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## An Evaluation of Cation Exchange Characteristics of Two Soils in South Western Nigeria

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**Abstract:** Studies were carried out on two soils of Itagunmodi and Alagba series found in South Western Nigeria. The studies evaluated the relationship among various methods of CEC determination and came out with different values for both soils. In both soils chemical properties such as pH, O. C., Ex. H<sup>+</sup>, Ex. bases (Ca, Mg, Na, K), ΔpH, Ex. Al, Ex. Acidity (from BaCl<sub>2</sub>-TEA, pH 8, Soil-Test, Mg (OAc)<sub>2</sub>, pH 7 and KCl) varied significantly ( $p = 0.05$ ) among the different soil horizons. However this did not affect the evaluated CEC in relation to the various methods of its determination. The CEC obtained from the various four methods of its determination indicated that there was this decreasing order of magnitude: Sum of cation CEC > neutral acetate CEC > Soil Test CEC > effective CEC. This showed that the CEC is a concept which is arbitrarily defined since no two different methods of its determination give the same value, even when the same extracting solution or the same pH value is used. In this investigation it has been shown that CEC value is method-dependent.

**Key words:** Evaluation, cation, exchange, characteristics, soils, Nigeria

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### INTRODUCTION

The Cation Exchange Characteristics (CEC) is a very important chemical property used to characterize soils for classification and fertility assessment.

The major international systems of soil classification do not define soil series for each locality. Hence it has become pertinent that individual countries develop their own classification system provided they are in consonance with the present knowledge of modern soil science. Already, virtually all the developed nations have a well documented soil classification system. A few of the developing economies also have, but many are either yet to have or are struggling to develop one.

Different methods exist for measuring the CEC of soils. However for a developing country such as Nigeria, the use of a multiplicity of CEC assessment approaches may not be advisable due to the high bills involved. Rather only one method may be sufficient.

Studies in CEC have been carried out for the soils of South-Western Nigeria by Juo *et al.* (1976), Pleysiera and Juo (1980). However, no effort has been made to examine the relationship among the various methods of CEC determination, neither has any attempt been made to choose or recommend any one method in preference to the others under a stated criterion.

Hence the objective of this study is to examine the relationship among four methods of CEC measurements of two soils of South-Western Nigeria so that, if possible, one method can be chosen in preference to the others for classifying the soils of this sub-region or even for the entire country.

### MATERIALS AND METHODS

This study was carried out in 2005 at pre-classified sites in Ife and Ijebu-Ode Towns, within latitudes 6° 7' and 7° 4' North and longitudes 4° 4' and 4° 7' East, in South-Western Nigeria. Soil samples were collected from the genetic horizons of two soil series, namely, Itagunmodi and Alagba and subjected to laboratory analysis. The Itagunmodi series is located in the rain forest vegetation zone with annual rainfall of 1400 mm on sedimentary rock, while the Alagba series is in the derived savannah vegetation with annual precipitation of 1900 mm on amphibolite. Both locations support rain fed agriculture.

**Laboratory analysis:** The chromic digestion method (Jackson, 1958) was used to determine the easily oxidisable carbon. The soil pH was determined in 1:1 soil-water ratio and 1:1 soil-1N KCl suspensions (Schofield and Taylor, 1955). 1N NH<sub>4</sub> OAc, pH 7 was used to extract the exchangeable bases. Magnesium was determined by

EDTA titration. The BaCl<sub>2</sub>-TEA extractable acidity (EA) was determined using the Soil Survey Staff (1972) procedure. Soil-Testing (Soil-Test) EA was determined by the Jackson (1958) method. The amounts of exchangeable H and Al in the extracts were determined by the Fluoride titration procedure outlined in No. 6 G1d, Soil Survey Investigation Report, No. 1 (1972). The CEC of the soils was carried out by four different methods, namely, Sum of cations, Soil-Test, Neutral acetate Displacement and Effective CEC. The results were then analyzed statistically at LSD (0.05) (Little and Hills, 1972).

