# PHOSPHORUS FORMS AND DISTRIBUTION IN SELECTED SOILS FORMED OVER DIFFERENT PARENT MATERIALS IN CROSS RIVER STATE OF NIGERIA

Ohaeri , J.E

National Root Crops Research Institute Umudike, Abia State

E-mail; owelleohuhu@yahoo.com.

**ABSTRACT**

The forms and distribution of phosphorus in selected soils formed over different parent materials in Cross River State of Nigeria were investigated. The parent materials of the soils are Cretaceous Sandstone, Olivine Basalt, and Crystalline Basement Complex Rock in Ogoja, Otiri Ikom and Atimaka Yala Ikom respectively. The result of various forms of phosphorus indicated that the pattern of their distribution with depth was not uniform in all the soils studied. Total P varied widely ranging from 181.7 to 693.9 mg / kg with overall mean of 337.46 mg/ kg. Ikom Red soils having higher values while Ogoja have lower values. The organic P also varied widely ranging from 62.86 to 136.49 mg /kg with a mean value of 75.61 mg/ kg. About 40% of the Total P in the surface horizon (Ap) of the fine-textured soils (Ikom Red) are in organic P form while the coarse-textured soils (Ogoja and Ikom grey soils) 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 comprised 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. Available P is low with values ranging from 5-22 mg/ kg with a mean value of 13.72 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. Its deficiency in soils is compounded by the highly weathered nature of the arable soils that are in the most area 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). Despite tremendous amount of research effort over the last 100 years, its behaviour in soil and availability to crop are still imperfectly understood.

The Ogoja soils formed on Cretaceous Sandstone and Shale parent material are Alfisols (Soil Survey Staff, 2006) and are classified as Luvisols (F.A.O./UNESCO, 1988). They are red to brown soils relatively high in base saturation and available P. The highly weathered and well-drained soils derived from Olivine Basalt (Volcanic ash) are found in restricted areas around Ikom (Ikom Red soils). These soils are Inceptisols (Soil Survey Staff, 2006) and are classified as Cambisols (F.A.O./UNESCO, 1988). They are acidic, low in P and base saturation, kaolinitic in clay mineralogy and of high P fixation (Udo and Uzu, 1972). Although Ca and Mg contents are low, K is however, high with inherent high fertility. The soils are dark red in colour and clayey with loamy clayey surface (Enwezor *et al*., 1990).

The Ikom Grey soils formed over Crystalline Basement Complex Rocks are acidic and of low C.E.C, and low in base saturation. They are particularly low in available P. While exchangeable Ca and Mg are deficient in soils, exchangeable K is relatively high. The dominant clay mineral is kaolinite. These soils are Ultisols (Soil Survey Staff, 2006) and are classified as Nitosols (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 of agricultural soils of Cross River 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 Southeastern Nigeria 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 is necessary.

## MATERIALS AND METHODS

The study was conducted at Ojoja and Ikom, both in northern part of Cross River 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. In choosing the 3 sampling sites used in the study, use was made of the Soil map of Southeastern Nigeria. In the selection of the sites, effort was made to reflect, as much as possible, the soils from different parent materials as itemized thus: Cretaceous Sandstone (Ogoja), Basalt (Itiri Ikom) and Basement Complex Rock (Atimaka Yala Ikom). A Profile Pit was dug in each of the 3 locations. The profiles were described and sampled following the procedures of Soils Survey Staff (2006). Six to seven 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 (1965). 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).

## RESULTS AND DISCUSSION

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

**Total phosphorus**

As show in Tables 5, the total P content in the entire study area varied widely ranging from 181.7 to 693.9 mg/kg with the mean value of 337.46 mg/kg. This is in agreement with the report of Uzu *et al*. (1975). The Ikom Red soils, derived from Basalt, contain the highest amount of total P (694 mg/kg). The Ogoja soils contain the lowest amount of total P among the three soil profiles studied (407 mg/kg). This is also in agreement with the report of Uzu *et al.*, (1975). The high total P in Ikom Red 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. Similar trend 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 Ikom Red soil (62.86 mg/kg) while the highest was found in the Ikom Grey soil (136.49 mg/kg) with mean values of 87.19, 91.25 and 100.72 mg/kg in the Ogoja, Ikom Red and Ikom Grey soils respectively. These values constitute 37.1, 20.1, and 25.9 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 Uzu *et al.*, (1975) in the soils of Southeastern Nigeria respectively; but comparable with the value of one 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 (Ikom Red soils) are in organic P form (Uzu *et al.*, 1975; Enwezor *et al*., 1990; Osodeke and Kamalu, 1992). However, the coarse and medium textured soils (Ogoja, and Ikom Grey soils) have a very low (<20%) organic P contribution to the total P. The low Organic P of these coarse and medium textured soils is a reflection of the low total P and organic carbon of these soils.

