PHOSPHORUS SORPTION CAPACITY OF SELECTED WETLAND AND UPLAND SOILS OF RIVERS STATE NIGERIA.

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ABSTRACT
Soil phosphorus (P) tends to be the most critical among the primary macronutrients in tropical soils as it pertains soil fertility and general productivity of soils. P sorption in soils is a key process governing its availability to crops, and this is poorly documented for soils of Rivers State, Nigeria. The study investigated P sorption capacity and its relation to soil properties for6 pedons of selected wetland and upland soils in the Niger Delta area of Nigeria. The phosphorus sorption data were obtained by equilibrating 3g of soil samples in 30ml, 0.0lm $CaCl_2$ containing various amount of KH_2P0_4 (0, 5, 10, 15, 20 and 25mg kg^{-1}). P sorption indices were estimated from sorption isotherms using Langmuir equations, and relationships between P adsorption and soil properties determined by correlations. The results of this studyshowed that Al + Fe + Clay + Ca were the principal soil physicochemical factors associated with P-Sorption in all the six studied pedons as they were found highly significant with Langmuir P- Sorption Maximum (qmax) R^2 = 1. Langmuir Isotherm was used to describe adsorption of Phosphorus for the six pedons. The highest phosphorus sorption capacity of 333.33mg/kg was found in Obor 1, Obor 2 and Rivers State University (RSU) followed by Isu (0.00mg/kg), Eagle-Island(-333.33mg/kg) and Ozuzu (-125mg/kg). The Obor 1, Obor 2 and RSU soils sorbed more phosphorus than other soils.

KEY WORDS: Phosphorus sorption, upland and wetland soils

INTRODUCTION

The current challenge for agriculture now and over the coming decades will be to meet the world increasing demand for food in a sustainable way. Declining soil fertility and mismanagement of plant nutrients have made this task more difficult. Phosphorous is an essential macronutrient for plant growth and it is generally added to soil as a fertilizer and thereby, increases the physiological efficiency of crops. When phosphate fertilizer is applied to soil and dissolved by the soil water, various reactions occur between phosphate and soil constituents which remove P from the solution phase and render it less available. This phenomenon is called P fixation or sorption (Amel Idris and Ahmed 2012). In living organisms, P is a structural component of deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), which are essential forenzymatic reactions and reproduction (Chude*et al.*, 2011). It is particularly necessary for cell division and stimulates root differentiation and development. Plants derive their internal energy from P-containing compounds, mainly adenosine tri-phosphate (ATP) which stimulates early growth, fruit development and seed formation (Fox, 1993). Inadequate Phosphorus supply thus results in a decreased synthesis of RNA the protein maker leading to depressed growth (Hue *et al.*, 2000). Phosphorus deficiency symptoms which include retards cell division in plants, retards growth, delays maturity and seed formation have been recorded in many regions of the world (Hue *et al.*, 2000; Fox, 1993). Soils are known to vary generally in their capacities to supply phosphorus to crops because only a small fraction of total phosphorus to crops is available to crops. Phosphorus has been identified as one of the most limiting nutrient element in acid soils because of excessive precipitation and fixation. Bechwith (1965) suggested phosphorus sorption as one of the promising technique for measuring both the intensity and capacity factor of soil for phosphorus. He suggested standard concentration of 0.2 mg kg-1 phosphorus in solution to compare soils' P sorption as it is the adequate concentration of P in solution for most crop species. Unfortunately, most soils of the tropics contains high amounts of iron and aluminum oxides or amorphous alumino-silicate clays, which react strongly with P, making it virtually unavailable for plant uptake (Silva and Uchida, 2000), when this occurs, acceptable crop production is not possible unless adequate P fertilizers are applied. Thus, it is necessary to have adequate information on phosphorus sorption capacity of wetland and upland soils of Rivers State, with a view for phosphorus management recommendations to enhance soil fertility management and improve crop production in the state.

