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PHOSPHORUS FORMS AND DISTRIBUTION IN SELECTED SOILS FORMED OVER DIFFERENT PARENT MATERIALS IN ABIA STATE OF NIGERIA

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ABSTRACT

The forms and distribution of phosphorus in selected soils formed over different parent materials in Abia State of Nigeria were investigated. Total P varied widely ranging from 175.6 to 1252.45 mg / kg with overall mean of 450.68 mg/ kg. Ajata soils having higher values while Amakama have lower values. The organic P also varied widely ranging from 31.03 to 127.71 mg /kg with a mean value of 61.0 and 92.91 mg/ kg respectively. About 40% of the Total P in the surface horizon (Ap) of the fine-textured soils (Ajata) are in organic P form while the coarse-textured soils (Amakama) have a very low (< 20%) organic P contribution to total P. The inorganic fractions of the soils occurred in the sequence of occluded P> Fe-P> Al-P> Ca-P. The occluded P constitutes between 26 and 68% of the total P in the various soils and 40 to 80% of the total inorganic P. The occluded P and Fe-P comprise more than 84% of the total inorganic P. The content of Ca-P and Al-P were very low (<16% of the total inorganic P). The active inorganic P constitutes between 18 and 38% of the total P. There is high content of Al-P in the lower horizons of the Ajata soil. Available P is low with values ranging from 4-21 mg/ kg with a mean value of 11.59 mg /kg. The surface horizon (Ap) contains more available P than the subsurface soil horizons. The multiple correlation analysis revealed that total P correlated negatively with sand and positively with clay, exchangeable Ca, occluded P, organic P, Ca-P, Fe-P. Organic P correlated positively with Fe-P, Al-P and total P. Ca-P correlated negatively with sand and positively with organic carbon, exchangeable Ca, Al-P and total P. Fe-P correlated positively with organic P, Al-P and total P. Al-P correlated positively with Fe-P, Ca-P and organic P. The occluded P correlated positively with clay and exchangeable Ca and negatively with sand and pH.

INTRODUCTION

Phosphorus is an essential element in the macro- element group and is therefore vital to plant growth. In most Nigerian soils, nitrogen, phosphorus, potassium, and magnesium and to some extent sulfur and zinc are the nutrients whose deficiencies most frequently limit the crop yield. That of P is further compounded by the highly weathered nature of the soils which are in the most areas acidic with high content of sesquioxides, Kaolinitic clays and exchangeable Al^{3+} which fix P (PPI, 1988). Several authors have characterized the P content of some soils (Uzu *et al.*, 1975; Udo and Ogunwale, 1977; Udo and Dambo, 1979) and their relative availability to crops (Enwezor, 1977; Adepetu, 1975; Ayodele, 1980) and P sorption studies (Udo and Uzu, 1972; Juo and Fox, 1974; Osodeke *et al.*, 1992).

Major differences between crops in their ability to take up different forms of P, numerous inorganic and organic forms of P that occur in soils as well as the wider variation in behaviour between soil types are some of the factors militating against proper understanding of P behaviours in soil.

The soils of Abia State of Nigeria are conveniently classified into groups based on morphology and degree of profile development (Jungerius, 1964).The Owerri/Umudike soil group which include Amakama Olokoro soils are Ultisols (Soil Survey Staff, 2006) and are classified as Nitosols (F.A.O./UNESCO, 1988). They are strongly acidic, low in C.E.C, low in base saturation and low in soil fertility level. They are highly leached upland ferralitic soils with kaolinite as dominant clay type. These soils are derived from Coastal Plain Sands and are low in total P (Uzu *et al*., 1975; Loganathan and Sotton,1987; Enwezor *et al*., 1990; Osodeke and Kamalu, 1992). The Ajata soils are derived from Shale and Sandstone parent material and are reddish to brown in colour with gravelly surface

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and high clay content and therefore poorly drained. Although they are acidic, they are relatively high in base saturation with inherent high fertility. These soils are Alfisols (Soil Survey Staff, 2006) and are classified as Luvisols (F.A.O./UNESCO, 1988).

