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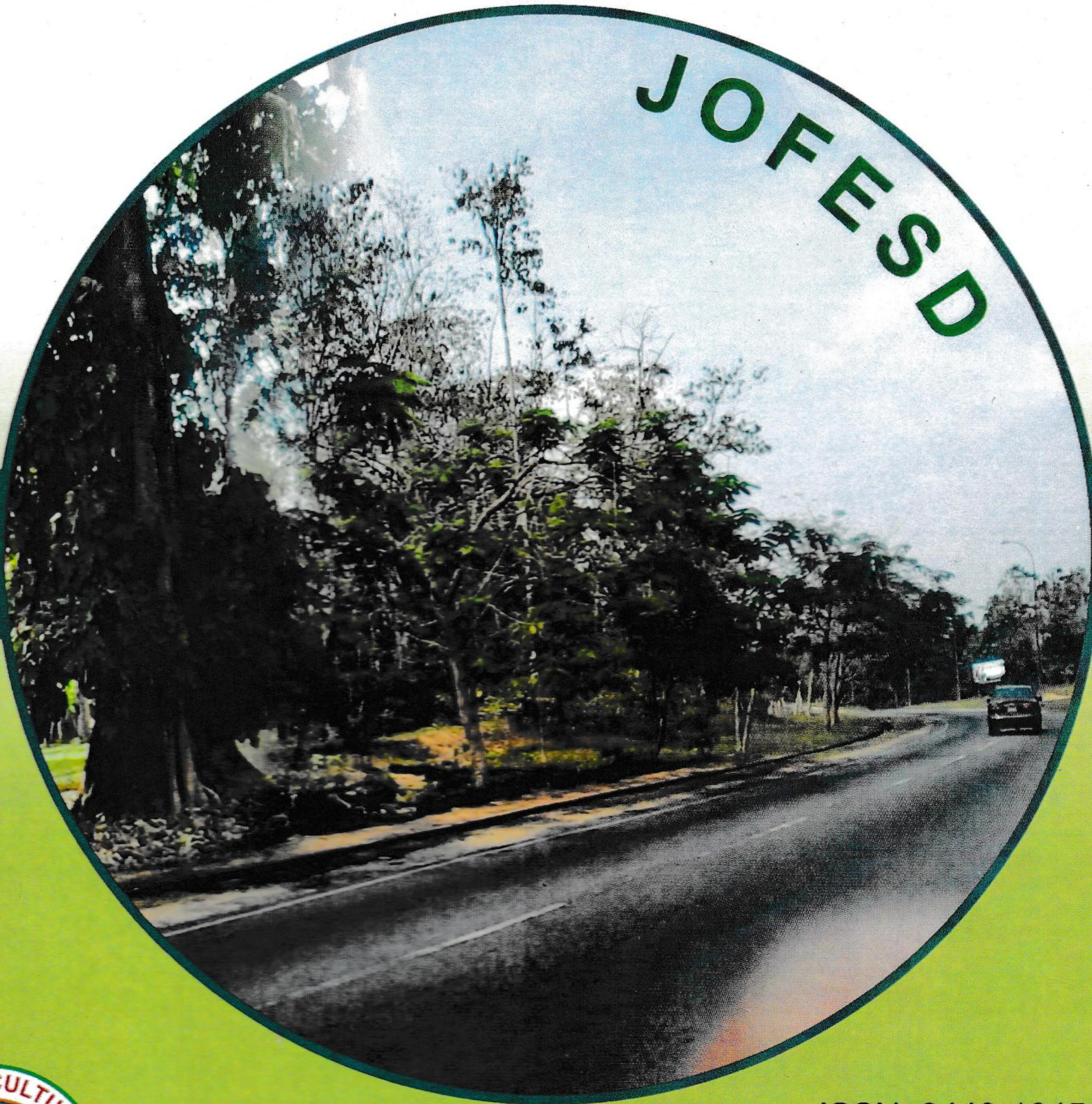

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PHOSPHORUS SORPTION CAPACITY AND EXTERNAL PHOSPHORUS REQUIREMENTS OF WETLAND SOILS IN AKWA IBOM STATE, NIGERIA.

