

Full Length Research Paper

## Influence of depths and soil pH on forms of magnesium in soils of four parent materials (*Rhodic paleudults, Rhodic tropudalfs, Oxic tropudalfs and Aquic tropossamment*)

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The role of depths and soil pH in the content and occurrence of the forms of magnesium in soils of the four parent materials in Edo and Delta States (Coastal plain sand, Shale, Basement complex and Alluvium) was investigated. Soils samples were collected from profiles that developed on these parent materials, with dimensions 1.2 x 1.2 x 1.5 m and demarcated according to depths ranging from 0 to 150 cm. Reagents were applied under regulated conditions and durations ranging from 10 min to 1 h. The results showed that different forms of magnesium were extracted from varying depths in each profile. In the alluvium the non available Mg content in the study ranged from 7.79 to 24.34 c mol kg<sup>-1</sup> and was highest in the top soils of the profile examined. The exchange Mg was between 0.16 to 0.24 c mol (+) kg<sup>-1</sup> decreasing also across depths, in the coastal plain sand, the non available Mg ranged from 17.56 to 19.97 c mol kg<sup>-1</sup> with greater amount realized from the bottom depths. Exchange Mg pool ranged from 0.12 to 0.52 c mol kg<sup>-1</sup> with higher records on surface depths of 0-3, 3-15 and 15-45 cm. In the Basement complex the non available Mg ranged from 12.26 to 18.97 c mol kg<sup>-1</sup> with greater value recorded from 45 to 62 cm depths. While exchangeable Mg ranged from 0.22 to 0.46 c mol kg<sup>-1</sup> and 3.22 to 6.25 c mol kg<sup>-1</sup> respectively with both forms distributed oppositely across the depth. The structural Mg ranged from 6.28 to 8.84 c mol kg increasing down the depths. The water sol Mg in the four parent materials were distributed in similar pattern in three out of the four parent materials, it ranged from 0.16 to 0.52 c mol kg<sup>-1</sup> and 0.09 to 0.19 c mol kg<sup>-1</sup> in coastal plain sand and alluvium. In Shale it ranged from 0.21 to 0.58 c mol kg<sup>-1</sup>, while in the basement complex 0.25 to 0.40 c mol kg<sup>-1</sup> with values decreasing down the depths across the four parent materials. The soil pH across the four parent materials ranged from 4.41 to 5.63 decreased from surface to the bottom.

**Key words:** Soil pH, horizon, depths, profile, available magnesium.

### INTRODUCTION

Depths and pH in soil profiles are important factors to be considered in plant nutrient availability and quantification study because plant nutrients are located in different

depths or horizons in the soils (Buzzle, 2011). Depth in this context refers to the vertical distance across the soil profile from the topmost surface to the last point dug at

