The use of different sorption models in evaluating P retention of soils in Southern Nigeria

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Abstract

This study was aimed to assess the soil chemical properties and effect of depth on P sorption potential of six coastal profile soils of Nigeria. The pH of the soils ranged from 3.90 – 7.40 with N values of 0.03 – 0.38% and P values of 0.40 – 10.30mg/kg. Each soil, however, exhibited a unique combination of soil chemical parameters. The soil samples were equilibrated with different P concentrations (50, 100 and 150mg/l), prior to evaluating the sorption potential. Laboratory estimates of P sorption potentials indicated differences in P sorption capacity among coastal soils and profile soils. P sorption capacity was highly correlated (r = 0.830, 0.900 and 0.996) with soil oxalate-extractable Al content in NIFOR, Igbogila and Abudu soil respectively. The regression equation obtained for the soils showed that P sorption capacities are site and depth specific.

Keywords: P sorption, South Nigeria, sedimentary rock, sorption potential

Introduction

The amount of phosphorus (P) in soil solution is usually low due to the very scanty release of P through natural processes and the huge sink of P at the ground of ocean (Moazed, 2010). On addition of soluble P compounds to soil, series of complex reactions (precipitation and sorption) takes place that leads to a decline in the availability of the added P. Soils differ greatly in their ability to hold P (Paini et al., 1999; Idris and Ahmed, 2012).

In Nigeria, there are two major groups of soils: the ferralitic (oxisols) and the tropical ferruginous (Alfisol). The most common is the tropical ferruginous type and is usually formed from basement complex metamorphic rocks. During the process of leaching, aluminum and iron accumulates due to loss of silica and bases from the soil. The effect of climate on the parent rock results in low soil pH (Rodhe and Herrera, 1988) and low pH tend to increase anion exchange capacity (Amelidris and Ahmed, 2012)

Phosphorus (P) is one of the essential elements for plant growth. The amount of available P in the soil is often inadequate to meet plant requirements. The main processes for P losses from agricultural fields are through erosion, surface runoff and subsurface transfer. Phosphorus subsurface transfer can occur both in dissolved form or bound to particles that are transported with the water (Sims, et al., 1998; Heckrath et al., 1995).

Phosphorus sorption in soil is an equilibrium reaction where the amount of sorbed P is described as a function of solution P concentration (Vaananen et al., 2008). Phosphorus sorption behaviour is influenced by some soil mineralogical and chemical properties. These properties act singly or in combination to influence sorption or desorption of soil P. The mineralogical properties

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influencing soil P include clay type, clay content, $CaCO_3$, Al and Fe (Burt et al., 2002; Giesle et al., 2005; Hadgu, 2014; Leclerc, 2001). Also soil properties, such as soil pH and organic carbon have been found to influence soil P-sorption (Dodor and Oya, 2000; Burt et al., 2002; Pierzynski, 2005).

Several studies have been conducted on P sorption to different soils using distilled water in batch experiments and the obtained data have been fitted into various adsorption models, including the Langmuir, the Freundlich and the Temkin models (Olsen and Watanabe, 1957; Mead JA, 1981; Polyzopoulos, 1985; Bhuiyan and Sedberry, 1995; Ioannou, 1998; Dodor and Oya, 2000; Bubba, 2003). It was reported that the Langmuir model provided more information including the calculation of adsorption maxima and binding energy constants than the other models, although, conflicting results have been obtained when experimental P-sorption data are fitted into the conventional Langmuir equation. Several authors have suggested the existence of more than one population of adsorption sites with different affinity for phosphorus to explain the observed behaviours (Syers JK, 1973; Holford ICR; Bubba, 2003).

The Langmuir and Freundlich equation that is used to describe P sorption equilibrium (Olsen and Watanabe 1957; Fitter and Sutton, 1975; M. Del Bubba., 2003; Riitta et al., 2008) describes only the chemical sorption whereas biological factors are most important for P retention in the subsurface soils (Wood et al., 1984). Earlier work by Schouman (2000) reported that P sorption differs among surface or sub-surface soil horizons.

