INFLUENCE OF DRAINAGE ON THE DISTRIBUTION OF SESQUIOXIDES IN SOILS DERIVED FROM COASTAL PLAIN SANDS OF DELTA STATE, NIGERIA.

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ABSTRACT

Three representative pedons of perfectly drained, poorly drained and very poorly drained profiles of some coastal plain soils in Delta State were studied. The aim was to investigate their influence on the distribution of the Dithionite-citrate-bicarbonate, Oxalate, Pyrophosphate and Total extractable forms of sesquioxides. Soil samples were collected from each of pedogenetic horizons of the pedons and analyzed for the initial physico-chemical properties. Free oxides of iron and aluminum contents of the soils, were extracted by the Dithionite-citrate-bicarbonate solution, the amorphous oxides (the oxalate Fe_2O_3 and Al_2O_3) by ammonium oxalate solution; the organic forms (Pyrophosphate) was by pyrophosphate solution and the total forms by dilute-HCl after fusion with Na_2CO_3. The reactivity of the sesquioxides was assessed by the values of the active ratio, while the ratio between dithionite-citrate-bicarbonate to their total contents was used to determine their extractability. The results showed that the values of total extractable form was higher than the dithionite-citrate-bicarbonate, oxalate and pyrophosphate forms in the different drainage classes investigated in both extractable Fe and Al, respectively. The active ratios of Al_2O_3 were higher than those of Fe_2O_3 indicating the presence of high amount of amorphous forms of Al_2O_3 in the soils. The extractability of the sesquioxides was higher in all the profiles implying that much of the free oxides exist in amorphous forms due to impeded drainage of the study locations. On the basis of drainage classes, the mean content of total Fe and Al was in the order of: very poor drained soil > poorly drained soil > imperfectly drained soil.

Keywords: Drainage classes, Sesquioxides, Coastal plain soils, Delta State.

INTRODUCTION

The Coastal plain soils are among the dominant soils that occupy the Niger-Delta region of Nigeria. The soils which are mainly hydromorphic, are found largely in the inland valley systems along the fringes of major rivers and their tributaries (Egbuchua, 2007). This group of soil is known to originate from geologic materials of Tertiary coastal plain sands and sandstones usually referred to as the "Acid sands" (Enwezor *et al*, 1990). In most cases, these soils are acidic, low in cation exchange capacity, base saturation and suffer from multiple nutrient deficiencies. The prominent clay type is the 1:1 clay minerals (Enwezor *et al*., 1990, Egbuchua, 2007).

In the tropics, the oxides and hydroxides of iron and aluminum otherwise known as Sesquioxides are among the major components of soils in which a small proportion is present in the forms of organic complexes (Lekwa and Whiteside, 1986). They are very important parameters that influence some soil chemical reactions and properties such as, anions adsorption; surface charges; specific surface area; swelling and aggregate formation, nutrient transformation and pollutant retention in the soil (Aghimien *et al*, 1988; Ibia, 2001).

Various methods have been used to extract their different forms. Amongst these methods are: The Acid-Ammonium Oxalate developed by Schwertmann, (1964) which extracts the amorphous forms of inorganic iron and aluminum oxides, the dithionite-citrate-bicarbonate method developed by Mehra and Jackson, (1960), which extracts the crystalline inorganic forms, and, while the sodium-pyrophosphate method developed by Mckeague and Day (1966) which dissolves the fractions of iron and aluminum in the form of organic complexes (Abdourahamane and Yaro, 2006). The dithionite-citrate-bicarbonate extractable method is widely acknowledged to give a reasonable estimate of the total pedogenetic free iron and aluminum oxides while, the oxalate extractable forms, represent the amorphous and crystalline iron and aluminum oxides in soils, respectively. The differences between the two chemical forms give a measure of the crystalline iron and aluminum oxides in soils (Ibia, 2001).

The study of Sesquioxides in soils developed over coastal plain sands is quite important. This is because the knowledge of it could be used to understand the genesis, properties of the soil and their classification. It is also used to identify soil diagnostic horizons, the different classes of soil and to estimate the age of the soil (McKeague and Day, 1966; Alexander, 1974). The oxalate and dithionite extractable forms and their ratios have been used to evaluate soil development and weathering (Omenihu *et al*, 1994). It is an indication of the relative amount of poorly ordered and crystalline iron and aluminum compounds in the soil (Blume and Schwertmann, 1969).

Considering the dearth of information on sesquioxides in the coastal plain soils and their importance in understanding the genesis and properties of soils, the objective of this study therefore, was to investigate the content and forms of iron and aluminum oxides (Sesquioxides) as influenced by different classes of drainage.

