Phosphorus Sorption in Soils Overlying Basement Complex Rock, Alluvium, Coastal Plain Sand and Imo Shale Parent Materials

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Authors' contributions

This work was carried out in collaboration among all authors. Author REO designed and supervised the study and author AE conducted and financed the study. Author EO assisted in laboratory analysis and finance and author AME managed the statistical analysis. Author AGB. managed the typing of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

This study aimed at evaluating phosphorus (P) sorption capacities in Soils overlying basement complex Rock (A), Alluvium (B), coastal plain sand (C) and Imo shale (C) parent materials.
Completely randomized design was used to collect soil samples from 5 depths in 3 replications from Idanre, Koko, NIFOR and Uhomora in Nigeria.
Samples collected were analyzed in the central analytical laboratory of the Nigerian Institute for Oil palm Research, Benin City, Nigeria between march 2016 and September 2017.
60 soil samples were equilibrated in 25 ml of 0.01 M $CaCl_2$ containing various concentration of P as KH_2PO_4 to give 0, 50, 100, 150, 200 and 250 mg/L P for 24 hours (h) at room temperature 25 ± 2 ^{o}C. Genstat statistical package was used to calculate Analysis of variance, correlation of

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Phosphorus sorption index (PSI) with soil properties, coefficient of variation, means separation and Least Significant difference (LSD).

The rate and %P adsorption increased with increasing concentration of P added to the soils. The P sorption capacities of the soils considering Freundlich model decreased in the order of D > B > C >A. %P adsorbed was highest in D soils with value of 15.19% for 100 mg/kg P added. The PSI correlated with organic carbon r = -0.58 *P* ≤ .05 in C soils, r = 0.44 *P* ≤ .05 in D soils, it also correlated with N r = -0.58 *P* ≤ .05 in C Soils, K r = 0.57 *P* ≤ .05, r = 0.49 *P* ≤ .05 in C and D soils respectively.

D soils sorbed more P than other soils hence the D soils will require more P fertilization to attain optimum P concentration in soil solution, however further study is required to determine the form of P sorbed by these parent materials.

1. INTRODUCTION

Phosphorus (P) is an essential macronutrient elements needed for plant growth, as it increases the physiological efficiency of crops. When phosphate fertilizers are applied to soils or dissolved by soil water, a substantial amount of the applied Phosphate are adsorbed on the solid phase reducing the use efficiency of the phosphate fertilizers [1]. P sorption can be said to occur when P added to soils or sediments undergo a fast surface reaction and slow reaction of P on solid phase [2]. Many tropical soils adsorb large amount of applied phosphates applied as fertilizers, P sorption is greatest in soils containing oxides, clay and allophane, followed by kaolinitic and lastly montmorillonitic clays [3,4].

In Acid soils P can largely be fixed by oxides, hydroxides and oxyhydroxides of iron (Fe), Aluminum (Al), Manganese (Mn) and clay minerals which makes it less available or effectively unavailable to plants. The availability of both native and applied P is largely controlled by sorption and desorption which makes phosphorus unavailable to plants. Such is the case of most Nigerian soils as it is dominated by sesquioxides and low activity clay [5,6]. The wide spread occurrence of P deficiency in most arable land in Nigeria has led to intensive use of P fertilizer. Nigerian soils may act as source or sink of P and may exhibit different P sorption capacities. While studies have been conducted on phosphorus sorption status of Nigerian upland soils [7,8,2,4]. None have been reported on the influence of Parent materials on P sorption characteristics thus there is paucity of research information on phosphorus sorption capacities of soils developed on different parent materials. This study was undertaken to provide information on Phosphorus Sorption in Soils Overlying Basement Complex Rock, Alluvium, Coastal Plain Sand and Imo Shale Parent Materials in Ondo, Delta and Edo states, Nigeria.