The studies on the forms and distribution of various forms of P in soil provided useful information in assessing the available P status and measuring the degree of weathering in the soil. The content and distribution of the active inorganic form of P (Fe-P, Al – P and Ca – P) in the soil are a useful index in assessing the P requirement of soils. Quantification of organic P is necessary to better understand the mineralization-immobilization turnover of P under particular environments and cropping systems in the soils. Adequate knowledge of total P, various fractions of P of some important agricultural soils of Abia State of Nigeria, as well as, their distribution and availability to crops, is important in P management of these soils and fertilizer recommendation.

Most of the investigation carried on P status and forms in soils of Abia State were done on surface soils. There has not been any concerted effort to investigate P forms along the genetic horizons. Therefore the need to have a detailed study of the forms of P and their distribution with depth along the genetic horizons of the soils seems warranted. Therefore, the objective of this study is to evaluate the forms of P, the pattern of their distribution with profile depth, as well as the relationship between these various forms of P in the selected soils of Abia State developed from different parent materials.

MATERIALS AND METHODS

The study was conducted at Amakama Olokoro and Ajata Ibeku, both in Abia State, Nigeria. A free survey method was used in the choice of sampling sites. The site was geo-referenced using handheld Global Positioning System (GPS) Receiver (Garmin Ltd Kansas, USA). Pedon sampling was based on identified pedogenic horizons. A Profile Pit was dug in each of the 2 locations. The profiles were described and sampled following the procedures of Soils Survey Staff (2006). Eight soil samples were collected from each profile pit.

In the laboratory, the Soil samples were air-dried for 3 days at room temperature. They were gently crushed with a wooden roller and passed through a 2-mm sieve. A small portion of each sample were crushed with a mortar and passed through 0.5-mm sieve for some analysis such as organic carbon, total N, total P and organic P. The particle size distribution was determined by Bouyoucos (1962) hydrometer method using sodium heaxmetaphosphate (calgon) as dispersing agents. The pH of the soil samples was determined in water and KCL by means of Bechman’s pH meter using a soil water ration of 1:2.5 (Thomas, 1996). Organic carbon was determined by the procedure of Walkley and Black (1934) using the dichromate wet oxidation method (Nelson and Sommers, 1996). Total nitrogen was determined by the microkjedahl distillation method (Bremner, 1996). Exchangeable bases (Ca, Mg, K, Na) were extracted with 1 N Ammonium acetate (NH_4OAc) pH 7.0. Ca and Mg in the extracts were determined by titration (Jackson, 1958) while Na and K were determined with flame photometer. Exchangeable Hydrogen and Al were determined by the method outlined by Mclean (1982). Effective cation exchange capacity (ECEC) was calculated as the sum of total exchangeable bases (TEB) and total exchangeable acidity (TEA). Percentage base saturation was calculated as outlined by Coleman and Thomas (1967). Total phosphorus in the soils was determined by perchloric acid digestion (Jackson, 1958) and organic P was estimated by the difference between 13 M HCL extractable inorganic P, before and after ignition, by the method of Leg and Black (1955). Inorganic P was fractionated by method of Chang and Jackson (1957) as modified by Peterson and Corey (1966). Available P was extracted by Bray and Kurtz No. 2 extractant (Bray and Kurtz, 1945), Phosphorus in the extracts was determined colorimetrically (Murphy and Riley, 1962). The results obtained were subjected to statistical analysis using statistical computer package of GenStat Release computer (2011).

Determination of phosphorus as aluminum phosphate (Al-P)

One gram of air dried soil (2 mm sieve) was weighed out placed in 250 ml plastic container. 35 ml of I N NH_4Cl was added and the mixture shaken on a mechanical shaker for 30 minutes. To remove water soluble and loosely bound P and exchangeable Ca, the suspension were filtered (Whatman filter paper No. 42) and the filtrate discarded, leaving the soil residues. To the residues in the plastic bottle were added 35 ml of 0.5 N NH_4F, covered tightly and shaken for 1hr on a mechanical shaker. The mixture was filtered and the clear filtrates were used for Al-P determination. The soils residues in the plastic bottle were reserved for Fe-P extraction. For Al-P determination, aliquots (10 ml) of the extract were pipetted out into 50 ml volumetric flask and 15 ml boric acid added (0.8 M). Blue colour was developed using

4 ml of reagent B solution and made up to mark with distilled water. Absorbance readings were recorded at 880 nm wavelength using the UV/VIS Unicam spectro-colorimeter.