MATERIALS AND METHODS

Location/Description of the Study Area

Three locations characterized by three drainage classes derived from FAO (1986) criteria were used for the study. These are Oko-anala typified by imperfect drainage, Koko (Poorly drained) and Bomadi (Very poorly drained). They are all in Delta State, Nigeria which lies between Latitude 5˚ 43` N and 5° 30` N and Longitude 6˚ 14` E and 6˚ 49`E. The soils are formed from coastal plain sands, alluvial and shale-rich sediments (Egbuchua, 2007). The geology is underlain by varying degree of quartzites, granites, gneiss, schists and isolated deposits of amphibolites (Perekeme, 2002). The ground water in most part of the year, comes very near to the soil surface and rarely below 10 meters during the rainy season. The rainfall pattern is bimodal with an average of 2,750mm in Bomadi and Koko which are more coastal, and 1,750mm/annum in Oko-anala. The average mean annual temperature varies between 25˚C and 28˚C. Relative humidity is high in Bomadi and Koko with mean annual values of about 58.3% in February and over 88.7% in June to September (NIMET, 2012).

The temperature and moisture regimes of the areas can best be described as hyper-isothermic and an udic moisture regime, respectively. The vegetation in Bomadi and Koko are dominated by mangrove forest type typical of *Rhizophoracea*, *Avicanniaceae* and *Palmae*. In Oko-anala, the vegetation is mainly a secondary forest type due to farming and lumbering activities which have reduced the area to a mere derived savanna. Artisanal fishing and petroleum exploration are the major activities especially in Bomadi and Koko locations.

Field Studies

A total of six representative soil profiles in relation to the topographical position and landform were studied. The co-ordinates and altitudes of the profile sites were obtained using Handheld Global Positioning (GPS) receiver (Garma Etrex 2000, Kansas, USA). Field characterization of the profiles was carried out and samples were collected from pedogenetic horizons for routine analysis.

Laboratory Analysis

Soil samples were air-dried, crushed and sieved through a 2mm mesh. Sub-samples were also collected, crushed and further sieved through a 100mm sieve mesh for the determination of the various forms of iron and aluminum-oxides. Particle size analysis was carried out by hydrometer method using calgon (Sodium-hexametaphosphate) as the dispersing agent (Gee and Bauder, 1986). Soil pH was determined potentiometrically in a soil water ratio of 1:2.5 using a glass electrode pH meter. Organic carbon was determined by Walkley-Black dischromate wet oxidation method (Nelson and Sommers, 1982). Available phosphorus was determined by Bray No 1 method (Bray and Kurtz, 1945). Cation exchange capacity (CEC) was determined by Neutral (pH 7.0) NH_4OAc saturation method (Rhoades, 1982). Free oxides of iron and aluminum (sesquioxides) were extracted by the dithionite-citrate-bicarbonate solution according to the methods of Mehra and Jackson (1960). The amorphous oxide that is, (the oxalate Fe_2O_3 and Al_2O_3) were extracted using ammonium oxalate solution (McKeague and Day, 1966). The organic forms were extracted using pyrophosphate solution as described by Mckeague and Day (1966), while the Total forms were extracted with dilute HCL after fusion with Na_2CO_3. The reactivity was assessed by the values of the active ratio, while the extractability percentage was derived as: the ratio of the dithionite-citrate-bicarbonate and the total extractable forms.

Statistical Analysis

Measured variables in the data set were analyzed using classical methods to obtain the mean, standard deviation and coefficient of variations of each location. A one-way analysis of variance (ANOVA) was performed to compare each variable between locations using a protected least ($P \leq 0.05$) significant (SAS Institute, 2004).

RESULTS AND DISCUSSION

Physico-chemical properties

The results of some initial physico-chemical properties of the soils studied are shown in Table 1. The particle size distribution showed that sand was the dominant fraction in imperfectly and poorly drained profiles of Oko-anala and Koko with mean values of 732.5 gkg^{-1} and 38.5 gkg^{-1} respectively. In the very poorly drained profiles (Bomadi), clay fraction was significantly dominant with a mean value of 478.8 gkg^{-1}. Generally, sand fraction decreases with increase in soil depth while clay fraction increases with increase in soil depth depicting clay migration by lessivage to produce the process of illuviation.

The silt fraction was generally low in the imperfectly drained profiles with a mean value of 5.0% but tend to increase significantly in the poorly and very poorly drained profiles with mean values of 213 gkg^{-1} and 238.8 gkg^{-1}. There was no definite order in the distribution of silt fraction of the soils.

Soil reaction varied from very strongly acid (4.5) to moderately acid (5.6) within pedogenetic horizons depicting the acid nature of soils of coastal plain soils. The mean values ranged from 4.91 in the imperfectly drained profiles, 5.44 in poorly drained profiles and 4.96 in the very poorly drained profiles, respectively (Table 1). The acidic nature of these soils is an indication that sesquioxides are likely to fix phosphorus in various forms. The organic matter content also varied significantly from one location to another and was more concentrated at the surface Ap-horizons. The mean values were low in the imperfectly drained and poorly drained profiles with mean values of 10.22 and 10.17 g kg^{-1}. It was moderate in the very poorly drained profiles (22.29 g kg^{-1}). The low organic matter content of some locations could be attributed to extensive cultivation, seasonal bush burning especially in the drier part of the year. On the other hand, the moderate content associated with the very poorly drained profiles could be as a result of slow decomposition rate of litters and extensive mangrove rootlets under water logged condition. Available phosphorus was generally low across the mapping units with mean values below 10 g kg^{-1} (Table 1). The low phosphorus content of the soils could be linked to the fixation of phosphorus by iron and aluminum sesquioxides under drained and undrained acidic condition in the soil (Akpan-Idiok *et a.l*, 1996, Egbuchua, 2007). The Cation exchange capacity (CEC) of the soils were also low depicting the low activity clay associated with most coastal plain sands.