2. MATERIALS AND METHODS

2.1 Description of Study Area

This study was conducted in Idanre, Koko, Nifor and Uhomora in Ondo, Delta and Edo state of Nigeria (Fig. 1). Soils of Idanre is located on latitude 06 ° 44 ' 30.9 '' N, longitude 05 ° 05 ' 10.6 '' E and developed on Basement complex rocks (A) with mean annual rainfall and temperature of 1500mm, 26 °C, the site consisted of cocoa (*Theobroma cacao*) at time of sampling. Koko is located on latitude 06 ° 00 ' 04 '' N and longitude 05 ° 28 ' 03 '' E, the soils are developed on Alluvium (B) parent materials with and mean rainfall of > 2500 mm and temperature of 25 °C per annum. The site was planted to rubber (*Hevea Brasiliensis*) at the sampling time. While the soils of NIFOR and Uhomora are developed coastal plain sand (C) and Imo Shale (D) parent materials, the site is located on latitude 06 ° 36 ' 59.7 '' N and longitude 05 ° 37 ' 15.8 '' E, Latitude 6 ° 30 '45 '' N and Longitude 06 ° 50 ' 26 '' E, with annual rainfall of > 1725 and > 1575 mm Mean annual temperature of 31 °C and 32 °C, consisted of Oil palm (*Elaeis guineensis*) and cocoa (*Theobroma cacao*) as at the time of sampling respectively.

2.2 Soil Sampling

Soil samples were collected randomly from five depths (0-15, 15-30, 30-60, 60-90 and 90-120) cm in three replications from four locations of the study area using the soil Auger. Sixty soil samples collected were stored in labeled polythene bag and taken to the laboratory for further processing and analysis.
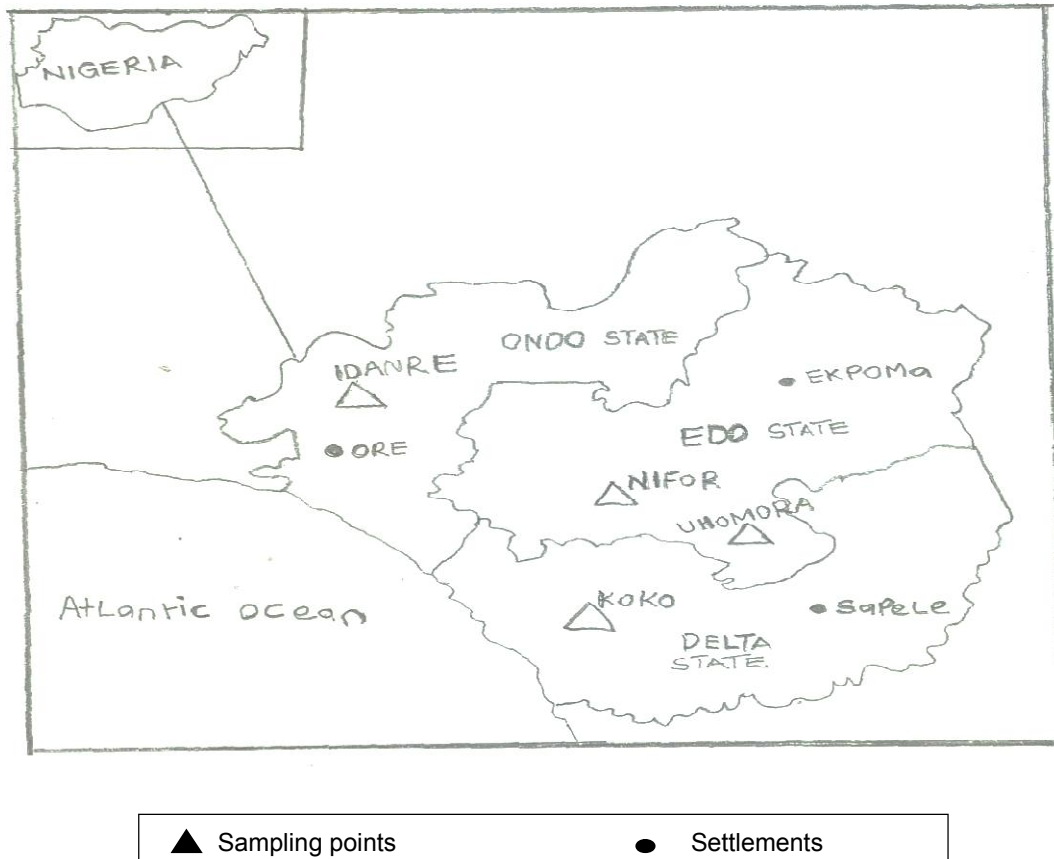
Fig. 1. Map showing the locations of the sampling point

2.3 Laboratory Analysis

The soils were air-dried at room temperature for 1 week, ground and sieved through a 2mm sieve for analysis. pH was determined in a 1:2 soil to water suspension using a glass electrode pH meter (Tan 1996). The Particle size analysis, Organic carbon, Cation exchange capacity (CEC) Available phosphorus Total nitrogen (N) and Total exchangeable acidity (EA), was determined by methods of Bouyoucos [9], Walkley and Black [10], Orhue, et al. [11], Bray and Kurtz [12], Bremmer and Mulvaney [13], Anderson and Ingram [14] respectively. Soil excheangeable bases were extracted by ammonium acetate method buffered at pH 7 [15]. From the extract, Ca and Mg was determined using Bunk scientific USA atomic absorption spectrophotometer (AAS), while K and Na were read with Jenway Germany flame photometer. Effective cation exchange capacity (ECEC) was determined by summation of CEC and EA [16,17].