MATERIALS AND METHODS

Description of the Study Areas

The study sites for this research were six (6) in three (3) locations, namely Ogba/Egema/Ndoni, Etche and Port Harcourt Local Government Areas in Rivers State of Nigeria (Table 1). The climate of Rivers State is the humid tropical type, characterized by the effect of the humid Marine Tropical (MT) air mass and dry Continental (CT) air mass with their associated South-westerly winds. The wet or rainy season usually begins about mid-March and ends mid-November with a little dry spell usually referred to as "August Break" occurring in the month of August. The dry season extend from November ending, through December to March. The distribution of the mean annual rainfall in the state is from about 2000mm inland to over 3000mm along the coast. The wettest months are June, July and September. January, February and March are usually the hottest months while July and September normally record the lowest temperatures. The relative humidity in the area is high, ranging from 75-95% decreasing from the coast towards inland. The entire Rivers State is in the tropical rainforest belt of Nigeria. However, the dominant vegetation is secondary which has almost entirely taken over the primary forest due to farming activities. Smallholder agriculture is a major socioeconomic activity in the area in addition to oil exploration and exploitation.

For each of the Local Government Areas (LGA), two sites representing upland and wetland soils were chosen as indicated in Table 1.

Table 1. Selected Study Sites

L G A	Location/ Geographic Coordinate of the Pedons				Parent Material
	Upland		Wetland		
Ogba Egema	Obor 1	06°.69΄98″ E 05° 38'39″ N	Obor 2	06°.69′ 85″ E 05°.39′ 89″ N	Sombreiro Warri Deltaic plain
Port Harcourt	RSU	06°.98′46″ E 04°.80′ 96″ N	Eagle-Island	06°.98′ 74″ E 04°.79′ 17″ N	Coastal plain sands
Etche	Ozuzu	06°.99′ 81″ E 05°.14′ 92″N	Isu	06°.02′ 07″ E 05°.15′ 58″ N	Coastal plain sands

(Ayolagha and Onuegbu, 2002)

Etche and Port Harcourt represent soils of Coastal Plain Sands which have dark to brown soil colour. The texture of the soil is predominantly coarse sand with clay content sometimes as much as 35%. The soil have been found to range from sand to sandy loam in the surface soil horizon with pH values of between 4.0 and 5.8 in water (Ayolagha and Onuegbu 2002). Ndoni represent soils of Sombreiro Warri Deltaic plain with texture ranging from coarse sandy loams through fine and silt loams to varying mixtures of clay. Thus they have low permeability and have pH of between 4.4 and 5.0 (Ayolagha and Onuegbu 2002).

Soil Sample Collection

Soil samples were collected from identified horizons insixpedonssunk; two each at the three locations. The three pedons at each location represent the wetlands while the other three represent the upland soils. The profiles measured 2m long, 1m wide and 2m deep; except where shallow water table is struck. The morphological characteristics of each pedon were described according to procedure outlined in Soil Survey Manual (Soil Survey Staff, 2010).

Soil Analytical Methods

Particle size distribution was determined by hydrometer method (Bouycous,1951) as modified by Udo *et al*. (2009), Exchangeable cations (Ca, Mg, K, N) were determined by Ammonium acetate extraction procedure,exchangeable potassium (K) and Sodium (Na) by flame photometer while Exchangeable Calcium (Ca) and Magnesium were determined by EDTA (Ethylenediaminetetracetic acid) titration. Exchangeable acidity was measured in 1 N KCland organic carbon was determined by the Walkley and Black wet oxidation method as modified by Udo et al, 2009). Total Nitrogen was determined by the Bremner and Mulvaney Kjeldahl digestion method and available phosphorus was determined by the method of Bray and Kurtz (1945) as modified by Udo *et al.* (2009).

Phosphorus Sorption

The sorption experiment was conducted in the six soils according to the standard procedures recommended by Parsons *et al.*(1984). 3g of air dried soil was weighed into 50ml plastic bottles containing 30ml of a series of equilibrating P concentrations (0, 5, 10, 15, 20, 25 ppm). The equilibrations were performed in duplicate. To reduce the effect of unequal ionic concentrations, 0.5ml of 0.01M $CaCl_2$ was added to each plastic bottle. Similarly, two drops of toluene was added to minimize potential bacteria uptake of P during the equilibration period. The plastic bottle was shaken for a 30minutes period twice daily for six days at room temperature. At the end of the equilibration period, the samples were filtered through a Whatman NO. 42 filter paper. The filtrates were calorimetrically analyzed for P at 882nm using ascorbic acid.The phosphorus sorbed was plotted against the solution phosphorus concentration to obtain isotherm for each sample.