Table 1: Profile Content of some physico-chemical properties of the coastal plain soils as influenced by drainage

Location/ Drainage class		Horizon design	Depth (cm)	Sand	Silt	Clay	Textural class	pH (H_2O)	O.M (gkg^{-1})	Total N (gkg^{-1})	Avail P. (gkg^{-1})	Ca	Mg	K	CEC
				→	%	←						→	→	$Cmolkg^{-1}$	←
Oko Anala	I	Ap	0-15	76	6	18	FSL	5.4	12.34	0.75	5.24	2.54	0.55	0.12	8.45
(Imperfect		Bg^1	15-30	74	4	22	SCL	4.8	12.52	0.70	4.32	2.47	0.74	0.07	8.35
drainage)		Bg^2	30-45	70	4	26	SCL	4.7	11.35	0.65	5.15	2.55	0.62	0.10	9.75
		Bg^3	45-60	64	6	30	SCL	4.9	8.47	0.53	5.25	2.60	0.84	0.15	10.75
	2	Ap	0-15	78	4	18	FSL	5.1	11.32	0.65	5.30	2.62	0.82	0.15	8.34
		Bg^1	15-30	76	6	18	FSL	4.9	10.25	0.60	4.35	2.58	0.75	0.93	8.45
		Bg^2	30-45	74	6	20	SCL	4.7	8.27	0.55	5.10	2.60	0.80	0.15	10.25
		Bg^3	45-60	74	4	22	SCL	4.8	7.25	0.47	5.15	2.64	0.84	0.18	12.34
		$\bar{x}$		**73.25**	**5.0**	**21.75**		**4.91**	**10.22**	**0.61**	**4.98**	**2.57**	**0.78**	**0.23**	**9.58**
		Sd		**4.40**	**1.07**	**4.33**		**0.24**	**19.9**	**0.09**	**0.40**	**0.06**	**0.08**	**0.08**	**1.47**
		CV%		**60.1**	**21.40**	**19.9**		**4.9**	**19.5**	**14.8**	**8.0**	**2.3**	**10.3**	**34.8**	**15.3**
Koko (Poorly		Apg	0-15	49	22	30	CL	5.4	13.34	0.85	4.75	2.48	0.75	0.12	7.84
Drained)		Bag	15-30	40	30	30	CL	5.6	10.35	0.80	4.35	2.45	0.62	0.07	8.30
I		$2Btg^1$	30-45	40	12	48	C	5.6	8.27	0.75	5.10	2.52	0.82	0.15	9.25
		$2Btg^2$	45-60	30	19	50	C	5.7	6.45	0.62	5.15	2.55	0.85	0.14	9.75
	2	Apg	0-15	47	19	34	CL	5.3	12.75	0.90	4.85	2.36	0.72	0.13	8.25
		Bag	15-30	42	22	36	CL	4.9	12.50	0.85	4.72	2.42	0.65	0.08	7.48
		$2Btg^1$	30-45	32	20	48	C	5.6	10.35	0.70	5.25	2.45	0.84	0.14	10.35
		$2Btg^2$	45-60	28	20	52	C	5.4	7.34	0.65	5.45	2.56	0.90	0.18	10.75
		$\bar{x}$		**38.5**	**21.50**	**41.0**		**5.44**	**10.17**	**0.77**	**4.95**	**2.47**	**0.77**	**0.13**	**8.99**
		Sd		**7.78**	**6.0**	**9.38**		**0.26**	**2.61**	**0.10**	**0.35**	**0.07**	**0.10**	**0.04**	**1.21**
		CV%		**20.2**	**27.9**	**22.9**		**4.8**	**25.7**	**12.9**	**7.0**	**2.8**	**12.9**	**30.8**	**14.3**
Bomadi (very		Ap	0-5	30	32	37	CL	4.7	22.35	1.35	6.75	2.75	0.65	0.03	8.43
poorly drained)		Bw	5-15	40	12	48	CL	4.5	22.15	1.25	6.38	2.65	0.72	0.04	8.40
I		Bw^1	15-35	30	19	52	C	5.3	21.35	0.85	6.54	2.85	0.75	0.07	12.52
		Bw^2	35-50	11	33	54	C	5.4	23.15	0.90	6.58	2.80	0.82	0.14	12.75
	2	Ap	0-5	36	28	36	CL	4.8	23.10	1.45	6.70	2.72	0.72	0.05	8.60
		Bw	5-15	32	27	41	CL	4.5	22.75	1.32	6.52	2.70	0.68	0.03	8.75
		Bw^1	15-35	25	22	53	C	5.2	21.35	0.75	6.75	2.80	0.72	0.12	9.75
		Bw^2	35-50	20	18	62	C	5.3	22.15	0.82	6.80	2.85	0.82	0.13	12.75
		$\bar{x}$		**28.0**	**23.88**	**47.88**		**4.96**	**22.29**	**1.09**	**6.63**	**2.78**	**0.74**	**0.08**	**10.24**
		Sd		**9.21**	**7.36**	**9.16**		**0.38**	**0.69**	**0.28**	**0.15**	**0.09**	**0.06**	**0.05**	**2.06**
		CV%		**32.9**	**30.8**	**19.1**		**7.7**	**3.1**	**25.7**	**2.3**	**3.2**	**8.10**	**62.5**	**20.1**