Phosphorus determination as iron phosphate (Fe- P)

The soil residue saved after Al-P extraction was washed twice with 25 ml saturated NaCl and filtered each time and the filtrate discarded. Thereafter, 35 ml O.I N NaOH was added to the plastic bottles, covered tightly and shaken for 17 hours. The suspensions were filtered and clear extract collected for Fe-P determination. The soil residues in the plastic bottle were reserved for Ca- P extraction. For Fe –P determination, 5 ml aliquot of the clear solution was pipetted into 50 ml volumetric flask, 4 ml of reagent B was added for the blue colour development and made up to mark with distilled water. Absorbance readings were recorded at 880 nm wavelength using a UV/VIS Unicam spectro-colorimeter.

Phophorus determination as calcium phosphate (Ca-P)

The soil residues saved after the Fe-P extraction was washed twice with 25 ml saturated NaCl solution (10%), filtered each time and discarded, 35 ml of 0.5 N H_2SO_4 was added to the soil in the plastic bottles, covered tightly and shaken on the mechanical shaker for I hour. The suspensions were filtered and clear solution obtained. 30 ml aliquot of the clear solution was pipetted into 50 ml of volumetric flask, 4 ml of the reagent B was added for colour development and the volume made up to mark with distilled water. Absorbance readings were recorded at 880 nm wavelength using a UV/VIS Unicam spectro-colorimete.

Determination of total phosphorus

One gram of finely ground (0.5 mm scene) soil was weighed out each into 250 ml conical flasks and 25 ml of HNO_3, 4 ml of perchloric acid and 2 ml of H_2SO_4 added respectively and mixed thoroughly. It was digested on a heater inside a fume cupboard until the colour due to organic matter disappeared. Then additional 20 minutes heating was allowed to dry completely. At this stage heavily white fumes due to HNO_3, $HClO_4$ and H_2SO_4 appeared and the insoluble materials looked like white sand. The flask was shaken occasionally during digestion. The digest was allowed to cool and 70 ml of distilled water was added to the digest and heated to warm. The suspension was filtered into 250 ml volumetric flask and made up to mark with distilled water. Then, 10 ml aliquot was pipetted into 50 ml volumetric flask, 4 ml of the reagent B was added and made up to mark with distilled water. The absorbance reading was recorded at 880 nm wavelength using a UV/VIS Unicam spectro-colorimeter.

Determination of organic phosphorus

One gram of finely ground (0.5 mm sieve) soils were weighed into crucible placed in a cool muffle furnace. The temperature of the furnace was increased at 550^0c and maintained for 1 hr. The crucible with the ignited soil samples were allowed to cool and soil transferred carefully to 250 ml plastics bottles. Comparable unignited soil samples were weighed into similar bottles. The plastic bottles containing both ignited and unignited samples were added 10 ml of 13 M HCl and heated in water bath for 10 minutes. The bottles were then removed from the water bath and an additional 10ml of concentrated HCl (13 M) added to each bottle and allowed to cool at room temperature for 1 hour. 15 ml of distilled water was added to each bottle, mixed thoroughly and filtered. The extracts were collected into 100 ml volumetric flask and made up to mark with distilled water. Thereafter, 15 ml of aliquot was pipetted into 50 ml volumetric flask. 4 ml of reagent B was added and made up to mark with distilled water. The absorbance reading was recorded for both ignited and unignited extracts at 880 nm wavelength using a UV/VIS Unicam spectro-colorimeter and the difference in phosphorus between the ignited and unignited samples were taken as the organic phosphorus content of the samples.

Determination of occluded phosphorus

The occluded phosphorus (inactive P) was calculated as the difference between the total phosphorus and the active phosphorus (Al-P, Fe-P, Ca-P).

RESULTS AND DISCUSSIONS

The site characteristics, as well as the results of morphological, physical, and chemical properties of the soils are given in Tables 1, 2, 3, and 4 respectively.