***Data* Analysis**

Amount of sorbed Phosphorus

The amount of Phosphorus sorbed onto the soil (adsorbents) $q_c$measured in mg/kg was calculated by a mass-balance relationship (Isa *et al*., 2007).

$$q_c = (Co\text{-}Ce)\ V/W \quad \text{----------------- } 1$$

Where,

Co = initial P concentrations (mg/l)

Ce = equilibum P concentrations (mg/l)

V = volume of the solution (l)

W = mass of adsorbent (soil) (g)

Efficiency of Adsorption

The efficiency of adsorption (R) was calculated using equation 2.

$$R = \frac{Co - Ce}{Co} \times 100 \text{---------} 2$$

Where,
Co = initial P concentration (mg/l)
Ce = equilibrium P concentration (mg/l)
R = Adsorption efficiency

a) Langmuir isotherm

The linear form of the Langmuir is represented as following:

$$q_e = \frac{q_m K C_e}{1 + q_m C_e} \text{ - - - - --- } 3$$

$$1/q_e = \left[\frac{1}{q_m k}\right] 1/C_e + 1/qm$$

Where:
q_e = amount of adsorbate adsorbed per unit weight of adsorbent (mg/g)
qm= adsorption capacity (mg/kg)
C_e = equilibrium concentration of the adsorbate (mg/l)

Plot of $1/q_e$ against $1/C_e$ yields a straight line graph with slope = $1/q_m$, intercept = $1/q_m$.

The essential characteristics of the Langmuir isotherm can be expressed in terms of dimensionless constant (Separation factor R_L) given by Hall *et al.*, (1996).

$$R_L = \frac{1}{1 + K_L C_o} \text{ - - - - - - - - - - - - - - -- } 4$$

Where:
R_L = Langmuir Separation Factor
K_L = energy of adsorption (l/mg) and
C_e = equilibrium concentration of the adsorbate (mg/l).

RESULTS AND DISCUSSIONS

Particle Size Distribution and Chemical Properties

The particle size distribution and chemical properties of the soils of the various horizons is as shown on Tables 2 and 3, respectively and as earlier discussed in a previous article. (Orji and Amaechi, 2019). The soils of the studied area were predominantly loamy sand and sandy loam. The soils were generally moderately acid, with the wetland soils having higher organic matter, total nitrogen and iron content and cation exchange capacity than the upland soils.

Table 2.MeanParticle Size Distribution of Selected Wetland and Upland Soils

LOCATION	PEDONS	%Clay	%Silt	%Sand	Texture
Ogba/Egbema/Ndoni (Upland)	OBOR1	11.4	10.6	78.0	Sandy Loam
Ogba/Egbema/Ndoni (Wetland)	OBOR2	10.1	7.4	82.5	Loamy Sand
Port Harcourt (Upland)	RSU	14.1	12.4	73.5	Sandy Loam
Port Harcourt (Wetland)	E/ISLAND	15.4	3.8	80.8	Sandy Loam
Etche (Upland)	OZUZU	12.2	4.2	83.6	Sandy Loam
Etche (Wetland)	ISU	8.6	3.4	88.0	Sandy Loam