Multiple correlation and regression analysis (Table 7) showed that the level of organic P in these soils is highly positively correlated with Fe-P, Al- P and total P. This is in agreement with the report of Mehlta and Patel (1963). There was no significance correlation with organic carbon contrary to the reports of Uzu *et al.* (1975), Udo and Ogunwale (1977), Udo and Dambo (1979). But it is 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 5. The mean values of various forms of P are also shown in table 6. The occluded P ranged on the average from 6.197 mg/kg in the Ogoja soil derived from Cretaceous Sandstone to 243.37 mg/kg in the Ikom Red soils derived from Olivine Basalt. Occluded P constituted 40 to 80% of total inorganic P forms in the soil. Fe-p ranged on average from 59.32 to 64.37 mg/kg in the Ogoja soils and the Ikom Grey soils. 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 (Ogoja). 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 (fig. 1). This order has been reported by several authors (Udo and Uzu, 1972a; Udo and Ogunwale, 1977; Udo and Dambo, 1979; Loganathan *et al.*, 1982; Loganathan and Sutton, 1987; Osodeke and Kamalu, 1992; Ojo *et al*., 2010).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

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**Available P**

The Bray P 2 test values are shown in Table 4. The available P ranged from 5.0 mg/kg to 22 mg/kg in the Ikom Red soils with mean value of 12.77 mg/kg. In all the studied soils, the surface horizon (Ap) contained more available P than the subsurface horizons. In general the soils studied area had less available P greater than the critical levels of 15 mg/kg by the Bray P 2 method (Enwezor *et al.,* 1989; Enwezor *et al.,* 1990).

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

| SOILS | CLASSIFICATION USDA | SAMPLING LOCATION | PARENT MATERIAL | VEGETATION | DRAINAGE | LOCATION | MAR (mm) |
|---|---|---|---|---|---|---|---|
| 1 Ogoja | Alfisols | Ogoja | Cretaceous sandstone | Secondary forest | Well drained | Lat. $6^0$ 35' 9"N Long: $8^{0\ 4}$8' 6''E | 1853 |
| 2 Ikom Red | Inceptisols | Ikom | Olivine Basalts | Orange Orchard<br>Secondary forest | Well drained | Lat: $5^0$ 56' 5" N Long; $8^0$ 34' 34" E | 2531 |
| 3 Ikom Grey | Ultisols | Ikom | Basement Complex rock | | Well drained | Lat: $5^0$ 58' 5" N Long; $8^0$ 28' 34" E | 2531 |