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ABSTRACT
Phosphorus sorption capacity, bonding energy and external P requirements of wetland soils in Akwa Ibom State, Nigeria, were assessed for effective and efficient fertilizer recommendation. Three wetland types (inland depression, river floodplain and coastal swamp) were selected for the study. In each wetland type, three locations were selected (9 locations) and in each location, soil samples were collected from 3 points at the depth of 0 -30cm and bulked to form composite samples using soil auger and taken to the laboratory for analysis. In the laboratory, a solution containing 0, 20, 40 and 80 ml of the stock solution to 100 ml prepared from 6.15g of Potassium hydrogen phosphate (KH_2PO_4) in 1500ml of distilled water and make up to two litres with distilled water and used for the study. 2.5g of soil samples were weighed into a 50ml plastic cup and 2.5ml of each of the 3 sorption treatments solution were added to each of the soil in the cups and mixed thoroughly. The experimental set up were covered and incubated for 7 days. The treated soil samples were watered with deionized water to keep the sample moist throughout the period of incubation. On the 7th day, P in each of the treated soil samples and the leachate were extracted using Bray-P-1 extractant. The P in the extract was determined using Murphy and Riley method. The P extracted from the soil samples were considered to be P adsorbed while P in the leachate samples were considered to be P in solution. Langmuir equation was used to determine P adsorption capacity and bonding energy while the linear form of the equation was used to determine external P requirements of the soils. The results showed that floodplain soils had the highest mean phosphate adsorption capacity (0.50 $mgkg^{-1}$), followed by soils of inland depression (0.32 $mgkg^{-1}$) while coastal swamp soils had the least (0.09 $mgkg^{-1}$). Coastal swamp soils had the highest mean bonding energy (0.54 Lmg^{-1}), followed by floodplain soils (0.27 Lmg^{-1}) while soils of inland depression had the least (0.07 Lmg^{-1}). Also, soils of coastal swamp required the highest quantity of P (0.129 mgl^{-1}) to maintain a concentration of P at 0.2 mg P per litre of soil solution, followed by soil of river floodplain (0.057 mgl^{-1}) while soils of inland depression required the least. Hence, the three wetland soil types were not the same in P sorption capacity, bonding energy and external P requirements.

Keywords: P requirements, P sorption capacity, wetland soils, Akwa Ibom State.

INTRODUCTION
External phosphorus requirements of soils (EPR), also known as standard P requirements (SPR) is the amount of P that must be added to the soil to maintain a concentration of P at 0.2 mg P per litre of soil solution (Boland *et al.*, 1990). This is soil solution concentration of P below which crops / plants will suffer P deficiency. For most crops, the amount of P in equilibrium with 0.2 mg P dm^{-3} (Po_4) has been shown to be the threshold over which no response to P is observed (Nziguheba *et al.*, 1998). When the 0.2 mg P per litre of soil solution is continuously maintained in solution, P will be adequately provided for optimum crop production (Nnadi and Haque, 1988). At that concentration, crop yields are not compromised due to under-fertilization and ground water/surrounding water are not polluted due to over –fertilization.

Phosphorus is the second most limiting nutrients after nitrogen in most soils of Sub-Saharan Africa (SSA), due to low P content in the parent material from which the soils were derived, and/or due to depletion of soil reserve P through intensive cultivation, without adequate external replenishment (Stoorvogel and Smaling, 1990). Phosphorus is one of the major essential nutrient elements required by plants. Phosphorus plays a vital role in energy transformation and photosynthesis. The quality of fruits, forages, vegetables and grain crops as well as disease resistance of crops are enhanced under adequate phosphorus availability (Sanyal and De Datta, 1991).

