Journal of Agriculture, Environmental Resource and Management
ISSN2245-1800(paper) ISSN 2245-2943(online)
4(1)164-174
www.saerem.com

DETERMINATION OF PHOSPHOROUS LEACHING POTENTIALS ON SELECTED SOILS DERIVED FROM THREE PARENT MATERIALS IN AKWA IBOM STATE, NIGERIA

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Abstract

This study was conducted to assess Phosphorus Leaching behavior of three (3) selected parent materials in Akwa Ibom State. The soils were formed from river alluvium, beach ridge sand and coastal plain sand. A treatment solution containing 0, 20, 40 and 80mg/l of P prepared from KH_2PO_4 were added to 20g of soil samples in duplicated cups, the upper cup perforated, mixed thoroughly and allowed to dry. The cups were carefully covered and allowed to incubate for 1, 7, 30, 60 and 90 days, respectively. The experiment was 3 x 4 factorial in completely Randomized Design with three (3) parent materials and four (4) rates of phosphorous at varying days. A total of 60 experimental units were generated for the incubation study. 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 were measured. The P concentrations with rates of P added were plotted against the days of incubations. The result shows that the leaching behavior of K in the parent materials varies under similar experimental conditions. Beach ridge sand (52.1mg L^{-1}) and coastal plain sand (21.1mg L^{-1}) with high sand content exhibits highest amount of leaching compared to river alluvium (9.16mg L^{-1}) with high clay and organic mater content. A higher P losses with high rates of P addition was observed and P decreased with time (days) of incubation in the studies soils. River alluvium has long lasting effect of added P with a strong correlation with clay while short lasting effect was observed in coastal plain sand and beach ridge sand with a weak relationship with sand.

Keywords: Phosphorous, leaching effect of P, parent material, incubation time, soil properties.

Introduction:

Phosphorous (P) is one of the essential nutrient elements required in large amount for growth and development of plants. When phosphorous is applied in the form of water soluble fertilizers, it can either be absorbed on the clay minerals, taken up by plants or leached out. The extent of each mechanism and component depends upon various factors including the nature of parent materials, soil physical and chemical properties, contact time, amount of P applied, rainfall or irrigation etc. (Alfaro *et al.*, 2004, Sharma and Sharma 2011). Leaching under Agricultural fields is regarded as the movement of nutrients from top soil down the profile beyond the root zone and potentially to surface water by lateral movement or lower to under ground water (Fink *et al*; 2016; Raphael *et al* 2018). Fertilizers are applied at high rates to increase yield, yet little is known about the leaching potential of nutrients from soils into the surrounding and underground water. Barman *et al.*, (2012) reported that Basic cations are known to be quickly solubilized in the soil solution with high quantity lost to leaching which leads to poor plant growth and quality. Blerina *et al.*, (2016) carried out a potted experiment to evaluate phosphorous leaching using two fertilizers rates in the presence and absence of plants and observed a reduced nutrient leaching on the pots cultivated with Ryegrass plant compared to a bare Pot with high leaching of P. Gikonyo *et al.*, (2010) reported that the amount of nutrient leached increase with increasing rate of fertilizer applied and total nutrient concentrations in the leachate varies with soils. Umoh et al., (2018) carried out an experiment to asses the leaching behaviour of K on six soil types in Easten Nigeria using column leach test. It was observed that soils with high sand content exhibits highest amount of leaching compared to soil with high clay content, a higher K losses with high rates of K addition was also observed and K decreased with time of incubation. The greater phosphorous loss to the sorrounding leads to enironmental pollution. Jarvie *et al.*, (2013); Armagan *et al.*, (2014) confirmed that Phosphate (Po_4) is associated with harmful algal blooms and eutrophication of lake and found to decrease water quality. Li *et al.*, (2018) reported that irrigation has more influence than fertilization of leaching, water quality and theat the optimal irrigation combined with optimal fertilization was efficient in reduing the potential environmental risk cause by excessive fertilization. Also reported that pH, and concerntration of P, K, Ca, Mg and Cu leach in soils was significantly decreased by irrigation under same fertilization condition. Fink *et al.*, (2016) observed a reduction in P mobility in sandy soils with small amount og Fe and Al ion present. Increasing costs of fertilizers, low yield of crops and concern with water quality have motivated interest to minimize losses through this medium and to improve the efficiency use of fertilizers. Informaiton on the leaching potential of phosphorous in these soils is limited. The study is therefore aim at determining the risk of phosphorous leaching in these soils using suction cups experiment.