MAR= Mean Annual Rainfall

**Table 2: Morphological properties of the soil profile**

| Horizon Designation | Depth (cm) | Colour (moist) | Colour (dry) | Texture | Structure | Consistence | Pores | Roots | Boundary |
|---|---|---|---|---|---|---|---|---|---|
| **Asherere Ogoja Soils, (2 – 4% slope), midslope.** | | | | | | | | | |
| $Ap_1$ | 0 – 8 | 2.5YR2/2 | 5YR5/2 | LS | 1,f,cr | Fr,nst,npl | 3,f | A,fb | cs |
| AB | 8-50 | 7.5YR4/4 | 7.5YR5/4 | LS | 1,m,sbk | Fr,nst,npl | 3,f | Vm,fb | cs |
| $Bt_1$ | 50-105 | 5YR5/8 | - | SCL | 1,m.sbk | Fi,st,pl | 3,f | F,fb | ds |
| $Bt_2$ | 105-148 | 2.5YR5/8 | - | SCL | 1,m.sbk | Fr,sst,spl | 2,f | F,fb | cs |
| $Bt_3$ | 148-178 | 2.5YR5/8 | - | SCL | 1,m.sbk | Fr,sst,spl | 2,f | f,w | cs |
| $Bt_4$ | 178-202 | 5YR6/6 | - | SCL | 1,m,sbk | Fr,sst,spl | 2,f | vf,w | - |
| **Otiri Ikom Red Soils, (0-2% slope), (flat).** | | | | | | | | | |
| $Ap_1$ | 0-9 | 5YR4/4 | - | CL | f | Fr,mst,mpl | 3,f | A,fb,w | cs |
| BA | 9-18 | 5YR4/6 | | C | 2,m,sbk | Fi,st,pl | 2,f | a,fb,w | cs |
| $Bt_1$ | 18-45 | 5YR5/6 | - | C | 2,m,sbk | Fi,mst,mpl | 2,f | c,fb,w | gs |
| $Bt_2$ | 45-95 | 5YR4/8 | - | C | 2,m,sbk | Fi,sst,spl | 2,f | f,fb,w | ds |
| $Bt_3$ | 95-144 | 5YR5/8 | - | C | 2,C,sbk | Fi,sst,spl | 2,f | f,w | ds |
| $Bt_4$ | 144-180 | 5YR5/8 | - | C | 2,C,sbk | Fr,sst,spl | 2,f | vf,w | cs |
| $Bt_5$ | 180-205 | 7.5YR6/6 | - | C | 1,sbk | Fi,mst,mpl | 2,f | vf,w | cs |
| **Atim Yala Ikom Grey soils, (2 – 4% slope) mid slope** | | | | | | | | | |
| | | | 10YR5/2 | | | | | | |
| $AP_1$ | O – 12 | 10YR3/3 | - | SL | 1,cr | Fr,sst,spl | 3f | A,fb | gs |
| BAt | 12 – 32 | 10YR4/3 | - | SCL | Sbk | Fr,mst,mpl | 2f | C,fb | ds |
| $Bt_1$ | 32 – 46 | 10YR5/6 | - | SCL | Sbk | Fi,st,pl | 2f | F,fb | cs |
| $Bt_2$ | 46 – 88 | 10YR5/4 | - | SCL | Sbk | Fi,sst,spl | 1f | F,fb | cs |
| $Bt_3$ | 88 – 120 | 2.5YR6/4 | - | SCL | Sbk | Fi,mst,mpl | 2f | V,f,w | cs |
| BC | 120 - 146 | 2.5YR6/4 | - | SL | Sbk | Fi,sst,spl | 2f | V,f,w | cw |
| C | 146– 196 | 5Y7/2 | | SL | m | Fr,nst,npl | 3m | - | - |

**SYMBOLS**

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

**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 |
|---|---|---|---|---|---|---|
| **ASHERERE OGOJA SOILS, 2-4% SLOPE, MID SLOPE** | | | | | | |
| $Ap_1$ | 0 – 8 | 83 | 6 | 11 | Loamy Sand | 0.53 |
| AB | 8-50 | 84 | 6 | 10 | Loamy Sand | 0.58 |
| $Bt_1$ | 50-105 | 67 | 2 | 31 | Sandy Clay Loam | 0.06 |
| $Bt_2$ | 105-148 | 66 | 5 | 29 | Sandy Clay Loam | 0.17 |
| $Bt_3$ | 148-178 | 65 | 8 | 27 | Sandy Clay Loam | 0.29 |
| $Bt_4$ | 178-202 | 70 | 5 | 25 | Sandy Clay Loam | 0.19 |
| **OTIRI IKOM OILS, 0-2%SLOPE, FLAT** | | | | | | |
| $Ap_1$ | 0-9 | 44 | 22 | 34 | Clay loam | 0.65 |
| BA | 9-18 | 33 | 14 | 53 | Clay | 0.26 |
| $Bt_1$ | 18-45 | 29 | 9 | 62 | Clay | 0.14 |
| $Bt_2$ | 45-95 | 26 | 9 | 65 | Clay | 0.13 |
| $Bt_3$ | 95-144 | 24 | 9 | 67 | Clay | 0.13 |
| $Bt_4$ | 144-180 | 23 | 10 | 67 | Clay | 0.14 |
| Bt | 180-205 | 25 | 8 | 67 | Clay | 0.11 |
| ATIMAKA YALA IKOM GREY SOIL, 2-4 % SLOPE, MIDSLOPE | | | | | | |
| $AP_1$ | O – 12 | 67 | 20 | 13 | Sandy loam | 1.49 |
| BAt | 12 – 32 | 67 | 12 | 21 | Sandy clay loam | 0.56 |
| $Bt_1$ | 32 – 46 | 63 | 8 | 29 | Sandy clay loam | 0.27 |
| $Bt_2$ | 46 – 88 | 54 | 11 | 35 | Sandy clay | 0.31 |
| $Bt_3$ | 88 – 120 | 63 | 12 | 25 | Sandy clay loam | 0.47 |
| BC | 120- 146 | 71 | 14 | 15 | Sandy loam | 0.90 |
| C | 146–196 | 79 | 12 | 9 | Sandy loam | 1.28 |