In acidic soils, adsorption of P on surfaces of Al and Fe oxides is primarily responsible for P fixation. Hydrous oxides of Fe and Al which occur as fine coating on surface of clay in soils attract and hold phosphorus ions (Greenland *et al.*, 1968 and Haynes, 1983). These coating, characterized by large surface area, hold an appreciable quantity of P (Ryden and Pratt, 1980). The type and amount of clay in the soil constitute another important factor in the fixation of applied or mineralized phosphorus. Kaolinite with 1:1 lattice clays retains or fixes more phosphorus ion in tropical soils especially at low pH than an equal amount of montmorillonite with 2:1 lattice clays due to large surface area. As the pH increases from 7.5 to 8.0, calcium phosphate ($Ca\ (H_2PO_4)$) increases in solubility. Therefore, phosphate fixation is at its lowest (plant availability is highest) when soil pH is maintained within 6.0 – 7.0 range. The low recovery by plants of phosphates added to the soils in a given season is partially due to high P fixation. Similar results have been observed by (Sharpley, 2000). Also, low availability of phosphorus in the soils is attributed to the nature of chemical forms of soil phosphorus. These factors affect the rate and the amount of phosphorus dissolved and available for plant use (Isirimah, 1987 and Chien and Hamond, 1989). This implies that P fixation or sorption is the major factor that limits P bioavailability in most acidic soils, including wetland soils of Akwa Ibom State.

To correct the P deficiency in acidic soils and other soils, and prevent under-fertilization or over-fertilization, the external P requirements (EPR) or standard P requirements (SPR) which is the amount of P that must be sorbed by soil to maintain P concentration at 0.2 kg^{-1} in soil solution must be determined (Fox, 1981). The relationship between the amount of P that a soil adsorbed from a phosphate solution and the concentration of P left in the solution known as P sorption isotherm has been used in the determination of external P requirements of crops in different soil systems (Yasin, 2008).

Several models have been developed to quantitatively described the sorption isotherm and relate the P concentration in soil solution to that retained by the solid phase. Sposito, (1989) reported that Langmuir isotherm can describe both adsorption and precipitation capacity of P in the soil. The Langmuir equation allows the estimation of an adsorption maximum and bonding energy constant. Information on P sorption capacity of soils based on sorption isotherm models is important in determination of external P requirements of crop in different soil types for making profitable fertilizer recommendations (Zhang *et al.*, 2005). However, there is little information on P sorption capacity and external phosphorus requirements of wetland soils in Akwa Ibom State. Therefore, this study was conducted to determine the P sorption capacity and external P requirements of wetland soils in Akwa Ibom State using Langmuir isotherm model for effective and efficient P fertilizer recommendation.

MATERIALS AND METHODS

The Study Area

The study was conducted in Akwa Ibom State, South-East Nigeria. The state lies within latitudes 4°30′ and 5°30′ N and longitudes 7°30′ and 8°20′ E. The climate is humid tropical with annual rainfall of about 2500 to 3000 mm with 1 to 3 dry months in the year. Mean annual temperature varies between 27 and 28°C with relative humidity of 75 to 80% (Petters *et al.*, 1989).

Field Study
Three wetland types were selected for the study. They were inland depression, river flood plains and coastal swamp. In each wetland type, three locations were selected (9 locations). In each location, soil samples were collected from 3 points at the depth of 0 -30cm and bulked to form composite samples using soil auger.

