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Assessment of Minerals and Trace Elements in *Termiteria* and Ten Meter (10 M) Adjacent Soils in Maiha Local Government Area of Adamawa State, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author JAN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ONM and DK managed the analyses of the study. Author MHS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This work was aimed at assessing minerals and trace element contents of *termiteria* and ten meter adjacent surface soils during dry and rainy seasons. The study area (Maiha), was stratified into east and west sampling locations from which a termiterium and its ten meter adjacent soils were randomly selected for sampling from each sampling location. Termiteria samples were collected with core scoop in three places while adjacent surface soil samples were collected at 0 – 50 cm depth in April 2014 and August 2014 for the dry and rainy seasons respectively. Samples were dried, ground and sieved to powder form to obtain gross samples and test samples were obtained through cone and quartering process. Samples were analyzed for mineral contents with X-ray diffractometer (XRD) and for trace elements contents, with X-ray fluorescence (XRF) at National

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Geological Science Laboratory Kaduna, Nigeria. XRD analysis determined thirteen minerals which can be arranged in terms of abumdance as: quartz (SiO_2) > {microcline (K Al Si_3O_8), rutile TiO_2} > montmorillonite ($Na_{0.3}$(Al, Mg)$_2$ $4H_2O$($Si_{3.1}$ $Al_{0.9}$) O_{10} $(OH)_2$) > {brucite $Mg(OH)_{2,}$ covellite (CuS), dickite (Al_2 $Si_2O_5(OH)$), dolomite (Ca.$_{1.13}$$Mg_{0.87}$ $(CO_3)_2$), greenalite ($Fe_3Si_2O_5(OH)_4$), ellite (K, H_3O)$Al_2Si_3AlO_{10}(OH)_2$, muscovite-3T (K, Na)(Al, Mg, Fe)$_2Si_4O_{10}(OH)_2.4H_2O$), orthoclase (K(Al, Fe)Si_2O_8), phillipsite (K Na Ca Fe Al $Si_{6.39}H_2O$),}. XRF analysis detected fifteen trace elements, viz: Zr > Ba > Ag >Sr > Rb > Eu > Ni >V > Re > Ir > Zn > Ga > Cu >Yb > Cr. Single factor analysis of variance (ANOVA) showed no significant differences between contents of termiteria and ten meter adjacent soils as well as seasonal variation ($P < 0.05$). Termiteria can be used as a tool for mineral exploration. Eating termiteria and its ten meter adjacent soil should be done with caution due to their trace element contents.

Keywords: Trace elements; minerals; Maiha; termiteria.

1. INTRODUCTION

Recently there has been growing interest in sourcing and developing of minerals the world over, especially in the developing nations like Nigeria. Nigeria is currently diversifying her economy to supplement the income from the mono-economy (the fuel sector of the economy).

The origin and distribution of mineral resources is related to the history of the earth and to the entire geologic cycle because nearly all aspects and processes of the geologic cycle are involved to some extent in producing local concentrations of useful materials, furthermore, the geologic processes and some biological processes selectively dissolve, transport and deposit elements and minerals [1].

Several workers have showed that termites can concentrate minerals in their termiteria through their daily activities which involve both the underground and on the ground activities. These termiteria can thus serve directly as sources of some minerals and or indirectly as indicators of nearby mineral deposits [2-4].

Termiteria are used by both man and other animals in several ways, for instance, it is used as soil amendment in farms, for making building bricks, as traditional medicine and abandoned termiteria are used by other animals as habitats [3,5,6]. Geophagia is a habit of eating soils. Human as well as over 200 other species of animals and birds consume soils especially termiteria soils [7]. Geophagia was explained as instinctive way of supplying the body with some deficient elements such as Fe and Zn more especially in some pregnant women and lactating mothers who crave for clays especially termiteria soils. It is also explained that termiteria soil act as detoxifier because it contains some minerals, such as kaolinite and or a form of montmorillonite which are negatively charged and can bind the toxins (bacteria and viruses) in the stomach and hence preventing them from reaching the bloodstreams and are removed in feces. In this way clay minerals remedy nausea, vomiting and diarrhea [7] hence the reason proffered for consumption of termiteria soils by other animals.