**Table 4: Chemical Properties of the Soils**

| DEPTH (cm) | pH $H_2O$ | pH 1N KCl | Exchangeable Bases (cmol/kg) Ca | Mg | K | Na | OC % | Total N % | C/N ratio | Exch. Al cmol/kg | Exch. H cmol/kg | TEA cmol/kg | Avail. P mg/kg | ECEC cmol/kg | B/S % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ASHERERE OGOJA SOILS, 2 – 4% SLOPE, MIDDLE SLOPE** | | | | | | | | | | | | | | | |
| 0 – 8 | 6.23 | 6.70 | 1.6 | 3.6 | 0.102 | 0.092 | 1.25 | 0.112 | 11.16 | 0.2 | 2.2 | 2.4 | 17.0 | 7.79 | 69 |
| 8 – 50 | 5.91 | 6.65 | 2.0 | 1.6 | 0.087 | 0.092 | 0.57 | 0.098 | 5.81 | 0.2 | 0.4 | 0.6 | 9.0 | 4.38 | 86 |
| 50 – 105 | 5.15 | 5.35 | 2.4 | 1.2 | 0.087 | 0.075 | 1.01 | 0.098 | 10.30 | 0.2 | 2.2 | 2.4 | 9.0 | 6.16 | 61 |
| 105 –148 | 4.40 | 5.15 | 2.0 | 1.2 | 0.107 | 0.092 | 0.87 | 0.056 | 15.53 | 1.2 | 1.4 | 2.6 | 21.0 | 5.99 | 57 |
| 148 –178 | 4.35 | 5.30 | 1.6 | 1.6 | 0.081 | 0.083 | 0.56 | 0.084 | 6.66 | 1.4 | 3.2 | 4.6 | 20.0 | 7.96 | 42 |
| 178 - 202 | 5.64 | 5.10 | 2.0 | 0.4 | 0.081 | 0.092 | 1.01 | 0.042 | 24.04 | 1.0 | 0.4 | 1.4 | 16.0 | 3.97 | 65 |
| **OTIRI IKOM RED SOILS, 0 –2% SLOPE MIDDLE SLOPE** | | | | | | | | | | | | | | | |
| 0 – 9 | 4.98 | 6.10 | 1.6 | 2.0 | 0.107 | 0.075 | 2.06 | 0.126 | 16.34 | 0.2 | 1.4 | 1.6 | 22.0 | 5.38 | 70 |
| 19-18 | 5.11 | 5.40 | 2.4 | 0.4 | 0.092 | 0.083 | 1.31 | 0.098 | 13.36 | 0.8 | 1.2 | 2.0 | 9.0 | 4.98 | 60 |
| 18-45 | 4.53 | 5.35 | 1.6 | 1.6 | 0.097 | 0.092 | 1.01 | 0.042 | 24.64 | 0.8 | 2.0 | 2.8 | 5.0 | 6.19 | 55 |
| 45-95 | 4.44 | 5.10 | 2.0 | 0.8 | 0.081 | 0.083 | 0.78 | 0.042 | 18.57 | 1.4 | 1.6 | 3.0 | 19.0 | 5.96 | 50 |
| 95-144 | 4.95 | 5.20 | 1.6 | 2.0 | 0.158 | 0.083 | 0.42 | 0.028 | 15.00 | 1.4 | 1.2 | 2.6 | 11.5 | 6.44 | 60 |
| 144-180 | 5.04 | 5.20 | 1.6 | 1.2 | 0.128 | 0.125 | 0.51 | 0.042 | 12.14 | 2.0 | 1.4 | 3.4 | 14.0 | 6.45 | 47 |
| 180-205 | 4.66 | 5.25 | 1.2 | 1.2 | 0.102 | 0.075 | 0.75 | 0.056 | 13.39 | 1.8 | 2.0 | 3.8 | 5.5 | 6.38 | 40 |
| **ATIMAKA YALA IKOM GREY SOILS, 2 – 4% SLOPE, MIDDLE SLOPE** | | | | | | | | | | | | | | | |
| 0 – 12 | 5.23 | 5.75 | 0.8 | 3.6 | 0.153 | 0.083 | 1.43 | 0.070 | 20.42 | 0.8 | 2.4 | 3.4 | 9.0 | 8.04 | 58 |
| 12-32 | 4.63 | 5.05 | 0.8 | 3.2 | 0. 153 | 0.083 | 1.34 | 0.070 | 19.14 | 2.4 | 1.6 | 4.0 | 9.0 | 8.24 | 51 |
| 32-46 | 4.04 | 5.30 | 1.2 | 1.6 | 0. 153 | 0.092 | 0.81 | 0.042 | 19.28 | 4.0 | 3.8 | 7.9 | 21.4 | 10.85 | 28 |
| 46-88 | 4.35 | 5.05 | 1.6 | 0.8 | 0.079 | 0.133 | 1.10 | 0.056 | 19.64 | 5.2 | 5.2 | 10.4 | 16.0 | 13.11 | 21 |
| 88-120 | 4.75 | 5.10 | 1.6 | 3.2 | 0.153 | 0.092 | 1.16 | 0.028 | 41.42 | 6.0 | 6.2 | 12.2 | 18.0 | 17.25 | 29 |
| 120-146 | 4.21 | 5.15 | 2.0 | 0.4 | 0.117 | 0.075 | 0.89 | 0.028 | 31.78 | 5.2 | 6.6 | 11.8 | 16.0 | 14.39 | 18 |
| 146-196 | 5.38 | 5.15 | 1.6 | 1.6 | 0.071 | 0.083 | 0.89 | 0.042 | 21.19 | 4.2 | 2.2 | 6.4 | 7.5 | 9.75 | 34 |