Materials and Methods

Description of the study area and soil sampling

The study area is in Akwa Ibom State, lies between Latitudes $4^0 32^1$ and 5^0 $33N^1$ and longitudes 7^0 25^1 and 8^0 25^1E. The cultivated area falls in the rainfed zone dominated by maize, cassava, legume, palms. The dominant forest types in the area include; The saline water swamp, fresh water swamp forest and the rain forest. Characterized by heavy rainfall ranging from 2000mm in land to over 3500mm along the coast and temperature range between 26^0c to 28^0c within a year. (Peters, 1989). Three surface soil samples (0 to 20cm) were collected to represent different parent materials. They include: River Alluvium (Okon in Ikot Abasi), Coastal Plain Sand (Obio Akpa in Oruk Anam) and Beach ridge sand (Uta Ewa in Ikot Abasi). The soil samples were air-dried, crush to pass through 2mm size sieve and use for the anaysis.

Soil Analysis

Parts of the soil samples sieved were used for the following analysis: Particle size distribution was analysed using hydrometer method Udo *et al*., (2009), soil PH was determined in water 1:2.5 soil and water ratio in KCl using glass electrode as described by Udo *et al.*, (2009). Organic matter was determined by wet-oxidation method described by Udo *et al.*, (2009). Available phosphorous was determined by Udo *et al.*, (2009), after extraction by Bray P-I extractant. Exchangeable cations were extracted with neutral NH_4OA_C. Calcium and Magnesium were determined in the extract by EDTA titration as described by Udo *et al.*, (2009). Potassium and Sodium by the use of flame photometer. Effective cation exchange capacity (ECEC) was obtained by the summation of the exchangeable cations and exchangeable acidity as described by Udo *et al.,* (2009) and Base saturation % was calculated by sum of exchange cation x 100 ECEC.

Incubation Procedure

Twenty (20) grams of soil was weighed into a duplicated cup with a capacity of 23cm in diameter and 13cm in length and the upper cups perforated Ukpong *et al.,* (2014). A 20ml portion of the treatment solution containing 0, 20, 40, 80mgl^{-1} prepared from ($K H_2 PO_4$) 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 cups were covered and allow to incubate for 1, 7, 30, 60 and 90 days respectively. The treatment combinations were then subjected into a Randomized Complete Block Design (RCBD) with a total of 30 sub samples. The soils were kept moist with 30ml distilled water at weekly intervals and covered for the duration of incubation. At the set days, the P in the leachate were determine using flame photometry to obtain available phosphorous.

Statistical Analysis

Analysis of Variance (ANOVA) were used to evaluate the differences among the soils. Pearson Correlation Coefficient were use to correlate the P obtained with some soil preperties

Result and Discussion

The physical and chemical properties of the soils are presented in Table Ia. The soil varied from sand to loamy sand. pH values in soils were low indicating moderately acid condition. Available P in river alluvium was sufficient. The values falls within the critical level of 12 – 15mgkg L^{-1} proposed by (Aduayi *et al.*, 2002). Organic matter content were low, falls below the critical level of < 20 and high 30gkg^{-1}. The order of abundance of exchangeable cation are (Ca > Mg > K > Na and were adequate in the soils (Okalebo *et al.*, 2002). The effective cation exchange capacity (ECEC) were low. The effective cation exchange capacity (ECEC) was high in all the soil with values remaining below 12 cmol/kg. The soils recorded high base saturation. This finding agreed with the work of Haulin and Beaton (2006) which stated that the release of nutrient by soils is influenced by the cations. The results obtained were significantly different from each parameter as indicated in Table Ib.