The aim of this study was to assess the soil chemical properties of six coastal profile soils of Nigeria and evaluate the effect of depth on P sorption potential of the profile soils.

Materials and methods

Soil sampling

The six profile soils used for this study were obtained from Igbogila, NIFOR, Agbor, Abudu, Otegbo and Kwale in the South-South Nigeria. The soil samples were collected from five depths (0 – 15cm, 15 – 30 cm, 30 – 60cm, 60 – 90cm, 90 – 120 cm) using an auger. The samples were placed and transported in polythene bags to the laboratory where they were air dried, sieved through a 2mm mesh and stored for the various analyses.

Soil analysis

Selected soil physicochemical properties such as pH, total organic carbon, total nitrogen, available phosphorus, cation exchange capacity (CEC) and particle size distribution were determined using standard methods (IITA, 1982). The pH of the soil samples (pH-H_2O) were determined using a 1: 2 soil weight/water volume ratio by a Suntex digital pH-metre (Folson et al., 1981; Uwumarongie-Ilori, et al., 2011).

Organic carbon content was determined by the wet digestion method of Walkley and Black (1982) and total nitrogen was determined by digesting 0.2 g soil samples with 98% H_2SO_4 and selenium catalyst in Kjeldahl digestion unit until sample became colourless. Nitrogen content was then determined colorimetrically using Hach spectrophotometer (Okalebo et al., 1993; Uwumarongie-Ilori, et al., 2012). The available phosphorus content was determined by the Olsen's method. Cation exchange capacity was estimated by summing the exchangeable cations determined in neutral ammonium acetate filtrates by flame photometric method (Na and K) and titration method (Ca and Mg) (Jackson, 1960; Rhoades, 1982; Uwumarongie-Ilori, et al., 2011). All reagents were analytical grade and all glass wares were washed, soaked in nitric acid and washed in distilled water. Standard solutions were used for the calibration and quality assurance for each analytical test. Procedural blank samples were subjected to similar extraction method using same amounts of reagents. All analyses were performed in triplicate.

Phosphorus sorption experiment

The sorpion study was conducted on 30 soil samples, collected from six (6) profile soils and five depths each using standard procedure recommended by Nair et al. (1984) and Murphy and Riley (1962). The amount of adsorbed P (mg/g) was calculated using the formulae reported by Vanderborght and Van Griekenm (1977). The data obtained were fitted into Langmuir, Freundlich and Temkin isotherms (Igwe and Abia, 2006). The amount of P sorbed, x (mg/100g), from addition of 1.50g P/kg of soil was also determined after shaking for 24 hours using 1:10 soil water ratio. The P sorption index (PSI) was then calculated using the quotient;

$$x/\log c \quad \ldots\ldots\ldots (1)$$

where c is the solution P concentration (Bache and Williams, 1971). This quotient correlate closely with P sorption maximum obtained from a Langmuir sorption isotherm for a wide range of soils.

Statistical analyses

Data were collected and statistically analyzed using SPSS statistical package

Results and discussion

The physical and chemical properties of the six profile soils are given in Table 1. The pH values of the soil samples from all locations were slightly acidic except the samples from Igbogila that was slightly alkaline. The pH values of the Igbogila soils ranged from 7.10 to 7.40. The phosphorus contents were below 10 mg/kg (Chude et al., 2011) indicating that the soils were low in P. The soils of

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the study sites were found to be sandy loam. The soil nitrogen content was moderate while the potassium content was low for all soil samples (Chude et al., 2011).