### RESULTS AND DISCUSSION

The results are shown in Table 1 and 2. Both soils were acidic in nature (mean pH < 7.0 in all the soils). Also, the pH (H<sub>2</sub>O) was higher than the pH (KCl). This indicated that the soils had excess negative charges (Gallez *et al.*, 1976). Charge variation with pH was less in the subsoils, probably due to their lower organic matter content compared to the topsoil. The influence of organic matter on the nature and distribution of CEC down the soil profile is well documented in literature. Hence the CEC of subsoils may be more reliable than that of the topsoils, for characterizing soils for classification purposes; though, that for the topsoils is preferred for fertility assessment purposes. The distribution of the CEC down the profiles of both soils is depicted in Fig. 1 and 2.

The four methods used to evaluate the CEC of the soils yielded different values and showed that the soils have low CEC. The low CEC may be due to the predominance of kaolinitic clays in the soils of Central Western Nigeria as reported by Smyth and Montgomery (1962). It is well established that CEC are strongly influenced by the type of clay mineralogy. The 1:1 clay minerals, for example kaolinite have CEC of 3-15 cmol kg<sup>-1</sup>, whereas 2:1 minerals like vermiculite and montmorillonites have values as much as 150 and 100 cmol kg<sup>-1</sup> respectively (Lambe and Whitman, 1969). However, the kaolinite of Central Western Nigeria may need further qualification. The measured CEC of kaolinite is known to be variable, depending on the degree of impurities in the clay and the pH at which the CEC is measured. If a few impurities are present the CEC should be very low, < 2 cmol kg<sup>-1</sup>, since most scientists agree that the degree of isomorphic substitution in kaolinite is small. Impurities of 0.1 to 10% smectitic, micaceous and vermiculitic layers in kaolinite (Moore and Reynolds, 1989) and anatase, rutile, feldspars, quartz and iron oxides are often present (Sparks, D.L., 2003). Another explanation for the often unexpected CEC that is measured for kaolinite is negative charge resulting from surface functional edge groups