The amount of P obtained from the leachate is presented in Table 2. Beach ridge sand had the highest mean of P in the leachate while river alluvium had the least. The trend were as follows: beach ridge sand (52.1 mg L^{-1}) > coastal plain sand (21.1mg L^{-1}) > river alluvium (9.16 mg L^{-1}). The result also revealed higher extractable P with high rate of P application. This indicated that the higher rate of P applied resulted in higher losses of P. This seems obvious as more quantity of P was available for reaction with soil properties, which resulting in higher of P moving out of the soil column. This clearly indicates that not all applied P is absorbed on the exchange complex. This observation is strongly affirmed with the positive relationship with the extractable P (Table 3). This results are in agreement with those obtained by Sharma (2011); Ukpong *et al.,* (2014) who reported that light textured soils are more prone to leaching losses.

Table 1a: Physico-chemical Properties of the Soil

Soil Properties	River alluvium (Ikot Abasi)	Beach ridge sand (Ikot Abasi)	Coastal Plan sand (Obio-Akpa)
Sand %	84.2	95.2	87..2
Silt %	6.8	1.4	3.8
Clay %	10.0	3.4	9.0
Texture	Loamy Sand	Sand	Sand
PH(H_20)	5.4	5.0	5.1
Ec (dsm^{-1})	0.12	0.07	0.08
Organic Matter (gkg^{-1})	3.2	3.01	5.76
Total N gkg^{-1}	0.09	0.08	0.14
Av. P gkg^{-1}	15.74	11.32	13.72
Ex.Ca $cmolkg^{-1}$	8.0	5.2	8.8
Mg $cmolkg^{-1}$	2.1	1.6	2.6
Na $cmolkg^{-1}$	0.07	0.06	0.08
K $cmolkg^{-1}$	0.21	0.08	0.20
EA $cmolkg^{-1}$	1.97	1.88	1.93
ECEC $cmolkg^{-1}$	12.4	8.9	13.8
Base Saturation (%)	84.01	77.8	85.82

Table 1b: Physico-chemical Properties of the Soil

Siginificant at 5% probability level

PM	and	silt	clay	pH	EC	ORG	TN	AVP	Ca	Mg	Na	**K**	**EA**	**ECEC**	**BS**
BRS	95.14	1.44	3.42	5.0	0.07	3.01	0.08	11.32	5.2	1.6	0.06	0.08	1.88	8.92	77.8
CPS	87.14	3.86	9	5.1	0.08	5.76	0.14	13.72	8.8	2.6	0.08	0.2	1.93	13.61	85.82
RAS	83.14	6.86	10	5.4	0.12	3.2	0.09	15.74	8	2.1	0.07	0.21	1.97	12.35	84.05
LSD	**6.11**	**2.72**	**3.55**	**0.21**	**0.11**	**1.54**	**0.03**	**2.21**	**1.89**	**0.50**	**0.01**	**0.07**	**0.05**	**2.43**	**4.21**

Table 2: Amount of P extracted at different rates of P addition over different days from the leachate