Table1: Soils physico-chemical properties [mean ± standard deviation (range of five (5) determination)]

	Igbogila	NIFOR	Agbor	Abudu	Otegbo	Kwale
pH	7.28 ± 0.13 (7.10 – 7.40)	5.18 ± 0.30 (4.90 – 5.70)	5.54 ± 0.13 (5.40 – 5.70)	4.96 ± 0.34 (4.50 – 5.40)	4.62 ± 0.15 (4.40 – 4.80)	4.52 ± 0.45 (3.90 – 4.90
C (%)	0.64 ± 0.50 (0.21 – 1.26)	3.28 ± 2.63 (1.06 – 7.30)	0.66 ± 0.11 (0.54 – 0.78)	1.28 ± 1.50 (0.18 – 3.74)	0.45 ± 0.45 (0.17 – 1.25)	0.56 ± 0.76 (0.15 – 1.90)
N (%)	0.17 ± 0.13 (0.05 – 0.38)	0.14 ± 0.13 (0.03 – 0.19)	0.11 ± 0.02 (0.10 – 0.14)	0.11 ± 0.04 (0.08 – 0.16)	0.17 ± 0.10 (0.09 – 0.34)	0.12 ± 0.07 (0.09 – 0.24)
K (cmol/kg)	0.11 ± 0.02 (0.08 – 0.14)	0.09 ± 0.04 (0.05 – 0.10)	0.03 ± 0.02 (0.01 – 0.05)	0.04 ± 0.03 (0.01 – 0.10)	0.11 ± 0.05 (0.05 – 0.18)	0.05 ± 0.03 (0.01 – 0.09)
Na (cmol/kg)	0.39 ± 0.09 (0.31 – 0.55)	0.20 ± 0.07 (0.15 – 0.33)	0.27 ± 0.10 (0.16 – 0.41)	0.27 ± 0.17 (0.12 – 0.51)	0.13 ± 0.04 (0.09 – 0.18)	0.21 ± 0.10 (0.12 – 0.33)
Ca (cmol/kg)	6.11 ± 0.73 (5.35 – 6.95)	0.14 ± 0.05 (0.10 – 0.20)	0.41 ± 0.02 (0.40 – 0.45)	0.19 ± 0.10 (0.10 – 0.35)	0.17 ± 0.08) (0.00 – 0.25)	0.14 ± 0.05 (0.10 – 0.20)
Mg (cmol/kg)	0.77 ± 0.41 (0.32 – 1.28)	0.51 ± 0.31 (0.16 – 0.96)	0.08 ± 0.00 (0.08 - 0.08)	0.16 ± 0.10 (0.08 – 0.32)	0.14 ± 0.07 (0.08 – 0.24)	0.18 ± 0.09 (0.08 – 0.32)
Exchange Acidity (cmol/kg)	0.72 ± 0.08 (0.65 – 0.85)	3.39 ± 2.60 (0.90 – 7.30)	0.42 ± 0.21 (0.24 – 0.76)	1.86 ± 1.36 (0.60 – 3.84)	2.12 ± 0.38 (1.48 – 2.36)	3.22 ± 1.12 (2.24 – 4.84)
Al (mg/kg)	0.60 ± 1.34 (0.00 – 3.00)	48.67 ± 24.76 (8.00 – 100.00)	71.92 ± 46.78 (43.40 – 155.00)	275.28 ± 181.43 (105.40 – 527.00)	287.06 ± 51.01 (235.60 – 341.00)	288.30 ± 185.59 (6.20 – 508.40)
Fe (mg/kg)	35.80 ± 31.69 (10.00 – 87.00)	67.67 ± 24.76 (36.00 – 104.00)	228.00 ± 88.55 (147.00 – 324.00)	94.20 ± 34.38 (56.00 – 126.00)	135.40 ± 143.76 (54.00 – 391.00)	42.60 ± 42.59 (14.00 – 118.00)
P (mg/kg)	6.70 ± 3.36 (1.00 – 9.70)	2.35 ± 1.59 (0.80 – 5.00)	3.96 ± 1.45 (1.80 – 5.60)	7.26 ± 2.03 (5.60 – 10.30)	1.64 ± 1.06 (0.40 – 3.20)	1.64 ± 1.84 (0.40 – 4.60)
Clay (%)	16.10 ± 1.67 (13.50 – 17.50)	5.50 ± 1.22 (3.50 – 6.50)	10.10 ± 2.22 (8.50 – 14.00)	22.80 ± 16.30 (6.00 – 40.00)	12.40 ± 3.38 (8.00 – 17.00)	14.40 ± 6.95 (7.00 – 24.00)
Silt (%)	5.30 ± 1.48 (3.50 – 7.50)	2.10 ± 0.89 (0.00 – 3.50)	3.10 ± 2.68 (1.00 – 7.50)	11.20 ± 10.80 (2.00 – 26.00)	2.80 ± 0.57 (2.00 – 3.50)	4.92 ± 1.32 (3.60 – 7.00)
Sand (%)	78.60 ± 0.89 (77.00 – 79.00)	92.20 ± 1.79 (0.00 – 95.00)	87.60 ± 1.82 (85.00 – 90.00)	66.20 ± 27.10 (34.00 – 92.00)	84.80 ± 2.95 (81.00 – 89.00)	80.80 ± 5.89 (73.00 – 86.00)
x/log C	7.76 ± 1.26 (6.51 – 9.79)	28.69 ± 13.48 (8.01 – 40.56)	26.32 ± 2.58 (24.24 – 29.29)	33.49 ± 33.30 (7.94 – 87.68)	23.85 ± 6.99 (13.14 – 30.90)	22.29 ± 8.88 (17.42 – 33.22)