Table 3: Chemical Properties for Upland and Wetland Soil

LOCATION	HORIZON	DEPTH(cm)	pH	Ava.P	% O.M	% O.C	% T.N	EXCHANGEABLE BASES (cmol/kg) Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Al^{3+}	H^{+}	Fe (mg/kg)	CEC (cmol/kg)	TEA
OBOR 1	Ap	0-11	5.80	11.40	2.29	1.33	0.07	0.75	0.95	0.32	0.21	1.00	0.20	166.67	2.23	1.20
	Hp	11-20	5.75	2.81	1.31	0.76	0.02	0.65	0.75	0.34	0.27	2.10	0.20	66.67	2.01	2.30
	Bt1	20-42	5.70	0.35	1.28	0.74	0.03	0.30	0.20	0.25	0.18	2.30	0.40	33.33	0.93	2.70
	Bt2	42-72	5.85	1.05	0.92	0.53	0.03	0.05	0.30	0.24	0.13	2.50	0.14	33.33	0.72	2.64
	C	72-200	5.50	0.70	0.55	0.32	0.00	0.10	0.10	0.33	0.18	2.00	0.44	33.33	0.71	2.44
		Mean	5.72	3.26	1.27	0.74	0.03	0.37	0.46	0.30	0.19	1.98	0.28	66.67	1.32	2.26
OBOR 2	Ap	0-10	6.10	35.09	4.61	2.68	0.13	0.45	0.30	0.33	0.24	1.20	1.18	1266.67	1.32	2.38
	Bh	10-23	5.60	14.04	0.89	0.52	0.06	0.30	0.05	0.35	0.22	2.10	0.68	66.67	0.92	2.78
	Bw1	23-49	5.75	11.40	1.48	0.86	0.01	0.13	0.17	0.27	0.16	1.40	0.58	66.67	0.73	1.98
	BW2	49-60	5.80	19.30	2.71	1.58	0.01	0.80	0.07	0.29	0.16	0.80	0.46	66.67	1.32	1.26
		Mean	5.81	19.96	2.42	1.41	0.05	0.42	0.15	0.31	0.20	1.38	0.73	366.67	1.07	2.10
RSU	Ap	0-15	5.80	35.96	2.39	1.39	0.02	0.90	0.55	0.32	0.22	0.60	0.90	166.67	1.99	1.50
	Bt1	15-45	5.75	16.67	2.10	1.22	0.01	0.25	0.30	0.27	0.19	1.80	0.64	33.33	1.01	2.44
	Bt2	45-75	5.55	7.02	1.23	0.72	0.02	0.65	0.30	0.30	0.16	1.90	0.54	33.33	1.41	2.44
	C	75-200	5.20	0.70	0.61	0.35	0.00	0.80	0.10	0.28	0.15	1.70	0.72	33.33	1.33	2.42
		Mean	5.58	15.09	1.58	0.92	0.01	0.65	0.31	0.29	0.18	1.50	0.70	66.67	1.44	2.20
EAGLE-SLAND	Ap	0-5	5.35	14.39	4.05	2.35	0.08	2.05	3.25	7.17	2.31	0.70	0.34	2000.00	14.78	1.04
	Bt1	5-16	5.15	14.74	1.60	0.93	0.02	0.95	2.70	3.70	1.79	0.40	0.82	2000.00	9.14	1.22
	Bt2	16-21	4.45	85.96	3.29	1.91	0.04	1.60	3.20	3.48	1.54	1.20	0.80	1266.67	9.82	2.00
	Bh	21-30	5.70	84.21	0.91	0.53	0.00	0.45	1.30	0.87	0.40	0.00	0.52	333.33	3.02	0.52
	Bw	30-63	4.65	78.95	17.18	9.99	0.08	7.15	11.90	8.70	2.18	5.10	5.72	3600.00	29.93	10.82
		Mean	5.06	55.65	5.41	3.14	0.04	2.44	4.47	4.78	1.64	1.48	1.64	1840.00	13.34	3.12
OZUZU	Ap	0-11	5.70	19.30	2.05	1.19	0.02	2.10	3.70	0.25	0.16	0.30	0.10	166.67	6.21	0.40
	Bt1	11-25	6.15	12.28	0.57	0.33	0.01	0.50	4.40	0.23	0.16	0.40	0.10	333.33	5.29	0.50
	Bt2	25-43	5.95	20.18	0.44	0.26	0.00	1.30	0.05	0.26	0.15	0.30	0.20	333.33	1.76	0.50
	Bt3	43-60	5.80	54.39	0.54	0.31	0.00	1.15	1.20	0.24	0.11	0.60	0.20	333.33	2.70	0.80
	C	60-200	5.75	43.86	0.30	0.17	0.00	0.90	0.65	0.23	0.11	0.40	0.26	333.33	1.89	0.66
		Mean	5.87	30.00	0.78	0.45	0.01	1.19	2.00	0.24	0.14	0.40	0.17	300.00	3.57	0.57
ISU	Ap	0-8	5.70	14.04	4.37	2.54	0.01	0.75	0.00	0.26	0.18	1.50	0.42	333.33	1.19	1.92
	Bh	8_17	5.80	17.54	3.80	2.21	0.01	0.30	0.05	0.25	0.12	2.00	0.00	333.33	0.72	2.00
	Bw	17-46	5.75	8.77	3.14	1.83	0.08	0.05	0.05	0.19	0.10	1.80	0.18	333.33	0.39	1.98
		Mean	5.75	13.45	3.77	2.19	0.03	0.37	0.03	0.23	0.13	1.77	0.20	333.33	0.77	1.97