Table 2: **Profile forms of sesquioxides (Extractable Fe) in a coastal plain soils as influenced by drainage classes**

Location/		**Horizon**	**Depth**	**DCB**	**Oxalate**	**Pyrophosphate**	**Total**	**Active ratio**	**Extractability**
Drainage class		**design**	**(cm)**	⟶	**Fe_2O_3**	⟵			**(%)**
Oko Anala	I	Ap	0-15	0.52	0.20	0.14	1.85	0.38	28.12
(Imperfect		Bg^1	15-30	0.48	0.18	0.09	1.76	0.38	27.27
drainage)		Bg^2	30-45	0.56	0.23	0.07	1.96	0.41	28.57
		Bg^3	45-60	0.58	0.27	0.08	1.90	0.47	30.53
	2	Ap	0-15	0.54	0.21	0.16	1.87	0.39	28.88
		Bg^1	15-30	0.46	0.18	0.10	1.76	0.39	26.4
		Bg^2	30-45	0.58	0.21	0.09	1.94	0.36	29.89
		Bg^3	45-60	0.58	0.23	0.12	1.98	0.40	29.29
			$\bar{x}$	**0.54**	**0.21**	**0.11**	**1.88**	**0.40**	**28.59**
			SD	**0.05**	**0.03**	**0.03**	**0.08**	**0.03**	**1.41**
			CV%	**9.26**	**14.29**	**27.27**	**4.26**	**7.50**	**4.93**
Koko (Poorly		Apg	0-15	0.28	0.13	0.20	3.45	0.46	8.11
Drained)	I	Bag	15-30	0.36	0.17	0.16	3.38	0.47	10.65
		$2Btg^1$	30-45	0.31	0.19	0.18	3.54	0.61	8.76
		$2Btg^2$	45-60	0.35	0.15	0.15	3.72	0.65	9.41
	2	Apg	0-15	0.27	0.13	0.19	3.48	0.48	7.76
		Bag	15-30	0.29	0.15	0.17	3.42	0.52	8.48
		$2Btg^1$	30-45	0.32	0.18	0.20	3.58	0.56	8.94
		$2Btg^2$	45-60	0.30	0.19	0.16	3.67	0.63	8.17
			$\bar{x}$	**0.31**	**0.16**	**0.18**	**3.53**	**0.55**	**8.79**
			SD	**0.03**	**0.02**	**0.02**	**0.12**	**0.08**	**0.92**
			CV%	**9.68**	**12.50**	**11.11**	**3.40**	**14.55**	**10.47**
Bomadi		Ap	0-5	0.47	0.25	0.15	5.75	0.53	8.17
(very poorly		Bw	5-15	0.44	0.27	0.12	4.38	0.61	10.05
drained)		Bw^1	15-35	0.47	0.29	0.17	5.84	0.62	8.05
I		Bw^2	35-50	0.53	0.31	0.16	5.78	0.58	9.17
	2	Ap	0-5	0.45	0.28	0.17	5.80	0.62	7.76
		Bw	5-15	0.48	0.31	0.13	5.35	0.65	8.97
		Bw^1	15-35	0.51	0.34	0.19	5.86	0.66	8.70
		Bw^2	35-50	0.50	0.29	0.18	5.72	0.58	8.74
			$\bar{x}$	**0.48**	**0.29**	**0.16**	**5.56**	**0.61**	**8.70**
			SD	**0.03**	**0.03**	**0.02**	**0.50**	**0.04**	**0.73**
			CV%	**6.25**	**10.34**	**12.50**	**8.99**	**6.56**	**8.39**

DCB = Dithionite-citrate bicarbonate
CV = Coefficient of variations

Extractable iron (Fe_2O_3)