Laboratory Study
Phosphate sorption Stock solution was prepared by dissolving 6.15g of KH_2 PO_4 (Potassium hydrogen phosphate) in 1500ml of distilled water and make up to two litres with distilled water. Three sorption treatments were prepared by diluting 20, 40 and 80ml of the stock solution to 100 ml. 2.5g of soil samples were weighed into a 50ml plastic cup and 2.5ml of each of the 3 sorption treatments solution were added to each of the soil in the cups and mixed thoroughly with the soil. The experimental set up were covered and incubated for 7 days. The treated soil samples were watered with deionized water once to keep the sample moist throughout the period of incubation (Ayodele and Agboola 1981). At the end of 7 days, P in each of the treated soil samples and the leachate were extracted using Bray-P-1 extractant (Bray and Kurtz 1945). The P in the extract was determined using (Murphy and Riley 1962) method. The P extracted from the soil samples were considered to be P adsorbed while P in the leachet samples were considered to be P in solution. Other analyses carried out in the study were: Particle size distribution was determined using the Bouyoucos hydrometer method as described by Udo *et al.* (2009). Soil pH was determined with a glass electrode pH meter in distilled water using 1:2.5 soil/water suspension as described by Udo *et al.* (2009). Organic carbon content was determined by the wet oxidation method of Walkley and Black as modified by Nelson and Sommers (1982). Crystalline forms of Fe and Al oxides were extracted from the soil samples using the Dithionite Citrate Bicarbonate procedure while the amorphous form of Fe and Al was extracted using ammonium oxalate acidified at pH 5.7. The content of Fe and Al in extracts was determined by atomic absorption spectrophotometer (Mckeaque *et al.*, 1971).

RESULTS AND DISSCUSION

Physicochemical properties of the study area
Soil Texture
In river floodplain soils, the sand fraction varied from 510 to 894gkg^{-1} with a mean of 694gkg^{-1}. The silt fraction ranged from 50 to170gkg-^{1} with a mean of 114gkg-^{1} and clay fraction varied from 60 to 320gkg-^{1} with a mean of 192gkg-^{1}. In inland depression soils, the sand fraction varied from 67gkg-^{1} to 93gkg-^{1} with a mean of 8217gkg-^{1}. The silt fraction ranged from 10 to 130gkg-^{1}with a mean of 667gkg-^{1} and clay fraction varied from 60 to 210gkg-^{1} with a mean of 1117gkg-^{1}. In coastal swamp soils, the sand fraction varied from 870 to 920gkg-^{1} with a mean of 9027gkg-^{1}. The silt fraction ranged from 10 to 120gkg-^{1} with a mean of 325gkg-^{1} and clay fraction varied from 70 to 210gkg-^{1} with a mean of 825gkg-^{1}. The mean sand fraction of coastal swamp (CS) soils (902.7gkg-^{1}) was significantly higher ($p < 0.05$) than that of river floodplain (FP) soils (694gkg-^{1}) but was not significantly different from that of inland depression (ID) soils (8217gkg-^{1}) in the study area. The mean silt fraction of FP soils (114gkg-^{1}) was significantly higher ($P < 0.05$) than that of CS soils (325gkg-^{1}) and ID (66.7gkg-^{1}) soils. The mean clay fraction of FP soils (192gkg-^{1}) was significantly higher ($P < 0.05$) than that of ID soils (1183gkg-^{1}) and CS soils (717gkg-^{1}). The low silt content of the study area agrees with the results of Akamigbo (1984) that soils of Southeastern Nigeria are low in silt as a result of the high degree and extent of weathering and leaching they have undergone.

Table 1: Minimum, Maximum and mean of selected soil properties in the study area

	Sand gkg^{-1}	Silt gkg^{-1}	Clay gkg^{-1}	pH (H_2O)	OC (%)	Fe_d (%)	Fe_o (%)	Al_d (%)	Al_o (%)
				River Floodplain soils					
Min.	510	50	60	5.5	0.24	0.10	0.13	0.03	0.02
Max.	89.4	170	320	6.1	5.34	0.18	0.21	0.11	0.10
Mean	**694**	**114**	**192**	**5.8**	**3.04**	**0.13**	**0.14**	**0.06**	**0.06**
				Inland depression soils					
Min.	670	10	60	6.2	0.95	0.10	0.13	0.03	0.03
Max.	930	130	210	6.7	4.10	0.19	0.27	0.06	0.14
Mean	**8217**	**667**	**1117**	**6.3**	**2.48**	**0.13**	**0.16**	**0.06**	**0.07**
				Coastal swamp soils					
Min.	870	10	70	4.3	0.34	0.9	0.12	0.03	0.05
Max.	920	120	210	6.6	5.64	0.17	0.27	0.09	0.15
Mean	**9027**	**325**	**825**	**5.1**	**2.62**	**0.12**	**0.19**	**0.05**	**0.08**
LSD(0.05)	1062	38	569	1.47	1.25	**0.04**	0.05	0.02	0.03