Total phosphorus

As show in Tables 6, the total P content in the entire study area varied widely ranging from 175.6 to 1252.45 mg/kg with the mean value of 450.68 mg/kg. This is in agreement with the report of Uzu *et al.* (1975). The Ajata soils, derived from Clay Shale, contain the highest amount of total P (1252 mg/kg). The Amakama soils contain the lowest amount of total P among the two soil profiles studied (301 mg/kg). This is also in agreement with the report of Uzu *et al.*, (1975). The Amakama soil, derived from

Coastal Plain Sands has a total P which ranged from 175.6 to 301.2 mg/kg with a mean of 237.5 mg/kg from 0-240 cm depth. These values are comparable with values obtained by Loganathan and Sutton (1987) in the Coastal Plain Sands of Rivers State. They are, however higher than the values reported by Osodeke and Kamalu (1992) in the Coastal Plain Sands of Eastern Nigeria rubber growing zones, and also the values obtained by Loganathan *et al.*, (1982) in Ultisols and Alfisols of coconut growing soils of Sri Lanka. The high total P in Ajata soils is a reflection of the high phosphate content of the parent rock from which the soils were formed (Akamigbo and Asadu, 1983). Total P correlated positively with clay and negatively with sand (Table 7). This is in agreement with reports of Osodeke and Kamalu (1992). Total P also correlated positively with exchangeable calcium, Ca-P, Al-P, occluded P and Organic P. However, there was no significant correlation between total P and pH on the one hand and organic carbon on the other hand. This was also reported by Osodeke and Kamalu (1992). The pattern of distribution of total P with depth was not uniform in all the soils studied (Udo and Dambo, 1979; Enwezor, *et al*., 1991; Brady and Weli, 2002).

Organic P contents in the soils

Organic P contents in the soils varied widely depending upon the parent material with the lowest being recorded in the Amakama soil (31.03 mg/kg) while the highest was found in the Ajata soil (127.71 mg/kg) with a mean values of 61.0 and 92.91 mg/kg in the Amakama and Ajata soils, respectively (Table 5). These values constitute 25.6 and 13.9 percent, respectively of the total P in these soils. These values are lower when compared with the values of 34 to 339 mg/kg and 30 to 900 mg/kg reported by Loganathan and Sutton (1987) in the Coastal Plain Sands of Rivers State and by Uzu *et al.*, (1975) in the soils of Southeastern Nigeria respectively; but comparable with the value of 1.0 to 90 mg/kg and 28.88 to 88 mg/kg reported by Lognathan *et al.* (1982), and Osodeke and Kamalu (1992). About 40% of the total P in the surface horizon (Ap) of the fine textured soils (Ajata soils) are in organic P form (Uzu *et al.*, 1975; Enwezor *et al.*, 1990; Osodeke and Kamalu, 1992). However, the coarse textured soils (Amakama soils) have a very low (<20%) Organic P contribution to the total P. The low Organic P of these coarse textured soils is a reflection of the low total P and organic carbon of these soils.