2.3.1 Phosphorus sorption studies

1g air dried soil was weighed into series of 50 ml plastic bottles and the samples were equilibrated in 25 ml of 0.01 M $CaCl_2$ containing 0, 50, 100, 150, 200 and 250 mg/L P for 24 h at room temperature as prescribed by Nair et al. [18]. Three drops of $CHCl_3$ were added to inhibit microbial activities responsible for organic P mineralization during equilibration. The suspension was shaken for 24 h on a B. Bran scientific and instrument company England reciprocating mechanical shaker. After equilibration, the soil suspension was centrifuged at 7000 rpm for 5 minutes and the clear supernatant was decanted and Phosphorus concentration determined colorimetrically [19] at 882 nm after 1h using the 1205 Vis spectrophotometer.. The difference between the quantity of P added and the quantity of P in solution after shaking with soil was calculated as the quantity of P sorbed. The P sorption data were calculated from linear Freundlich and Langmuir sorption isotherm. Freundlich equation

is given by $X = a + C^n$. Linearizing the equation it becomes $\log X = \log a + 1/n \log C$. Where **X** is the amount of P sorbed per unit weight of soil (mg P kg^{-1} soil), **C** is the concentration of P in the equilibrium solution (mgL^{-1}) **a** is constant related to sorption capacity, it is the Y-intercept of the plot, **n** is the phosphate sorption energy obtained from dividing the slope of the plot by 1. A plot of log X against log C gives a straight line with slope 1/n. Langmuir equation is given by $C/x = 1/Kb + C/b$ Where, C = Concentration of P in soil solution at equilibrium (mg P L^{-1}), x = Amount of P adsorbed (mg kg^{-1} soil), b = Adsorption maximum (mg P kg^{-1} soil), 1/K b = Y-Intercept and K = Constant, i.e. adsorption affinity (L mg^{-1} P) K was obtained by dividing the slope (1/b) by intercept (1/K b). Plots of C/x versus C produce a straight line with a slope 1/b.PSI was determined according to procedure of Bache and Williams [20]. Adopted by Aghimien et al. [2] where the amount of P sorbed (x) mg kg^{-1} from addition of 1.5 g P kg^{-1} soil was determined after shaking with B. Bran scientific and instrument company England reciprocating mechanical shaker for 24 h at a water to soil ratio of 10 : 1. The PSI was then calculated using the quotient X /log C. where C is the solution equilibrium P concentration.

2.4 Statistical Analysis

Data obtained were subjected to analysis of Variance (ANOVA), correlation of PSI and soil physical and chemical properties, Duncan multiple range test at 5% level of probability and LSD at α = .05 using the VSN international Ltd 12.1 (PC/windows vista) UK Genstat statistical package (8th Edition). Difference between means ≥ LSD value were reported to be significantly different while difference between means < LSD value were not significantly different

3. RESULTS AND DISCUSSION

3.1 Physical and Chemical Properties

The physical and chemical properties of the soils are shown in (Table 1 and 2). The chemical properties were moderately acidic in the D and A soils, and strongly acidic in B and C soils, which could be due to the nature of the Parent material overlying the soils. The Organic carbon content of the soils varied and decrease significantly down the soils depths amongst the parent materials in the order of A > C > B > D. The high Organic carbon content at the surface soil could

be due to high liter fall from vegetations growing on the location. The soils total N and available P were also low. The low total N and available P status of the soils may be attributed to low organic matter contents as organic matter is a major reservoir of soil P and N. Particle size distribution showed that Sand is the dominant soil fraction and tends to decrease with soils depths in all the parent materials except in B soils. The dominant sand fraction could be attributed to the nature of the parent materials as reported by Brady and Weil [21]. The textural classes were sandy clay loam in all the parent materials except in B soils which was loamy sand.