OC= organic carbon, 0= oxalate, d= dithionate

Soil Reaction (Soil pH)

In river floodplain soils, soil reaction ranged from 5.5 to 6.1 with a mean of 5.8. While in inland depression soils, the soil reaction varied from 6.2 to 6.7 with a mean of 6.3. In coastal swamp soils, soil reaction varied from 4.3 to 6.6 with a mean of 5.1. The mean soil pH was moderately acid in soils of river floodplain, slightly acid in inland depression and strongly acid in coastal swamp soils. Similar result was observed by (Enwezor *et al.*, 1989). The trend of mean soil pH was as follows: CS < FP < ID soils. The mean soil pH values were not significantly different ($p < 0.05$) from each other. Acidic reaction is characteristic of soils of Southeastern Nigeria because of the acidic nature of the parent rocks, coupled with the influence of the leached profile under high annual rainfall condition (Eshett *et al.*, 1990). Coastal swamp soils had the lowest mean soil pH (5.8). This could be associated with the presence of pyrites in these soils, which oxidized to sulphuric acid on drying and aeration of the soils, thus lowering the pH values or increasing the acidity of the soils (Uniuyo Consults, 2001).

Organic Carbon

In river floodplain soils, organic matter ranged from 0.24 to 5.34% with a mean of 3.0%. In inland depression soils, OM varied from 0.95 to 4.10% with a mean of 2.5%. In coastal swamp soils, OM varied from 0.34 to 5.64% with a mean of 2.6%. Generally, mean organic carbon was high in river floodplain, moderate in inland depression and coastal swamp soils. Statistically, there was no significant difference ($p < 0.05$) in organic carbon among the three wetland types. The values obtained agree with the result of Ojanuga *et al.,* (2003), that the Cross River floodplains, part of which falls within Akwa Ibom State are characterized by levee soils, with moderate amount of organic matter (2% or more).

Iron Oxides

Dithionate Fe (Fe_d) of river floodplain soils, ranged from 0.10 to 0.18% with a mean of 0.13%. In inland depression soils, varied from 0.10 to 0.19% with a mean of 0.13%. In coastal swamp soils, dithionate Fe (Fe_d) varied from 0.09 to 0.17% with a mean of 0.12%. Statistically, there was no significant difference ($P < 0.05$) in means dithionate Fe among the wetland soil types under consideration.

In river floodplain soils, oxalate Fe (Fe_o) ranged from 0.13 to 0.21% with a mean of

0.14%. In inland depression soils, oxalate Fe (Fe_o) varied from 0.13 to 0.27% with a mean of 0.16%. In coastal swamp soils, oxalate Fe (Fe_o) varied from 0.12 to 0.27% with a mean of 0.19%. The mean oxalate Fe of CS soils (0.19%) was significantly ($P < 0.05$) higher than that of FP (0.13%) soils but was not significantly different ($P < 0.05$) from that of ID soils (0.16%). The trend was as follows: CS soils > FP soils = ID soils. The mean values of Fe_o in the three wetland soils were greater than the means of Fe_d indicating the prevalence of amorphous Fe in these soils than the crystalline Fe. This suggests that the soils are relatively less weathered with high proportion of ferrihyrite, a feature of most hydromorphic soils (Udo, 1980). The higher values of Fe_o also suggest that gleziation (major pedogenic process) is prevalence in the soil and induces the alteration, mobilization and fixation of iron following water movement (Khan *et al.*, 1997). It has been reported that P and metal sorptivity are higher with amorphous than crystalline oxides (Uzoho and Oti, 2005). This indicates that ion sorption was controlled by amorphous Fe rather than Al in these soils especially in inland depression and coastal swamp soils.