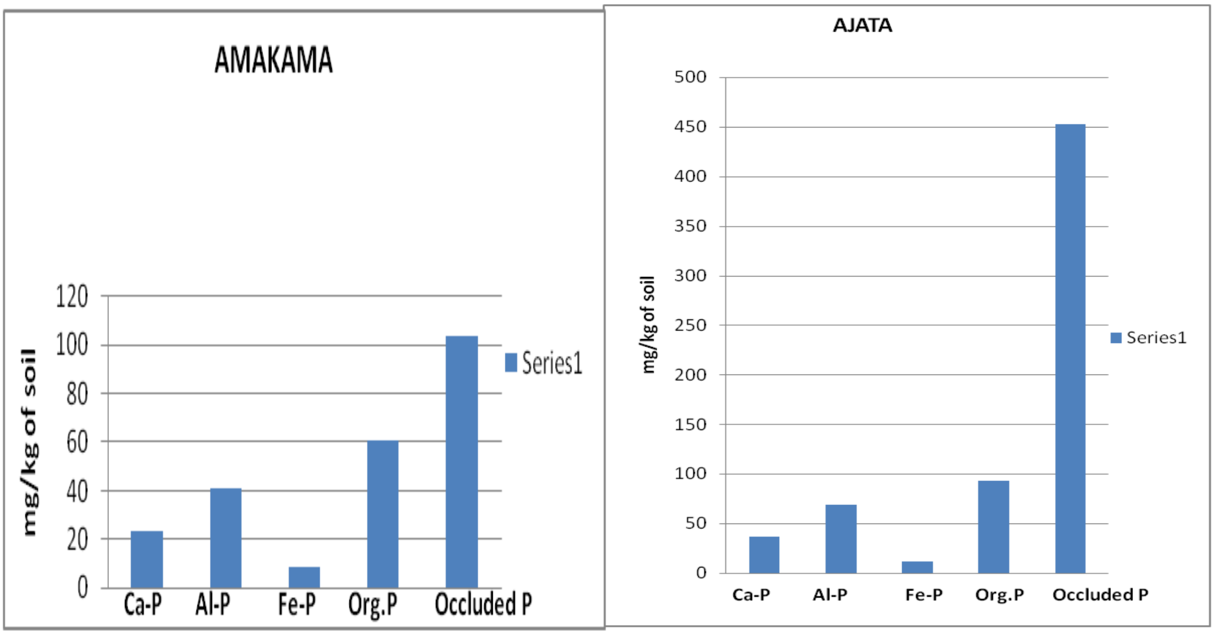

Fig. 1 Distribution of P forms

Table 1: Sampling location, parent material, and vegetation of the sampling site

Soils	Classification usda	Sampling Location	Parent material	vegetation	D drainage	location	mar (mm)
1 Amakama Olokoro	Ultisols	Umuahia	Coastal Plain sands	Secondary forest	Well drained	Lat.5^0 26' 40"N Long: 7^0 28'49''E	1976
2 Ajata Ibeku	Alfisols	Umuahia	Clay shale	Secondary forest	Poorly drained	Lat: 5^0 32' 5" N Long; 7^0 33' 34" E	1976

MAR = Mean Annual Rainfall

Table 2. Morphological properties of the soil profiles

Désignation	Depth (cm)	Colour (moist)	Colour (dry)	Texture	Structure	Consistence	Pores	Roots	Boundary
Amakama Olokoro Soils, (0 – 2% slope), midslope.									
Ap$_2$,	13-27	2.5YR3/2	7.5YR4/4	SCL	1,m,sbk	fr,sst,spl	1,f	m,fb	cs
B$_1$	27-63	2.5YR3/2	-	SC	1,m.sbk	fr,sst,spl	3,f	m,w	gs
B$_2$	63-99	2.5YR3/6	-	SC	1,m.sbk	fr,sst,spl	3,f	vf,w	gs
B$_3$	99-127	2.5YR4/6	-	SC	1,m.sbk	fr,sst,spl	3,f	f,w	cs
B$_4$	127-159	2.5YR4/6	-	SC	2,f,bsk	fr,sst,spl	3,f	vf,w	cs
B$_5$	159-210	2.5YR4/6	-	SC	2,f,bsk	fr,sst,spl	3,f	vf,w	ds
B$_6$	210-240	2.5YR4/6	-	SCL	2,f,bsk	fr,sst,spl	3,f	vf,w	-
Ajata Ibeku Soils, (0-5% slope), upper slope.									
Ap$_1$	0-9	10YR3/4	10YR5/4	CL	1,f,cr	Fr,sst,spl	1,f	f,fb	Gs
Ap$_2$	9-28	5YR4/3		C	2,m,sbk	Fr,sst,spl	1,f	f,fb	Gs
Bt$_1$	28-60	5YR4/6	-	C	2,m,sbk	Fr,sst,spl	2,f	f,fb	Gs
Bt^2	60-80	10YR4/1	-	C	2,m,sbk	Fi,sst,spl	3,f	f,fb	Gs
Bt$_3$	80-101	10YR5/2	-	C	2,C,sbk	Fi,sst,spl	3,f	f,fb	Ds
Bt$_4$	101-128	10YR6/2	-	C	2,C,sbk	Fi,st,pl	3,f	f,fb	Gs
Bt$_5$	128-164	10YR6/2	-	C	2,C,sbk	Fi,vst,pl	3,f	f,fb	Gs
Bt$_6$	164-190	10YR6/2	-	C	2,C,sbk	Fi,vst,pl	3,f	F,fb	-

SYMBOLS

Pores: 3= many, 2 = common, 1 = few; c = coarse, m = medium, f = fine.s

Structure: 1 = weak, 2 = moderate, 3 = strong; abk angular blocky, sbk = sub-angular blocky, cr crumb, m =massive.