In spite of its utility, there is uncertainty concerning the safety of its consumers as it may contain some trace elements, some of which are harmful to the body at certain concentrations [8], some are poisonous to both plants and animals. Trace elements are natural contents of the earth's crust which are released by parent rocks into the soils in varying quantities. Geochemical cycles as well as biochemical balance of trace elements are changed and are concentrated more than their natural speciation through anthropogenic activities [9]. Should presence of harmful trace elements be scientifically established in termiteria, it can be deduced that not only are these trace elements indirectly taken into the body via food chain but they are directly taken through the habit of geophagia.

The current study analyzed soils from termiteria and their ten meter (10 M) surrounding soils during rainy and dry seasons with the aim of assessing minerals and trace element contents of termiteria and that of their immediate vicinity (10 M away) in Maiha, Adamawa State, Nigeria.

2. MATERIALS AND METHODS

Materials used in this study includes; X-ray Fluorescence Spectrophotometer (XRF), X-ray diffractometer (XRD), core scoop, hammer, polythene bags, sieve, Pestle and mortar, spade, crucibles, analytical balance and some glass wares.

2.1 Study Area, Sampling Locations and Sites

The study area, Maiha is the headquarters of Maiha local government area, one of the twenty one local government areas in Adamawa State, Nigeria. It is located at the Nigeria-Cameroon border with coordinates: 9° 59' 44" N and 13° 13' 05" E. The study area was stratified into two sampling locations (east- west) from where a termiterium and its 10 M adjacent soil were chosen as sampling sites in each sampling location.

2.2 Sample Collection

2.2.1 Termiteria soils

Method of Dhembare [10] was adopted with some modifications, where *termiteria* were surveyed in the sampling locations from which a termiterium was randomly selected for sample collection. Suitable sampling tool for termiterium soil (15 cm by 6cm) core scoop, was used to collect the termiterium soil samples. The dry season samples were collected in April, 2014 while rainy season samples were collected in August, 2014.

Three increment samples were collected to form a gross termiterium soil sample of each sampled termiterium, starting from 0.5 M above the base, this is to eliminate collection of samples with foreign sediments which might have been brought to the base by agents like wind. Two samples were obtained from each sampling location while the study area provided four samples for each season.

2.2.2 Soil sample

Soil samples were collected as described by Okonkwo and Maribe [11], where surface soil from depth of 0-50 cm was collected using soil probe after using a spade to dig a hole to the sampling depth of 0 –50 cm. Soil sampling sites were located 10 M from each *termiterium* sampling site in the four cardinal directions. Each of the four soil sample increments collected were mixed to represent the gross soil sample Soil samples collected were kept in a labeled polythene bags and transported to laboratory for further work.

2.3 Sample Preparation

Soil samples were dried by spreading them on clean polythene sheet in the laboratory for seven days. The dried soil samples were ground using mortar and pestle and sieved with < 2 mm sieve to obtain powder form. Gross samples were reduced to test sample sizes through the process of cone and quartering [12]. The method involved forming cone shape with the sample and dividing it into four equal portions and taking the two opposite sides of the quarter while the other two quarters were discarded. The retained two quarters were recombined and the process was repeated until about 100 g of the sample was obtained.

2.4 Analytical Studies of the Samples

2.4.1 X-ray Diffraction (XRD) analysis

XRD analysis of the samples were carried out at National Geoscience Research Laboratory Centre, Kaduna (Nigerian Geological Survey Agency) following a modified method outlined by Adesakin and Olunlade [13]. Ground soil sample weighing 0.35 g was placed into a sample holder of the computer interfaced XRD instrument and then smeared uniformly on a glass slide. This was then packed into a sample container and sprinkle on double sticky tape. X- ray of CuKa with wavelength of 1.5418 was used to scan between 2Ɵ 0f 10° and 2Ɵ of 45° at increments of 0.04° with count time of four seconds for each step. Intensity of the diffracted rays was recorded continuously as the sample and the detector rotated through their respective angles. Peak intensity occurred when mineral containing lattice with d-spacing diffract x-ray at that value of Ɵ. Each peak was made up of two separate reflections _k1 and k2, at small values of 2Ɵ the peak locations overlapped with k2 and appeared as a hump on the side of k1, these combined peaks were considered as one. Higher values of Ɵ yield greater separation of peak where the 2λ position of the diffraction peak was measured at the center of the peak at 80% peak height.

Presentation of result of x-ray analysis was at peak positions at 2Ɵ and x-ray counts (intensity) in the form of x-ray plot. Intensity was reported as peak height intensity. Relative intensity was recorded as the ratio of the peak to that of the most intense peak. Thus;

$$\text{Relative intensity} = \frac{I \times 100}{Ii}$$

Where I = peak intensity, Ii = most intense peak.

