INTERNATIONAL JOURNAL OF NATURAL AND APPLIED SCIENCES (IJNAS) VOL. 1, No. 1: pp. 10 – 14, 3 TABLES.

Determination of phosphorus fractions in selected soils of southeastern Nigeria.

V. E. Osodeke[*1] and A. F. Ubah[1]

ABSTRACT

The phosphorus fractions of soil samples from sixteen locations selected from southeastern Nigeria were determined. Available phosphorus was extracted by 2 methods (Bray – P-$_1$ and Bray-P-$_2$). Other forms of P were also determined. The results obtained indicated that total soil P varied from 125 to 750µgg^{-1} and organic P from 20 to 180µgg^{-1}. The values of the active inorganic P forms for the various soils varied from 1.17 µgg^{-1} to 101.5 µgg^{-1} for Al-P, 3.5 µgg^{-1} to 189 µgg^{-1} for Fe-P and 1.5 µgg^{-1} to 4.7 µgg^{-1} for Ca-P. The relative abundance of the various inorganic P forms was in the order of inactive P>Fe-P>Al-P>Ca-P. Available P extracted by the two methods correlated significantly with Al-P and organic P. The higher correlation coefficient with Al-P showed that it contributes more to soil available P in these soils. In addition, the levels of phosphorus in these soils portray the need to understand the role played by the various forms of P in any phosphorus fertilization programme.

Keywords: Phosphorus fertilization, phosphorus fractions.

INTRODUCTION

Finding solution to the problems of low and variability in phosphorus distribution in soils of Nigeria has been a major pre occupation of soil chemists in the last several years (Mokwunye and Bationo, 2001). They further stated that the recycling of phosphorus in cultivated fields is poor because most of the phosphorus taken up by the crops is retained in the grains, seeds and tubers which are generally harvested for food. In most Nigerian soils nitrogen, phosphorus, potassium, and magnesium and to some extent, sulphur and zinc are the nutrients whose deficiencies most frequently limit crop yield (Ahn, 1993). That of phosphorus is further compounded by the highly weathered nature of the arable soils that are in most parts acidic with high content of sesquioxides, kaolinitic clays and exchangeable Al^{3+} which fix P (Udo and Dambo, 1979; Osodeke and Kamalu, 1992). Some of the P will form compounds with Ca, Fe and Al, whether it comes from apatite, fertilizer, or organic matter. Most of these compounds are not available to plants because they are insoluble and are said to be the fixed forms (Tiessen, 1998). Phosphorus exists in soils in organic and inorganic P forms (Kuo, 1996). The soil organic P fraction may be derived from plant residues and from soil flora and fauna tissue and residues that resist rapid hydrolysis (Condron *et al*., 1990).

Although a number of studies on phosphorus have been conducted in the Southeastern zone, most of these are either on single parent material (Loganathan and Sutton, 1987; Ibia and Udo, 1993), or on few sample locations (Udo and Ogunwale, 1979). Because of the dynamics of phosphorus in soils, there is a need for the evaluation of forms of phosphorus in these highly weathered soils. Therefore the objective of the study was to evaluate the forms of phosphorus in selected soils, representing the major parent materials of southeastern Nigeria to update information available in this area.

MATERIALS AND METHODS

Surface soil samples representative of sixteen locations in southeastern Nigeria were collected and used for the study. The samples were air dried and sieved through 2 mm sieve. A small portion of each sample was ground with a mortar and pestle to pass through 0.05 mm mesh sieve and used for the study. Particle size analysis was carried out by the hydrometer method (Day, 1965), organic carbon by the method of Walkley and Black (1934) and pH was read using pH meter in soil: water ratio of 1:25. Available Phosphorus in soil was extracted by Bray P_1 and 2 method of Bray and Kurtz (1945). Total P was determined by $HClO_4$ digestion (Jackson, 1958) and organic P was estimated by difference between extractable inorganic P, before and after ignition, by the method of Leg and Black (1955). Inorganic P was fractionated by the method of Chang and Jackson (1957) as modified by Peterson and Corey (1966).