3.2 P Adsorption Isotherms

The relationship between amount of P adsorbed versus amount of P in solution at equilibrium are shown in Fig. 2. It was observed that the amount of P adsorbed increased with increased amount of P added. At specific amount of P in concentration the amount of P adsorbed by soil B was higher than other soils parent material, this could be due to high adsorbtion capacity of B soils. A close linear relationship between P adsorbed and P remaining at equilibrium was established and the correlation coefficient obtained from the plot were 0.93, 0.89, 0.94 and 0.93 for A, B, C and D soils respectively. The P adsorbed by the soils is shown in (Tables 3 and 4). The amount of P adsorbed increased with increase in the concentration of P added to the different soils this could be due to difference in the maximum P adsorption capacities of the different parent materials. At 0, 50, 100 mg/L P added, mean amount of P adsorbed varied in all the soils. However it was very close. The mean amount of P sorbed by B soils was highiest when 150 and 200 mg/kg P was added. It had values of 97.20 and 133.20 mg/kg P respectively. In A and B Soils (Table 3), C and D (Table 4), %P adsorbed increased with the increased amount of P added. The %P adsorbed was highest in D soils with values of 9.14% and 15.19% at 50 and 100 mg/kg P added. In A soil %P adsorbed had the highest values of 31.04% at 250 mg/L P added. The difference in the %P adsorbed could be attributed to differences in the capacities of the soils to adsorb P versus nature of parent material. C soil had the least CV value of 1.90% versus amount of P adsorbed. While A, B and D soils were more variable with CV values of 2.30%, 6.90% and 4.90% respectively. The Relationship between PSI versus soils physical

and chemical properties have been reported by Aghimien et al. [2]. In this study PSI significantly correlated positively and negatively with some soil chemical properties in C and D soils at P ≤ .05 level of significance (Table 5). In C soils, the PSI was significantly and negatively correlated with organic carbon with r = -0.578 P ≤ .05, total N r = -0.578 P ≤ .05 and K r = 0.566 P ≤ .05. However, in D soils PSI significantly and positively correlated with organic carbon r = 0.438 P ≤ .05, K r = 0.497 P ≤ .05.

Langmuir and Freundlich generated parameter presented in (Table 6 and 7) shows that Freundlich model was superiority over the Langmuir model on the basis of average correlation coefficient (R^2) values. Freundlich model had average R^2 values of 0.940, 0.939, 0.949, 0.902 for soils A, B, C and D respectively, as against Langmuir average R^2 values of 0.832, 0.875, 0.802 and 0.899 for A, B, C and D soils

respectively. Bakheit and Pakermanjie [22], Gregory et al. [23] found that ability of the Freundlich model to describe P adsorption curves was superior to Langmuir model for calcareous soils. However, Amjad et al. [24] had reported comparable results for prediction of P adsorption by both Langmuir and Freundlich models. The Feundlich equation described P sorption satisfactorily in these soils. The goodness-of fit of Freundlich model to the sorption data may indicate that adsorbed P by the soils and the Concentrations of added P are within the range of validity of the isotherms. This is consistent with findings of Aghimien et al. [2], which found that P sorption data obtained from some hydromorphic soils of southern Nigeria fitted well to freundlich data with r^2 values > 0.95 indicating very high conformity of the adsorption data to the Freundlich model.