Available Phosphorus

The results obtained for available P in the study area showed a general range of 0.35 – 85.96 mg/kg (Table 3). The range in Obor 1, horizon was 0.35 – 11.40 mg/kg with average of 3.26mg/kg; Obor2 had 11.40 - 35.09mg/kg with mean of 19.96 mg/kg; RSU had 0.70 – 35.96mg/kg with mean of 15.09 mg/kg, Eagle-island 14.39 – 85.96 mg/kg with mean 55.65mg/kg, Ozuzu 12.28 -54.39 mg/kg with mean 30.00mg/kg and Isu 8.77 – 17.54 mg/kg. The result showed that the average amount of available P of Obor2 (19.96mgkg^{-1}) was significantly higher than that of Obor1 which was 3.26mg/kg, 55.65mg/kg for Eagle-Island was higher than 15.09 mg/kg of RSU; while that of Ozuzu (30.00mg/kg) was higher than 13.45mg/kg of Isu. The highest value was recorded in Eagle-Island with mean of 55.65mg/kg while the least value was recorded in Obor1 with 3.26mg/kg. Available P was observed to be higher in the wetland soils except in Isu (13.45mg/kg) pedon which was lower than the upland soil. The increase in available P could be due to runoff deposit during the periods of flooding in these soils (Reddy and Clark 2008). The critical level of available P (by Bray 1) was 20mg/kg. Considering available P. of the surface as a single soil quality (fertility). The index showed that the available P of the soils are low to high qualifying for rich soils (having high level of available P.) for few pedons. Using available P. as fertility index, the soil quality trend for the various was of the following order: Eagle-Island >Ozuzu> Obor2 > RSU >Isu> Obor1.

Phosphorus Sorption Isotherm

The graphic representation of sorption Isotherms of six pedons used in the study is shown in Figures 1-2. These curves relate the amount of P sorbed by the soil to the concentration of P in equilibrium solution. The curves showed a continuous increase in P-sorption with increasing levels of added P concentration in the equilibrium solution in the soils. However, Figure 2 compared the amount of P sorbed by the soils base on land/soil type (upland and wetland soils) in the studied locations. In Ogba/Egbema/Ndoni: Obor 1 (upland soil) sorbed more Phosphorus than wetland soil Obor 2, in Port Harcourt: Eagle-Island (wetland soil) sorbed more Phosphorus than RSU (upland soil) while in Etche: Ozuzu (upland soil) sorbed more Phosphorus than Isu (wetland soil). These result revealed that the sorption ability of these soils does not depend on soil type but rather in the content of the physicochemical properties.

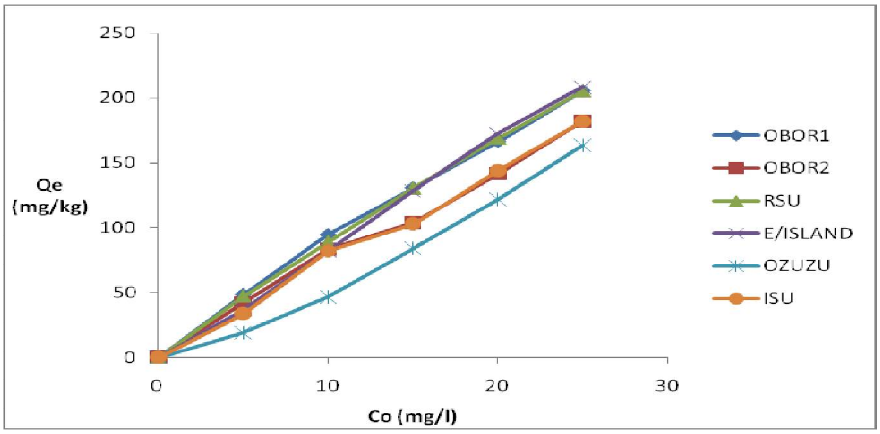
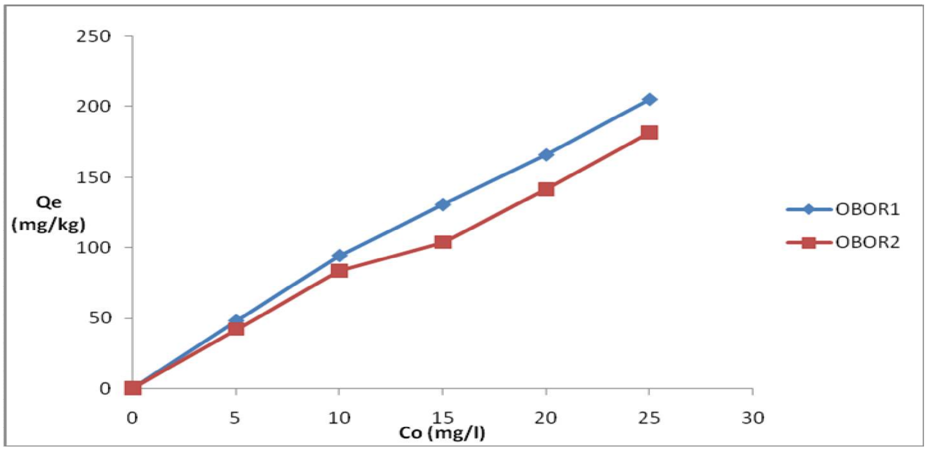
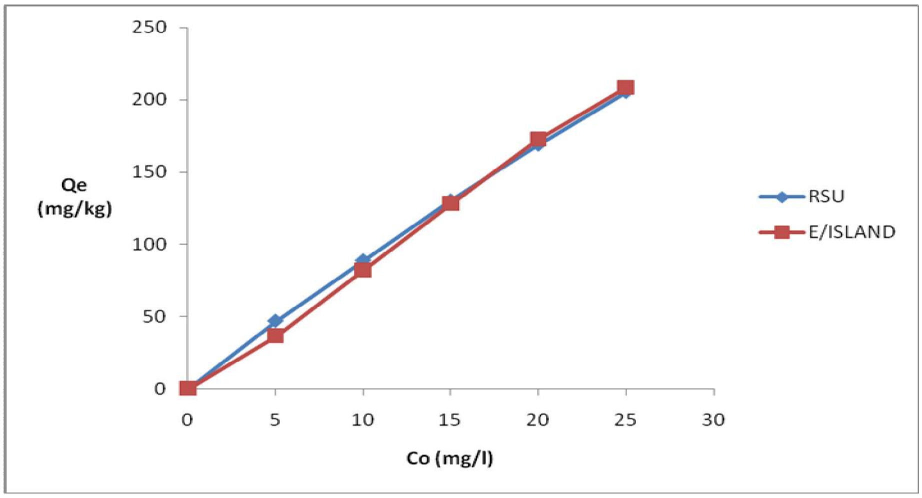


