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Phosphorus status of five wetlands in Edo State

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Abstract

This experiment was performed to determine the phosphorus levels in certain wetland soils in Edo State, Nigeria. Soil samples were collected from five wetlands at two depths: 0–15 cm and 15–30 cm. The samples were air-dried, sieved, and analyzed to ascertain the physical and chemical properties of the soils using standard laboratory techniques. The findings indicated that the majority of soil pH levels were slightly acidic, ranging from 6.6 to 7.0 (neutral), with the exception of soils from Obiemen, Agwa, and Benin, which exhibited moderate acidity (4.2–4.8). Soils from Irrua (Obiemen and Agwa) and Benin (Ikpoba Okha) demonstrated elevated phosphorus content, with a P range of 11.41–15.70 mg/kg, whereas soils from Ekpoma (Opoji), Benin (Oka-Naruovia), and Benin (Orhiomwon) exhibited low phosphorus levels, ranging from 2.88 to 5.56 mg/kg. There was a direct relationship between soil pH and the available phosphorus content. Therefore, there is need to augment the soils with P-fertilizers for increase crop productivity.

INTRODUCTION

Phosphorus is a non-metallic chemical element and a constituent of vital compounds, including nucleic acids, phospholipids, and adenosine triphosphate (ATP); hence, it is a necessary nutrient for plant development. Plants cannot thrive without a consistent supply of this nutrient. Phosphorus plays a crucial role in regulating significant enzyme activities and metabolic pathways (Theodorou and Plaxton, 2013). Phosphorus is categorized as a primary nutrient due to its common deficiency in crop production and its need for plants in substantial quantities. The overall phosphorus content in agricultural crops typically ranges from 0.1 to 0.5 percent. It can only be digested as soluble phosphate species; yet, when inadequate, it significantly adversely affects the overall performance of crops and biodiversity (George and Richardson, 2008). Suboptimal phosphorus levels result in a 5 to 15 percent reduction in crop output (Hinsinger, 2011). Consequently, in intensive agricultural techniques, a larger quantity of phosphoric fertilizer is used to mitigate phosphorus deficiencies and improve crop yields. However, most soluble phosphorus is swiftly immobilized or forms complexes with other soil elements after application, making it unavailable to plants.

Wetlands provide a significant interface between terrestrial and aquatic ecosystems, linked hydrologically by surface and/or subsurface fluxes (Mitsch and Gosselink, 1993). Wetlands are regions characterized by marshes, fens, peatlands, or water bodies, whether natural or manmade, permanent or temporary, containing static or flowing water that is fresh, brackish, or saline, including coastal areas where the depth at low tide does not surpass 6 meters. Hydrology and hydrochemical regimes are the primary determinants of wetland vegetation, composition, and structure

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(Kennedy, 2014).

The Dissolved Reactive Phosphorus (DRP) component represents the most bioavailable form of phosphorus in aquatic environments. There is increasing interest in the transport, transformation, and bioavailability of organic phosphorus. Phosphorus in natural waterways exists in both particulate and dissolved forms, with the dissolved portion consisting of molecules such as inositol phosphates, nucleic acids, sugar phosphates, condensed phosphates, and orthophosphates. The predominant types of dissolved phosphorus are Dissolved Reactive Phosphorus (DRP) and Total Dissolved Phosphorus (TDP). Phosphorus may infiltrate wetlands as suspended solids or as dissolved phosphorus, with substantial amounts linked to sediments (Walbridge and Struthers 2020). Phosphorus removal from water in wetlands transpires through uptake by vegetation and soil microorganisms, adsorption by aluminium and iron oxides and hydroxides, precipitation as aluminium, iron, and calcium phosphates, and entrapment as adsorbed substances or within sediments or organic matter (Walbridge and Struthers 2020). A significant amount of phosphorus in wetlands is retained in organic forms due to the low mineral matter concentration and high organic matter composition. Organic phosphorus in wetlands originates from herbicides, pesticides, fungicides, algae, and agricultural runoff.