Parent Material/Location	Rates of P added (mg/l)	Incubation Period Days Amount of P extracted from Leachate					
		1	**7**	**30**	**60**	**90**	**Mean**
River alluvium (RSA)	0	10.30	4.67	10.70	10.70	1.38	
	20	18.70	6.67	11.30	11.30	1.06	
	40	13.00	8.00	12.00	12.30	2.80	
	80	12.00	15.30	17.30	18.70	2.70	
	0	**13.8**	**8.66**	**12.8**	**8.57**	**1.99**	**9.16**
Costal Plain Sand (CPS)	0	12.00	16.70	17.30	14.00	2.30	
	20	16.70	19.30	35.30	16.00	2.10	
	40	18.70	22.00	16.00	22.00	3.80	
	80	17.30	71.30	66.70	26.70	3.30	
		16.2	**32.3**	**33.8**	**19.7**	**2.88**	**21.1**
Beach ridge sand (BRS)	0	48.70	12.00	53.30	62.00	12.20	
	20	27.50	66.70	102.00	67.30	15.00	
	40	50.70	88.00	60.00	62.70	13.20	
	80	52.70	90.00	74.00	69.30	14.20	
		44.9	**64.2**	**72.3**	**65.3**	**13.7**	**52.1**

Effect of Leaching on Soil Parent Materials

The effect of leaching on parent material are shown on figure 1. The amount of available P in leachate at each time interval increesed with increasing rate of P added, Omg L^{-1} being the lowest and 80mg L^{-1} being the highest for the three soils studied. This reflected the fact that amount of P loss increase with increasing rate of addition. The rates of leaching in the soils showed no uniform pattern on incubation days (1 – 90 days). The P leaching in river alluvium soil was low inspite of high rates of addition. Beach ridge sands soils had the highest leaching rate while river alluvium had the lowest leaching rates. The trend is as fallowed: Beach ridge sand (BRS) > coastal plain sand (CPS) > river alluvium (RAS). The high P losses in beach ridge sand soils could be attributed to the sandy nature of the soil, The low P losses in river alluvium soils could be due to high clay and organic matter content which has ability to retain applied P (Table 1). The result gives a clear evidence of a greater risk of P leaching from high rates of application. This is in agreement with the finding of Gurpal *et al*., (2006) who observed high leaching rate of total P on five soils with four fertilization levels.

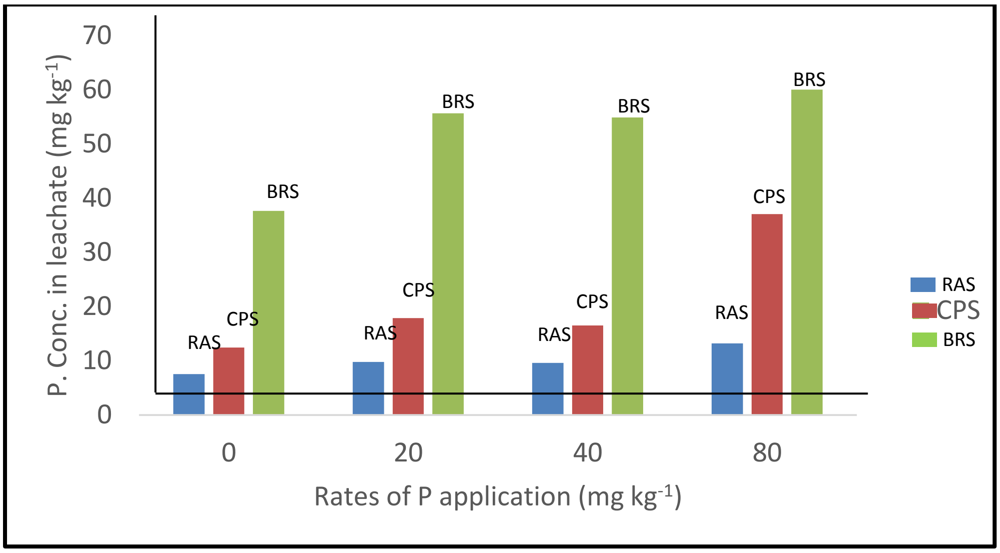


Fig 1: Effect of leaching behaviour on Soil Parent Materials

The Leaching Behavior of Phosphorous (P) in Soils.

