15	7.54	11.61
AB	15-35	51.30	21.25	7.83	13.42
Bss1	35-60	42.04	23.10	8.14	14.96
Bss2	60-80	50.70	24.30	7.37	16.93
Bss3	80-100	59.36	24.65	7.49	17.16
Bss4	100-130	57.49	23.98	8.10	15.88
Pedon 14					
Ap	0-20	51.10	20.12	7.24	12.89
Bw1	20-40	49.20	20.20	7.33	12.87
Bw2	40-65	46.01	20.85	7.12	13.73
Bss1	65-90	49.27	22.18	6.85	15.32
Bss2	90-115	45.20	24.35	7.05	17.30
Bss3	115-140	45.18	24.90	7.31	17.59

Λ Transported soil

more than 2.5 indicating the soils were non-lateritic. Similar results were reported by Gidisagu and Gawu (2016) in black soils.The silica / alumina ratios varied from 4.36 to 476.17 with the highest value of 476.17 observed in 2C1 horizon of pedon 12 and the lowest value of 4.36 was noticed in Bss3 horizon of pedon 14. The silica / iron oxide ratio varied from 9.66 to 320.26. The highest value of 320.26 was recorded in 2C3 horizon of pedon 12 while, the lowest value of 9.66 was noticed in Bss2 horizon of pedon 8.

The Al_2O_3 / Fe_2O_3 ratios ranged from 0.45 to 6.17. The lowest value of 0.45 was exhibited by 2C1 horizon of pedon 12 while, the highest value of 6.17 was recorded in Ap horizon of pedon 1.

The critical observation of data emphasized that majority of pedons in the Krishna delta region outline narrow SiO_2 / R_2O_3 and SiO_2 / Al_2O_3 ratios except pedons 9, 11 and 12, which might be due to higher clay content and less sand content while, pedons 9, 11 and 12 reported wider SiO_2 / R_2O_3 and SiO_2 / Al_2O_3 ratios which could be ascribed to silication, a dominant process operating in these pedons. High ratios in coarse textured soils could be due to less weathering and profile development (ref). Overall a decline in these ratios in soil indicates poor drainage (ref). Similar observations were reported by Manjulatha*et al*. (2001) in soils of Guntur district.

The irregular trend of SiO_2 / R_2O_3, SiO_2 / Al_2O_3 and Al_2O_3 / Fe_2O_3 could be attributed to heterogeneous nature of parent materials (Khan *et al*., 1997). Variations within the pedons could be due to variation in chemical composition of parent material deposited at different periods in the past. The results are in concurrence with those of Tiwary and Mishra (1992). The decreasing trend of SiO_2 / R_2O_3 and SiO_2 / Al_2O_3 ratios with depth might be due to decrease in sand content and increase in clay content.

The higher SiO_2 / R_2O_3, SiO_2 / Al_2O_3 and SiO_2 / Fe_2O_3 ratios might be due to siliceous nature of the parent material and earlier stage of weathering. Similar results were also reported by (Ramalakshmi*et al*., 2001) in Psamments of Bapatla-Karlapalem region of Guntur, Andhra Pradesh and in the eastern region of Varanasi (Singh and Agarwal, 2005).

Phosphorus Pentoxide (P_2O_5)

The P_2O_5 content of the pedons ranged from 0.003 to 0.069 per cent. The highest value of 0.069 per cent was noticed in AB horizon of pedon1 and the lowest value of 0.003 per cent was observed in both 2C2 and 2C3 horizons of pedon 12.

The total P_2O_5 content decreased with depth. High total phosphorus in soil might be due to use of higher dose of phosphatic fertilizers. This could also be attributed to addition of manures or crop residues, which contribute considerable as contributing of organic phosphorus are high. This can be evident by significant correlation between organic carbon and total P_2O_5 (r=+0.488**). The accumulation was better reflected in black soils due to restricted leaching and drainage. Relatively higher values of P_2O_5 in the soils might also be due to the occurrence of phosphorus bearing minerals. Similar findings were reported by Thangasamy*et al*. (2004) and Raina *et al*. (2006).