Few studies on phosphorus distribution in wetlands in Nigeria currently pertains to the variability in phosphorus distribution. There is little or no information on the distribution of phosphorus in some soils in Edo State. This research aimed to assess the phosphorus levels in five wetlands in Edo State, Nigeria, as well as to analyze their physical and chemical features.

MATERIALS AND METHODS

Study area

Edo State has an area of about 1125 km² and features an uneven landscape with elevations reaching roughly 8.5 km above sea level. Situated between latitudes 6° 44'N and 6° 21'N, and longitudes 5° 35'E and 5° 44'E, Edo State is situated at heights ranging from 500 feet (150 m) in the south to about 1,800 feet (550 m) in the north. The state is mostly populated by the Edo (Bini) people, who are associated with the historical kingdom of Benin. The research area is situated in the tropical rainforest zone.

This study was carried out in five different locations in Ekpoma, Irrua and Benin. Sample one was obtained from Irrua, Obiemen and Aqwa community located at latitude 6.7369 E, longitude 6.2367 N with elevation of 360 m. Sample two was obtained from Ekpoma, Opoji located at latitude 6.7369 E, longitude 6.2367 N with elevation of 340 m. Sample three was obtained from Benin, Oka ~Naruovia located at latitude 6.2743 E, longitude 5.6801 N. Sample four was obtained from Benin, Ikpobaokha local government at latitude 6.2057 E, longitude 5.7539 N with elevation of 10 m. Sample five was obtained from Benin, Orhionmon local government at latitude 6.2041 E, longitudes 5.7561 N with elevation of 10 m.

Climate

The region endures elevated temperatures, excessive humidity, and significant rainfall (Remison, 2005). In Edo State, the wet season is oppressive and gloomy, while the dry season is humid and partially cloudy. The region has a consistently mild tropical climate, with annual rainfall ranging from 1200 to 2500 mm and around 250 rainy days per year. The mean annual temperatures vary from 27°C to 32°C, while the mean annual relative humidity varies from 30.5% to 94.0% (Weppa farms, 2013). Precipitation peaks between July and October, with a brief respite in mid-August. The arid season starts in early November and concludes by March. The lowest precipitation is seen in December, whilst the fewest wet days are noted in February. The climate of Edo State is tropical. It comprises two different climatic seasons: the rainy season and the dry season. The arid season extends from November to April, with a chilly, humid, and dusty harmattan phase from December to January. The mean temperature fluctuates between 28°C during the rainy season and 34°C in the dry season.

Geology/parent material

The soils of the study area are underlain by sedimentary rocks with about 90% of sandstone and shale intercalation (Alile et al., 2018). The sedimentary rock constitutes Benin formation and geologically in the southwestern extension of the Niger Delta Basin.

Vegetation

The vegetation of Edo State includes mangrove swamps, freshwater swamps, rainforests, and savanna grasslands. However, the savanna grasslands are located in the northern region of the state.

Relative humidity

The peak relative humidity (RH) in the morning (0900 hrs.) in Edo State reaches around 84.0%, often in July, and the minimum occurs in January at around 59.0%. The relative humidity (RH) is consistently higher at 0900 hours compared to 1500 hours throughout the months.

Land use

The land usage types in the research region are arable agriculture, animal husbandry, and firewood extraction. Arable farming encompasses subsistence agriculture, distinguished by intense and ongoing cultivation practices. The primary crops cultivated in the region are cassava, maize, yam, pineapple, pawpaw, bamboo, rice, and economically significant trees such as mango and oil palm.

Field work

Each site was divided into different homogenous units based on the visual observation and dominant vegetation. Surface debris was cleared while samples were obtained from surface and subsurface soil depths (0–15 cm, 15–30 cm) using a soil auger. Samples were subjected to sieving using a 2 mm sieve and then packaged for laboratory examination.

