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Assessment of phosphorus leaching potentials on soil from diverse parent materials in Akwa Ibom State, Nigeria.

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Abstract

This study was carried to assess phosphors leaching potentials of soil derived from three (3) selected parent materials in Akwa Ibom State. The soils were Alluvium, Shale and Sand stone. A treatment solution containing 0, 20, 40 and 80mgL^{-1} of Phosphorus prepared from KH_2P0_4 were added to 20g of soil samples in duplicated cups, the cupper cup perforated was mixed thoroughly and was allow drying. The cups were carefully covered and allowed to incubate for 1, 7, 30 and 60 days respectively. A total of forty eight (48) experimental units were generated and the treatment combinations were 3x4 factorial experiment fitted into a Randomized Complete Block Design (RCBD) with three (3) parent material; 4 rate of P for each of the incubation periods. The soil samples were kept moist with distilled water at weekly interval throughout the duration of incubation. At the set days, the concentrations of P in the leachate at each day of incubation were determined using flame photometry. The result shows that the leaching potential of P in the soil varies under similar experiential conditions. The highest P obtained were in this order; Alluvium (6.91mgkg^{-1}) > Shale (5.64mgkg^{-1}) > Sand Stone (5.36mgkg^{-1}). The highest P losses with high rate of P added were observed. The trend is as followed: O (Control) 2.14mg kg^{-1}) < 20 (4.90 mg kg^{-1}) < 40 (6.68 mg kg^{-1}) < 80 (10.2mgkg^{-1}). The interaction effect of Parent material and P rates give an indication of short lasting effect of P in Alluvium soil and long lasting effect of P in sand Stone and Shale Soil. The rate of P lose in those soils decrease in days of incubation

Keywords: Phosphorus; Leaching potentials; Parent material; Incubation days; Phosphate rate.

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1.0 Introduction

Phosphorus (P) is second most essential nutrient element needed by plant in a large quantity for growth and development. (Agbede 2009).The application of Phosphorus in excess to plant requirements can lead to a buildup of Phosphorus in soil and may loss to leaching. Lingan *et al.,* (2016) reported that the proportion of reactive Phosphorus in farmland which is transferred through soil by leaching is higher than through surface runoff. Many studies have shown that the amount of Phosphorus being lost by leaching is equivalent to or greater than the amount is lost by surface-runoff and by soil erosion (Broschat, 1995). When phosphate is applied in the form of water soluble fertilizer, it either absorbed by the clay minerals, taken up by plants, or leached down beyond the root zone leading to a wide spread phosphate deficiency mostly occur in the humid tropics. Leaching is a natural process cause by precipitation, acidification or phosphorus saturation. Havlin *et al., (1999)*

Umoh *et al.,* (2018) carried out a study to assess the potassium leaching behavior in six soils of Eastern Nigeria using column leach test experiment and observed short lasting effects of added K in high clay soil and higher leaching potential in soils with high sand content. Baman *et al.,* (2012) reported that the rate of nutrient leach in soil decreased over time with increased nutrient lost, leading to poor plant growth and development. Umoh *et al.,* (2019) reported that the amount P loss in soils increase with increasing rate of fertilizer applied and total nutrient (P) concentrations in the leachate varies with soils. (Borling 2003). Fertilizers are applied at high rates to increase crop yield, yet little is known about the leaching of this nutrients from soil to the surrounding or underground water. Increasing cost of fertilizers, poor yield of crops and concern for water quality have motivated interest to improve the efficiency use of fertilizers to the farmers. Less attention has being paid on P leaching potential and information on the leaching of P in these soils is limited. Therefore, the study aims at assessing the risk level of Phosphate losses in these soils using suction cups experiments and to set up management strategies of reducing the P loss in soils.

2.0. **Materials and Methods**

2.1. Location of the study area: The study was conducted in selected locations representing different parent materials in Akwa Ibom State which lies between Latitudes $4^0.32^1$ and $5^0.33N^1W$ and longitudes $7^0.25^1$ and $8^0.25^1E$. It is bounded with Abia State in the North, Cross River State in the southeast and the offshore of the Atlantic Ocean in the south. It has a land mass of 8,412km^2 and a shore line of 129km^2 long encompassing Akwa Ibom River Basin, the eastern part of lower Cross River Basin and half of the Imo River estuary.