The contents of dithionite-citrate-bicarbonate, oxalate, pyrophosphate and total extractable forms of iron are presented in (Table 2). Their means, standard deviations and coefficient of variations values are also shown in (Table 4). Dithionate-citrate-bicarbonate extractable, Fe_2O_3 ranged from 0.46 – 0.58 mg kg^{-1} with a mean value of 0.54 mg kg^{-1} and a coefficient of variation of 9.26% in the imperfect drained profiles, and 0.27 – 0.36 mg kg^{-1}, with a mean value of 0.31 mg kg^{-1} and a coefficient of variation of 9.68% in the poorly drained profiles. The values in the poorly drained profiles were 0.44 – 0.53 mg kg^{-1} with a mean of 0.48 mg kg^{-1} and a coefficient of variations of 6.25%. Oxalate extractable Fe_2O_3 ranged from 0.18 – 0.29 mg kg^{-1} with a mean of 0.21 mg kg^{-1} and a coefficient of variation of 14.29% in the imperfectly drained profiles, and 0.13 – 0.19 mg kg^{-1} with a mean of 0.16 mg kg^{-1} and a coefficient of variations of 12.50% in the poorly drained profiles (Table 4). The very poorly drained profiles had a range value of 0.25 – 0.34 mg kg^{-1} with a mean of 0.29 mg kg^{-1} and a coefficient of variations of 10.34%. The values of pyrophosphate extractable Fe_2O_3 ranged from 0.88 – 0.16 mg kg^{-1} with a mean of 0.11 mg kg^{-1} and a coefficient of variations of 27.27% in the imperfectly drained profiles and 0.15 – 0.20 mg kg^{-1} with a mean of 0.18 mg kg^{-1} and a coefficient of variations of 11.11% in the poorly drained profiles. In the very poorly drained profiles, the values ranged from 0.12 – 0.19 mg kg^{-1} with a mean of 0.16 mg kg^{-1} and a coefficient of variation of 12.50% (Table 4). The values of total extractable Fe_2O_3 ranged from 1.76 – 1.98 mg kg^{-1} with a mean of 1.88 mg kg^{-1} and a coefficient of variations of 4.26% in the imperfectly drained, and 3.38 – 3.72 mg kg^{-1} with a mean of 2.53 mg kg^{-1} and a coefficient of variation of 3.40% in the poorly drained profiles. In the very poorly drained profiles, the total extractable Fe_2O_3 values ranged from 4.38 – 5.86 mg kg^{-1} with a mean of 5.56 mg kg^{-1} and a coefficient of variations of 8.99%. Generally, the mean values of dithionite-citrate-bicarbonate, oxalate and pyrophosphate extractable Fe_2O_3 were lower than the total extractable Fe_2O_3. The total extractable Fe were found to concentrate more in the lower horizons than in the Ap-horizons thereby resulting in a buldge of iron-content in the B-horizons.

Table 3: **Profile forms of sesquioxides (Extractable Al) in a coastal plain soils as influenced by drainage classes**

Location/ Drainage class		Horizon design	Depth (cm)	DCB	Oxalate	Pyrophosphate	Total	Active ratio	Extractability (%)
				$\longrightarrow$	Al_2O_3	$\longleftarrow$			
Oko Anala (Imperfect drainage)	I	Ap	0-15	0.14	0.06	0.27	15.70	0.43	0.89
		Bg^1	15-30	0.18	0.10	0.30	34.20	0.55	0.53
		Bg^2	30-45	0.22	0.15	0.28	20.14	0.68	0.99
		Bg^3	45-60	0.26	0.18	0.28	18.70	0.69	1.39
	2	Ap	0-15	0.16	0.07	0.29	14.90	0.45	1.07
		Bg^1	15-30	0.18	0.09	0.32	32.40	0.50	0.56
		Bg^2	30-45	0.19	0.10	0.30	18.37	0.53	0.59
		Bg^3	45-60	0.23	0.12	0.32	16.45	0.52	1.37
			$\bar{x}$	**0.20**	**0.11**	**0.30**	**21.36**	**0.54**	**0.92**
			SD	**0.04**	**0.04**	**0.02**	**7.58**	**0.10**	**0.35**
			CV%	**20.0**	**36.36**	**6.67**	**35.49**	**18.52**	**38.04**
Koko (Poorly Drained)	I	Apg	0-15	0.21	0.11	0.52	46.32	0.52	0.45
		Bag	15-30	0.18	0.09	0.50	38.42	0.50	0.47
		2Btg^1	30-45	0.09	0.06	0.46	12.45	0.67	0.72
		2Btg^2	45-60	0.10	0.08	0.45	12.30	0.80	0.81
	2	Apg	0-15	0.18	0.09	0.50	45.30	0.50	0.40
		Bag	15-30	0.19	0.10	0.48	38.18	0.53	0.50
		2Btg^1	30-45	0.20	0.13	0.46	14.18	0.65	1.41
		2Btg^2	45-60	0.20	0.13	0.46	12.40	0.65	1.61
			$\bar{x}$	**0.17**	**0.10**	**0.48**	**27.44**	**0.61**	**0.80**
			SD	**0.05**	**0.02**	**0.03**	**15.89**	**0.10**	**0.47**
			CV%	**29.41**	**20.0**	**6.25**	**57.91**	**16.39**	**58.75**
Bomadi (very poorly drained)	I	Ap	0-5	0.20	0.13	0.62	22.30	0.65	0.90
		Bw	5-15	0.20	0.13	0.34	17.45	0.65	1.15
		Bw^1	15-35	0.25	0.18	0.54	25.14	0.72	1.00
		Bw^2	35-50	0.25	0.19	0.52	19.37	0.76	1.28
	2	Ap	0-5	0.19	0.13	0.58	20.85	0.68	0.91
		Bw	5-15	0.20	0.13	0.43	18.36	0.65	1.09
		Bw^1	15-35	0.21	0.15	0.56	26.10	0.71	0.80
		Bw^2	35-50	0.21	0.15	0.49	20.15	0.71	1.04
			$\bar{x}$	**0.21**	**0.15**	**0.51**	**21.24**	**0.69**	**1.02**
			SD	**0.02**	**0.02**	**0.09**	**3.09**	**0.04**	**0.15**
			CV%	**9.52**	**1.33**	**17.65**	**14.55**	**5.80**	**14.71**