Potassium Oxide (K_2O)

The potassium oxide values ranged from 0.045 to 0.804 per cent. The lowest value of 0.045 per cent was noticed in pedon 12 and the highest value of 0.804 per cent was observed in pedon 14. Total potassium was higher in fine textured soils and relatively less in coarse textured soils. Wide variation in potassium might be due to variation in parent material and irregular distribution of clay in the profiles. Lower quantity of K_2O in all the pedons suggests the presence of low amount of K-bearing minerals like micaceous minerals. These findings are in conformity with those of Thangasamy*et al*. (2004).

Sodium Oxide (Na_2O)

The sodium oxide content ranged from 0.084 to 0.753 per cent. The lowest value of 0.084 per cent was observed in ^Aphorizon (transported horizon) of pedon 12. The highest value of 0.753 per cent was noticed in Aphorizon of pedon 1.

Calcium Oxide (CaO)

The calcium oxide values of Krishna delta soils ranged from 0.84 to 8.05 per cent. The lowest value of 0.84 per cent was noticed in 2C2 horizon of pedon 12 and the highest value of 8.05 per cent

Table 2. Molar concentrations and molar ratios of the soils.

Profile No.& horizon	depth (m)	Molar concentration				Molar ratio			
		SiO_2	Fe_2O_3	Al_2O_3	R_2O_3	SiO_2 / R_2O_3	SiO_2/ Al_2O_{-3}	SiO_2/ Fe_2O_3	Al_2O_{-3}/ Fe_2O_3
Pedon 1									
Ap	0-15	1.119	0.035	0.219	0.254	4.40	5.11	31.57	6.17
AB	15-40	1.155	0.050	0.180	0.230	5.03	6.42	23.22	3.61
Bw1	40-60	1.123	0.055	0.181	0.236	4.76	6.21	20.44	3.29
Bw2	60-90	0.989	0.052	0.189	0.241	4.11	5.24	19.02	3.63
Bw3	90-130	0.943	0.049	0.198	0.248	3.81	4.76	19.08	4.01
Pedon 2									
Ap	0-18	0.982	0.058	0.155	0.214	4.60	6.34	16.80	2.65
Bw	18-43	1.026	0.058	0.131	0.189	5.43	7.83	17.74	2.26
Bss1	43-72	1.148	0.055	0.200	0.255	4.50	5.75	20.74	3.61
Bss2	72-90+	1.184	0.057	0.187	0.243	4.87	6.34	20.92	3.30
Pedon 3									
Ap	0 -20	1.102	0.055	0.089	0.144	7.63	12.31	20.04	1.63
Bw	20-40	1.048	0.058	0.116	0.173	6.04	9.04	18.21	2.01
Bss1	40-55	0.978	0.058	0.122	0.180	5.44	8.01	17.00	2.12
Bss2	55-74	0.936	0.065	0.120	0.185	5.07	7.81	14.46	1.85
Bss3	74-100	0.936	0.067	0.129	0.196	4.77	7.26	13.95	1.92
Bss4	100-140	0.975	0.068	0.148	0.215	4.54	6.61	14.44	2.18
Pedon 4									
Ap	0-15	0.968	0.056	0.088	0.144	6.73	10.99	17.38	1.58
Bw1	15-40	1.003	0.062	0.077	0.139	7.21	13.03	16.16	1.24
Bw2	40-60	0.968	0.064	0.075	0.139	6.95	12.84	15.16	1.18
Bss1	60-90	0.950	0.066	0.090	0.156	6.09	10.59	14.35	1.35
Bss2	90-120	0.930	0.069	0.128	0.197	4.72	7.29	13.43	1.84
Bss3	120-150	0.774	0.068	0.137	0.205	3.78	5.63	11.46	2.03
Pedon 5									
Ap	0-15	1.133	0.052	0.075	0.127	8.88	15.01	21.78	1.45
AB	15-35	1.109	0.056	0.072	0.129	8.61	15.31	19.66	1.28
Bw1	35-60	1.054	0.053	0.096	0.149	7.06	10.95	19.84	1.81
Bw2	60-80	1.031	0.057	0.086	0.143	7.21	11.99	18.08	1.51
Bw3	80-100	1.139	0.070	0.059	0.128	8.87	19.45	16.31	0.84
Bw4	100-120	1.026	0.060	0.087	0.147	6.97	11.76	17.13	1.46
Pedon 6									
Ap	0-20	1.134	0.054	0.099	0.153	7.41	11.51	20.82	1.81
AB	20-35	0.954	0.056	0.089	0.145	6.56	10.68	16.99	1.59
Bss1	35-63	0.948	0.058	0.076	0.134	7.09	12.50	16.40	1.31
Bss2	63-90	0.982	0.058	0.091	0.149	6.60	10.77	17.03	1.58
Bss3	90-110	0.924	0.059	0.098	0.157	5.89	9.43	15.70	1.67
Pedon 7									
Ap	0-15	0.984	0.066	0.076	0.142	6.94	12.95	14.94	1.15
AB	15-36	0.942	0.069	0.115	0.184	5.11	8.16	13.67	1.68
Bss1	36-56	0.905	0.070	0.112	0.181	4.99	8.11	13.00	1.60
Bss2	56-75	0.992	0.073	0.100	0.173	5.73	9.87	13.66	1.38
Bss3	75-105	0.917	0.060	0.124	0.184	4.99	7.42	15.22	2.05
Bss4	105-130	0.877	0.062	0.155	0.217	4.04	5.64	14.19	2.52