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

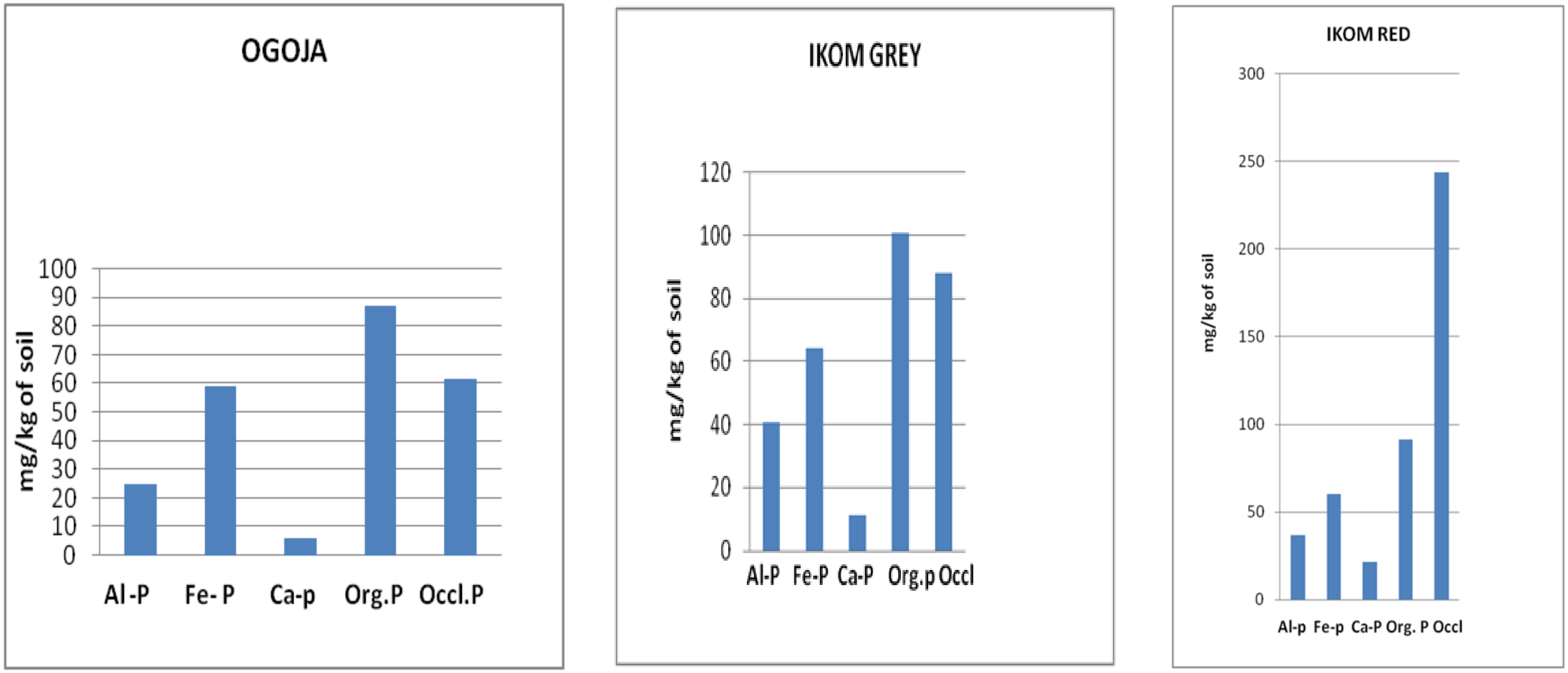


**Fig. 1; Mean values of various forms of P in the soils**

| Al-P | Fe - P | **Ca-P** | **Organic P** | **Occluded P** | **Total P** | **Bray 2 P** | |
|---|---|---|---|---|---|---|---|
| | mg/kg | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** | **mg/kg** |
| | | **ASHERERE OGOJA SOILS** | | | | | |
| 0--8 | 10.44 | 53.45 | 8.38 | 87.74 | 46.08 | 206.09 | 17.00 |
| 8--50 | 51.18 | 57.01 | 0.99 | 87.74 | 15.27 | 212.19 | 9.00 |
| 50--105 | 19.49 | 71.12 | 1.97 | 71.65 | 243.08 | 407.31 | 9.00 |
| 105--148 | 25.34 | 80.10 | 12.83 | 99.35 | 12.86 | 230.48 | 21.00 |
| 148--178 | 17.54 | 47.13 | 3.95 | 89.20 | 23.88 | 181.70 | 20.00 |
| 178--202 | 25.34 | 47.13 | 9.37 | 87.50 | 30.66 | 200.00 | 16.00 |
| | | **OTIRI IKOM RED SOIL** | | | | | |
| 0--9 | 52.50 | 58.24 | 42.89 | 90.17 | 340.16 | 584.14 | 22.00 |
| 9--18 | 19.49 | 54.19 | 14.03 | 73.27 | 326.60 | 486.58 | 9.00 |
| 18--45 | 57.01 | 57.35 | 40.94 | 62.86 | 166.09 | 384.25 | 5.00 |
| 45--95 | 29.73 | 80.00 | 2.47 | 131.95 | 48.75 | 293.90 | 19.00 |
| 95--144 | 25.14 | 58.65 | 17.54 | 112.05 | 17.10 | 230.48 | 11.50 |
| 144--180 | 57.01 | 88.55 | 21.69 | 105.29 | 226.24 | 498.78 | 14.00 |
| 180--208 | 15.78 | 24.55 | 11.69 | 63.20 | 578.68 | 693.90 | 5.50 |