Laboratory analysis

Soils obtained from each location were air-dried and sifted using a 2 mm sieve. The filtered samples were examined for various physical and chemical parameters. Particle size distribution was determined by the hydrometer method (Bouyoucos, 1962) after the removal of organic matter content with hydrogen peroxide and dispersion with sodium hexametaphosphate. Available P was determined by Bray-P-1 method (Murphy and Riley, 1962). The pH was determined with glass electrode pH meter in soil: soil and water at ratio 1:1 (Maclean, 1982). Exchange Bases (Na, K, Ca and Mg) were extracted with neutral normal ammonium acetate (NH_4OAC at pH 7.0); Na and K were determined by flame photometer while Ca and Mg were determined by atomic absorption spectrophotometer (Thomas, 1982). Total N was determined by Macro Kjedhal method (Bremner and Mulvaney, 1982). Exchangeable Acidity was determined by titration method (Anderson and Ingram, 1993). Organic Carbon was determined by Walkley Black method (Page et al., 1982). Effective Cation Exchange Capacity (ECEC) was obtained by the summation of Exchangeable Acidity and exchange bases (Tan, 1996). Base Saturation was calculated by dividing the sum of Exchangeable Bases (Na, K, Ca and Mg) by the ECEC and multiplying the quotient by 100. ECEC (clay) was obtained by dividing ECEC (soil) by percentage clay and multiplying the quotient by 100.

RESULTS AND DISCUSSION

As shown in Table 1, the soil texture was loamy sand in samples obtained from Irrua (Obiemen and Aqwa), but sand in soil sample two was obtained from Benin (Oka~Naruovia), Benin (IkpobaOkha), Ekpoma (Opoji). Benin (Orhiomwon) soil sample was Loamy sand. At a soil depth of 0–15 cm, the soil root abundance at Irrua (Obiemen and Aqwa) ranged from medium to high, while at a depth of 15–30 cm, the soil root abundance was fine to few at soil. At soil depths of 0–15 and 30 cm, the soil root abundance ranged from very fine to few was found at Ekpoma (Opoji), Benin (Oka~Naruovia), Benin (IkpobaOkha), and Benin (Orhiomwon).

The result of physical and chemical analysis of the soils in this study as shown in Table 2, indicates that pH ranged was 4.2 to 7.0 at the two depths; Available Phosphorus ranged from 2.88 $mg.kg^{-1}$ to 15.70 $mg.kg^{-1}$ at the two depths; Calcium ranged from 192.38 $cmol.kg^{-1}$ to 545.09 $cmol.kg^{-1}$ at the two depths. Magnesium ranged from 19.54 $cmol.kg^{-1}$ to 166.70 $cmol.kg^{-1}$ at the two depths. Sodium ranged from 24.04 $cmol.kg^{-1}$ to 50.06 $cmol.kg^{-1}$ at the two depths. Potassium ranged from 23.28 $cmol.kg^{-1}$ to 106.23 $cmol.kg^{-1}$. The result of the potassium contents of the soil indicates the high level of potassium contents in the soil. According to Anjorin et al. (2015), soils have low capacity to fix K and can therefore release applied K fertilizer appropriately for crop uptake. The high-K status of the soil can be corrected by application of low or zero K fertilizers or skip the fertilizer entirely. Potassium (K) is an essential and major nutrient for agricultural crop production (George and Michael, 2002), and in spite of the high total K content of most soils, a small portion of this element is accessible for plants uptake (Al-Zubaidi et al., 2008). Exchangeable acidity (E.A) ranged from 0.20 $cmol.kg^{-1}$ to 0.60 $cmol.kg^{-1}$ at the two depths. Total Nitrogen ranged from 0.04 $g.kg^{-1}$ to 0.89 $g.kg^{-1}$