Contd….

Table 2. cont.....

Profile No.& horizon	depth (m)	Molar concentration				Molar ratio			
		SiO_2	Fe_2O_3	Al_2O_3	R_2O_3	SiO_2 / R_2O_3	SiO_2/ Al_2O_{-3}	SiO_2/ Fe_2O_3	Al_2O_{-3}/ Fe_2O_3
Pedon 8									
Ap	0-20	1.029	0.062	0.105	0.167	6.17	9.79	16.66	1.70
AB1	20-40	0.932	0.064	0.101	0.164	5.67	9.25	14.67	1.59
AB2	40-60	0.797	0.061	0.118	0.179	4.44	6.76	12.98	1.92
Bw1	60-80	0.697	0.064	0.119	0.182	3.82	5.87	10.92	1.86
Bw2	80-115	0.707	0.063	0.126	0.189	3.74	5.61	11.24	2.00
Bss	115-150	0.633	0.066	0.136	0.202	3.13	4.64	9.66	2.08
Pedon 9									
Ap	0-10	0.903	0.048	0.091	0.140	6.47	9.88	18.77	1.90
A2	10-22	1.167	0.042	0.027	0.070	16.78	42.56	27.71	0.65
AC1	22-40	1.167	0.033	0.034	0.067	17.50	34.57	35.46	1.03
AC2	40-60	1.217	0.041	0.048	0.088	13.75	25.55	29.79	1.17
AC3	60-90+	1.228	0.037	0.018	0.055	22.32	66.80	33.53	0.50
Pedon 10									
Ap	0-15	0.998	0.055	0.118	0.174	5.75	8.43	18.05	2.14
AB1	15-35	0.977	0.057	0.111	0.168	5.82	8.84	17.05	1.93
AB2	35-50	0.968	0.060	0.134	0.194	4.99	7.25	16.01	2.21
Bw1	50-70	0.918	0.064	0.138	0.201	4.57	6.67	14.46	2.17
Bw2	70-100	0.819	0.063	0.140	0.203	4.04	5.84	13.06	2.24
Pedon 11									
^Ap	0-15	0.896	0.011	0.051	0.062	14.35	17.54	78.71	4.49
AC	15-40	1.210	0.011	0.005	0.016	75.88	235.57	111.93	0.48
2C1	40-65	1.263	0.006	0.010	0.016	77.55	121.52	214.32	1.76
2C2	65-85	1.426	0.009	0.008	0.018	80.46	171.59	151.49	0.88
2C3	85-110	1.396	0.009	0.004	0.013	104.79	320.06	155.79	0.49
Pedon 12									
^Ap	0-15	1.482	0.007	0.015	0.022	67.76	98.70	216.20	2.19
AC	15-38	1.463	0.007	0.005	0.012	119.07	294.71	199.78	0.68
2C1	38-60	1.596	0.007	0.003	0.011	148.28	476.17	215.34	0.45
2C2	60-75	1.626	0.006	0.005	0.011	148.28	340.38	262.74	0.77
2C3	75-90	1.644	0.005	0.020	0.026	64.37	80.55	320.26	3.98
Pedon 13									
Ap	0-15	0.890	0.047	0.114	0.161	5.52	7.81	18.85	2.41
AB	15-35	0.855	0.049	0.132	0.181	4.73	6.50	17.44	2.69
Bss1	35-60	0.701	0.051	0.147	0.198	3.54	4.78	13.74	2.88
Bss2	60-80	0.845	0.046	0.166	0.212	3.98	5.09	18.31	3.60
Bss3	80-100	0.989	0.047	0.168	0.215	4.60	5.88	21.10	3.59
Bss4	100-130	0.958	0.051	0.156	0.206	5.45	7.22	22.18	3.07
Pedon 14									
Ap	0-20	0.852	0.045	0.126	0.172	4.96	6.74	18.79	2.79
Bw1	20-40	0.820	0.046	0.126	0.172	4.76	6.50	17.86	2.75
Bw2	40-65	0.767	0.045	0.135	0.179	4.28	5.70	17.19	3.02
Bss1	65-90	0.821	0.043	0.150	0.193	4.25	5.46	19.14	3.50
Bss2	90-115	0.753	0.044	0.170	0.214	3.52	4.44	17.06	3.84
Bss3	115-140	0.753	0.046	0.173	0.218	3.45	4.36	16.45	3.77