[*] Corresponding author
Manuscript received by the Editor November 30, 2004; Revised manuscript accepted August 30, 2005.
[1]Department of Soil Science, Michael Okpara University of Agriculture, Umudike, P.M.B. 7267, Umuahia, Abia State, NIGERIA

Phosphorus in the extracts was determined colorimetrically (Murphy and Riley, 1962). The standard phosphate requirement (SPR) of the soil was estimated by the method of Juo and Fox (1974). Correlation between forms of P and some soil parameters were carried out using the Spearman correlation coefficient as outlined by Wahua (1999).

RESULTS AND DISCUSSION

The physical and chemical properties of the soils are presented in Table 1. Particle size analysis showed that the soils varied from sandy loam to sand, with clay values between 8.12 to 32.8 percent and sand 20.0 to 88.4 percent. This is a reflection of the characteristics of the acid sands of Southeastern Nigeria (Enwezor *et al.* 1989). Organic carbon content varied from 0.11 to 6.9 percent. The pH values ranged from 4.5 to 6.0. The soils are therefore acidic.

Total P

Total P content in the soils ranged from 125 to 750µgg^{-1} with a mean value of 350µgg^{-1}. Generally, total phosphorus was in the order of coastal plain sand (390 µgg^{-1}) > shale (333 µgg^{-1}) > basalt (300 µgg^{-1}) > beach ridge sand (225 µgg^{-1}) > sandstone (203 µgg^{-1}). This confirms the findings of Ibia and Udo (1993) that the soils of the Coastal Plain Sands are higher in P reserve than other soil types. These values are higher than the values reported by Loganathan and Sutton (1987) in soils of the Meander Belt and Osodeke and Kamalu (1992) in Hevea growing soils of Nigeria. Total P correlated positively with sand (r = 0.24) and negatively with clay (r = -0.02), but the relationships were not significant.

Organic P

The soil organic P ranged from 20.0 in Okigwe to 180.0µgg^{-1} in Aba with a mean value of 92.19µgg^{-1}. These values are lower than the values of 34 to 339 µgg^{-1} reported by Loganathan and Sutton (1987) in the Coastal Plain Sand of Nigeria.

The highest organic P values were recorded in soils formed on shale with a mean of 112 µgg^{-1} while the lowest organic P were recorded in soils formed on Basalt parent material with a mean of 50.3 µgg^{-1} of P. As a fraction of total P, organic P constituted about 27% of the total P. The low organic P of these soils is a reflection of the total P and organic carbon content of the soils. Organic P had a significant positive correlation with silt (r = 0.49*) indicating that increase in silt of soils increases the organic P. Organic P also had a significant relationship with organic carbon, (r = 0.60**). The strong relationship between organic P and soil organic matter indicates the role of soil organic matter in P reserve in these soils in line with the report of Udo and Dambo (1979).

Inorganic P fractions

Total inorganic P is divided into active and inactive P forms, the former consisting of Al-P, Fe – P and Ca-P and latter consisting of occluded, reductant soluble and residual P (Kuo, 1996). The relative proportion of the various P forms are shown in Table 2. Inactive inorganic P forms was highest, varying from 7.13 in Ogoja (sandstone) to 363.35 µgg^{-1} in Afikpo (shale). The inactive P forms varied in these soils in the following order: shale > coastal plain sand > beach ridge > basalt > sandstone. Inactive inorganic P forms had