2.2. Climatic condition of the studied area: The climate of Akwa Ibom State depends on the movement in tropical discontinuity, which is the zone separating the warm humid maritime air mass with its associated south westerly wind from dry continental air mass (North westerly winds). This wind gives rise to wet and dry season in the area. The rain fall pattern is bimodal and, begins about March and ends in November with a little dry spell which gives rise to two maximum rain fall regimes with the heaviest rainfall in June for first rainfall and September for the second maximum. The annual rain fall in the wet season is usually heavy ranging from 2000mm inland to over 3500mm along the coast. The dry season starts from November and last till February with the mean annual temperature between 26^{0}C and 28^{0}C. The highest temperatures are experienced between January and February, a period which coincides with overhead of the sun and high relative humidity of 75-90%.

2.3.Vegetation and land uses: The state is located within the humid forest of Nigeria, due to the population pressure and increasing number of settlements, there is drastic transformation of the natural vegetation. The overall effect is that, large area has been brought under cultivation urbanization. Tradition subsistence crops like; Plantain, Cassava, Maize, Vegetables, Yam, Cocoyam, Oil Palm etc, are capital typical features in the study area. The dominant forest types in the area include; the saline water swamp, fresh water, swamp forest and the rain forest. The native vegetation has been completely replaced by secondary forest of predominantly oil palms, woody shrubs as chromolaena and grasses. Peter *et al.,* (1989) observed that human population pressure coupled with poor management and improper land use has led to forest depletion with the attendant soil degradation and low productivity. However, these secondary forests are noticeable around hamlets, water course, crop plantation and forest reserves and mangrove cover considerable arts of the state example Itu, Uyo, Uruan and IkotAbasi, Esit Eket, etc. Raphia palm is very common in most of the swamps while the mangroves are colonized by mangroves plants such as (Avicenna Africana, Rhizophraracemosa). Three classes of vegetation communities can be broadly recognized in the state, these are wetland forest. Farmland /secondary mosaic and oil palm forest and native forest. The predominant land use in the state is farming. Human intervention through agriculture, construction, environmental modification and quest for the fuel wood, timber non timber forest product has greatly altered the vegetation.

2.4. Descriptions of the parent materials:

2.4.1. Shale: **(**Mbong Ikot Udo in Ini Local Government**):** These soils are intermittently associated with the northern parts of the state. It is a Tropical Rain Forest vegetation cover and is used for Rice, Yam and Cassavas cultivation. It consists mainly of medium to coarse grained sandstone which is restricted to the northern fringe of the state when they form ridges and hills. The Imo state formation is a manure sequence consisting mainly state unit. They are strongly weathered and well drained. The texture varies from sand clay to clay on the surface soil. They have undulating topography. These soils are intensely dissected into broken valley and ridges terrain. They consist of rough and sharp crested sandstone ridges. They are marginally suitable for arable crops and tree crops like oil palm and rubber but quite suitable for cocoa cultivation because of the relatively clay content (Peters *et al.,* 1989).

2.4.2. Sand Stone Soil (Afua from Ibiono Ibom Local Government): Sandstone are spread from the shoreline with a wide range sandy and surf beach to about 10km inland where there is a strip of recently deposited marine sands. It is a Tropical Rain Forest vegetation cover and is use in Oil Palm and cassava plantation. They are deep well drained, porous and heavily reached. Texturally they have sand to loamy soil on the surface. Agricultural potentials of these soils are very poor. They are marginally suitable for arable crops because of the fragile nature of the soils, coconut and cashew tree have been known to thrive (Ibia*et al., 2009*).

2.4.3. Alluvium Soil (AS): **(**Ayadehe in Itu Local Government**):** These soils are deep, poorly drained to very poorly drain. It is texture varies widely from coarse to medium and fine loamy on the soil surface. They are suitable for production of short season crops like vegetables and grains during the short dry period. They are acidic soils (Peter *et al., 1989*). The soil is a Mangrove vegetation cover and it use Maize, Timber, and Cassava cultivation.