Table 1. Some morphological features of samples

Location	Horizon Designation	Depth (cm)	Texture	Roots Abundance
Irua (Obiemen and Aqwa)	Sp 1a	0 – 15	Loamy Sand	Medium-many
	Sp 1b	15 – 30	Loamy Sand	Fine-few
Ekpoma (Opoji)	Sp 2a	0 – 15	Sand	Very fine-few
	Sp 2b	15 – 30	Sand	Very fine-few
Benin (Oka~Naruovia)	Sp 3a	0 – 15	Loamy Sand	Very fine-few
	Sp 3b	15 – 30	Sand	Very fine-few
Benin (IkpobaOkha)	Sp 4a	0 – 15	Sand	Very fine-few
	Sp 4b	15 – 30	Sand	Very fine-few
Benin (Orhiomwon)	Sp 5a	0 – 15	Loamy Sand	Very fine-few
	Sp 5b	15 – 30	Loamy Sand	Very fine-few

Remarks: Sp = sample.

Table 2. Physical and chemical properties of soil sample

Location	Horizon Designation	Horizon Depth	pH (1:1)	AV.P	Ca	Mg	Na	K	E.A.	N	Organic C	Clay	Silt	Sand
		cm	H_2O	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	cmol/kg	%	%	%	%	%
Irua (Obiemen and Aqwa)	Sp 1a	0–15	4.5	15.70	288.58	38.90	28.94	66.79	2.00	0.89	9.15	6.08	18.4	75.52
	Sp 1b	15–30	4.2	13.37	192.38	33.06	28.73	55.36	3.00	0.83	8.58	9.08	20.4	70.52
Ekpoma (Opoji)	Sp 2a	0–15	6.9	2.93	320.64	19.45	32.82	34.43	0.30	0.05	0.29	7.08	1.4	91.52
	Sp 2b	15–30	7.0	2.88	288.58	19.45	30.47	30.94	0.30	0.04	0.26	7.08	1.4	91.52
Benin (Oka~Naruovia)	Sp 3a	0–15	6.7	5.56	545.09	19.45	25.57	35.98	0.40	0.08	0.67	8.08	2.4	89.52
	Sp 3b	15–30	6.9	3.23	416.83	58.35	24.35	23.28	0.40	0.06	0.45	12.08	3.4	84.52
Benin (IkpobaOkha)	Sp 4a	0–15	7.0	11.41	3142.27	166.70	39.96	98.38	0.30	0.25	2.56	6.08	7.4	86.52
	Sp 4b	15–30	6.6	13.06	2436.86	149.76	50.06	106.23	0.30	0.60	5.25	6.08	7.4	86.52
Benin (Orhiomwon)	Sp 5a	0–15	4.8	5.52	192.38	38.90	28.02	48.19	0.60	0.11	1.02	14.08	5.1	80.82
	Sp 5b	15–30	4.8	3.25	192.38	38.90	24.04	42.08	0.60	0.07	0.61	16.38	3.4	80.22

Remarks: Sp = sample.

at the two depths. The result of total N is a reflection of the organic carbon content of the soils (Onyekwere et. al., 2009).

Organic carbon ranged from 0.26 g.kg^{-1} to 9.15 g.kg^{-1} at the two depths. The presence of a good content of organic matter status in these soils is highly important. Clay ranged from 6.08% to 16.38% at the two depths. Silt ranged from 1.4% to 18.4% in layers of soil horizon. Sand ranged from 70.52% to 91.52%.