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the bottom that is accessible (Henson, 2007; Buzzle, 2011). Soil pH is the soil reaction in the area examined and refers to the sum total effects of the hydrogen and associate acid ions concentration in the soil (Manjula, 2009). SQMN (2011) emphasized that depth and soil pH have important influence on nutrient availability status of most soils in the tropics stating that weathering is a major factor that determines the forms and level of these nutrients in the soil. Plant roots are the major physical and biological instruments that are used for absorption of nutrients from the soil and the rate of plant nutrient adsorption is influenced by depths (Mitchall et al., 2005). Depth influence the adsorption of nutrients by plant roots as most plants have their functional roots and root hairs located in the top soil region of the profiles. Usually plants have vast arrays of root network scattered in this region, while perennial crop has its' growth and development among other factors tailored to the ability of the crops to utilized nutrients at all depths across the profile. Tennakoon (2003) reported that arable crops such as maize, millet, vegetables and peas utilizes and sourced their nutrients from the top soils of profiles but added that most palms would however source for their nutrients in diverse depths or horizons far as 45 to 200 cm. Depths are influenced by the geological and climatic characteristics of the soil micro environment which exposes the lithographical constituents within the soil structure in a micro scale. The parent materials and the geological structure of a profile is a direct function of the component materials that make up the physico-chemical constituents of the soil (Brady and Weil, 1999). These however are mainly of plant and animal materials with added geo-mineral constituents that are bio-chemically synthesized into both macro and micro nutrients which become plant nutrients in soils. Kamaljit (2005) stated that, plant nutrients are utilized at different depths where they occur, and are taken from vast array of reserves of nutrient in these horizons with biophysical mechanism by plants. Soils developed from various parent materials in the states are differentiated and classified into several soil types and series. Such soils are characterized into several land capability and suitability status which can influence the cropping and farming systems done in any area. Tennakoon (2003) and Fayemi and Lombin (1975) stated that the magnesium forms and content of Nigerian soils varied with the magnesium content of different parent materials and the climatic locations. Okpamen (2011) however added that the content and forms of magnesium in a soil is dependent on the status of the primary magnesium bearing mineral found in such soils, adding that it is subjected to vast environmental forces such as weathering and other physical factors. Weathering occurs at different areas in the states but the intensity of occurrence is dependent on the prevailing bio-physico chemical factors present in the area, and it has been established that weathering occurs higher in the top soils than in lower depths (Brady and Weil, 1999).

## MATERIALS AND METHODS

### Study areas, site description and sample collection

The influences of depths and soil pH on forms of magnesium in soils developed on four parent materials in Edo and Delta states (Coastal plain sand, Shale, Basement complex and Alluvium) were investigated. Soil samples were collected from four locations representing four parent materials. The locations were NIFOR developed on coastal plain sand, Uhumora developed on Shale; Sobe developed on Basement complex all in Edo state while the fourth location is in Koko in Delta state developed on alluvium parent material all in two ecological zones of Edo and Delta states of Nigeria. Samples were collected from depths demarcated, and a physical assessment of profile pits dogged on fields was made. Then, these soil samples were stored in labeled polythene bags and transported to the laboratory for physico-chemical analysis namely; Soil pH (H<sub>2</sub>O), exchangeable acidity, exchangeable bases, organic matter.

### Particle size analysis and effective cation exchange capacity (ecec)

#### *Characterization of soil of the four parent materials (coastal plain sand, shale, alluvium, and basement complex)*

The sites of these parent materials chosen were NIFOR, an Agricultural Research Institute in Edo State about 24 km from the state capital Benin City. It is located on latitude 06°33'N and longitude 05°37'E and on altitude 149.4 m. NIFOR soil is classified into four soil series namely; Alagba, Kulfo, Ahieria and Orlu (Ogunkunle, 1983) which is Typic/Rhodic paleudults (FAO/UNESCO, 1994) the pits were dug on Orlu/Alagba series of the institute. Samples were collected from pits dug with dimensions 120 x 120 x 150 cm and vegetation is rainforest with mean annual temperature of 31°C and a bimodal rainfall regime. The second site is at Uhumora; Cocoa Research Institute of Nigeria substation in Edo State, the soil is described as Rhodic tropudualf (FAO/UNESCO, 1994). Site was on old Cocoa plot about one kilometer from the administrative block of the institute. The pit was 120 x 120 x 150 cm dimensions and soil samples were collected from depths by similar process described above. This site is located in North East central end of Edo State; temperature is same as NIFOR, though rainfall is within 1575 to 1725 mm across the year not as high as in NIFOR. Koko is the third site; it is in Delta state, Southern part of former Bendel State soil samples were collected from the profile pits dug on an old cassava farm with 120 x 120 x 150 cm dimension, located 500 m north of Total Bitumen plant Plc. The area is with high rainfall > 2500 mm per annum an average temperature of 25°C and fresh water swamp vegetation, soils are hydromorphic and humus with high water table. The profile was studied, and described while samples collected were bagged for laboratory analysis. The fourth site was at Sobe farm settlement plot, where 120 x 120 x 150 cm area was laid out and dug for sampling. The soils in the site are on a gentle sloping surface with stones and pebbles as common features, it occurs in the derived savanna zone under forest soil, derived from metamorphic and igneous rocks from inselbergs of granite, gneiss, Schist and quartzite (Fagbami, 1985) of the old Bendel State now Edo and Delta States. Its rainfall is about 1450 to 1650 mm year<sup>-1</sup> the least in the study with average bimodal temperature of 31°C.