The leaching rates of applied P in the study soils were obtained from the relationship between P concentration in the leachate at different rates of P added and at different incubation days and are presented in figures below, the letters A to D denote the rates of P added as A – Control (O) B – 20, C – 40 and D – 80mg kg^{-1}. The graphs are plots of the concentration of P in leachate and incubation days.

Fig 2: The plot of P. Concentration in leachate VS incubation days in river alluvium soil

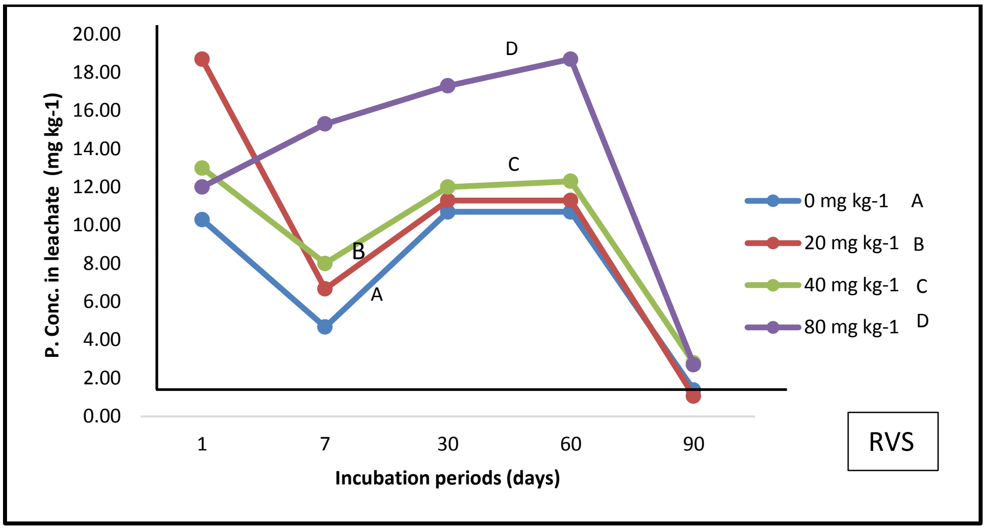
It was observed from Figure 2 in alluvium soils that the rates of leaching increases with increasing rates of P added. The concentrations of P in the leachate were low and highest concentration within the rates added were obtained at 60 days of contact time and declined days after indicating long period of leaching effect of added P in alluvium soil, the long lasting effect of P in that soil could be attributed to high clay and organic matter content. (Table 1) and other soil properties with a positives relationship indicated in (Table 3). The results are in agreement with those obtained by *Ibia et al.,* (2008) who reported that phosphorous in solution exists as negatively charged phosphate ion, low leaching, extremely reactive and binds with aluminum, iron, Calcium when present in soil at high level. Umoh, *et al*., (2014) also affirm the strong energy bonding of this monovalent cation (P) in the soil of this zone. This causes the P to form new chemicals in the soil which held the nutrient tightly with the soil clay and organic matter.

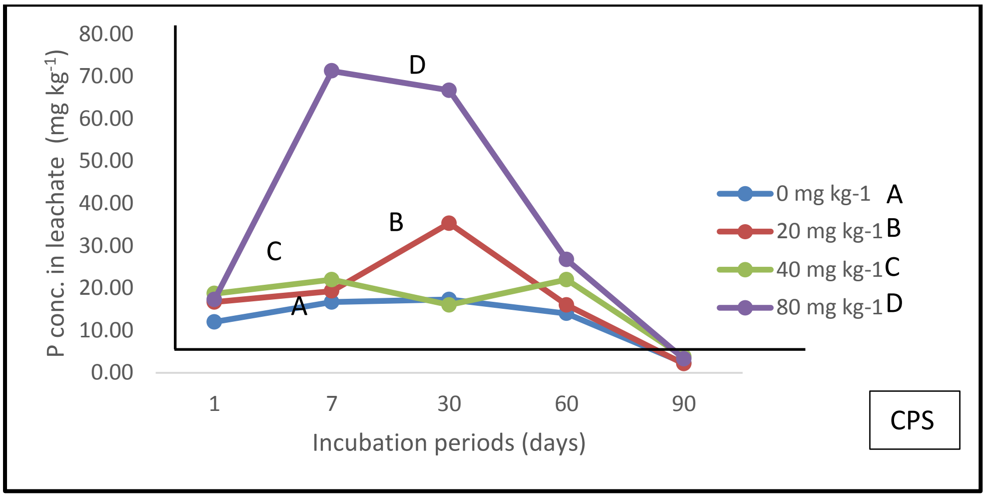
Fig 3: Plot of P concentration in leachate VS incubation days in Coastal Plain Sand (CPS)