Fig.1: Phosphorus Sorption Isotherm for the various locations

P – concentration in solution





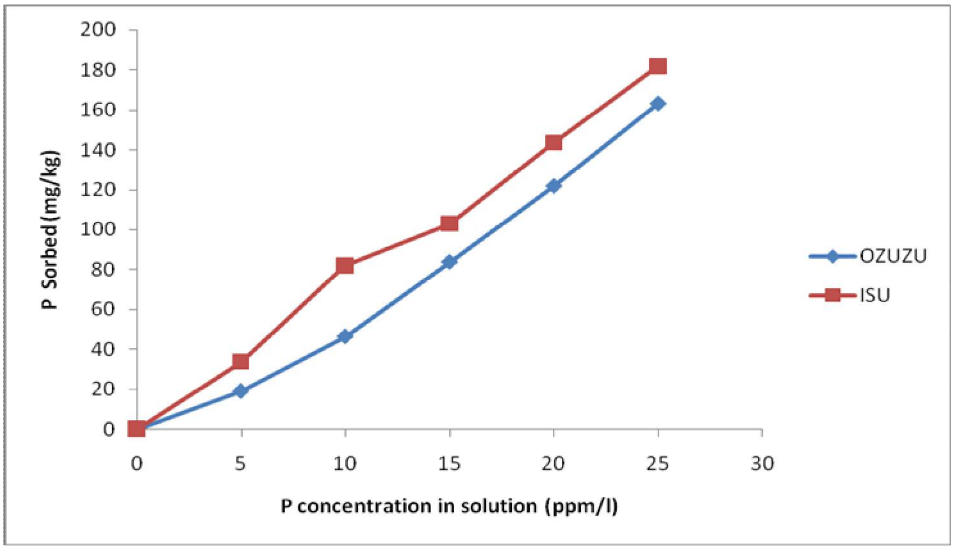


Figure 2: Comparing phosphorus sorption isotherm for the upland and wetland soils

The analysis of the Isotherm data was fitted to Lanqmuir Isotherm models to understand phosphate adsorption, evaluate Phosphorus Sorption Maximum andexplain adsorption of phosphorus. The applicability of the Isotherm model to the adsorption study was compared by judging the correlation of determination, R^2 (Values). The result are presented in Table 4.