In all the soils, phosphorus sorption indexes (PSI) were influenced by differences in soil characteristics at varying levels. It was observed in Table 2 that PSI was significantly (P ≤ 0.01 for NIFOR and P ≤ 0.05 for Abudu) and negatively correlated (r = -0.95** and – 0.894**) with pH. PSI was significantly (P ≤ 0.05 for NIFOR and Kwale) and positively correlated with clay (r = 0.867** and 0.950** respectively). Several reports have shown that clay content is a major contributor to P adsorption (Singh and Gikes, 1991; Fisseha et al., 2014). It was observed that the clay contents of the samples are positively correlated with PSI than the sand content. This may be due to the large surface area of clay as compared to sand. No significant correlation was observed between the carbon content in all location samples except Abudu sample with a positive correlation of 0.997**.

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Table 2: Relationship between phosphorus sorption index (PSI) and soil chemical properties

Parameters	Igbogila	NIFOR	Agbor	Abudu	Otegbo	Kwale
pH	-0.516	-0.957**	0.361	-0.894*	-0.622	0.621
C (%)	0.451	0.542	0.131	0.997**	-0.304	-0.188
N (%)	-0.635	-0.548	-0.588	0.887*	-0.541	-0.057
K (cmol/kg)	-0.316	0.416	0.172	0.963**	0.183	0.366
Na (cmol/kg)	-0.351	-0.030	0.159	0.278	0.332	0.527
Ca (cmol/kg)	0.671	-0.247	0.575	0.464	-0.256	-0.636
Mg (cmol/kg)	-0.322	0.234	NC	0.162	-0.271	-0.531
EA (cmol/kg)	-0.399	0.731	-0.319	0.976**	0.959**	-0.953*
Al (mg/kg)	0.900*	0.830*	-0.309	0.966**	0.498	-0.207
Fe (mg/kg)	0.421	-0.689	0.967**	0.574	0.390	-0.169
Clay (%)	-0.871	0.867*	0.719	0.871	0.816	0.950*
Silt (%)	0.902*	0.823*	-0.328	0.962**	-0.417	-0.714
Sand (%)	0.135	0.727	-0.838	-0.915*	-0.855	-0.930*
P (mg/kg)	0.300	0.605	-0.804	0.066	-0.603	-0.399