According to USDA-NRCS (2019), soil pH of 6 to 7.5 is ideal for the availability of phosphorus (P) for plant use. This study showed that the soil sample obtained from the horizon in Irrua (Obiemen and Aqwa) was moderately acidic (pH 4.5) at a depth 0–15 cm, while at the depth of 15–30 cm, it was strongly acidic (pH 4.2). This indicates that the soil in this location is not favourable for plant use as it results in unavailability of phosphorus (P) for plant use. Soil sample obtained from Benin (Orhiomwon) with depths of 0–15 cm and 15–30 cm were moderately acidic (pH 4.8). Potential for loss of P in these soils could be associated mainly with erosion and runoff. The soil samples obtained from the two depths in Ekpoma (Opoji), Benin (Oka~Naruovia) and Benin (Ikpoba Oka) with depths of 0–15 cm and 15–30 cm had normal acidic level for plants growth respectively with pH range of 6.6 to 7.0. This indicated the availability of phosphorus in the soil in this location, making it suitable for plant growth. This was evaluated in line with USDA (1975) on soil pH classification. Values of less than 5.5 and 7.5 to 8.5 is the limit availability of P as a result of fixation by aluminum, iron, or calcium, which commonly are associated with soil parent material (USDA-NRCS, 2019). Moderate concentrations of phosphorus do not easily leach from the root zone in the majority of soils. Soils with elevated phosphorus levels are susceptible to the leaching of soluble phosphorus via surface runoff and groundwater at shallow depths, particularly in sandy soils. Organic soils are susceptible to phosphorus loss by leaching. Available phosphorus was deficient, with values between 4 and 21 mg/kg and a mean of 11.59 mg/kg. The topsoil (0–15 cm) has a higher concentration of accessible phosphorus compared to the underlying soil.

Classification of soil macro and micro nutrient. Values of less than 7 indicate low phosphorus content, values of 7–20 indicates medium phosphorus content, and values greater than 20 indicates high phosphorus content. This study showed that the soil samples obtained from Irua (Obiemen and Aqwa) and Benin (IkpobaOkha) had medium phosphorus content with values of (15.70) 0–15 cm, (13.27) 15–30 cm, and (11.41) 0–15 cm, (13.06) 15–30 cm respectively. While soil samples obtained from Ekpoma (Opoji), Benin (Oka ~Naruovia), and Benin (Orhiomwon) recorded low phosphorus content with value of (2.93) 0–15 cm, (2.88) 15–30 cm, (5.56) 0–15 cm, (3.23) 15–30 cm, and (5.52) 0–15 cm, (3.25) 15–30 cm respectively.

CONCLUSIONS

This research aimed to assess the phosphorus condition of five wetlands in Edo State, Nigeria, and to analyze their physical and chemical features. Soil samples were collected from Irrua (Obiemen and Aqwa), Ekpoma (Opoji), Benin (Oka-Naruovia), and Benin (Ikpoba Okha and Orhiomwon) at depths of 0–15 cm and 15–30 cm. Soil samples were collected and analyzed using conventional laboratory techniques. The analysis indicated that the soil sample collected from Irua (Obiemen and Aqwa) exhibited considerable acidity, with a pH of 4.5 at a depth of 0–15 cm and a pH of 4.2 at a depth of 15–30 cm. Soil samples collected from Benin (Orhiomwon) at depths of 0–15 cm and 15–30 cm exhibited significant acidity, with a pH of 4.8. This implies that the soil in this region is unsuitable for plant cultivation due to the absence of phosphorus (P). The potential for phosphorus loss in these soils is mostly linked to erosion and runoff. However, the soil samples obtained from Ekpoma (Opoji), Benin (Oka~Naruovia) and Benin (Ikpoba-Okha) with depths of 0–15 cm and 15–30 cm were within neutral level suitable to plants respectively with pH range of 6.6 to 7.0. According to FAO (1990) on classification of soil macro and micro nutrient, values less than 7 indicate low phosphorus content, values 7–20 indicates medium phosphorus content while values greater than 20 indicates high phosphorus content. This study showed that the soil samples obtained from Irua (Obiemen and Aqwa) and Benin (IkpobaOkha) had medium phosphorus content. Meanwhile, soil samples obtained from Ekpoma (Opoji), Benin (Oka ~Naruovia), and Benin (Orhiomwon) recorded low phosphorus content. This indicates the presence of phosphorus in the soil at these areas, making it conducive for plant output. To mitigate sedimentation and the loss of soluble phosphorus, it is essential to meticulously manage soils with elevated or very high phosphorus levels, ensuring they are not susceptible to erosion and runoff. The foundation of an organic soil fertilization program for phosphorus should be organic matter and microbial activity. Crop leftovers, animal manures, and compost are recycled on the farm and should satisfy most nutrient requirements.

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