### Laboratory analysis of the physico-chemical properties

Soil samples were air dried and passed through a 2 mm sieve,

while some samples were ground to pass through 0.5 mm sieve and stored for determination of organic matter and total nitrogen. Analyses of samples were carried out using the known conventional procedures outlined as follow:

1. Soil pH (H<sub>2</sub>O): This was determined in 1 : 1 soil – water suspension. 20 g sample of air dried soil was passed through a plastic 2 mm sieve and weighed into 100 ml beaker. 20 ml distilled water was added and stirred thoroughly and allowed to equilibrate in 30 min. A glass electrode pH meter was used to read the pH of the suspension after standardization with pH buffer 7.0 and 4.0 as outlined by Schofield and Taylor (1955).
2. Exchangeable acidity: The exchangeable acidity was extracted with 1N KCl and determined by titration with 0.05M NaOH using phenolphthalein as the indicator (Jackson, 1964).
3. Exchangeable bases and organic matter: the exchangeable cations, Na, K, Ca and Mg were extracted with 1 N Ammonium Acetate solution (NH<sub>4</sub>OAC) buffered at pH 7.0. Exchangeable Na, K and Ca content of the extracts were determined on flame photometer, while exchangeable Mg was read on Atomic Absorption Spectrophotometer (Jackson, 1964). Organic Matter Content was determined by wet dichromate-acid oxidation as outlined by Walkley and Black (1934) and modified by Piper (1942).
4. Particle size analysis and effective cation exchange capacity (ECEC): Particle size analysis was carried out using hydrometer method outlined by Bouyoucos (1951) as modified by Day (1965). ECEC was determined by summation method. (Hearse, 1971) (i) Exchangeable acidity (EA) (H<sup>+</sup> and Al<sup>3+</sup>) (ii) Total exchangeable bases (TEB).

#### Determination of forms of magnesium in the four parent materials

Magnesium forms in the soils were fractionated in the following ways

1. Water soluble magnesium content procedure: This form of magnesium was determined with deionized water in 1:10 soil – water ratio. 5 g of the soil samples were weighed into 250 ml plastic bottles, 50 ml of deionized water was added to each sample in the bottles and shaken on a mechanical shaker for 30 min and filtered with whatman No.42 filter paper into a 100 ml volumetric flask. The magnesium in the extract was determined with an Atomic Absorption Spectrophotometer (AAS).
2. Exchangeable magnesium content: the residue from the water extract was treated with 1N NH<sub>4</sub>OAC solution buffered at pH 7.0 at soil : solution ratio of 1 : 10 for 30 min. The suspension was then filtered and magnesium in the filtrate was determined using AAS.
3. Difficultly exchangeable magnesium pool; 1N HNO<sub>3</sub> extractable magnesium: the residue from (ii) above in the centrifuge tube was treated with 50 ml of 1N HNO<sub>3</sub> acid. The suspension was boiled for 10 min in a digester and the content allowed cooling for 20 min before centrifuging. They were then decanted and the extracts read with the AAS.
4. 1N HCl extractable magnesium: To the residue from the 1N HNO<sub>3</sub> acid extract was added 50 ml of 1N HCl and stirred with a glass rod to re - suspend it and the suspension placed on a digester to boil for 1 h, before cooling. The suspension was then centrifuged, to cool for 20 min before filtration was carried out on suspension. The magnesium content of the extract was determined on an AAS.
5. Fixed magnesium reserve pool: This form of magnesium was obtained by computation using the difference between the 1 N HCl extractable Mg values and the exchangeable Mg in the samples. The difference represents the fixed Mg reserve pool in the samples. This was in accordance with the procedure of (Flinck, 1962).
6. Structural magnesium content: This form of magnesium was also obtained by computation. The result obtained from the difference

between the total Mg content and the 1N HCl extractable Mg content was tagged structural Mg or residual magnesium.