** indicate significance at 0.05 and 0.01 level respectively

The relationships between the amounts of sorbed phosphorus and phosphorus concentrations of the different depths of the profile soil samples are shown in Figure 1 – 5. Several authors have reported an increase in P sorbed with increase in the concentration of P added to the soil (Barrow, 1978; Aghimien et al., 2014). In this study it was also observed that the amount of P sorbed increased with an increase in the concentration of phosphorus added to the soil. The result showed that at any specific P-concentration, the amount of P sorbed by the profile soils varied with soil depth.
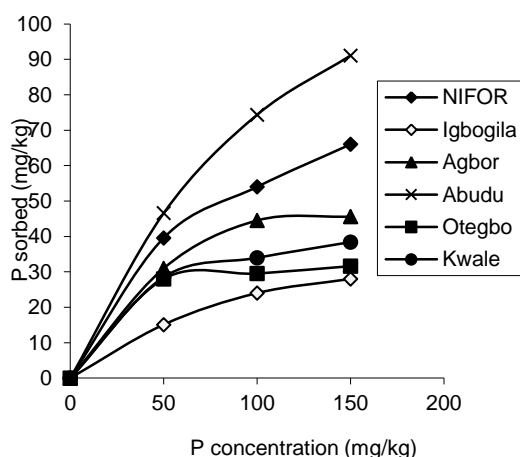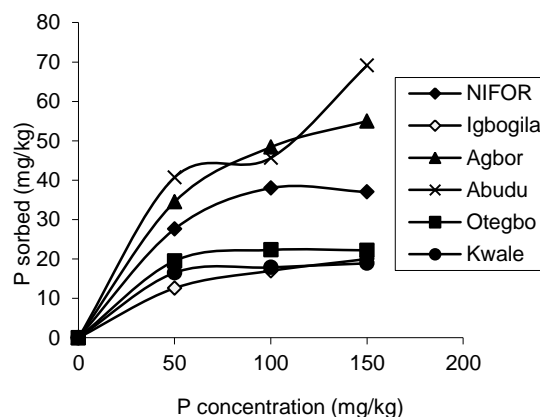

Fig 1: P sorption isotherm for 0 - 15 cm profile soils

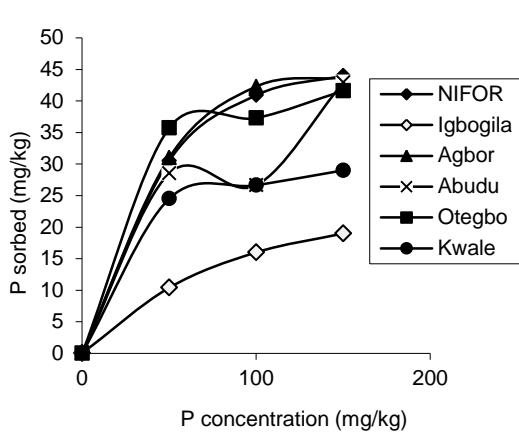**Fig 2:** P sorption isotherm for 15 - 30 cm profile soils.

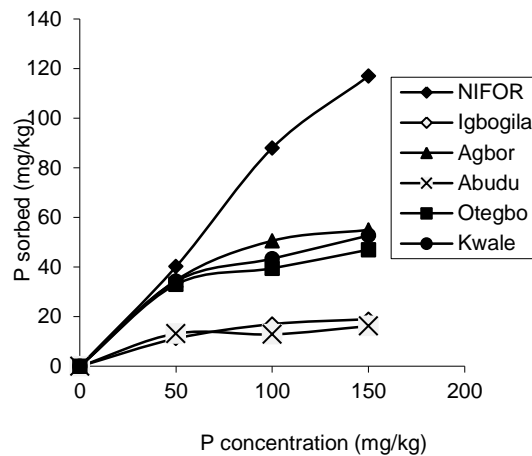**Fig 3**: P sorption isotherm for 30 - 60 cm profile soils