Aluminium Oxides

In river floodplain soils, dithionate Al (Al_d) ranged from 0.03 to 0.11% with a mean of 0.06%. In inland depression soils, dithionate Al (Al_d) varied from 0.03 to 0.06% with a mean of 0.06%. In coastal swamp soils, dithionate Al (Al_d) varied from 0.03 to 0.09% with a mean of 0.05%.. Statistically, there was no significant difference ($P < 0.05$) in mean dithionate Al among the three wetland soil types studied. In river floodplain soils, oxalate Al (Al_d) ranged from 0.02 to 0.10% with a mean of 0.06%. In inland depression soils, oxalate Al (Al_d) varied from 0.03 to 0.14% with a mean of 0.07%. In coastal swamp soils, oxalate Al (Al_d) varied from 0.05 to 0.15% with a mean of 0.08%. Statistically, there was no significant difference ($P < 0.05$) in oxalate Al mean among the three wetland soil types studied. This result is in tandem with the low mean Al_o values (0.02 – 0.09%) of some floodplain soils of Southeastern Nigeria (Ibia, 2005). The mean values of Al_o in the three wetland soils were greater than the mean Al_d indicating the prevalence of amorphous Al in these soils than the crystalline Al which confirms that the soils are relatively less weathered and more reactive.

Adsorption Capacity of Soils of the Study Area

The adsorption capacity of soils of the study area is presented in Table 2.The result showed that floodplain soils had the highest mean maximum phosphate adsorption capacity (60.3mgkg^{-1}), followed by soils of inland depression (6.0 mgkg^{-1}) while coastal swamp soils had the least (2.6 mgkg^{-1}). The trend was as follow: floodplain soils > soils of inland depression > coastal swamp soils. The high maximum adsorption capacity of river floodplain soils is an indication that floodplain soils had the highest P adsorption capacity (high adsorption sites) compared to that of inland depression and coastal swamp soils. This could be attributed to the high cation exchange capacity of river floodplain soils which is due to high finer soil particles (silt and clay fraction) with permanent charge surfaces, resulting in high adsorption sites compared to soils of inland depression and coastal swamp soils (Reddy and Delune, 2005). The low adsorption capacity of coastal swamp soil despite the significantly higher amorphous Fe and Al could be due to organic matter content in the soil which is not significantly different ($p < 0.05$) from that of the floodplain soil. This is because organic matter in the soil with pH < 6.0 decreases P- adsorption due to the following reasons. Either the organic acid produced by the mineralisation of organic matter compete for adsorption sites with P thereby reducing adsorption sites for P or repuls phosphate or the combination of organic acid with Fe (Fe-P) and Al (Al-P) oxides reduces the P adsorption capacity of the oxides (Hunt *et al.*, 2007).

Table 2: Langmuir constants and linear equation for phosphate adsorption in the study area

Wetland type	P added (mg/l)	Equation	R^2	Maximum Adsorption (1/b)	Bonding Energy (1/kL/ 1/b
Inland depression	0	C/S = 44.52 + 0.06612C	0.098	15.10	$1.5x10^{-3}$
	20	C/S = 53.89 + 0.1310C	0.43	7.60	$2.4x10^{-3}$
	40	C/S = 50.31 + 1.316C	0.47	0.76	$2.6x10^{-2}$
	80	C/S = 100.6 + 1.7789C	0.036	0.56	$1.8x10^{-2}$
	Mean			**6.00**	**$1.2x10^{-2}$**
Floodplain soils	0	C/S = 7.25 +0.4039C	0.34	2.48	$5.6x10^{-2}$
	20	C/S = 34.28- 0.00513 C	0.0000197	195	$2.2x10^{-4}$
	40	C/S = 31.28- 0.02332C	0.00097	42.9	$7.5x10^{-4}$
	80	C/S = 46.46 - 1.167C	0.3188	0.86	$2.5x10^{-2}$
	Mean			**60.3**	**$2.0x10^{-2}$**
Coastal swamp Soils	0	C/S = 2.027 + 0.3198C	0.79	3.13	$1.6x10^{-1}$
	20	C/S = 21.36 + 0.2833C	0.28	3.53	$1.3x10^{-1}$
	40	C/S = 42.09 + 0.3957C	0.056	2.53	$9.4x10^{-3}$
	80	C/S = 59.98 + 0.7275C	0.034	1.37	$1.2x10^{-2}$
	Mean			**2.64**	**$4.9x10^{-2}$**