Λ Transported soil

Table 3. Chemical composition of soils.

Profile No. & horizon	depth (m)	P_2O_5	K_2O	Na_2O	CaO	MgO	MnO_2	CuO	ZnO
		(%)							
Pedon 1									
Ap	0-15	0.025	0.465	0.753	1.75	0.88	0.282	0.017	0.012
AB	15-40	0.069	0.309	0.439	1.58	0.50	0.125	0.014	0.015
Bw1	40-60	0.038	0.252	0.098	2.10	0.63	0.231	0.015	0.013
Bw2	60-90	0.032	0.192	0.122	4.90	1.50	0.229	0.014	0.011
Bw3	90-130	0.029	0.180	0.128	2.45	0.38	0.171	0.013	0.011
Pedon 2									
Ap	0-18	0.031	0.240	0.115	2.80	0.25	0.179	0.017	0.014
Bw	18-43	0.034	0.255	0.513	3.15	0.75	0.190	0.017	0.014
Bss1	43-72	0.046	0.279	0.405	2.10	10.77	0.182	0.014	0.018
Bss2	72-90+	0.032	0.273	0.419	2.45	0.75	0.208	0.016	0.013
Pedon 3									
Ap	0 -20	0.023	0.237	0.405	2.10	2.00	0.191	0.014	0.014
Bw	20-40	0.020	0.258	0.371	1.75	1.25	0.201	0.015	0.014
Bss1	40-55	0.023	0.255	0.368	2.80	0.75	0.151	0.016	0.014
Bss2	55-74	0.042	0.318	0.392	2.10	1.25	0.232	0.018	0.016
Bss3	74-100	0.044	0.327	0.388	2.35	1.27	0.231	0.018	0.018
Bss4	100-140	0.048	0.351	0.388	4.20	2.25	0.224	0.019	0.017
Pedon 4									
Ap	0-15	0.047	0.309	0.294	2.80	0.25	0.196	0.019	0.017
Bw1	15-40	0.045	0.309	0.395	2.10	1.25	0.203	0.018	0.015
Bw2	40-60	0.039	0.330	0.473	3.15	0.75	0.201	0.018	0.016
Bss1	60-90	0.036	0.303	0.527	2.10	1.00	0.201	0.018	0.019
Bss2	90-120	0.039	0.456	0.641	2.80	0.75	0.190	0.021	0.017
Bss3	120-150	0.026	0.462	0.624	2.45	0.25	0.174	0.018	0.017
Pedon 5									
Ap	0-15	0.043	0.288	0.351	3.50	0.63	0.135	0.015	0.014
AB	15-35	0.040	0.231	0.402	5.60	0.88	0.247	0.014	0.014
Bw1	35-60	0.038	0.195	0.459	3.33	0.38	0.172	0.017	0.016
Bw2	60-80	0.033	0.195	0.486	4.20	0.88	0.194	0.016	0.015
Bw3	80-100	0.029	0.231	0.446	3.68	0.67	0.228	0.020	0.018
Bw4	100-120	0.028	0.234	0.439	3.12	0.46	0.229	0.018	0.016
Pedon 6									
Ap	0-20	0.051	0.249	0.300	3.15	1.00	0.187	0.014	0.013
AB	20-35	0.030	0.231	0.321	2.45	2.25	0.169	0.015	0.013
Bss1	35-63	0.016	0.228	0.307	2.31	1.26	0.173	0.015	0.012
Bss2	63-90	0.016	0.225	0.294	3.50	0.75	0.191	0.016	0.013
Bss3	90-110	0.015	0.246	0.311	2.80	0.50	0.198	0.016	0.013
Pedon 7									
Ap	0-15	0.059	0.360	0.263	3.85	2.76	0.228	0.020	0.016
AB	15-36	0.057	0.399	0.311	4.90	0.50	0.226	0.020	0.016
Bss1	36-56	0.053	0.402	0.361	2.42	0.00	0.227	0.020	0.016
Bss2	56-75	0.044	0.402	0.395	2.46	0.00	0.235	0.021	0.018
Bss3	75-105	0.033	0.408	0.405	1.85	0.65	0.210	0.017	0.016
Bss4	105-130	0.040	0.315	0.402	1.03	0.58	0.015	0.003	0.001