2.5. Field sampling: The Soil sample was collected from three locations in Akwa Ibom State based on their parent material. Samples was collected at a depth of 0.20cm with the aid of soil auger, from ten points and bulked, from which sub samples was obtained. These was air dried crushed and sieved through 2-mm mesh and the used for routine analysis and incubation study.

2.6. Layout of samples: The soil sample from the Three (3) locations was treated with four different rates of P solution, using **(KH_2P0_4)** as followed: 0, 20, 40, 80, mg/L. This was incubated for varying periods of 1, 7, 30 and 60 days respectively, making a total of 16 samples for 4 incubated days with a total of 48 sub-samples generated. The treatment combinations (3x4 factorial experiments) were then fitted into a randomized complete block design (RCBD), with 3 parent materials representing the blocks (replication) for each of the incubation periods.

2.7. Incubation procedure:

Twenty grams (20g) of soil was weighed into duplicated cups with a capacity of 23cm in length and the upper cups perforated. Ayodele and Agboola (1981). A solution containing 0, 20, 40, 80mg/L prepared from **(KH_2P0_4)** was used for the study. A 20ml of **(KH_2P0_4)** treatment solution was added to each of the soil in the cups. Mixed thoroughly for effective mixing of the P solution with the soils and allowed to dry. The cup was carefully covered and allowed to incubate for 1, 7, 30, and 60 days respectively. The soil samples were kept moist with distilled water at weekly intervals and covered for the duration of incubation days. After each incubation day the P in the leachate was determined using flame spectro photometry to obtain available phosphorus.

2.8. Statistical analysis: The data generated were subjected to analysis of variance (ANOVA) means were separated among the different at different level of sufficient. Regression analysis was also carried out to compare the relationship with incubation data and the physical and chemical properties.

3.0. Results and Discussion

3.1. The Physical and Chemical Properties of the Studied Soils:

The physical and chemical properties of the soils are presented in Table 1. The sandstone had the highest sand content (81.8%) while Shale had the least sand content (74.2%). The shale had the highest Silt (11.4%) and clay (14.4%) content. While sandstone had least Silt (7.6%) and clay (10.6%) content. The variation in percentage sand, silt and clay reflects the differences in the parent materials. The texture of a soil would affect the water, nutrient retention and nutrient leaching in soils. (Umoh *et al.,* 2018).The soil pH in water ranged from 5.25 to 5.67 with a mean of 5.4 respectively.

3.2. Effect of Parent Material and Phosphorous Rates on Leachate at Days of Incubation:

The effect of parent materials and P rates on leaching of P with days of incubation is presented in the tables below. Tables 2 Alluvium soil has the highest P in the leachate while shale had the least in day one. The trend were as follows: Alluvium (7.49mgl^{-1}) > Sandstone (5.08 mgL^{-1}) > shale (1.52 mgL^{-1}). The account of available P in leachate in day one increasing with rate of P added. At 0mgl^{-1} being the lowest and 80 mgl^{-1} being the highest that leaches. This reflect the fact that amount of P loss increase with increasing rate of addition. From Table 3 and 4 similar trend were also observed except in table 5 while Alluvium

Table 1: Physical and Chemical Characteristic of Soils

Tested Parameters	Unit	Alluvium	Shale	Sand Stone
Particle Size Analysis Sand	%	78.6	74.2	81.8
Silt	%	8.8	11.4	7.6
Clay	%	12.6	14.4	10.6
Textural class		Ls	Ls	Ls
pH		5.25	5.38	5.67
EC	ds/m^{-1}	0.06	0.24	0.06
Organic Matter	%	2.59	3.01	2.54
Total Nitrogen	%	0.06	0.08	0.06
Av. P.	mgkg^{-}	16.25	23.75	37.50
Exchangeable Basis				
K	Cmolkg^{-1}	0.17	0.25	0.46
Ca	‘’	3.12	4.28	2.68
Mg	‘’	0.11	0.33	0.23
Na		2.31	2.76	2.41
EA	‘’	2.80	2.56	3.11
ECEC	‘’	8.51	10.18	8.89
B. Sat.	%	67.1	74.5	65.02

Ec = Exchangeable Cation, Ls = loamy sand, Sl = Sandy loam, OM = Organic Matter, TN = Total Nitrogen, Av.P = Available Phosphorus, EA = Exchangeable Acidity, ECEC= Effective Cation Exchange Capacity, BS = Base Saturation.