Consistence: l = loose, fr = friable, fi = firm; nst = non sticky, sst = slightly sticky, mst = moderately sticky, st= sticky; npl = non plastic, spl = slightly plastic, mpl = moderately plastic, pl = plastic

Root: f = few, c = common, a – abundant; fb = fibrous, w = woody

Boundary: c = clear, w = wavy, g = gradual, ir= irregular; d = diffused, b = broken, s = smooth.

Texture: LS = loamy sand, SL = sandy loam, SCL = sandy clay loam, SC = sandy clay, CL = Clay loam, C = clay.

Table 3: Some Physical Properties of the Soil Profile

Horizon Designation	Depth (cm)	Sand (%	Silt (%)	Clay (%)	Texture	Silt/Clay Ratio
AMAKAMA OLOKORO SOILS, 0.2% SLOPE, MID SLOPE						
Ap_1	0-13	67	7	26	Sand clay loam	0.25
Ap_2	13-27	69	4	27	Sand clay loam	0.13
Bo_1	27-63	60	3	37	Sand clay	0.08
Bo_2	63-99	60	3	37	Sand clay	0.08
Bo_3	99-127	59	4	37	Sand clay	0.09
Bo_4	127-159	58	5	37	Sand clay	0.13
Bo_5	159-210	58	5	37	Sand clay	0.13
Bo_6	210-240	60	5	35	Sand clay loam	0.13
AJATA IBEKU SOILS, 0-5%SLOPE, UPPER SLOPE						
Ap_1	0-9	43	20	37	Clay loan	0.52
Ap_2	9-28	33	19	48	Clay	0.38
Bt	28-60	13	10	77	Clay	0.12
2Btg	60-80	18	10	72	Clay	0.13
$2Bssg_1$	80-101	19	7	74	Clay	0.09
$2Bssg_2$	101-128	22	5	73	Clay	0.06
$2Bssg_3$	128-164	15	11	74	Clay	0.14
$2Bssg_4$	164-190	19	12	69	Clay	0.17

Table 4: Chemical properties of the soils

DEPTH	pH	pH	Exchangeable Bases (cmol/kg)				OC	Total N	C/N	Exch.Al	Exch.H	TEA	Avail.P	ECEC	B/S
(cm)	H_2O	1N KCl	Ca	Mg	K	Na	%	%	ratio	cmol/kg	cmol/kg	cmol/kg	mg/kg	cmol/kg	%
AMAKAMA OLOKORO SOILS, 0 – 2% SLOPE, MIDDLE SLOPE															
0-13	4.11	5.30	2.4	1.6	0.092	0.083	1.91	0.084	22.73	2.4	1.4	3.8	20.0	7.90	52
13-27	4.45	5.40	2.0	1.2	0.076	0.083	1.16	0.084	13.80	1.2	1.4	3.6	6.50	6.96	48
27-63	4.48	5.30	1.2	1.6	0.081	0.083	1.28	0.070	18.28	2.0	1.6	3.6	5.50	6.56	45
63-99	4.55	5.60	1.6	0.8	0.071	0.075	0.54	0.056	9.64	1.8	1.2	3.0	17.00	5.55	46
99-127	4.42	5.20	1.6	2.0	0.097	0.125	0.75	0.056	13.39	1.2	1.8	3.0	9.50	6.82	56
127-159	4.71	5.25	2.0	1.6	0.071	0.075	0.33	0.028	11.78	0.8	1.6	2.4	13.00	6.15	61
159-210	4.85	5.30	1.6	2.0	0.071	0.083	0.39	0.028	13.92	1.0	0.6	1.6	16.00	5.35	70
210-240	5.32	5.50	2.0	1.6	0.061	0.075	0.29	0.042	6.90	0.8	2.0	2.8	4.00	6.54	57
AJATA IBEKU SOILS, 0 – 5% SLOPE, UPPER SLOPE															
0 – 9	4.83	5.50	4.0	2.4	0.133	0.083	0.92	0.098	9.38	0.6	1.2	1.8	20.0	8.42	79
9 -28	4.38	5.15	2.4	0.8	0.112	0.083	1.64	0.112	14.64	4.4	3.6	8.0	8.5	11.39	30
28 -60	4.28	4.85	3.2	1.6	0.122	0.092	0.72	0.056	12.85	5.0	4.6	9.6	21.0	14.61	35
60 - 80	4.48	4.95	2.8	2.0	0.174	0.083	0.95	0.070	13.57	16.0	12.4	28.4	9.0	33.46	15
80 - 101	4.53	4.80	4.4	3.2	0.153	0.100	0.95	0.070	13.57	18.0	13.4	31.4	8.5	39.25	20
101 - 128	4.57	4.70	8.0	4.0	0.199	0.108	1.16	0.042	27.6	17.0	15.0	32.0	12.0	44.31	27
128 - 164	4.30	4.10	9.6	6.4	0.204	0.083	0.78	0.042	18.57	14.2	10.4	24.6	9.5	48.89	33
164 - 190	3.91	4.90	11.2	11.6	0.199	0.100	1.10	0.056	19.64	6.8	11.6	18.4	5.5	41.50	56