Soil A: y = 1.39x + 21.38
R^2 = 0.93

Soil B: y = 1.34x + 26.68
R^2 = 0.89

Soil C: y = 1.41x + 21.63
R^2 = 0.94

Soil D: y = 1.24x + 23.56
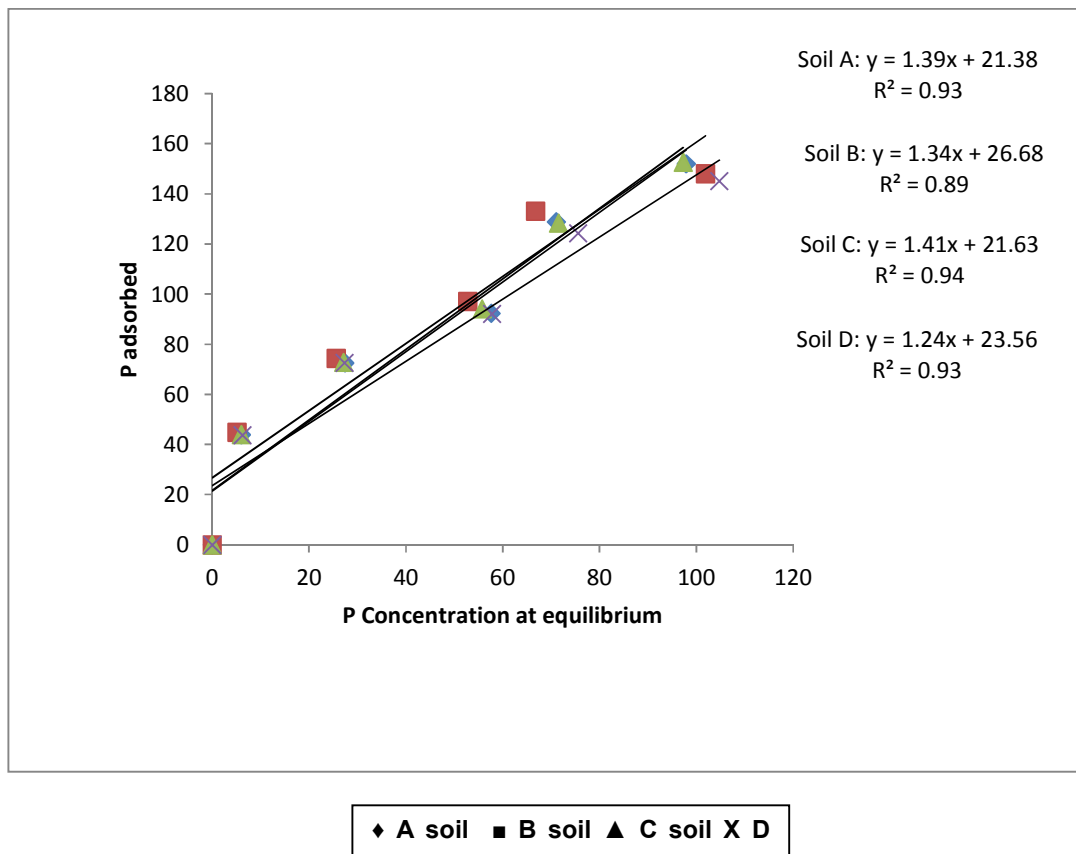R^2 = 0.93

♦ A soil ■ B soil ▲ C soil X D

Fig. 2. P adsorbed versus P concentration at equilibrium for Soil A, B, C and D

Table 1. Chemical properties of A and B soils

Parent materials	Depth	pH(1:2)	Organic C	N	P	K	Ca	Mg	Sand	Silt	Clay	TC
			← (g/kg) →		(mg/kg)	← (cmol/kg) →			←	(g/kg)	→	
A	0-15	6.30a	13.54a	1.32a	13.14a	0.28a	2.29a	0.51a	680.00a	110.00a	210.a	SCL
	15-30	6.27a	10.63ab	0.81b	8.53b	0.42a	1.19a	0.21a	640.00a	140.00a	223.00a	SCL
	30-60	5.93a	7.60bc	0.54bc	5.76c	0.99a	2.43a	0.48a	623.00a	156.70a	220.00a	SCL
	60-90	5.87a	6.13bc	0.44c	4.02d	0.76a	1.71a	0.13a	583.00a	180.00a	237.00a	SCL
	90-120	5.77a	5.51c	0.39c	4.98c	0.62a	1.49a	0.15a	583.00a	146.70a	270.00a	SCL
	SD	0.24	3.36	0.38	3.68	0.28	0.53	0.18	41.02	25.50	23.33	
	LSD	ns	4.52	0.32	1.61	ns	ns	ns	ns	ns	ns	
B	0-15	4.53a	11.53a	0.93a	6.86a	0.12a	1.36a	0.39a	820.00a	50.00a	130.00a	SL
	15-30	4.63a	6.81b	0.59b	6.11a	0.13a	0.72b	0.25b	840.00a	50.00a	110.00a	LS
	30-60	4.80a	6.42b	0.46bc	5.90a	0.23a	0.47c	0.06c	843.30a	36.70a	120.00a	LS
	60-90	4.57a	3.68d	0.26c	6.90a	0.14a	0.44c	0.04c	843.30a	46.70a	110.00a	LS
	90-120	4.57a	3.52d	0.25c	5.48a	0.17a	0.39c	0.06c	830.00a	56.70a	113.30a	LS
	SD	0.11	3.25	0.28	0.62	0.04	0.40	0.15	10.15	7.29	8.50	
	LSD	ns	1.75	0.22	ns	0.06	0.12	0.08	ns	ns	ns	

ns, Not significant. Means with same letters within columns are not significantly different at α = .05 using LSD. TC, Textural class. SCL, Sandy clay Loam. SL, Sandy Loam. LS, Loamy Sand. SD, Standard deviation. Means with same letters within column are not significantly different at α = .05 LSD