Langmuir equation: x/m = bKC/ 1 + KC. where: C= concentration of P in solution at equilibrium (mg P ml^{-1}), x/m =amount of P adsorped per kg of soil, b= adsorption maximum ($mgkg^{-1}$ soil), K= adsorption affinity (ml per kg P).C/S=Coastal swamp

Bonding Energy of Soils of the Study Area

The bonding energy coefficient of the study area which represents whether the added P is being adsorbed loosely or tenaciously on soil surface is presented in Table 2. The result showed that coastal swamp soils had the highest bonding energy ($4.9x10^{-2}$ Lmg^{-1}) (adsorbed P tenaciously), followed by floodplain soils ($2.0x10^{-2}$ Lmg^{-1}) while soils of inland depression had the least ($1.2x10^{-2}$ Lmg^{-1}) (adsorbed P loosely). The trend was as follow: coastal swamp soils > floodplain soils > soils of inland depression. This shows that phosphate ions are held more tenacious in coastal swamp soils, less tenacious in floodplain soils and loosely in soils of inland depression. The high bonding energy of the coastal swamp soil compared to others could be attributed to the high content of amorphous Fe and Al in the soil with specific adsorption of phosphate on the oxide surfaces. Oxides of Fe have variable charge. At hydroxylated or hydrated surfaces of Fe oxides, positive or negative charge is created by adsorption or desorption of H^+ or OH^- ions, which is controlled by H^+ or OH^- ion concentration in solution (pH dependent). Sorption of P occurs through ligand exchange on variable charge surfaces by the exchange of OH^- on the surfaces for phosphate ion. Sorption takes place at specific coordination sites (OH^-) on the oxides or hydroxides. There is a covalent bond between metal ion and phosphate ion. Specifically bound P is more strongly surface - associated through covalent bonds formed by ligand exchange with the oxide surface OH^- group while non-specifically bound P is weakly surface - associated due to electrostatic interaction (Yuji and Sparks, 2001; Hunt *et al.*, 2007).

External Phosphorus Requirements of Wetland Soils

The soil external P requirements of soils of the study area were determined by substituting the values of adsorption maximum (b) and adsorption affinity (K) (Table2) into linear form of Langmuir equation: x/m = bKC/ 1 + KC. where: C= concentration of P in solution at equilibrium (mg P ml^{-1}), x/m =amount of P adsorped per kg of soil, b= adsorption maximum ($mgkg^{-1}$ soil), K= adsorption affinity (ml per kg P). The results are presented in Table 3. Soils of inland depression required 0.0085 to 0.023 mgl^{-1} of P (mean 0.017 mgl^{-1}) to maintain a concentration of P at 0.2 mg P per liter of soil solution. River floodplain soils required 0.021 to 0.13 mgl^{-1} (mean 0.057 mgl^{-1}) of P to maintain a concentration of P at 0.2