TEA = Total Exchangeable Acidity, ECEC = Effective Cation Exchange Capacity, B/S = Base Saturation

Table 5 Mean values of various forms of phosphorus in the soil in mg/kg

Depth (cm)	AlP mg/kg	Fe - P mg/kg	Ca-P mg/kg	Organic P mg/kg	Occluded P mg/kg	Total P mg/kg	Bray 2P mg/kg
AMAKAMA OLOKORO SOILSL							
0-13	27.29	68.07	20.70	69.71	38.62	224.39	20.00
13-27	45.70	59.62	11.35	103.34	65.35	285.36	6.50
27-63	28.79	29.24	3.94	44.03	152.53	258.53	5.50
63-99	10.44	27.29	0.99	31.03	191.22	260.97	17.00
99-127	17.54	33.02	6.41	34.93	95.96	187.86	9.50
127-159	13.26	35.09	6.41	74.90	76.43	206.09	13.00
159-210	23.39	43.38	16.26	54.19	38.38	175.60	16.00
210-240	20.32	33.14	2.36	75.87	169.52	301.21	4.00
AJATA IBEKU SOILS							
0—9	16.77	89.52	6.20	113.09	608.56	834.14	20.00
9—28	23.17	79.12	5.08	79.94	549.28	736.59	8.50
28—60	38.99	58.00	20.32	86.28	429.33	632.92	21.00
60—80	41.49	74.09	17.74	78.80	384.22	596.34	9.00
80--101	59.83	72.63	7.39	103.34	17.79	260.97	8.50
101--128	30.20	52.64	7.89	70.35	282.82	443.90	12.00
128--164	29.59	33.02	2.14	83.84	405.06	553.65	9.50
164--190	50.20	95.12	27.29	127.71	952.13	1252.45	5.50

Table 6: Content of various forms of phosphorus in the soils

LOCATION	AL – P	Fe –P	Ca – P	Org. P	Occluded P	Total P	Avail. P
AMAKAMA	23.29	41.07	8.55	61.00	103.50	237.50	11.43
AJATA	36.28	69.29	11.75	92.91	452.64	663.81	11.75

Table 7 Correlation coefficient between soil phoshorus and some soil properties

	Al- P	Fe-p	Ca-p	Org-p	Occluded p	Total p
Bray 2 p	0.23	-0.05	0.17	0.11	-0.20	-0.17
pH (water)	0.06	0.01	-0.17	0.08	-0.30*	-0.270
Exch Ca	0.10	0.16	0.03	0.19	0.61***	0.61***
Exch Al	0.23	0.08	-0.02	0.10	0.22	0.24
O/C	0.19	0.24	0.29*	0.05	0.14	0.18
Sand	0.14	-0.09	0.29*	0.08	0.57***	0.57***
Clay	0.06	-0.03	0.19	-0.001	0.49**	0.47**

Multiple correlation analysis (Table 7) showed that the level of organic P in these soils with organic carbon contrary to the reports of Uzu *et al.* (1975), Udo and Ogunwale (1977), Udo and Dambo (1979). But it was in agreement with the reports of Loganathan and Sutton (1987), Osodeke and Kamalu (1992).