Table 2: Effect of Parent material and P rates in leachate at day1

			Rate			
Parent Material	**0**	**20**	**40**	**80**	**PM Total**	**PM Means**
Alluvium	13.4	21.51	25.77	29.18	89.86	7.49
Sandstone	6.27	13.49	17.83	23.41	61	5.08
Shale	2.5	4.25	4.75	6.73	18.23	1.52
Rate Total	22.17	39.25	48.35	59.32	169.09	
Rate Mean	2.46	4.36	5.37	6.59		

Table 3: E ffect of Parent material and P rates in leachate at day 7

			Rate			
Parent Material	**0**	**20**	**40**	**80**	**PM Total**	**PM Means**
Alluvium	3.68	9.93	16.63	31.6	**61.84**	5.15
Sandstone	1.49	4	6.58	9.07	**21.14**	1.76
Shale	5.13	7.23	7.86	10.01	**30.23**	2.52
Rate Total	**10.3**	**21.16**	**31.07**	**50.68**	**113.21**	
Rate Mean	1.14	2.35	3.45	5.63		

Table 4: Effect of Parent material and P rates in leachate at day 30

	Rate					
Parent Material	**0**	**20**	**40**	**80**	**PM Total**	**PM Means**
Alluvium	9.68	33.07	45	60.8	**148.55**	12.38
Sandstone	0.49	0.64	5.28	6.2	**12.61**	1.05
Shale	8.51	12.23	13.35	15.54	**49.63**	4.14
Rate Total	**18.68**	**45.94**	**63.63**	**82.54**	**210.79**	
Rate Mean	2.08	5.10	7.07	9.17		

Table 5: Effect of Parent material and P rates in leachate at day 60

	Rate					
Parent Material	**0**	**20**	**40**	**80**	**PM Total**	**PM Means**
Alluvium	1.01	5.26	7.71	17.37	**31.35**	2.61
Sandstone	0.97	32.4	41	88.4	**162.77**	13.56
Shale	23.88	32.44	48.6	67.4	**172.32**	14.36
Rate Total	**25.86**	**70.1**	**97.31**	**173.17**	**366.44**	
Rate Mean	2.87	7.79	10.81	19.24		

soil had the least p in leachate while shale soil had the highest. The trend were as follows; Alluvium Soil (2.61 mgl^{-1}) < Sand stone (13. 56 mgl^{-1}) < Shale (14.36 mgl^{-1}). The following rate indicates short lasting effect of P in shale soil and it could be attributed to high clay content in that soil as show in Table 1, and it also has a strong positive relationship with clay (Table 7). This result is in agreement with line finding of Gurpal et al, (2006) who observed high leaching of P with high rate of fertilizer application in five soils.

3.3. Effect of Parent Material and P Rates on the Amount of P in Leachate at Day 1, 7, 30 and 60.

The effects of leaching on the soils that are derived from different parent material are shown in Table 6. Alluvium soil had the highest mean of available P in the leachate while Sand Stone had the least. The Trend were as follow: Alluvium (6.91mgl^{-1}) > Shale (5.36 mgl^{-1}) > Sand Stone (5.36 mgl^{-1}). The rate of P loss in this soil was not significantly different from each other. This could be attributed to the high clay content of the soil as show in Table 1. The result also revealed that the highest P losses were observed with longer days of incubation. The trend was Day 1 (0.32 $mgkg^{-1}$) < Day 7 (0.48mgl^{-1}) <30 (0.55$mgkg^{-1}$) Day 60 (1.33mgl^{-1}). Highest P loss was observed with increasing rates of P addition, the ranged from 2.14 $mgkg^{-1}$ (0 - control) < 4.90 $mgkg^{-1}$(20) < 6.68 $mgkg^{-1}$ (40) < 10.16$mgkg^{-1}$ (80mgL^{-1}).The rate of P added has a strong interaction with leaching rates. The correlation matrix on leaching rates in Table 7 showed a positive relationship with clay. Umoh *et al.,* (2019) observed a long lasting effect of P in soils with high content of clay.