In this study the LanqmuirIsotherm model gave a good correlation with the six pedons. However, Obor 2 had better correlation than other pedons as shown in Table 4. The value of the separation factor of the Langmuir Isotherm RL lying in between O and < 1 for Obor1, Obor2 and RSU indicating that isotherm processes are favourable and < 0 which indicate desorption for Eagle Island and Ozuzu and = 1suggesting Linear adsorption for Isu

Table 4: Phosphorus Sorption parameters for Langmuir Models

LOCATION	HORIZON	DEPTH(cm)	R^2	K (mg p-1)	Qmax (mg kg-1)
OBOR1	Ap	0-11	0.965	5	166.67
	Hp	11-20	0.816	1	250
	Bt_1	20-42	0.037	0.182	90.91
	Bt_2	42-72	0.99	0.6	200
	C	72-200	0.589	1	500
OBOR2	Ap	0-10	0.937	33	1000
	Bh	10-23	0.949	1.6	200
	Bw_1	23-49	0.972	5.25	250
	BW_2	49-60	0.868	0.8	200
RSU	Ap	0-15	0.954	2.4	200
	Bt_1	15-45	0.922	0.667	166.67
	Bt_2	45-75	0.034	0	100
	C	75-200	0.593	0.75	250
E/ISLAND	Ap	0-5	0.919	111.11	-0.556
	Bt_1	5-16	0.846	4.368	-52.632
	Bt_2	16-21	0.514	2	1000
	Bh	21-30	0.799	-9.276	-6.41
	Bw	30-63	0.35	0.273	90.909
OZUZU	Ap	0-11	0.975	15.5	500
	Bt_1	11-25	0.969	-9.495	-10.526
	Bt_2	25-43	0.005	1.462	76.923
	Bt_3	43-60	0.99	-10.14	-47.619
	C	60-200	0.628	14.75	250
ISU	Ap	0-8	0.000	0.842	5.65
	Bh	8-17	0.004	0.000	100
	Bw	17-46	0.065	-0.667	83.667

Relationship between some Soil Physicochemical Properties and Phosphorus Sorption.

For this study, correlation coefficient (r^2) and multiple regression were used to evaluate the effect of soil physicochemical properties on Langmuir P – Sorption Maximum (qmax).

Soil properties were correlated individually with langmuir P. Sorption Maximum (qmax) to ascertain the principal factors associated with P. Sorption (Tables 5 and 6).

The individual soil properties correlation showed that Fe > Mg > Al > H^+> pH were significantly correlated with P. Sorption on few pedons.AtObor 2 location, the correlation between Fe and qmax was $r^2 = 0.996$, Al correlated well with qmax at the Isu location (r = 0.941), Mg correlated well with qmax at Isu (r^2 = 0.974). H had good correlation with qmaxat Obor2 ((r^2 = 0.918) and Isu (r^2 = 0.924). However, pH correlated well with qmax in most of the locations: Isu (r^2 = 0.874), Obor 2 (r^2 = 0.845), Obor 1 (r^2 = 0.597) and Eagle-Island (r^2 = 0.518). This might be attributed to decrease in pH values of the soils. This result agreed with previous research reported by Shinjiro and Nicholas (2005) on a study Influence of soil pH on inorganic phosphorus sorption and desorption in humid Brazilian Ultisols. These results strongly suggest Fe, Mg Al and H and pH as the major or dominant regulators of P. adsorption at Obor2, Isu and Obor1 soils. The most correlated soils with qmax was recorded in Etche wetland (Isu) > Ogba-Egbema/Odoni Wetland (Obor2) >Etche

Upland (Ozuzu) while Obor1, RSU and Eagle-Island had poor correlation.

Other soil properties including Na and K did not have significant effect on P. Sorption.Generally, no single soil properties correlated with qmax in all the study area.However, the combined effect of most of the soil physicochemical properties were found to have significant correlation with P – Sorption in all pedons. The step wise multiple regression analysis of the data suggest that qmax was adequately predicted from (Al + Fe + Clay + Ca) for the six locations examined, with perfect r^2 value (1.000) and therefore considered principal factors associated with P. Sorption in Rivers State soils.