| | | **ATIMAKA YALA IKOM GREY SOIL** | | | | | |
| 0--12 | 74.09 | 77.50 | 1.97 | 96.53 | 16.98 | 267.07 | 9.00 |
| 12--32 | 15.59 | 66.89 | 2.46 | 86.92 | 15.94 | 187.80 | 9.00 |
| 32--46 | 29.57 | 41.49 | 19.49 | 63.49 | 70.32 | 224.39 | 21.00 |
| 46--88 | 21.44 | 24.15 | 6.52 | 86.72 | 103.85 | 242.68 | 16.00 |
| 88--120 | 42.89 | 52.78 | 25.63 | 122.67 | 68.22 | 312.19 | 18.00 |
| 120--46 | 31.60 | 95.50 | 10.84 | 112.27 | 242.47 | 492.68 | 16.00 |

**Table 6: Mean values of various forms of phosphorus in the soil in mg/kg**

| LOCATION | AL – P | Fe –P | Ca – P | Org. P | Occluded P t | Total P | Avail. P |
|---|---|---|---|---|---|---|---|
| OGOJA | 24.88 | 59.32 | 6.24 | 87.19 | 61.97 | 234.62 | 15.33 |
| IKOM RED | 36.66 | 60.21 | 21.0 | 91.25 | 243.37 | 453.11 | 12.28 |
| IKOM GREY | 40.69 | 64.39 | 11.39 | 100.72 | 88.00 | 305.22 | 13.78 |
| MEAN | 32.42 | 58.63 | 11.97 | 86.00 | 198.56 | 387.69 | 12.77 |

**Table 7: Correlation coefficient between soil and some soil properties**

| | Al- P | Fe-p | Ca-p | Org-p | Occluded p | Total p |
|---|---|---|---|---|---|---|
| Bray 2 p | 0- 0.23 | -0.05 | 0.17 | 0.11 | -0.20 | 0.17 |
| pH (water) | 0.06 | 0.01 | -0.17 | 0.08 | -0.30* | -0.27* |
| 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** |

## 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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