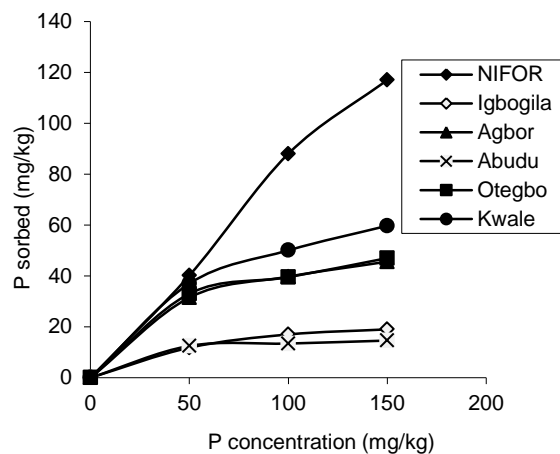**Fig 4:** P sorption isotherm for 60 - 90 cm profile soils

Fig 5: P sorption isotherm for 90 - 120cm profile soils

Comparing the amount of P adsorbed in each depth of the six profile soils by estimating the sorbed P from the two isotherms (Langmuir and Freundlich) used for this study, it was observed that each profile and depth of soil has different capacities to adsorb P. It was also observed that P sorption calculated using the Langmuir isotherm showed differences in P sorption with variations in magnitude from that of Freundlich isotherm. Although it has been reported several times that P sorption can be described well by Langmuir or Freundlich isotherms (Iaja, 1989). The sample from Abudu had the highest P sorption (357.14mg/g) value while Igbogila had the lowest value of 17.01 mg/g for the 0-15cm depth. For the 15-30cm depth, Otegbo sample had the highest P sorption value of 172.41 mg/g while Igbogila had the least value of 14.88 mg/g sorbed P. It was observed that in all soil depth, Igbogila had the least P sorbed values. The Langmuir P sorption maximum values ranged from 17.01 mg/g to 354.14mg/g in the 0-15cm depth; 14.88 mg/g to 172.41 mg/g in the 15 – 30cm depth; 10.80 mg/g for Igbogila soil to 2000 mg/g in Agbor soil for 30 to 60 cm depth; 12.74 mg/g in Igbogila soil to 166.67 mg/g in NIFOR soil for 60 – 90 cm depth and 14.84 mg/g in

Igbogila soil to 270.27 mg/g in Kwale soil. The highest P sorption maximum value was found in 30 – 60 cm soil depth and in Agbor profile soils. This may be due to relatively higher amount of clay, Al and Fe content in the soils.

In the Freundlich model, slope (1/n) is a measure of the heterogeneity of a system. A more homogenous system will have (1/n) value approaching unity and a more heterogeneous system will have 1/n value approaching zero (Gregory et al., 2005; Fisseha Hadgu et al., 2014). In this study, it was observed that the soils had different linear Freundlich sorption isotherm curves, although the Freundlich equations well fitted the data on all the soils. The linear plot obtained for Freundlich model revealed exponent (1/n) values of less than one in all soils (Table 3). Several authors (McLaren and Cameron, 1990; Fisseha Hadgu et al., 2014) have reported the empirical nature of Freundlich model and showed that P sorption decreases exponentially with increasing saturation of exchange site. This study therefore revealed from Table 3 that in 0 - 15cm soils, Otegbo had the minimum (1/n) value of 0.06 while Igbogila had the maximum (1/n) value of 0.50; in the 15 –

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30 cm soils, Kwale had the minimum (1/n) value of 0.08 while Igbogila had the maximum (1/n) value of 0.37; in the 30 -60 cm soils, Otegbo had the minimum value of 0.07 while Igbogila had the maximum (1/n) value of 0.53; in the 60 – 90 cm soils, Abudu had the minimum (1/n) value of 0.14 while Igbogila had the maximum (1/n) value of 0.45; in the 90 – 120cm soils, Abudu had the minimum (1/n) value

of 0.12 while NIFOR had the maximum (1/n) value of 0.70. It therefore shows that the 90 – 120 cm soils depth and NIFOR profile soil have relatively more homogeneous adsorption than other soil depths and profiles which tend to have more heterogeneous sites.