The result (Al + Fe + Ca + Clay) suggest that P. Sorption in the studied sites was associated with amorphous and some poorly crystalline forms of Fe and Al. Amorphous forms of Fe and Al are highly reactive, and tend to retain P by adsorption on surface and by forming insoluble complexes and precipitates. This result is similar with findings of the other researchers (Borling et al 2001, Samadi, 2006, Muindi et al. 2015). It has also beenreported that those clay minerals that posses greater anion exchange capacity have inadequate phosphorus due to formation of insoluble calcium phosphate compounds (AmelIdris and Ahmed 2012)

Table 5:Correlation Coefficient of Phosphorus Sorption Maximum (qmax) and Soil physicochemical Properties of Upland and Wetland Soils of Rivers State

Parameter	Obor1	RsuOzuzu	Obor2	Eagle Island	Isu	
	r^2					
	← Upland		→	← Wetland		→
pH	0.597	0.185	0.437	0.845	0.518	0.875
OM	0.381	0.039	0.605	0.775	0.005	0.557
Ca_{2+}	0.133	0.149	0.564	0.001	0.004	0.751
Mg_{2+}	0.125	0.066	0.047	0.833	0.004	0.974
Al	0.001	0.123	0.372	0.047	0.001	0.941
Fe	0.073	0.049	0.739	0.996	0.037	0.000
CEC	0.088	0.022	0.181	0.275	0.009	0.695
Clay	0.290	0.034	0.046	0.272	0.037	0.000
OC	0.381	0.039	0.605	0.775	0.005	0.557
Ava. P	0.066	0.000	0.049	0.874	0.263	0.002
K	0.000	0.000	0.067	0.498	0.002	0.845
Na	0.319	0.002	0.049	0.106	0.002	0.224
N	0.431	0.575	0.596	0.794	0.001	0.125
TEA	0.093	0.000	0.038	0.869	0.220	0.003
H	0.169	0.437	0.039	0.918	0.010	0.924

Ava.P = Available Phosphorus, Al= Aluminum, Fe= Iron, Ca= Calcium, OC= Organic carbon, TN= Total Nitrogen, H= Hydrogen, CEC= Cation Exchange Capacity, TEA= Total Exchangeable Acidity. K = Potassium, TEA = Total Exchangeable Acidity, CEC = Cation Exchange Capacity, Na = Sodium, Mg = Magnesium H = Hydrogen, OM = Organic Matter. r^2 values>0.4 are significant, r^2 values<0.5 are not significant

Table 6:Stepwise Multiple regression Correlation for prediction phosphorus SorptionMaxinmum (qmax) From Soil Properties

Step	Correlation equation	Obor1	RSU	Ozuzu	Obor2	E/lsland	Isu
		←			r^2		→
I	Al	0.001	0.123	0.372	0.047	0.001	0.941
III	Al+Fe	0.557	0.996	0.799	0.047	0.001	0.941
III	Al+clay	0.727	0.124	0.503	0.999	0.038	0.941
IV	Ca+Al	0.250	0.170	0.687	0.074	0.443	1.000
V	Clay+Ca	0.497	0.948	0.564	0.432	0.060	0.751
VI	Fe+Clay	0.714	0.053	0.763	0.996	0.071	0.000
VII	Al+Fe+ca	0.561	1.000	0.800	1.000	0.448	1.000
VIII	Al+Fe+cla	0.727	1.000	0.993	1.000	0.208	0.941

XV	Clay+Ca+Fe	0.772	1.000	0.763	1.000	0.089	0.751
X	PH+TEA	0.715	0.209	0.807	0.999	0.692	1.000
XI	OC+TN	0.673	0.917	0.596	0.993	0.287	1.000
XII	CEC+TEA	0.644	0.106	0.454	0.834	0.056	1.000
XIII	TN+OM	0.432	0.642	0.605	0.945	0.012	1.000
XIV	K+Na	0.752	0.038	0.084	0.913	0.073	1.000
XV	Al+Clay +ca	0.924	1.000	0.800	1.000	0.515	1.000
XVI	Al+Fe+Clay+ca	1.000	1.000	1.000	1.000	1.000	1.000

CONCLUSION

Phosphorus sorption capacity in soils, which is a key process governing its availability to crops, was investigated for some selected wetland and upland soils in Rivers State Nigeria. P sorption indices were estimated from sorption isotherms using Langmuir equations, and relationships between P adsorption and soil properties determined.

The Obor 1, Obor 2 and RSU soils sorbed more phosphorus than other soils, suggesting that these soils need phosphorus fertilization to attain optimum phosphorus concentration in the soil solution.The amounts of sorbed phosphorus were found to be affected by soil physiochemical properties such as Al, Fe, Clay and Ca, this trend was attributed to the presence of positive charges on the surface of the soil (adsorbents) that have greater affinity for phosphate ions.

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