7. Total magnesium reserve pool: total magnesium in the sample was determined by the sodium carbonate fusion procedure as describe by Jackson (1958). 0.2 g of air dried soil was ground to pass through 100  $\mu$  sieve and weighed into platinum crucible in duplicate. 5 g of anhydrous Na<sub>2</sub>CO<sub>3</sub> was added to the weighed sample and the mixture was thoroughly mixed. An additional 1 g of Na<sub>2</sub>CO<sub>3</sub> was weighed and spread evenly on top of the mixtures. And was covered at an angle and ignited using a mekker burner for about 10 min. The cover was lifted with a pair of tongs to let in air through a slit when frothing sound had ceased. Heating was continued until the soil carbonate mixture melted. The crucible was gently rotated to allow the melt spread evenly on the sides of the crucible. The cover was then removed and heating discontinued. The crucible was then put into a 400 ml beaker, distilled water added to cover the crucible and the beaker heated cautiously to dissolve the melt. The platinum crucible was lifted and the sides washed into the beaker with a wash bottle. 5 ml of 6 N HCl was added to the beaker and warmed over a low flame to avoid too vigorous effervescence with loss of material. When all the melt had dissolved, the solution containing gelatinous silica was filtered into a 250 ml volumetric flask. The residue was washed several times with hot distilled water and the washings were added to the volumetric flask. Magnesium in the filtrate was determined by atomic absorption spectroscopy (Okpamen et al., 2011).

#### Categorization of forms of magnesium

1. Available magnesium: The available magnesium comprise of the water soluble magnesium and the exchangeable magnesium (H<sub>2</sub>O Sol. Mg + 1N NH<sub>4</sub>OAC Mg) in the study (Chevalier, 1971; Fayemi and Lombin, 1975).
2. Non available magnesium: The non available magnesium consists of all the other forms extracted from the samples less the available magnesium. This comprises the acid magnesium, fixed Mg Reserve and structural Mg. (Hearse, 1971)

#### Statistical analysis of the data

The statistical method as described Alika (1997) and an SPSS package were employed for data obtained from the laboratory analysis. Simple linear and multiple correlations were carried out on factors that had influences on the magnesium species studied. The level of probability used in tests of significance was 1 % and 5 % respectively.

## RESULTS AND DISCUSSION

The content and forms of Magnesium extracted was examined relative to profiles depths and soil pH in this study, it is to ascertain the level of influences both parameters had on the presence and contents of forms of magnesium in the four parent materials. Depths and soil pH were correlated with water soluble Mg, exchangeable Mg and non available Mg and results showed that soil pH in the various profiles and parent materials were low and they fell within acid range. The values recorded fluctuated with depths for two of the parent materials examined except in the basement complex and Shale parent materials. In the Basement complex, a soil pH of 5.6 was recorded at the surface of 0 to 15 cm and declined to 5.2 at a depth of 30 cm and remains constant. While the

**Table 1.** Correlation of Depth and Soil pH with Forms of Magnesium.

		Depth	Soil ph	Water Mg	Exch. Mg	Non avail. Mg
Pearson correlation	Depth	1.000	-0.489	-0.912	-0.346	0.015
	Soil pH	-0.489	1.000	0.235	0.693	-0.550
	Water Mg	-0.912	0.235	1.000	0.391	-0.077
	Exch. Mg	-0.346	0.693	0.391	1.000	-0.930
	Non. avail. Mg	0.015	-0.550	-0.077	-0.930	1.000
Sig. (1-tailed)	Depth	-	0.202	0.015	0.284	0.491
	Soil pH	0.202	-	0.352	0.097	0.168
	Water Mg	0.015	0.352	-	0.258	0.451
	Exch. Mg	0.284	0.097	0.258	-	0.011
	Non. avail. Mg	0.491	0.168	0.451	0.011	-