Table 3. Cont.....

Profile No. & horizon	depth (m)	P_2O_5	K_2O	Na_2O	CaO	MgO	MnO_2	CuO	ZnO
		(%)							
Pedon 8									
Ap	0-20	0.045	0.279	0.294	5.25	1.00	0.200	0.018	0.017
AB1	20-40	0.040	0.273	0.324	5.78	1.88	0.216	0.018	0.015
AB2	40-60	0.033	0.201	0.415	5.95	2.38	0.249	0.019	0.014
Bw1	60-80	0.029	0.162	0.523	5.95	2.13	0.193	0.021	0.018
Bw2	80-115	0.030	0.231	0.489	6.13	2.13	0.192	0.020	0.016
Bss	115-150	0.026	0.294	0.493	3.33	2.38	0.165	0.020	0.015
Pedon 9									
Ap	0-10	0.026	0.321	0.273	2.45	0.13	0.106	0.012	0.012
A2	10-22	0.015	0.216	0.253	2.80	1.00	0.098	0.010	0.011
AC1	22-40	0.014	0.123	0.257	2.45	0.25	0.109	0.008	0.009
AC2	40-60	0.014	0.108	0.294	1.37	0.21	0.116	0.012	0.012
AC3	60-90+	0.010	0.087	0.294	0.85	0.22	0.104	0.011	0.011
Pedon 10									
Ap	0-15	0.040	0.258	0.388	5.43	1.86	0.205	0.019	0.014
AB1	15-35	0.026	0.156	0.496	6.65	0.50	0.226	0.018	0.014
AB2	35-50	0.025	0.324	0.530	5.25	2.00	0.197	0.020	0.012
Bw1	50-70	0.028	0.336	0.547	8.05	1.25	0.251	0.020	0.012
Bw2	70-100	0.028	0.411	0.645	4.55	3.26	0.261	0.019	0.012
Pedon 11									
^Ap	0-15	0.013	0.096	0.125	2.10	0.50	0.035	0.001	0.002
AC	15-40	0.008	0.081	0.128	1.75	0.50	0.036	0.002	0.003
2C1	40-65	0.005	0.069	0.118	1.75	0.25	0.021	0.001	0.001
2C2	65-85	0.005	0.066	0.111	0.88	0.13	0.055	0.001	0.001
2C3	85-110	0.007	0.048	0.105	1.05	0.25	0.041	0.001	0.001
Pedon 12									
^Ap	0-15	0.006	0.060	0.084	1.58	0.38	0.039	0.002	0.001
AC	15-38	0.005	0.045	0.098	1.23	0.13	0.049	0.001	0.001
2C1	38-60	0.005	0.054	0.091	1.08	0.21	0.038	0.001	0.001
2C2	60-75	0.003	0.060	0.091	0.84	0.21	0.030	0.001	0.001
2C3	75-90	0.003	0.054	0.088	1.05	0.25	0.022	0.001	0.001
Pedon 13									
Ap	0-15	0.055	0.684	0.219	2.98	0.75	0.188	0.007	0.019
AB	15-35	0.038	0.663	0.267	2.80	1.00	0.203	0.008	0.014
Bss1	35-60	0.035	0.576	0.270	3.50	3.51	0.193	0.008	0.017
Bss2	60-80	0.025	0.651	0.307	2.10	0.75	0.167	0.007	0.012
Bss3	80-100	0.028	0.696	0.348	2.71	1.31	0.181	0.007	0.011
Bss4	100-130	0.031	0.801	0.395	2.74	1.33	0.196	0.008	0.013
Pedon 14									
Ap	0-20	0.052	0.630	0.216	3.50	1.25	0.164	0.007	0.017
Bw1	20-40	0.048	0.666	0.273	5.08	0.88	0.171	0.007	0.013
Bw2	40-65	0.045	0.732	0.277	2.63	0.50	0.159	0.007	0.012
Bss1	65-90	0.034	0.717	0.341	4.55	0.50	0.150	0.009	0.012
Bss2	90-115	0.028	0.804	0.378	2.80	0.75	0.150	0.008	0.011
Bss3	115-140	0.021	0.723	0.429	4.55	1.50	0.160	0.006	0.010