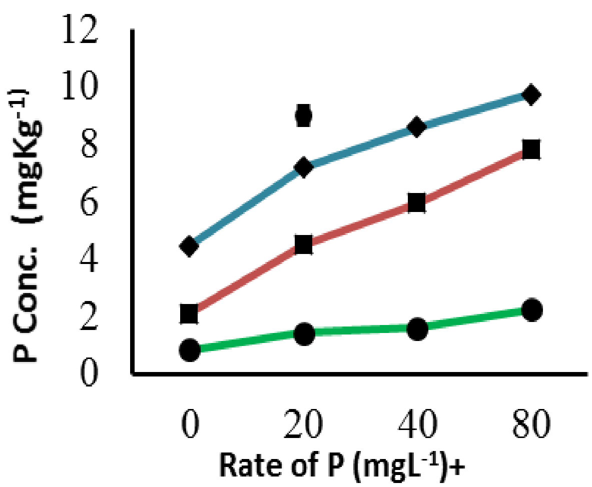
3.4. The Interaction Effect of Parent Material and P Rate on the Amount of P Obtained In Leachate at Different Days Intervals:

The interaction effects of parent materials and P rates on the amount of p obtained in leachate are presented fully in the figures 1 At Day 1 (a) day 7 (b) day 30 and (d) day 60 respectively. The concentration of p in leachate and rates of p added were plotted. It was observed from figures (2) that the rate of leaching increases with increasing rates p

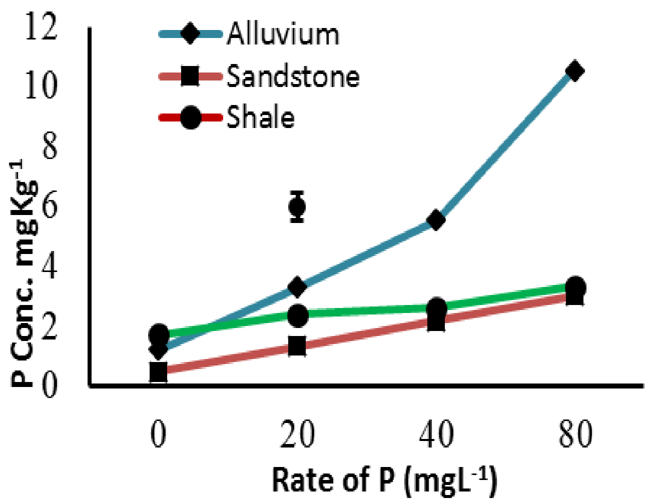
Table 6: Effect of parent material and P rate on the amount of P in leachate at days 1, 7, 30 and 60.

Parent Material	**DAY 1**	**DAY 7**	**DAY 30**	**DAY 60**	**Mean**
Alluvium	7.49	5.15	12.38	2.61	6.91
Sandstone	5.08	1.76	1.05	13.56	5.36
Shale	1.52	2.52	4.14	14.36	5.64
LSD (0.05)	0.32	0.48	0.55	1.33	
P Rate(mgL^{-1})					
0	2.46	1.14	2.08	2.87	2.14
20	4.36	2.35	5.10	7.79	4.90
40	5.37	3.45	7.07	10.81	6.68
80	6.59	5.63	9.17	19.24	10.16
LSD (0.05)	0.37	0.56	0.63	1.54	
Parent Material x P Rate Interaction*					
LSD (0.05)	0.64	0.97	1.09	2.67	

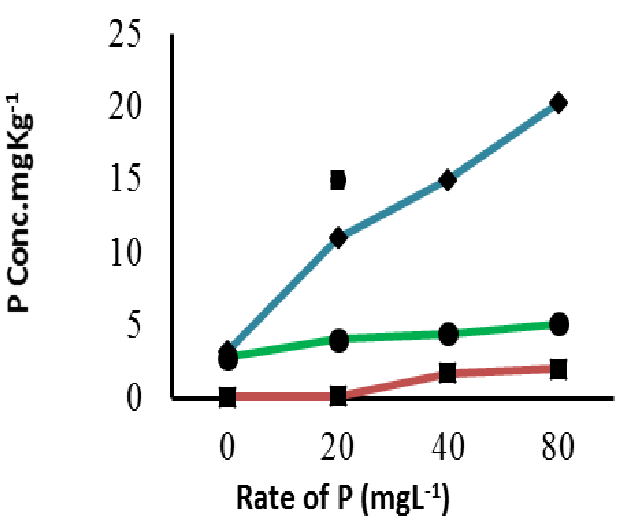
* Interaction effects are presented in full in Figures 4.1