Table 1. Physical and chemical properties of the soils

S/N	Locations	% Clay	% Silt	% Sand	Texture	pH	Org. C %	N %	Na	K	Ca	Mg	Ex. Acidity	ECEC Cmol/kg
									→ Cmolkg^{-1} ←					
1.	Akwete	18.0	12.0	70.0	SL	5.0	2.15	0.12	0.19	0.35	0.20	1.20	2.00	5.75
2.	Aba	15.0	34.5	50.5	SL	4.7	3.0	0.17	0.10	0.16	2.10	1.08	4.20	6.84
3.	Ikot Ekpene	10.2	5.4	88.4	LS	5.0	6.9	0.09	0.30	0.20	1.20	0.15	1.10	4.3
4.	Owerri	21.6	1.8	76.6	SCL	5.0	4.27	0.91	0.09	0.07	0.30	2.30	6.10	10.3
5.	Umudike	16.8	3.2	80.0	SCL	4.90	2.08	0.23	0.19	0.17	2.58	1.65	3.40	7.99
6.	Afikpo	32.8	19.2	48.0	SCL	5.00	2.14	0.28	0.05	0.30	2.13	0.68	3.10	6.29
7.	Igbariam	30.0	10.0	60.0	SCL	5.2	1.11	0.28	0.16	0.20	0.40	1.60	2.40	4.76
8.	Enugu	32.2	19.2	48.0	CL	5.2	1.56	0.18	0.08	0.22	2.40	0.80	2.50	6.00
9.	Edda	30.0	20.0	40.0	CL	4.9	2.0	0.19	6.40	0.38	2.50	2.80	3.80	9.88
10.	Bende	15.9	28.3	45.8	CL	4.9	1.14	0.20	0.28	0.48	6.00	2.60	3.50	12.86
11.	Nsukka	20.0	30.1	49.9	SC	5.3	1.09	0.10	0.13	0.28	3.90	1.27	2.50	8.01
12.	Ikom	10.0	70.0	20.0	SIL	6.0	0.11	0.19	0.05	0.26	1.00	0.30	2.20	3.60
13.	Ohafia	24.7	20.0	55.3	SCL	4.5	4.0	0.15	0.30	0.36	6.0	4.00	3.00	13.62
14.	Okigwe	19.0	18.8	62.2	SL	5.0	1.8	0.08	0.30	0.30	3.50	1.60	2.10	7.8
15.	Ogoja	8.1	15.6	76.2	SL	4.90	0.96	0.11	0.58	0.34	3.00	2.00	1.40	7.32
16.	Bonny	20.2	17.4	62.4	SCL	5.70	1.57	0.12	0.19	0.28	2.00	4.00	1.80	8.27

the higher percent of the total P constituting 41.2% of the total P in all the soils. The mean values of the active inorganic P forms for the various soils varied from 35.17 μgg^{-1} for the soils formed on sandstone to a mean of 114.99 μgg^{-1} for the soils formed on shale. The Fe-P dominated the active P forms in the soils. This is in line with the report of Ibia and Udo (1993) that Fe-P are the dominant P in southeastern Nigeria soils. The active P form constitutes the lower percent of the total soil P accounting for 31.8% of the P. The relative abundance of the various forms of inorganic P was in the order of inactive P > Fe-P > Al-P > Ca-P. A similar trend had been reported by several authors (Uzu *et al*., 1975; Ibia and Udo, 1993; Loganathan *et al*., 1982; Loganathan and Sutton, 1987 and Osodeke and Kamalu, 1992). The intense chemical weathering of soils in these areas may have given rise to high proportion of inactive and Fe-P in the soils. Al-P significantly correlated with the available P indicating that the increase in Al-P increases the available P (r = 0.91*, r = 0.95*) in the soil. However, available P correlated negatively but not significantly with Ca-P.

Available P

Table 2 shows the values of available P extracted by Bray 1 and 2 methods. Bray P-2- extracted higher amount of P varying from 4.5 to 76μgg^{-1} with a mean value of 18.94μgg^{-1}. The Bray P-1-method extracted lesser amount varying from 4.0 to 46.7μgg^{-1} with a mean value of 12.36μgg^{-1}. Most of the soils had available P less than the critical P level for the Bray P-1 and 2 of 8 μgg^{-1} and 15μgg^{-1} respectively (Enwezor *et al.,* 1989). At low medium P range plants respond to P-fertilizer application, but not likely at higher level. The P extracted by the Bray-P-1-method had significant correlation with Al-P (r = 0.91*) (Table 3). This indicates that Al-P contribute more to soil available P in these soils. Similar result was reported by Osodeke and Kamalu (1992). The correlation coefficient (r) between available P and the active P fraction are in the order of Al-P>Fe-P>Ca-P. This trend has been reported by several authors (Loganathan and Sutton, 198; Osodeke and Kamalu, 1992; Ibia and Udo, 1993). From this study Al-P and Fe-P are ascertained to be the most important P fractions as far as the availability of P to plants is concerned in these soils.