Table 2. Chemical properties of C and D soils

Parent materials	Depth	pH(1:2)	Organic C	N	P	K	Ca	Mg	Sand	Silt		TC
			←—— (g/kg) ——→		(mg/kg)	←—— (cmol/kg) ——→			………… g/kg ……………			
C	0-15	5.00a	10.24a	0.84a	12.71a	0.19a	1.27a	0.28a	757.00a	66.70a	177.00a	SL
	15-30	4.80ab	7.70b	0.60b	11.19a	0.19a	1.26a	0.25a	743.00a	46.70ab	210.00ab	SCL
	30-60	4.43b	5.51c	0.39c	8.05a	0.52bc	0.78b	0.46a	693.00ab	30.00b	277.00bc	SCL
	60-90	4.30b	5.28c	0.38c	7.56a	0.38cd	0.69c	0.14a	647.00b	30.00b	323.00c	SCL
	90-120	4.30b	4.27c	0.30c	6.93a	0.32ad	0.74bc	0.09a	630.00b	30.00b	340.00c	SCL
	SD	0.32	2.39	0.22	2.52	0.14	0.29	0.14	56.29	16.24	70.54	
	LSD	0.46	1.81	0.20	ns	0.18	0.09	ns	84.70	27.79	84.20	
D	0-15	6.07a	9.58a	4.13a	15.70a	0.42a	2.26a	0.51a	653.00a	126.70a	220.00a	SCL
	15-30	6.23a	7.72a	3.36a	11.30a	0.44a	1.88a	0.53a	667.00a	123.30a	210.00a	SCL
	30-60	5.83a	4.92b	0.35b	13.10a	1.05b	2.55a	0.69a	633.00a	96.70ab	270.00ab	SCL
	60-90	5.53a	4.08b	0.29b	13.30a	0.90b	2.52a	0.62a	580.00bc	70.00b	350.00b	SCL
	90-120	5.27a	3.52b	0.25b	7.70a	0.81b	2.88a	0.52a	533.00c	76.70b	357.00b	SCL
	SD	0.39	2.59	1.91	2.97	0.28	0.37	0.08	56.69	25.98	69.68	
	LSD	ns	2.33	2.90	ns	0.27	ns	ns	85.10	38.45	121.30	

ns, Not significant. Means with same letters within columns are not significantly different at α = .05 using LSD. TC, Textural class. SCL, Sandy clay Loam. SL, Sandy Loam. SD, Standard deviation Means with same letters within column are not significantly different at α = .05 LSD

Table 3. P adsorption data for soil A and B soils

Location	Parent Materials and Depth	EPC (mg/L)	Amount sorbed (mg/kg)	EPC (mg/L)	Amount sorbed (mg/kg)	EPC (mg/L)	Amount sorbed (mg/kg)	EPC (mg/L)	Amount sorbed (mg/kg)	EPC (mg/L)	Amount sorbed (mg/kg)	EPC (mg/L)	Amount sorbed (mg/kg)
		0 mg/kg P added		50 mg/kg p added		100 mg/kg p added		150 ppmp added		200 mg/kg p added		250 mg/kg p added	
Idanre	**A**												
	0-15	0.017	-0.017	5.82	44.18	27.56	72.44	59.62	90.38	72.57	127.43	101.30	148.70
	15-30	0.013	-0.013	5.80	44.20	27.21	72.79	59.42	90.58	76.55	123.45	98.50	151.50
	30-60	0.015	-0.015	6.37	43.63	27.55	72.45	55.29	94.71	69.48	130.52	97.00	153.00
	60-90	0.006	-0.006	6.23	43.77	27.41	72.59	56.00	94.00	69.26	130.74	95.80	154.20
	90-120	0.006	-0.006	5.95	44.05	27.33	72.67	57.72	92.28	67.44	132.56	96.90	153.10
	Mean		-0.01[a]		43.97[b]		72.59[c]		92.39[d]		128.94[e]		152.10[f]
	P sorbed (%)				8.97		14.82		18.85		26.32		31.04
	%CV	2.30											
Koko	**B**												
	0-15	0.012	-0.012	4.88	45.12	25.68	74.32	52.20	97.80	66.97	133.03	119.60	130.40
	15-30	0.015	-0.015	5.00	45.00	25.03	74.97	43.20	106.80	65.50	134.50	109.10	140.90
	30-60	0.018	-0.018	5.11	44.89	24.58	75.42	53.20	96.80	63.03	136.97	98.00	152.00
	60-90	0.017	-0.017	5.14	44.86	25.91	74.09	57.70	92.30	65.82	134.18	91.10	158.90
	90-120	0.019	-0.019	5.50	44.50	26.73	73.27	57.80	92.20	72.52	127.48	91.60	158.40
	Mean		-0.01[a]		44.90[b]		74.40[c]		97.20[d]		133.20[e]		148.10[f]
	P sorbed (%)				9.02		14.95		19.53		26.76		29.74
	%CV	6.90											