mg P per liter of soil solution. Coastal swamp soils required 0.016 to 0.43 mgl^{-1} (mean 0.129 mgl^{-1}) of P to maintain a concentration of P at 0.2 mg P per liter of soil solution. Soils of coastal swamp required the highest quantity of P (0.129 mgl^{-1}) to maintain a concentration of P at 0.2 mg P per liter of soil solution, followed by soil of river floodplain soils (0.057 mgl^{-1}) while soils of inland depression required the least quantity of P (0.017 mgl^{-1}) to maintain a concentration of P at 0.2 mg P per liter of soil solution. The trend was as followed: coastal swamp soils > River floodplain soils > soils of inland depression. The high quantity of P required by soils of coastal swamp to maintain a concentration of P at 0.2 mg P per liter of soil solution than other wetland types could be attributed to the sandy texture of the soil with low water and nutrients holding capacity. The second highest quantity of P required by soils of river floodplain to maintain a concentration of P at 0.2 mg P per litre of soil solution than soils of inland depression could be attributed to high fixing capacity of the soil. This is because soil with high adsorption capacity (high surface area) required larger quantity of P fertilizer application to maintain a concentration of P at 0.2 mg P per liter of soil solution for optimum crop yield than those with low adsorption capacity (low surface area) (Ibia and Udo, 1993).

Table 3: External P requirements of soils in the study area

Wetland type	P added (mg/l)	Equation	R^2	Maximum Adsorption (1/b)	Bonding Energy (1/kL/ 1/b	External P requirements (EPR)
Inland depression	0	C/S = 44.52 + 0.06612C	0.098	15.10	$1.5x10^{-3}$	$2.3x10^{-2}$
	20	C/S = 53.89 + 0.1310C	0.43	7.60	$2.4x10^{-3}$	$1.8x10^{-2}$
	40	C/S = 50.31 + 1.316C	0.47	0.76	$2.6x10^{-2}$	$1.9x10^{-2}$
	80	C/S = 100.6 + 1.7789C	0.036	0.56	$1.8x10^{-2}$	$8.5x10^{-3}$
	Mean			**6.00**	**$1.2x10^{-2}$**	**$1.7x10^{-2}$**
Floodplain soils	0	C/S = 7.25 +0.4039C	0.34	2.48	$5.6x10^{-2}$	1.32x10
	20	C/S = 34.28- 0.00513 C	0.000197	194.9	$2.2x10^{-4}$	$4.29x10^{-2}$
	40	C/S = 31.28- 0.02332C	0.00097	42.88	$7.5x10x^{-4}$	$3.21x10^{-2}$
	80	C/S = 46.46 - 1.167C	0.3188	0.86	$2.5x10^{-2}$	$2.10x10^{-2}$
	Mean			**60.3**	**$2.0x10^{-2}$**	**$5.7x10^{-2}$**
Coastal swamp Soils	0	C/S = 2.027 + 0.3198C	0.79	3.13	1.6x10	4.31x10
	20	C/S = 21.36 + 0.2833C	0.28	3.53	$1.3x10^{-2}$	$4.53x10^{-2}$
	40	C/S = 42.09 + 0.3957C	0.056	2.53	$9.4x10^{-3}$	$2.36x10^{-2}$
	80	C/S = 59.98 + 0.7275C	0.034	1.37	$1.2x10^{-2}$	$1.62x10^{-2}$
	Mean			**2.64**	**$4.9x10^{-2}$**	**1.29x10**

Langmuir equation: x/m = bKC/ 1 + KC. where: C= concentration of P in solution at equilibrium (mg P ml^{-1}), x/m =amount of P adsorped per kg of soil, b= adsorption maximum ($mgkg^{-1}$ soil), K= adsorption affinity (ml per kg P).C/S=Coastal swamp

CONCLUSION

The study revealed that floodplain soils had the highest mean phosphate adsorption capacity, followed by soils of inland depression while coastal swamp soils had the least. The trend was as follow: floodplain soils > soils of inland depression > coastal swamp soils. Coastal swamp soils had the highest bonding energy, followed by floodplain soils while soils of inland depression had the least. The trend was as follow: coastal swamp soils > floodplain soils > soils of inland depression. Also, coastal swamp soils required the highest P addition to maintain a concentration of P at 0.2 mg P per liter of soil solution, followed by floodplain soils while soils of inland depression had the least. The trend was as follow: coastal swamp soils > floodplain soils > soils of inland depression. Hence, the three wetland soil types were not the same in P sorption capacity, bonding energy and external P requirement.

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