Table 3: Langmuir, Freundlich and Temkin Isotherm constants for the P adsorption in the soil profile samples

0-15 cm	Langmuir isotherm				Freundlich isotherm				Temkin isotherm			
	K (L/mg)	b	Q_o (mg/g)	R^2	$1/n$	n	a	R^2	A_T (L/mg)	b_T	B (J/mol)	R^2
Igbogila	65.33	0.0009	17.01	0.9989	0.50	2.00	1.82	0.9817	2.08	9.50	260.76	0.9946
NIFOR	9.20	0.0005	217.39	0.9996	0.23	4.35	2.75	0.9820	0.88	8.21	301.63	0.9648
Agbor	5.63	0.0008	222.22	1.00	0.24	4.17	2.59	0.8940	0.63	11.05	224.18	0.9098
Abudu	5.60	0.0005	357.14	0.9907	0.23	4.35	2.95	0.9940	1.81	6.57	377.14	0.9818
Otegbo	4.83	0.0012	172.41	0.9915	0.06	16.67	2.76	0.8885	10.85	49.67	49.88	0.9035
Kwale	10.40	0.0010	96.15	0.9950	0.19	5.26	2.61	0.9947	1.76	16.94	146.25	0.9777
15 – 30 cm	Langmuir isotherm				Freundlich isotherm				Temkin isotherm			
	K (L/mg)	b	Q_o (mg/g)	R^2	$1/n$	n	a	R^2	A_T (L/mg)	b_T	B (J/mol)	R^2
Igbogila	44.80	0.0015	14.88	0.9917	0.37	2.70	1.92	1.0000	1.49	16.88	146.78	0.9974
NIFOR	8.00	0.0010	125.00	0.9999	0.20	5.00	2.58	0.8184	1.50	15.89	155.93	0.8031
Agbor	15.33	0.0006	108.70	0.9961	0.25	4.00	2.64	0.9979	0.30	8.72	283.99	0.9998
Abudu	13.50	0.0006	123.46	0.8654	0.19	5.26	2.81	0.6158	1.62	9.85	251.65	0.5706
Otegbo	3.41	0.0017	172.41	0.9997	0.09	11.11	2.57	0.7639	6.30	48.81	50.76	0.8602
Kwale	5.75	0.0020	86.96	1.0000	0.08	12.50	2.49	0.9975	6.06	57.62	43.00	0.9895
30 – 60 cm	Langmuir isotherm				Freundlich isotherm				Temkin isotherm			
	K (L/mg)	b	Q_o (mg/g)	R^2	$1/n$	n	a	R^2	A_T (L/mg)	b_T	B (J/mol)	R^2
Igbogila	66.14	0.0014	10.80	0.9992	0.53	1.87	1.57	0.9903	2.23	13.77	179.93	0.9991
NIFOR	16.88	0.0008	74.07	0.9989	0.22	4.55	2.60	0.9692	0.80	12.13	204.30	0.9848
Agbor	0.56	0.0009	2000.00	0.9939	0.21	4.76	2.63	0.9434	1.19	12.91	191.97	0.9374
Abudu	24.78	0.0009	44.84	0.6795	0.17	5.88	2.60	0.2930	1.30	16.30	151.98	0.3040
Otegbo	11.89	0.0009	93.46	0.9841	0.07	14.29	2.86	0.7708	11.30	39.27	63.09	0.7526
Kwale	4.57	0.0014	156.25	0.9990	0.10	10.00	2.65	0.9158	5.63	36.18	68.48	0.9425
60 – 90cm	Langmuir isotherm				Freundlich isotherm				Temkin isotherm			
	K (L/mg)	b	Q_o (mg/g)	R^2	$1/n$	n	a	R^2	A_T (L/mg)	b_T	B (J/mol)	R^2
Igbogila	52.33	0.0015	12.74	0.9966	0.45	2.22	1.75	0.9698	1.91	15.21	162.93	0.9824
NIFOR	12.00	0.0005	166.67	0.9916	0.24	4.17	2.77	0.9868	1.05	8.15	304.05	0.9951
Agbor	16.33	0.0006	102.04	0.9990	0.26	3.85	2.64	0.9693	0.36	8.66	286.11	0.9769