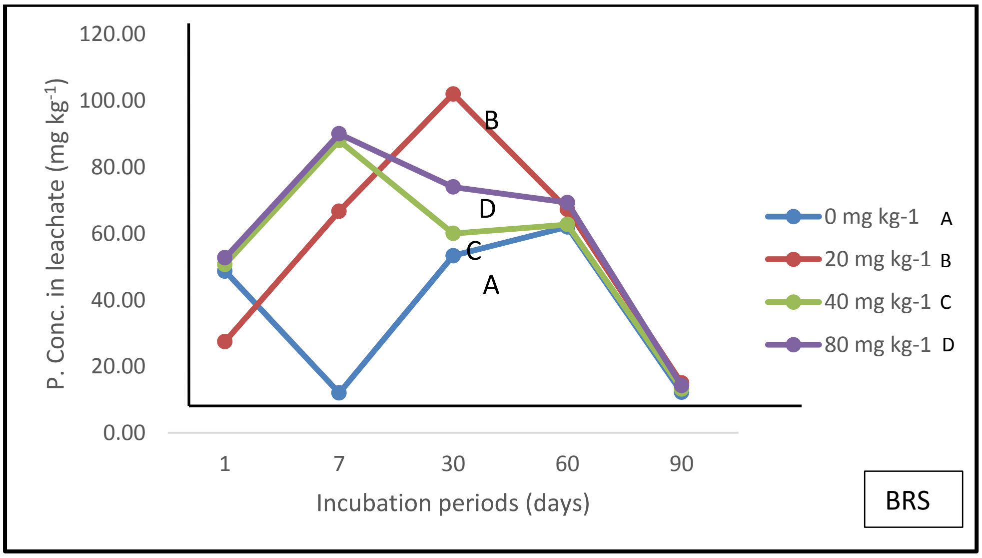
In coastal plain sand soils (figure 3), there was a gradual increase in the P leaching with rates of P added. The highest P losses was observed at 7^{th} days of contact time and decreases at 30 days, indicating that P in coastal plain sand has short period of leaching effect of added P. This could be attributed to the Sandy nature of the parent material with large pore space Table 1. This showed that light texture soils are more prone to high leaching losses, as indicated in (Table 3) Which has a negative relationship with sand and fractional recovery. The results are in agreement with those obtained by Sharma and Sharma (2011); Umoh *et al.*, 2018 who reported higher leaching of nutrient in sandy loam soil.

Fig 4: Plot of P concentration in leachate VS incubation days in beach ridge sand (BRS)

In beach ridge sand soils (figure 4) a gradual increase in P losses with increase rates of P added in the soil was observed. The variation in days of incubation indicated an irregular pattern with high concentration as fitted in the figure. The highest P losses were observed at 30 day of incubation with the highest rate of P (80mg L^{-1}) added and declined at 60 days. This result revealed that the soils can give a significant yield reduction after 30 days of contact time. These findings could be attributed to the high sand content in that soil (Table 1) which also indicated a negative relationship with sand (Table 3). Sandy soils has weak interaction of nutrient in the soil solution (Kolachi and Jahali, 2007) which is eventually leached out to the surrounding and underground water.