The general low extractable values of the various forms of Fe_2O_3 have been attributed to the poor drainage conditions of the coastal plain soils which invariably prevents strong weathering and subsequent formation of sesquioxides in the soils. This view was buttressed by Aghimien *et al*., (1986) in their studies of Fe and Al oxides in some hydromorphic soils of Nigeria. Generally, there was an observed increase with depth of profiles in respect of dithionite-citrate-bicarbonate, oxalate and total extractable Fe_2O_3 and in most cases, showed a maximum concentration in the B-horizons of the poorly and very poorly drained profiles (Table 2). The high content of Fe_2O_3 in these profiles indicates the dynamics of iron in the coastal plain soils and high incidence of dissolution of Fe-compounds including the transformation of dithionite, oxalate, pyrophosphate and total Fe_2O_3 in the profiles.

Extractable Al_2O_3

The mean, standard deviation and coefficient of variations values of the various extractable forms of Al_2O_3 are given in (Tables 3 and 4), respectively. The content of dithionite-citrate-bicarbonate Al_2O_3 in the imperfectly drained profiles ranged from 0.14 – 0.26 mg kg^{-1}, with a mean of 0.20 mg kg^{-1} and a coefficient of variations of 20.0%. In the poorly drained profiles, the values ranged from 0.09 – 0.21 mg kg^{-1} with a mean of 0.17 mg kg^{-1} and a coefficient of variations of 29.41%, while in the very poorly drained profiles, the values ranged from 0.19 – 0.25 mg kg^{-1} with a mean of 0.21 mg kg^{-1} and a coefficient of variations of 9.52%.

The content of Oxalate extractable Al_2O_3 ranged from 0.06 – 0.18 mg kg^{-1} with a mean of 0.11 mg kg^{-1} and a coefficient of variations of 36.36% in the imperfectly drained profiles, and 0.06 – 0.13 mg kg^{-1} with a mean of 0.10 mg kg^{-1} and a coefficient of variation 20.0% in the poorly drained profiles. The very poorly drained profiles had a range values of 0.13 – 0.19 mg kg^{-1} with a mean of 0.15 mg kg^{-1} and a coefficient of variation of 1.33%. There was a general low content of extractable aluminium oxalate over aluminium dithonite and this could be attributed to neoformation process of clay silication.

The values of pyrophosphate extractable Al_2O_3 ranged from 0.27 – 0.36 mg kg^{-1} with a mean of 0.30 mg kg^{-1} and a coefficient of variation of 6.67% in the imperfectly drained profiles; 0.45 – 0.52 mg kg^{-1} with a mean of 0.48 mg kg^{-1} and a coefficient of variations of 6.25% in the very poorly drained profiles and 0.34 – 0.51 mg kg^{-1} and a coefficient of variations of 17.65% in the very poorly drained profiles. The values of total extractable Al_2O_3 were higher in all the drainage classes than those of Diothionite, Oxalate and Pyrophosphate extractable forms (Table 3). These higher values are indications of higher weathering state of the soils.

Table 4: Mean, Standard deviation and coefficient of variation of profile forms of sesquioxides as influenced by different drainage classes in a coastal plain sand, Delta State, Nigeria