Water mg, Water soluble magnesium; Exch. Mg, exchangeable magnesium; non avail Mg; non available magnesium.

various forms of magnesium varied across depths in different pattern in all the parent materials, water soluble Mg and exchangeable Mg pool which represents the available magnesium had values decreasing from topmost depths (0 to 3 cm) to bottom (90 to 150 cm) in all the profiles examined (Table 1). The non available Mg forms had values varying increasingly with depths from the surface to the bottom of the profiles. The soil formed on shale (CRIN) location had a pH of 5.32 on surface, 4.41 in mid profile and 4.46 at the bottom. The amount of magnesium recorded were; water soluble Mg; 0.58 to 0.42 cmolkg<sup>-1</sup> (0 to 75 cm) and 0.32 to 0.21 cmolkg<sup>-1</sup> (75 to 150 cm), exchangeable Mg values ranged from 1.03 to 0.83 cmolkg<sup>-1</sup> (0 -150 cm) (Table 2). While the non available Mg form ranged from 7.79 to 24.34 cmolkg<sup>-1</sup> (between 0 - 150 cm) in the four parent materials studied. In coastal plain sand parent material the pH of the soil were 5.34 on surface 5.16 in mid profile and 5.32 at depth while the various forms of Mg ranged from water soluble Mg; 0.16 to 0.52 cmolkg<sup>-1</sup> (0 to 150 cm) increasing from top to bottom. Exchangeable Mg ranged from 0.42 to 0.12 cmol kg<sup>-1</sup> (0 to 150 cm) while the non available Mg ranged from 17.54 to 19.97 cmolkg<sup>-1</sup> this results indicates an increase to a depth of 150 cm. In alluvium the pH ranged from 5.15 on surface to 4.57 at depth while the different forms of magnesium were; water soluble Mg having 0.18 to 0.09 cmolkg<sup>-1</sup> between 0-150 cm, exchangeable Mg ranged from 0.24 to 0.16 cmolkg<sup>-1</sup> (0 - 150 cm) while the non available Mg in this parent material ranged from 7.79 to 9.86 cmolkg<sup>-1</sup> (0 - 150 cm) decreasing from top to bottom, this represents the least values extracted for this form of magnesium in the study. In Basement complex, the soil pH ranged from 5.63 to 5.2 but the various forms of magnesium extracted ranged from water soluble Mg having 0.25 to 0.40 cmolkg<sup>-1</sup> (0 to 150 cm) Exchangeable Mg pool ranged from 0.22 to 0.46 cmolkg<sup>-1</sup> (0 to 62 cm) and the non available Mg pool ranged from 12.28 to 18.59 cmolkg<sup>-1</sup>. The pattern of distribution of the various forms of magnesium in the

respective parent materials can further be categorized into two fashions; the water soluble Mg and exchangeable Mg that constitute the available magnesium, tended towards the surface depths of most of the profiles. The reasons attributed for this finding is the prevalence organic matter in the surface depths of the profiles that are open to bio-physical and chemical weathering agents in the environments. These actions cause the breakdown of the complexes in minerals and organic materials which exists at different stages which available magnesium constitute a part (Table 1).