Λ Transported soil

Table 4. Correlation relationships.

Variables			r-values
Sand	vs	Silica	0.771**
Clay	vs	R_2O_3	0.894**
Organic carbon	vs	Total P	0.488**
Organic carbon	vs	Total Mn	0.455**

was observed in Bw1 horizon of pedon 10. The soils of Krishna delta reported higher values of CaO indicating the presence of minerals rich in calcium (Mall and Mishra, 2000).

Magnesium Oxide (MgO)

The coarse textured soils recorded lower (0.13 to 3.51 %) content of MgO than fine (0.25 to 3.51 %) pedons. The magnesium oxide content in all profiles was next to CaOvaried from 0.13 to 3.51 per cent. The highest value of 3.51 per cent was observed in Bss1 horizon of pedon 13 while, the lowest value of 0.13 per cent was recorded in Ap, 2C2 and AC horizons of pedons 9, 11 and 12, respectively. Higher value of magnesium oxide indicates the presence of minerals rich in magnesium. Presence of iron oxide and magnesium oxide indicates the possible occurrence of smectite group of minerals reported by Mall and Mishra (2000) in Alfisols of Bihar and Raina *et al*. (2006) in soils of Rajasthan.

Manganese dioxide (MnO_2)

The manganese dioxide values of the soils varied from 0.015 to 0.282 per cent. Pedon 8 showed increased per cent up to depth of 60 cm and pedon 12 showed decreased trends from 15 to 90 cm. The values did not show a particular trend down the depth in many of the pedons.

The wide variation in contents of manganese oxide could be ascribed to the variation in the content of manganese bearing minerals, clay, organic carbon, CEC and other associated elements. The total manganese content showed significant positive correlation with organic carbon content (r = +0.433**). Similar findings were reported by Madhuvani*et al.* (2001) in soils of Vetticherukurmandal of Andhra Pradesh.

Cupric oxide (CuO) and Zinc oxide (ZnO)

The cupric and zinc oxide contents in the soils varied from 0.001 to 0.021 per cent and 0.001 to 0.019 per cent.The highest value 0.019 per cent was observed in Bss1 and Ap horizons of pedon 4 and 13, respectively. The lowest zinc oxide content was observed in coarse textured pedons (11 and 12). The zinc oxide content in fine textured (1, 2, 3, 4, 5, 6, 7, 8, 10, 13 and 14) soils varied from 0.006 to 0.019 per cent and in coarse textured (11 and 12) soils varied from 0.001 to 0.003 per cent. These values did not show any specific trend with depth. The fine textured recorded higher cupric and zinc oxide content than coarse textured pedons and overall values low, it might be attributed to low content of copper and zinc bearing minerals. Similar views were reported by Ramalakshmi*et al*. (2001) in the soils of Bapatla – Karlapalem region of Andhra Pradesh. The variation in zinc oxide content might be due to variation in clay content, parent material and organic carbon in soils. Similar results were reported by Sathish*et al*. (2008).

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