Inorganic P The amount and distribution of various forms of inorganic P are shown in Table 6. . The occluded P on the average was 103.5 mg/kg in the Amakama soil derived from Coastal Plain Sands and 452.64 mg/kg in the Ajata soils derived from Shale. Occluded P constituted 40 to 80% of total inorganic P forms in the soil. Fe-P ranged from 27.29 to.68.07 mg/kg in the Amakama soils derived from Coastal Plain Sands, and 33.02 to 95.12 mg/kg in the Ajata soil (Shale). The occluded P constituted between 26 and 68 percent of the total P in the various soils. The ranges of percentage of occluded P to total inorganic P and total P are in firm agreement with the report of Osodeke and Kamalu (1992) (30 to 80% and 11 to 67% of occluded P to total inorganic P and occluded P to total P respectively). The occluded P and Fe- P occupied more than 84% of the total inorganic P. This indicates the high degree of chemical weathering of these soils (Chang and Jackson, 1958). The content of Ca-P and Al-P are very low (<16% of the total inorganic P) especially in the soils derived from Sandstone (Amakama). This is in agreement with the report of Uzu *et al.* (1975). The low Al-P content and the predominance of the occluded P in these soils suggest the limited capacity of these soils in supplying plant-available P from the inorganic P (Chang and Juo, 1963; Smith, 1965; Juo and Ellis, 1968b). The active P constitute between 18 and 38% percent of the total soil P. These values are comparable to the values of 13 to 33 percent reported by Osodeke and Kamalu (1992). The relative abundance of various forms of inorganic P was increasing in order of Ca-P, Al-P, Fe-P, and occluded P (figure 1). This order has been reported by several authors (Udo and Uzu, 1972; Udo and Ogunwale, 1977; Udo and Dambo, 1979; Loganathan *et al.*, 1982; Loganathan and Sutton, 1987; Osodeke and Kamalu, 1992; Ojo *et al.*, 2010). The high content of Al-P in the lower horizons of the Ajata soil is due to poor drainage condition rather than degree of weathering. Similar reports were obtained from Juo and Ellis (1968b), Westin and de Brito (1969), and Uzu *et al.* (1975). Calcium-P correlated negatively with sand and positively with organic carbon, exchangeable Ca, Al-P and total P. Fe-P correlated positively with organic P, Al-P and total P. Al-P correlated positive with Fe-P, Ca-P, and organic P. Occluded P correlated positively with clay and exchangeable Ca and negatively with sand. *Available P* The Bray P 2 test values are shown in Table 4. The available P ranged from 4.0 mg/kg in the Amakama soil to 21 mg/kg in the Ajata soil with mean value of 11.59 mg/kg. In all the studied soils, the surface horizon (Ap) contained more available P than the subsurface horizons. The available P in Amakama and Ajata soils is the same.

In general the soils of studied area had less available P than the critical levels of 15 mg/kg by the Bray P 2 method (Enwezor *et al.*, 1989; Enwezor *et al.*, 1990).

CONCLUSION

The result of various forms of phosphorus indicated that the pattern of their distribution with depth was not uniform in all the soils studied. The relative abundance of various forms of inorganic P were in the sequence of Ca-P < Al-P < Fe-P < occluded P. In all the studied soils, the surface soils contain more available P than the subsurface soil. In general, the soil available P is below the critical level (15 mg/kg).

It could be concluded therefore, that the status of the total phosphorus as well as the various forms they exist in the soils studied depend upon the type of different parent materials from which these soils were formed. Therefore, parent materials have very significant influence on the overlaying soils when the soil is formed in-situ from parent material.

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