	K (L/mg)	b	Q$_o$ (mg/g)	R^2	1/n	n	a	R^2	A$_T$ (L/mg)	b$_T$	B (J/mol)	R^2
Abudu	17.74	0.0023	24.51	0.9459	0.14	7.14	2.29	0.4874	2.95	51.17	48.42	0.4791
Otegbo	9.63	0.0008	129.87	0.9943	0.18	5.56	2.69	0.9283	1.61	13.59	182.27	0.9266
Kwale	20.00	0.0006	83.33	0.9871	0.23	4.35	2.65	0.9827	0.73	10.33	239.90	0.9454
90 – 120cm	Langmuir isotherm				Freundlich isotherm				Temkin isotherm			
	K (L/mg)	b	Q$_o$ (mg/g)	R^2	1/n	n	a	R^2	A$_T$ (L/mg)	b$_T$	B (J/mol)	R^2
Igbogila	42.13	0.0016	14.84	0.9997	0.40	2.50	1.85	0.9791	1.61	16.80	147.44	0.9894
NIFOR	65.33	2×10^{-19}	100.00	2×10^{-16}	0.70	1.43	2.43	0.6655	1.17	1.92	1292.80	0.7612
Agbor	8.75	0.0008	142.86	0.9905	0.21	4.76	2.63	0.9962	1.00	12.45	199.00	0.9872
Abudu	11.19	0.0026	34.36	0.9954	0.12	8.33	2.30	0.9898	4.33	63.53	39.00	0.9416
Otegbo	10.50	0.0008	119.05	0.9925	0.19	5.26	2.69	0.9884	1.89	14.06	176.21	0.9606
Kwale	6.17	0.0006	270.27	0.9804	0.23	4.35	2.71	0.9976	0.65	8.73	283.73	0.9816

The choice of using Langmuir and Freundlich models is often based on the goodness of fit. It can be observed from Table 3 that both models proved good based on average correlation coefficients values (r = 0.945 for Langmuir and r = 0.892 for Freundlich) in all soils under investigation. Although both models were good they have slight differences. On the basis of the correlation coefficient values obtained, Langmuir model was better than in all soils except in 90 -120 cm soil depth. Several authors (Polyzopoulos et al., 1985; Del Bubba et al., 2003) reported better results of the Langmuir model than the Freundlich model in describing P sorption curves.

Temkin isotherm takes into account the various interactions that occur in the sorption process and assumes that all the sorption sites are identical. It also assumes a linear decrease in the heat of adsorption of all molecules when low and large value of concentration is ignored (Temkin and Pyzhev, 1940; Aharoni and Ungarish, 1977). In this study, the values of AT varied within depth and profile soils. It was observed that the A$_T$ values ranged from 0.63 – 10.85 L/mg in the 0-15 cm depth; 0.30 – 6.30 L/mg in the 15-30cm; 0.80–11.30 L/mg in the 30-60cm; 0.36- 2.95 L/mg in the 60-90 cm and 0.65-4.33L/mg in the 90–120cm. The B values of the soils which is an indication of the heat of sorption showing a physical adsorption process revealed a variation in the rate of heat sorption within soil depth and profile soils. It was observed that the B values ranged from 49.88–377.14J/mol in the 0-15cm depth; 43.00-283.99J/mol in the 15-30cm depth; 63.09-204.30J/mol in the 30-60cm depth; 48.42-304.05J/mol in the 60-90cm depth and 39.00-283.00J/mol in the 90-120cm depth. The R^2 values obtained using Temkin model ranged from 0.3040 – 0.9991 with the lower depths have the lower R^2 values. This revealed that the sorption data did not fit well in some profile depth soil samples.

Conclusions

The results of this study revealed differences in P sorption among the studied soils and better results of the Langmuir model in describing the P sorption curves than Freundlich model in the soils analyzed. The results obtained showed that P sorption characteristics were influenced by some soil mineralogical and chemical properties such as clay, Al and Fe content. The results also revealed that each profile and soil depth differ from others in its capacity to adsorb P.

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