Amount of P obtains in Day 1 (mg kg^{-1})

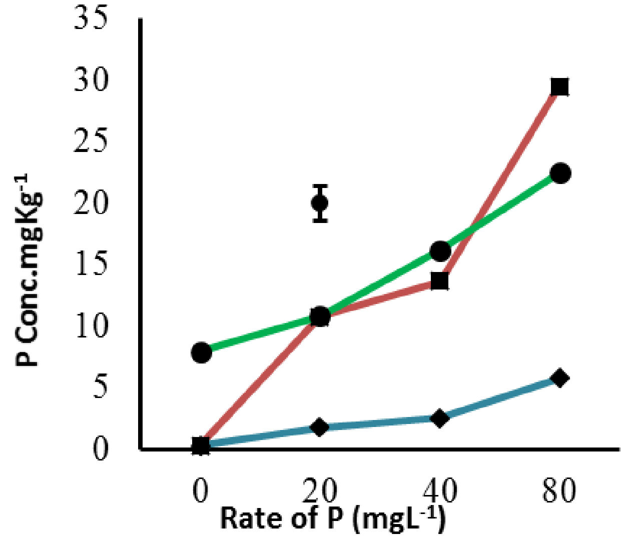


Amount of P obtains in Day 7 (mg kg^{-1})



Amount of P obtains in Day 30 (mg kg^{-1})

Amount of P obtains in Day 60 (mg kg^{-1})



Figures 2: Interaction effect of Parent material and P rate on the amount of P extracted in leachate at (a) Day 1 (b) Day 7 (c) Day 30 and (d) Day 60

4.0. Conclusion and Recommendation

(1.33mgl^{-1}). Highest P loss was observed with increasing rates of P addition, the ranged from 2.14 mgkg^{-1} (0 - control) < 4.90 mgkg^{-1}(20) < 6.68 mgkg^{-1} (40) < 10.16mgkg^{-1} (80mgL^{-1}).The rate of P added has a strong interaction with leaching rates. The correlation matrix on leaching rates in Table 7 showed a positive relationship with clay. Umoh *et al.,* (2019) observed a long lasting effect of P in soils with high content of clay.

3.4. The Interaction Effect of Parent Material and P Rate on the Amount of P Obtained In Leachate at Different Days Intervals:

The interaction effects of parent materials and P rates on the amount of p obtained in leachate are presented fully in the figures 1 At Day 1 (a) day 7 (b) day 30 and (d) day 60 respectively. The concentration of p in leachate and rates of p added were plotted. It was observed from figures (2) that the rate of leaching increases with increasing rates p added in all the days. Among the soils, Alluvium soil had the highest leaching rates indicating short lasting effect of added **P** as shown in day 60 with lowest concentration in the figure. While shale had long lasting effect with highest concentration in day (60) sixty. The retention of P in shale soil could be attributed to the high clay content as shown in Table 1. These results are in agreement with those obtained by Ibia *et al.,* 2008 who reported that phosphorous in solution exists as negatively changed phosphate ion, low leaching, extremely reactive and binds with aluminum, iron, and calcium when present in soil at high rates.

The physical and chemical properties of the soils shows that, soil were high in nutrients. The concentration of P in leachate at different incubation period increase with increasing rate of P added and decrease with days of incubation. In term of Alluvium soil, but in sandstone and Shale it increased with increasing days of incubation. Shale and sand stone soil had long lasting effect of added P and found to have low leaching potential, while soil from Alluvium had short lasting effect of added P and higher leaching potential. Therefore, for effective application and utilization of P, a split application of fertilizer is recommended for Alluvium soil which has high leaching. For the soil derived from sand stone and shale the application of P will be based on crop requirement, to reduce the risk of the Phosphorus leaching.

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