EPC, equilibrium Phosphorus concentration; %, percentage; CV, coefficient of variation

Table 4. P adsorption data for soil C and D soils

Location	Parent materials and Depth	EPC (mg/L)	Amount sorbed (mg/kg)	EPC (mg/L)	Amount sorbed (mg/kg)	EPC (mg/L)	Amount sorbed (mg/kg)	EPC (mg/L)	Amount sorbed (mg/kg)	EPC (mg/L)	Amount sorbed (mg/kg)	EPC (mg/L)	Amount sorbed (mg/kg)
		0 mg/kg P added		50 mg/kg p added		100 mg/kg p added		150 mg/kg p added		200 mg/kg p added		250 mg/kg p added	
NIFOR	**C**												
	0-15	0.008	-0.008	6.27	43.73	27.94	72.06	56.30	93.70	71.69	128.31	95.50	154.50
	15-30	0.005	-0.005	6.48	43.52	27.60	72.40	57.23	92.77	71.24	128.76	100.10	149.90
	30-60	0.003	-0.003	5.35	44.65	26.85	73.15	55.34	94.66	72.25	127.75	94.20	155.80
	60-90	0.002	-0.002	5.60	44.40	26.94	73.06	53.67	96.33	67.59	132.41	98.30	151.70
	90-120	0.002	-0.002	5.35	44.64	26.39	73.61	56.25	93.75	74.91	125.09	98.41	151.60
	Mean		0.00a		43.99b		72.85c		94.24d		128.46e		152.70f
	P sorbed (%)				8.94		14.79		19.15		26.10		31.02
	%CV	1.90											
Uhomora	**D**												
	0-15	0.002	-0.002	6.51	43.49	27.98	72.02	57.89	92.11	78.66	121.34	106.70	143.30
	15-30	0.002	-0.002	6.43	43.57	27.19	72.81	56.43	93.57	76.65	123.35	107.40	142.60
	30-60	0.004	-0.004	6.44	43.56	28.21	71.79	61.01	88.99	75.59	124.41	117.40	132.60
	60-90	0.005	-0.005	6.01	43.99	26.26	73.74	58.22	91.78	74.24	125.76	93.90	156.10
	90-120	0.001	-0.001	5.94	44.06	27.03	72.97	55.41	94.59	72.89	127.11	98.40	151.60
	Mean		0.00a		43.73b		72.67c		92.21d		124.39e		145.24f
	P sorbed (%)				9.14		15.19		19.28		26.00		30.40
	%CV	4.90											

EPC, equilibrium Phosphorus concentration; %, percentage; CV, coefficient of variation.

Table 5. Correlation between PSI versus soils Chemical and physical properties

	A	B	C	D
pH (1:2)	0.193	-0.152	-0.405	-0.263
Org. C (g/kg)	-0.220	0.015	-0.578*	0.438*
N	-0.311	0.036	-0.578*	-0.460
P (mg/kg)	-0.090	0.214	-0.327	-0.404
Exchangeable cation (cmol/kg)				
K	0.127	-0.302	0.566*	0.497*
Ca	-0.057	0.148	-0.427	0.341
Mg	-0.112	0.330	0.133	0.206
Na	-0.063	0.086	0.295	0.413
Acid.	-0.020	0.081	0.205	-0.213
ECEC	-0.019	0.148	0.294	0.493
BS (%)	0.012	0.211	-0.141	0.356
Particle size (g/kg)				
SAND	-0.034	-0.268	-0.243	-0.392
SILT	0.263	0.278	-0.655	-0.245
CLAY	-0.041	0.005	0.378	0.364

Significant at 5% level of probability. Org. C, Organic Carbon

Table 6. Freundlich and Langmuir sorption parameters for basement complex and Alluvium soils