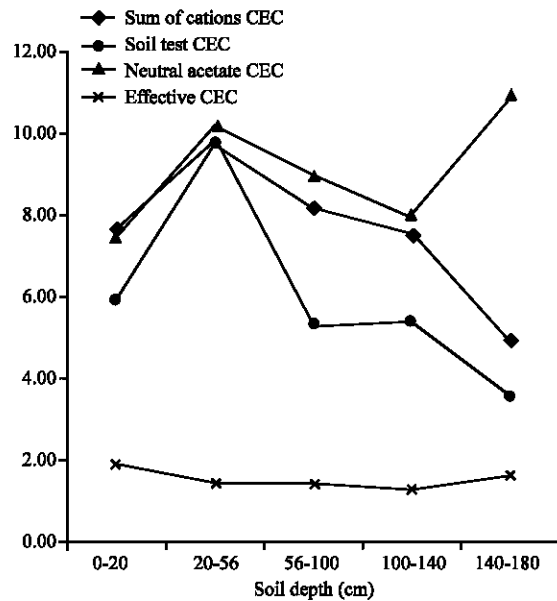


Fig. 1: Itagunmodi Series: CEC distribution down the profile

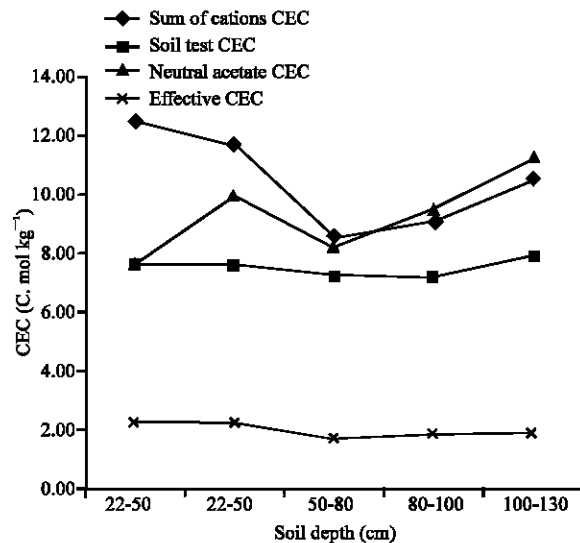


Fig. 2: Alagba Series: CEC distribution down the profile

such as AlOH which are deprotonated when neutral pH extracting solutions (e.g. ammonium acetate) are employed in CEC measurements (Sparks, 2003).

The four different methods yielded different values of CEC, in this decreasing order of magnitude: sum of cations CEC > neutral acetate CEC > Soil-Test CEC > effective CEC. For the soils of Itagunmodi series, there was a significant difference (LSD 0.05) between the CEC values obtained by sum of cation and effective CEC; and between Soil-Test CEC and effective CEC. Also, there was a significant difference (LSD 0.05) in values between sum

**Table 1: Physical and chemical properties of itagunmodi series**

Soil Depth (cm)	0-20	20-56	56-100	100-140	140-180	Mean	LSD (5%)
pH (H <sub>2</sub> O)	5.78	5.60	5.61	6.00	5.95	5.79	0.48
pH (KCl)	4.45	4.80	5.45	5.55	5.60	5.17	1.33
ΔpH	-1.33	-0.80	-0.16	-0.45	-0.35		
Organic carbon (g kg <sup>-1</sup> )	0.77	0.41	0.20	0.12	0.12	0.32	0.71
Extract Al (cmol kg <sup>-1</sup> )	Traces	Traces	Traces	Traces	Traces	Traces	Traces
Ex. H <sup>+</sup>	0.14	0.10	0.10	0.10	0.10	0.11	0.05
<b>Extractable bases (cmol kg<sup>-1</sup>)</b>							
Ca	0.75	0.75	0.80	0.85	0.70	0.77	0.15
Mg	0.95	0.55	0.44	0.23	0.78	0.59	0.73
Na	0.05	0.05	0.06	0.06	0.05	0.05	0.02
K	0.02	0.01	0.01	0.01	0.01	0.01	0.01
<b>Extractable acidity (cmol kg<sup>-1</sup>)</b>							
BaCl <sub>2</sub> -TEA, pH 8	5.88	8.35	6.87	6.37	3.40	6.17	4.64
Soil-test	4.05	8.45	4.05	4.05	2.05	4.53	6.06
Mg (OAc) <sub>2</sub> , pH	75.73	8.89	7.69	6.85	9.46	7.72	3.88
KCl	0.14	0.10	0.10	0.10	0.10	0.11	0.05
<b>CEC (cmol kg<sup>-1</sup>)</b>							
BaCl <sub>2</sub> -TEA, pH 8	7.65	9.71	8.18	7.52	4.94	7.60	4.43
Soil-test	5.82	9.81	5.36	5.40	3.59	6.00	5.91
Mg (OAc) <sub>2</sub> , pH 7	7.50	10.25	9.00	8.00	11.00	9.15	3.79
Effective, KCl	1.91	1.46	1.41	1.25	1.64	1.54	0.65
<b>Base saturation (g kg<sup>-1</sup>)</b>							
Sum of cations	23.00	14.00	16.00	15.00	31.00	19.80	18.48
Soil-test	30.00	14.00	24.00	21.00	43.00	26.40	28.07
Neutral acetate	24.00	13.00	15.00	14.00	14.00	16.00	11.64
Effective	93.00	93.00	93.00	92.00	94.00	93.00	1.82