			Extractable Fe_2O_3				
Location/ Drainage class		**DCB**	**Oxalate**	**Pyrophosphate**	**Total**	**Active ratio**	**Extractability (%)**
		→	**mgkg^{-1}**	←			
Oko Anala (Imperfect drainage)	**Range**	0.46-0.58	0.18-0.27	0.08-0.16	1.76-1.98	0.36-0.47	26.14-30.53
	$\bar{x}$	**0.54**	**0.21**	**0.11**	**1.88**	**0.40**	**28.59**
	SD	**0.05**	**0.03**	**0.03**	**0.08**	**0.03**	**1.41**
	CV%	**9.26**	**14.29**	**27.27**	**4.26**	**7.50**	**4.93**
Koko (Poorly Drained)	**Range**	0.27-0.36	0.13-0.19	0.15-0.20	3.38-3.72	0.46-0.65	7.76-10.65
	$\bar{x}$	**0.31**	**0.16**	**0.18**	**3.53**	**0.55**	**8.79**
	SD	**0.03**	**0.02**	**0.02**	**0.12**	**0.08**	**0.92**
	CV%	**9.68**	**12.50**	**11.11**	**3.40**	**14.55**	**10.47**
Bomadi (very poorly drained)	**Range**	0.44-0.53	0.25-0.34	0.12-0.19	4.38-5.86	0.53-0.65	7.76-8.97
	$\bar{x}$	**0.48**	**0.29**	**0.16**	**5.56**	**0.61**	**8.70**
	SD	**0.03**	**0.03**	**0.02**	**0.50**	**0.04**	**0.73**
	CV%	**6.25**	**10.34**	**12.50**	**8.99**	**6.56**	**8.39**
				Extractable Al_2O_3			
Oko Anala (Imperfect drainage)	**Range**	0.14-0.26	0.06-0.18	0.27-0.36	14.90-34.20	0.43-0.69	0.53-1.39
	$\bar{x}$	**0.20**	**0.11**	**0.30**	**21.36**	**0.54**	**0.92**
	SD	**0.04**	**0.04**	**0.02**	**7.58**	**0.10**	**0.35**
	CV%	**20.0**	**36.36**	**6.67**	**35.49**	**18.52**	**38.04**
Koko (Poorly Drained)	**Range**	0.09-0.21	0.06-0.13	0.45-0.52	12.30-46.32	0.50-0.80	0.40-1.61
	$\bar{x}$	**0.17**	**0.10**	**0.48**	**27.44**	**0.61**	**0.80**
	SD	**0.05**	**0.02**	**0.03**	**15.89**	**0.10**	**0.47**
	CV%	**29.41**	**20.0**	**6.25**	**57.91**	**16.39**	**58.75**
Bomadi (very poorly drained)	**Range**	0.19-0.25	0.13-0.19	0.34-0.62	17.45-26.10	0.65-0.76	0.80-1.28
	$\bar{x}$	**0.21**	**0.15**	**0.51**	**21.24**	**0.69**	**1.02**
	SD	**0.02**	**0.02**	**0.09**	**3.09**	**0.04**	**0.15**
	CV%	**9.52**	**1.33**	**17.65**	**14.55**	**5.80**	**14.71**

DCB = Dithionite-citrate bicarbonate
CV = Coefficient of variations

Active ratio

The active ratio of the dithionite and oxalate extractable Fe_2O_3 and Al_2O_3 have been used to evaluate soil development and weathering (Omehihu et *al.*, 1994). It is also a measure of the reactivity of sesquioxides which indicate the relative amount of poorly ordered and crystalline iron and aluminum compounds in the soil (Blurne and Schertamann, 1969, Ibia, 2001).

The mean values of active ratio of Al_2O_3 were higher than the extractable Fe_2O_3 across the profiles (Table 4). This was an indication of the presence of higher amount of amorphous forms of aluminum oxides in the soil. Active ratio greater than 0.35 represent poorly drained soils while lower values indicate well drained conditions (McKeague and Day, 1966). Results of active ratio obtained in this study showed higher values due to the drainage conditions of the soil profiles resulting to crystallization of iron as inhibited by organic matter and clay content.

Extractability function

The extractability of free oxides of dithionite-citrate-bicarbonate extractable Fe_2O_3 and Al_2O_3 to total content is a useful index of evaluating the degree of weathering of soil. The mean extractability values (Table 4) were much higher in extractable Fe_2O_3 than in Al_2O_3. In some similar studies, Uzere (2010) obtained extractability value of less than 10%, while Ibia (2001), obtained values ranging from 8-29% for iron and 0.26 – 2.09% for aluminum. Low extractability values suggest a relative low degree of weathering of soils (Ibia, 2001).

Conclusion

Forms of iron and aluminum-oxides are important pedogenetic parameters that are known to influence some soil properties. The study showed that oxalate and pyrophosphate extractable Fe_2O_3 and Al_2O_3 were low in soils formed over coastal plain sands due to the poor drainage condition of the soils.

The active ratio showed a relative amount of poorly ordered crystalline iron and aluminum compound in the coastal plain soils. The relative higher extractability values of Al_2O_3 over Fe_2O_3 seemed to suggest that the coastal plain soils are relatively less weathered and this is a common feature of most soils with impeded drainage. However, on the basis of drainage classes, the mean contents of total iron and aluminum was in the order of; very poor drained> poorly drained > imperfectly drained profiles.

Recommendations

Further research should be carried out in Fe and Al extractability in less weathered soils in comparism to well drained soils formed on basement complex rocks. This is because the oxides of iron and aluminum are important pedogenetic parameters that have some influence on soil properties.