This finding is in line with work done by Tennakoon (2003) and Kamaljit (2005) who studied the status of major elements in soils of Sri Lanka and those of grassland in Central Queensland Australia and reported high amount of K, Mg, and Ca in higher depths. Secondly, the non available magnesium which constitute the acid, fixed Mg reserve, structural and total Mg pool are distributed in similar pattern as the exchangeable Mg. They tend to increase down the profiles; higher values were recorded for these forms of magnesium at depths almost in all the four parent materials. This finding is corroborated also by the earlier reports of Fayemi and Lombin (1975) that had worked on status of magnesium in soils of south western Nigeria and reported that these forms are usually higher in depths than the available forms. Kamaljit (2005) concluded that the variability in amount of nutrients may have been as a result of extent of weathering across depths and other biophysical and chemical activities which had varied in such areas. From Table 1, there was significant negative correlation between depths and the distribution of water soluble Mg in the study ( $r = -0.912^{**}$ ) and between non available magnesium and exchangeable magnesium distribution ( $r = -0.930^{**}$ ). There was also a fair positive correlation between soil pH and exchangeable Mg ( $r = 0.693$ ) while most other parameters examined fall short of a significant statistical positive and negative correlations which would have imparted more on this investigation or work however

**Table 2.** Distribution of depths and soil pH with forms of magnesium in the study.

Depth (cm)	Soil pH	Forms of magnesium			Parent materials
		H <sub>2</sub> O Sol. Mg	Exch. Mg	Non avail. Mg	
0-3	5.34	0.16	0.42	17.56	Coastal plain sand
3-15	5.43	0.27	0.51	15.94	
15-45	5.32	0.31	0.52	16.30	
45-75	5.16	0.30	0.48	19.84	
75-90	4.93	0.48	0.20	19.97	
90-150	5.32	0.52	0.12	19.17	
0-3	5.32	0.58	1.03	19.72	Shale
3-15	4.91	0.49	0.64	24.31	
15-45	4.41	0.51	0.66	24.13	
45-75	4.41	0.42	0.75	21.62	
75-90	4.98	0.32	0.76	21.78	
90-150	4.46	0.21	0.83	20.40	
0-3	5.15	0.18	0.24	9.86	Alluvium
3-15	5.09	0.12	0.23	9.82	
15-45	4.99	0.19	0.20	0.18	
45-75	4.65	0.22	9.67	8.07	
75-90	4.87	0.12	0.17	7.79	
90-150	4.57	0.09	0.16	7.79	
0-3	5.63	0.40	0.46	12.28	Basement complex
3-15	5.48	0.31	0.37	17.64	
15-45	5.58	0.20	0.36	18.59	
45-75	5.40	0.25	0.22	19.73	
75-90	na	na	na	na	
90-150	na	na	na	na	

na, Not available; cm, centimeters H<sub>2</sub>O sol, water soluble; Exch Mg, exchangeable magnesium; Non Avail Mg, non available magnesium.

the correlation of the non exchangeable Mg with soil pH was only slightly negative correlated ( $r = -0.550$ , Table 1). The results above implicated the following; that a strong linearity exists between those soils properties that had significant correlation with each other such as stated above in this study. This findings is in line with earlier reports given by Fayemi and Lombin (1975) working on soils of south western Nigeria who reported a significant relationship between soil pH and exchangeable magnesium and depth respectively.

## Conclusion

In summary, the pattern of distribution of the various forms of magnesium in the respective parent materials have been categorized into two; the water soluble Mg and exchangeable Mg that constitute the available magnesium which appears to be concentrated in the surface depths and reasons attributed for this, was the prevalence of organic matter in the surface depths of the

profiles where many bio-physical and chemical weathering activities in the environments seem to be occurring. The other forms of magnesium tagged the non available magnesium also responded to depths by continuous downward increased in amount. An indication that these forms of magnesium are more in the bottom depths than in the surface, this suggests slower weathering actions to be occurring at depths. Brady and Weil (1999) stated that the non available forms of most cations in their parent forms are rendered to their primary and secondary forms by processes of breakdown sponsored by actions of weathering. The relevant of this work is hinged on the fact that the two classes of magnesium defined from the various forms in this work are depths and soil pH related to a great extent.

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