**Table 2: Physical and chemical properties of Alagba series**

Soil depth (cm)	0-5	5-22	22-50	50-80	80-110	110-130	Mean	LSD (5%)
pH (H <sub>2</sub> O)	5.10	5.10	5.00	5.00	5.05	5.08	5.06	0.16
pH (KCl)	3.75	4.10	4.05	4.00	4.00	4.05	3.99	0.32
ΔpH	-1.35	-0.90	-0.95	-1.00	-1.05	-1.03		
Organic carbon (g kg <sup>-1</sup> )	2.15	0.73	0.29	0.20	0.08	0.04	0.58	2.26
Extract Al (cmol kg <sup>-1</sup> )	Traces	0.46	0.78	0.78	1.11	1.15	0.71	0.75
Ex. H <sup>+</sup>	0.10	0.07	0.13	0.17	0.04	0.04	0.09	0.13
<b>Extractable bases (cmol kg<sup>-1</sup>)</b>								
Ca	1.50	0.65	0.55	0.30	0.30	0.20	0.58	1.23
Mg	1.27	0.87	0.56	0.25	0.40	0.30	0.61	1.01
Na	0.09	0.09	0.12	0.01	0.01	0.09	0.07	0.12
K	0.03	0.03	0.06	0.01	0.03	0.04	0.03	0.04
<b>Extractable acidity (cmol.kg<sup>-1</sup>)</b>								
BaCl <sub>2</sub> -TEA, pH 8	10.33	10.83	10.33	7.86	8.35	9.84	9.59	3.09
Soil-test	5.65	5.89	6.29	6.53	6.45	7.25	6.34	1.43
Mg (OAc) <sub>2</sub> , pH 7	7.86	6.09	8.71	7.58	8.76	10.62	8.27	3.87
KCl	0.10	0.53	0.91	0.95	1.15	1.19	0.81	1.60
<b>CEC (cmol kg<sup>-1</sup>)</b>								
BaCl <sub>2</sub> -TEA, pH 8	13.22	12.49	11.62	8.53	9.09	10.47	10.90	4.81
Soil-test	8.54	7.55	7.58	7.20	7.19	7.88	7.66	1.30
Mg (OAc) <sub>2</sub> , pH 7	10.75	7.75	10.00	8.25	9.50	11.25	9.58	3.54
Effective, KCl	2.99	2.19	2.20	1.62	1.89	1.82	2.12	1.24
<b>Base saturation (g kg<sup>-1</sup>)</b>								
Sum of cations	22.00	13.00	11.00	8.00	8.00	6.00	11.33	14.87
Soil-test	34.00	22.00	17.00	9.00	10.00	8.00	16.67	25.89
Neutral acetate	27.00	21.00	13.00	8.00	8.00	6.00	13.83	21.65
Effective	97.00	76.00	59.00	41.00	39.00	35.00	57.83	63.22

of cation CEC and effective CEC for Alagba series. However, it is recommended that a much larger number of samples of both soils be evaluated before a more reliable statement of relationship among the various CEC determination procedures can be derived. What may make this task more challenging is the fact that the different methods are carried out at varying pH values. Therefore, it is not possible at this point to say that one method of CEC evaluation for the soils is better than the

others. Rather any one method may be adopted by a developing economy to minimize cost of classifying her soils.

However, it is instructive that in most humid tropical soils 1 N KCl extractant will not raise the soil pH, according to the findings of Udo, E.J. and J. A. Ogunwale (1986). This fact obviously recommends the effective CEC as the preferred method for soil fertility assessment purposes.

### CONCLUSION

In conclusion, the study has shown that the different methods of evaluating the CEC of the soils of Itaganmodi and Alagba series of South-Western Nigeria yielded different values. Generally there was a significant difference (LSD 0.05) observed among the various pairs of the different approaches. Further research will be needed to derive a more reliable relationship among the various methods. Furthermore it is not possible to say that any one method is better than another since the different approaches are carried out at varying pH values.

Therefore it would be prudent and at the same time sufficient for a developing economy to simply adopt any one of the four CEC measurement methods to characterize the soils for classification purposes. For soil fertility assessment, however, the effective CEC is to be preferred to the other methods.

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