REFERENCES

Abdourahamane, I. I. and Yaro, D.T. (2006) Pedogenic distribution of Pyrophosphate extractable iron and aluminum in plinthitic soils in a landscape at Zaria, Nigeria. *Proceedings of the 31st Annual Conference of the Soil Science Society of Nigeria, 12th – 17th Nov. 2006. Ahmadu Bello University, Zaria, Nigeria p. 52 – 59.*

Aghimien, E. A. Udo, E. J. and Ataga O. (1988). Profile distribution of forms of iron and aluminum in the hydromorphic soils of southern Nigeria. *Journal of West African Science Association. Vol. 31: p. 57 – 70.*

Akpan – Idiok, A. U. Opuwaribo, E. E. and Longanathan P. (1996) Available phosphorus status of selected soils of the Niger-Delta and their relationship with iron and other soil characteristics. *Delta Agriculture, Vol. 3: p. 96-105.*

Alexander, E. B. (1974) Extractable iron in relation to age. *Soil Science Society American Proceeding Vol. 38: p. 121-124.*

Blume, H. P. and Schwertman, U. (1969). Genetic evaluation of distribution of Al, Fe and Mn-oxides. *Soil Science Society, American Proceeding Vol. 33: p. 438 – 449.*

Bray, R. H. and Kurtz, L. T. (1945). Determination of total, organic and available forms of phosphorus in soils. *Soil Science Vol. 59: p. 39-45.*

Egbuchua, C. N. (2007) Pedogenetic Characterization of some wetland soils in Delta State (Unpublished) Ph.D Thesis, Delta State University, Abraka, Nigeria. 285p.

Enwezor, W.O. Udo, E. J. Ayotade, K. A. Chude V. O. and Udegbe, C. E. (1990). Soil fertility investigation in Nigeria (in 5 volumes) FMAWR & RD, Lagos-Nigeria, 163p.

F.A.O.- Food and Agricultural Organisation of the United Nations (1986). Soil map of the World. Revised legend. *World Soil resources, Report 60. FAO, Rome,* 160 p.

Gee, G. W. and Bauder, J. W. (1986) Particle size analysis. In: Klute, A. (ed). Methods of soil analysis. Part 2. Chemical and microbiological properties (2nd ed.) *Agronomy monograph 9 ASA and SSSA, Madison, WI. USA*. 143p.

Ibia, T.O. (2001) Forms of iron and aluminum in soil profiles of inland flood plains of South-Eastern, Nigeria. *Proceedings of the 27th Annual Conference of Soil Science Society of Nigeria 5th – 9th Nov. 2001 p. 165 – 176.*

Lekwa, G. and Witeside, E. P. (1986) Coastal plain soil of South Eastern Nigeria. Forms of extractable iron, aluminum and phosphorus. *Soil Science American Journal Vol. 50: 160 - 166.*

McKeague, J. A. (1966) An evaluation of 0.1M pyrophosphate and pyrophosphate dithionite in comparison with oxalate as extractants of the accumulation product in podzols and some other Soil. *Canadian Journal of Soil Science Vol. 47: p. 95-99.*

Mehra, O. P. and Jackson, M. L. (1960) Iron oxide removal from soils and clays by dithionite-citrate system buffered with sodium bicarbonate. *Proceedings of the 7th National Day. Clays Dinner, Pergamon Press, New York.* pp. 317-327.

Nelson, D. W. and Sommers, I. E. (1982) Total carbon, organic carbon and organic matter. In A. L. Page et al (ed.) Methods of Soil analysis Part 2 (2nd edition) *Agronomy Monograph 9 ASA and SSSA Madison, W.I. USA. p. 539 – 577.*

NIMET (2012) Climatic data (2000 – 2012) of Delta State, Nigeria. 45p.

Omenihu, A. A., Opuwaribo, E. E. and Sutton, P. M. (1994). Forms of extractable iron and aluminum oxides in coastal plains soils of South-Eastern, Nigeria. *Proceedings of the 21st Annual Conference of Soil Science Society of Nigeria. University of Uyo, Nigeria. 20th – 4th February, 1994. p. 74 – 80*

Perekeme, J. J. (2002) Soil geology of the Niger-Delta Swamp areas of Delta State. *Geology Journal Vol. 5: No. 41 p. 38-51.*

Rhoades, J. D. (1982) Cation exchange capacity In: Page, A.L. Miller, R. H and Keeney, D. R. (eds) Methods of Soil analysis Part 2. *Agron. 9 Madison W.J. pp. 149-157.*

SAS Institute (2004) SAS/STST User's Guide, Version 8 (6th ed.) Volumes 4 and 5 SAS Institute, Carry NC 327 157p.

Uzere, F. C. (2010) Profile distribution of iron sesquioxides in some selected Niger-Delta soil. *Experimental soil science Vol. 3, No. 2: p. 38 – 49*