Depth	Freundlich Freundlich equation	Parameter P sorption Capacity (a) (mg/kg)	P sorption energy (n) (L kg⁻¹)	Slope = (1/n)	Correlation Coefficient (R^2)	Langmuir Adsorbtion Affinity (k) (ml/µg)	Adsorption maximal(b) (mg/kg)	Parameters Correlation Coefficient (R^2)
			A SOILS					
0-15	$X = 1.307C^{2.457}$	1307	2.457	0.407	0.935	0.0302	0.0056	0.837
15-30	$X = 1.310C^{2.469}$	1310	2.469	0.405	0.937	0.0303	0.0056	0.833
30-60	$X = 1.250C^{2.222}$	1250	2.222	0.450	0.954	0.026	0.0051	0.849
60-90	$X = 1.259C^{2.242}$	1259	2.242	0.446	0.946	0.0061	0.0051	0.831
90-120	$X = 1.281C^{2.314}$	1281	2.314	0.432	0.930	0.0285	0.0053	0.812
Average	$X = 1.281C^{2.341}$	1281.4	2.341	0.428	0.940	0.0240	0.0053	0.832
			B SOILS					
0-15	$X = 1.400C^{2.806}$	1400	2.806	0.356	0.950	0.052	0.006	0.962
15-30	$X = 1.367C^{2.531}$	1367	2.531	0.395	0.971	0.046	0.005	0.971
30-60	$X = 1.339C^{2.427}$	1339	2.427	0.412	0.947	0.034	0.005	0.879
60-90	$X = 1.329C^{2.417}$	1329	2.417	0.413	0.909	0.031	0.005	0.773
90-120	$X = 1.310C^{2.400}$	1310	2.400	0.416	0.922	0.030	0.005	0.792
Average	$X = 1.349C^{2.516}$	1349	2.516	0.399	0.939	0.039	0.005	0.875

X, amount of P sorbed. C, equilibrium P concentration.

Table 7. Freundlich and Langmuir sorption parameters for Coastal plain sand Imo shale soils

Depth (cm)	Freundlich	Parameter				Langmuir		Parameter
	Freundlich equation	P sorption Capacity (a) (mg/kg)	P sorption energy (n) L kg^{-1}	Slope = (1/n)	Correlation Coefficient (R^2)	Adsorbtion Affinity (k) (ml/μg)	Adsorption maximal (b) (mg/kg)	Correlation Coefficient (R^2)
			C SOILS					
0-15	$X = 1.257C^{2.250}$	1257	2.250	0.444	0.946	0.026	0.0052	0.827
15-30	$X = 1.256C^{2.272}$	1256	2.272	0.440	0.953	0.027	0.0053	0.855
30-60	$X = 1.319C^{2.424}$	1319	2.424	0.412	0.941	0.041	0.0161	0.591
60-90	$X = 1.302C^{2.352}$	1302	2.352	0.425	0.953	0.030	0.0053	0.872
90-120	$X = 1.334C^{2.510}$	1334	2.510	0.398	0.951	0.032	0.0056	0.867
Average	$X= 1.294C^{2.362}$	1294	2.362	0.424	0.949	0.031	0.0075	0.802
			D SOILS					
0-15	$X = 1.281C^{2.413}$	1281	2.413	0.414	0.971	0.030	0.0058	0.905
15-30	$X = 1.526C^{1.198}$	1526	1.198	0.834	0.962	0.031	0.0058	0.922
30-60	$X = 1.583C^{1.560}$	1583	1.560	0.641	0.851	0.035	0.0063	0.922
60-90	$X = 1.537C^{1.115}$	1537	1.115	0.896	0.804	0.029	0.0054	0.814
90-120	$X = 1.508C^{1.038}$	1508	1.038	0.963	0.924	0.029	0.0054	0.870
Average	$X= 1.487C^{1.465}$	1487	1.465	0.7496	0.902	0.031	0.0057	0.899

X, amount of P sorbed. C, equilibrium P concentration.

4. CONCLUSION

P sorption characteristics are important in designing best p management practice to reduce the risk loss or under application of p. the results obtained in this study reveal that estimation can be done on PSI as difference in the magnitude of change in PSI between the soils indicate that soil parent material in addition to the amount of P added to the soil will determine a soil potential to release P. the study reveal that D soils sorbed more P than soils of other parent materials studied indicating that soil d will need more p fertilization to attain optimum P concentration in soil solution. The results of the study showed that P adsorbtion increased with increased amount of P added indicating that the amount of P adsorbed versus P concentration at equilibrium gives an indication of the adsorption process in different soils. the result also showed that both langmuir and freundlich adsorption models are robust in predicting p adsorption however in comparing both models it may be concluded that the freundlich model is better fitted over the langmuir model considering the r^2 value.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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