Correlations between soil chemical properties and fractional recovering in the leachate

Table 3 shows the correlations among the various soil parameters with recovering of P in the leachate, there was significant ($P \leq 0.05$) Positive correlation between the soil properties with the fractional recovery (except) sand with a negative relationship indicated by the R^2 values in (Table 3). This trends shows that the nutrients were positively contributed to the leaching of phosphorous in the studied soils.

Table 3: Correlation Matrix between fractional recovery of added P soils with soil properties

	sand	*silt*	*clay*	*Ph*	*EC*	*ORG*	*TN*	*AVP*	*Ca*	*Mg*	*Na*	*K*	*EA*	*ECEC*	*BS*	*PE__1*	*PE_7*	*PE_30*	*PE_60*	*PE_90*
sand	1																			
silt	-0.968	1.000																		
clay	-0.982	0.903	1.000																	
Ph	-0.891	0.976	0.788	1.000																
EC	-0.408	0.167	0.575	-0.051	1.000															
ORG	-0.249	0.000	0.430	-0.217	0.986	1.000														
TN	-0.339	0.094	0.513	-0.125	0.997	0.996	1.000													
AVP	-0.990	0.994	0.945	0.946	0.276	0.111	0.204	1.000												
Ca	-0.854	0.698	0.938	0.525	0.823	0.716	0.779	0.773	1.000											
Mg	-0.655	0.446	0.787	0.240	0.957	0.895	0.933	0.542	0.952	1.000										
Na	-0.655	0.446	0.787	0.240	0.957	0.895	0.933	0.542	0.952	1.000	1.000									
K	-0.965	0.870	0.997	0.742	0.632	0.494	0.573	0.919	0.960	0.829	0.829	1.000								
EA	-0.992	0.992	0.950	0.941	0.290	0.126	0.218	1.000	0.782	0.554	0.554	0.925	1.000							
ECEC	-0.828	0.662	0.919	0.483	0.850	0.750	0.809	0.741	0.999	0.966	0.966	0.945	0.750	1.000						
BS	-0.855	0.699	0.938	0.527	0.822	0.715	0.778	0.774	1.000	0.952	0.952	0.961	0.783	0.999	1.000					
PE__1	-0.781	0.912	0.647	0.979	-0.252	-0.410	-0.322	0.861	0.342	0.039	0.039	0.591	0.853	0.296	0.344	1.000				
PE_7	-0.744	0.554	0.858	0.360	0.913	0.832	0.881	0.643	0.983	0.992	0.992	0.893	0.654	0.991	0.983	0.636	1.000			
PE_30	-0.842	0.950	0.724	0.995	-0.149	-0.312	-0.221	0.909	0.439	0.144	0.144	0.672	0.903	0.394	0.441	0.628	0.821	1.000		
PE_60	-0.792	0.919	0.661	0.983	-0.234	-0.393	-0.305	0.870	0.360	0.057	0.057	0.605	0.863	0.313	0.361	0.900	0.737	0.859	1.000	
PE_90	-0.804	0.927	0.676	0.986	-0.215	-0.376	-0.287	0.879	0.378	0.077	0.077	0.621	0.872	0.331	0.379	0.876	0.711	0.838	0.992	1.000

Conclusion

Physico-chemical properties of the soils shows that, soil were moderately acidic, light texture, salt free and some of the soils were low in nutrients. The concentration of P in leachate at different incubation period increase with increasing rate of P added and decrease with time (days) of Incubation. The soils of river alluvium had long lasting effect of added P and found to have low leaching potential, while soils from beach ridge sand and coastal plain sand had short lasting effect of added P and higher leaching potential. Therefore, for effective application and utilization of P, split application is recommended for these soils to reduced the risk of the nutrient leached out of the soil profile beyond the assess of the plant root or leached out to underground water and make farming practices more sustainable and community friendly.

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