Standard P requirement

Standard Phosphorus Requirement (SPR) is the quantity of P required to attain a standard P concentration of 0.2 μgg^{-1} in equilibrium solution as indicated by Beckwith (1965). The values ranged from 6.0 to 150μgg^{-1} (Table 2). With a mean value of 28.8μgg^{-1}. These values for these soils are very low compared to the findings of other authors (Udo and Uzu, 1972; Juo and Fox, 1974 and Osodeke and Kamalu, 1992). This results ascertained that P requirement of the Southeastern Nigeria cultivating soils is relatively low, hence low

Table 2. Various phosphorus fractions in the soils (μgg^{-1})

					Active P			Available P			
S/N Bray-2	Locations SPR*	Parent materials	Total P	Organic P	Al-P	Fe-P	Ca-P	Inactive P	Bray-1	SPR	
1.	Akwete	Coastal Plain sand	375	20.0	1.17	28.0	1.50	317.63	6.7	10.0	20
2.	Aba	Coastal Plain sand	450	180.0	101.5	80.5	3.5	187.8	46.7	76.0	40
3.	Ikot-Ekpene	Coastal Plain sand	450	180.0	17.0	112.0	3.5	120.3	16.7	17.0	10
4.	Owerri	Coastal Plain sand	250	80.0	2.3	24.5	4.7	131.17	7.0	8.5	18
5.	Umudike	Coastal Plain sand	425	40.0	49.0	92.8	4.7	222.5	16.0	20.0	10
6.	Afikpo	Shale	675	90.0	28.9	161.0	1.75	363.35	10.0	20.0	38
7.	Igbariam	Shale	225	100.0	16.33	38.5	3.50	50.67	16.0	23.0	12
8.	Enugu	Shale	150	100.0	7.0	10.5	1.75	24.25	6.7	7.0	25
9.	Edda	Shale	650	160.0	67.7	189.0	3.5	210.5	19.3	40.0	16
10.	Bende	Shale	225	110.0	9.3	31.5	4.7	65.47	4.0	7.0	150
11.	Nsukka	Basalt	150	65.0	4.67	17.5	4.70	47.43	10.7	7.0	6.0
12.	Ikom	Basalt	750	40.0	7.0	56.0	4.7	638.3	4.0	9.5	50
13.	Ohafia	Sandstone	200	120.0	7.0	24.5	3.50	38.50	6.7	7.0	26
14.	Okigwe	Sandstone	275	20.0	7.0	49.0	1.95	193.25	4.0	7.0	14
15.	Ogoja	Sandstone	125	100.0	4.37	3.5	4.70	7.13	5.3	7.0	16
16.	Bonny	Beach ridge sand	225	70.0	4.20	73.5	1.75	19.75	18.0	37.0	9.6

SPR = Standard Phosphorus Requirement

Table 3. Correlation coefficients between soil P and some soil properties.

	Total P	Organic P	Fe-P	Al-P	Ca-P
Bray – 1- P	0.36	0.59*	0.39	0.91*	-0.01
Bray – 2- P	0.42*	0.55*	0.49*	0.95*	-0.19
PH (Water)	-0.19	0.10	-0.18	-0.20	0.26
Organic Carbon	-0.04	0.60*	0.28	0.12	0.04
Clay	-0.07	-0.25	-0.19	-0.23	0.08
Sand	0.24	-0.07	0.28	0.03	-0.32
Silt	-0.27	0.49*	-0.21	-0.05	0.26
Exchangeable acidity	-0.29	-0.19	-0.42*	-0.10	0.14

Significance: * P = 0.05

amount of P would be required to saturate the sorption sites. Therefore supplementary P application is recommended for efficient utilization in these soils.

REFERENCES

Ahn, P. M. (1993). *West African Soils. Vol.2*. West African Agriculture, Oxford.

Beckwith, R. S. (1965). Sorbed P at standard supernatant concentration as estimate of P needs of soils. *Australian J. of Experimental Agriculture and Animal Husbandry*, 5:52-58.

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

Chang, S. C. and Jackson, M. L. (1957). Fractionation of soil phosphorus. *Soil Sci.,* 84:133-144.

Condron, L. M., Mior, J. O., Tiessen, H. and Stewart, J. W. B. (1990). Critical evaluation of methods for determining total organic P is tropical soils. *Soil Sci. Soc. Am.* J., 54: 1261 – 1266.

Day, P. R. (1965). Particle fractionation and particle size analysis. *In Methods of Soil Analysis*, (Ed. C.A. Black), pp 545 – 567.

Dormaar, J. F. and Webster, G. R. (1964). Losses inherent in ignition procedures for determining total organic phosphorus. *Can. J. Soil Sci.,* 44: 1-6.

Enwezor, W. O. (1977). Soil testing for phosphorus in some Nigeria soils: 2. predicting responses to phosphate application for soils of southeastern Nigeria. *Soil Sci.,* 123:11-16.

Enwezor, W. O., Ohiri, A. C., Opuwaribo, E. E. and Udo, E. J. (1990). *Literature review on soil fertility investigations in Nigeria*. Federal Ministry of Agriculture and Natural Resources, Lagos.

Enwezor, W. O., Udo, E. J., Usoroh, N. J., Ayotade, K. A., Adepetu. J. A., Chude, V. O. and Udegbe, C. I. (1989). *Fertilizer use and management practices for crops in Nigeria. Series No. 2.* Bobma Publishers, Ibadan p. 18.

Ibia, T. O. and Udo E. J. (1993). Phosphorus forms and fixation of representative soils in Akwa Ibom State of Nigeria. *Geoderma,* 58:95 – 106.

Jackson, M. L. (1958). *Soil chemical analysis*. Prentice Hall, New York. p. 498.

Juo, A. S. R. and Fox, R. L. (1974). Phosphate sorption characteristics of some benchmark soils of West Africa. *Soil Sci.,* 124: 370 – 136.

Kuo, S. (1996). Phosphorus. *In: Chemical Methods of Soil Analysis - Part 3 (eds) D. L. Sparks, A. L. Page, P. A. Helmke, R. H. Loeppert, P. N. Soltanpour, M. A, Tabatabi, C. T. Johnston and M. E. Summer*. Soil Science Society of America, American Society of Agronomy, Madison USA pp 869-919.

Leg, J. O. and Black, C. A. (1955). Determination of organic phosphate in soils: 2. Ignition Method. *Soil Science Society of America Proceedings*, 19:139-142.

Loganathan, P., Dayaratne, M. N. and Shanmuganathan (1982). Evaluation of the phosphorus states of some coconut growing soils of Sri Lanka. *J. of Agricultural Science,* 99: 25-33.

Loganathan, P. and Sutton P. M. (1987). Phosphorus fractions and availability in soils formed on different geological deposits in Nigeria. *Soil Sci.,* 143:16-25.

Mokwunye, U. and Bationo, A. (2002). Meeting the phosphorus needs of the soil and crops of West Africa: the role of indigenous phosphate rocks. *In: Vaulauwe et al. (eds) Integrated plant nutrition management in Sub-Sahara Africa*. Cabi Publishing, USA. 352 pp.

Murphy, J and Riley, J. P (1962). A modified single solution method for determination of P in natural waters. *Annual Chem. Acta.,* 27: 31-36.

Osodeke, V. E. and Kamalu, O. J. (1992). Phosphorus status of Hevea growing soils of Nigeria. *Indian J. of Natural Rubber Research,* 5:107-112.

Peterson, G. W. and Corey, R. B. (1966). A modified Chang and Jackson procedure for routine fractionation of inorganic soil phosphorus. *Plant and Soil,* 22: 313 –316.

Thomas G. W. and Pearslee, D. E. (1973). Testing soils for phosphorus. *In: Soil testing and plant analysis (Ed. L. M. Walsh and J. D. Beaton). Soil Sci. Soc. Am.,* Madison Wisconsin, pp. 115-132.

Tiessen, H. (1998). The study of phosphorus cycles in ecosystems. *In J.M. Anderson and J. S. I. Ingram (eds). Tropical soil biology and fertility – A handbook of methods*.

Udo, E. J. and Dambo, U. I. (1979). Phosphorus status of the Nigeria Coastal Plain Sands. *J. of Agricultural Science*, 93: 281-289.

Udo, E. J. and Ogunwale, J. A. (1977). Phosphorus fraction in selected Nigeria Soils. *Soil Sci. Soc. Am. Proc.,* 24 (3): 325-327.

Udo, E. J. and Uzu, F. O. (1972). Characteristics of Phosphorus absorption by Nigerian Soils. *Soil Science Society of America Proceedings*, 36:879-883.

Uzu, F. O., Juo, A. S. R. and Fayemi, A. A. A. (1975). Forms of phosphorus in some important agricultural soils of Nigeria. *Soil Sci.,* 120: 212-218.

Wahua T. A. T. (1999). *Applied statistics for scientific studies*. Africa-link Books, Ibadan, Nigeria. 214 pp.

Walkley, A. and Black, I. A. (1934). Determination of organic carbon in soil. *Soil Science,* 37: 29-38.