The d-spacing of each peak was obtained by solution of the Bragg's equation for appropriate value of λ, that is; nλ = 2dsinƟ. when d-spacing was determined, automated search/match routines compared the d- spacing of the unknown to the known substance.

2.4.2 X-ray Fluorescence (XRF) analysis

X-ray fluorescence procedure for determination of trace elements was carried out as described by Baranowska and Baranowski [14]. 20 g of each of the ground soil samples was fused with 0.40 g stearic acid in a 20 ml platinum crucible and press with hydraulic press. The fused button was then x-rayed and counted to determine the elements, the excitation source emitted Ag-k x-ray (22.1 KeV) hence all elements with lower characteristics excitation energy were detected in the samples.

3. RESULTS AND DISCUSSION

Table 1 contains list of thirteen minerals determined in Maiha sampling area. The minerals arranged in accordance with their decreasing abundance in the sampling sites were; quartz (SiO_2) > {microcline (K Al Si_3O_8), rutile TiO_2} > montmorillonite ($Na_{0\cdot3}$(Al, Mg)$_2$ $4H_2O(Si_{3\cdot1}$ $Al_{0.9})$ O_{10} $(OH)_2$) > {brucite $Mg(OH)_2$, covellite (CuS), dickite (Al_2 $Si_2O_5(OH)$), dolomite ($Ca._{1.13}Mg_{0.87}(CO_3)_2$), greenalite ($Fe_3Si_2O_5(OH)_4$), ellite (K, $H_3O)Al_2Si_3AlO_{10}(OH)_2$, muscovite-3T $(K,Na)(Al,Mg,Fe)_2Si_4O_{10}(OH)_2.4H_2O$), orthoclase (K(Al, Fe)$Si_2O_8$), phillipsite (K Na Ca Fe Al $Si_{6.39}H_2O$),}. Quartz was detected in all the sampling sites while rutile and microcline were detected in three sampling sites each; rutile in 10 M^r of Maiha East (ME) and T^r and T^d of Maiha West (MW) sampling locations. Quartz and rutile dominated all the other minerals detected in this study, this may be due to the status of their elements (Si and Ti) as members of the most abundant elements in the earths' crust [1].

The most abundant form of TiO_2 in the study area was rutile this is because it is the most stable polymorph compared to anatase. Both anatase and rutile are oxides of titanium, rutile (TiO_2) occupies important place in paint industries because it has high refractive index, strong absorption of UV region of light spectrum and strong reflectance in the visible spectrum which gives it a light scattering properties in addition to particle size which makes it effective pigment for brightness and opacity [15].

Montmorillonite was detected in two sampling sites (T^r and T^d) of ME only. The remaining elements were detected in only one sampling site each. Dolomite, greenalite, ellite, muscovite – 3T, orthoclase and phillipsite were detected in termiteria soil samples only. Each of the termiteria sampling sites consisted of three minerals in ME and four minerals in MW while, apart from 10 M^d of MW all the other 10 M sampling sites consisted of three minerals. Seven of the minerals determined in the current work were all aluminosilicates minerals (dickite, ellite, montmorillonite, muscovite-3T, microcline, orthoclase and phillipsite), they were all detected in termiteria soils, aluminosilicates minerals have been shown to be present in termiteria soils [16]. Abundance of aluminosilicate minerals in the samples can be ascribed to the fact that their constituent elements (O_2, Si Al) are the first, second and the third most abundant elements in the earth's crust [1]. In addition, 95% of the earth's crust is made up of silicate minerals-aluminosilicate clays, contents of which generally include; Al, Si, Ca and Fe [17].

Fig. 1 represents the trace elements detected in the current study area. Fifteen trace elements were determined which can be arranged based on decreasing quantity as; Zr > Ba > Ag >Sr > Rb > Eu > Ni >V > Re > Ir > Zn > Ga > Cu >Yb > Cr Predominant trace elements in the study area were; Zr with range of values as (3.00 - 0.99) PPM, Ba ranged from (0.86 – 0.06) PPM, Ag had a range of (0.54 – 0.05) PPM and (0.42 – 0.18) PPM was range of values for Sr. Lesser prominent ones have highest concentration values as; 0.35 PPM for Rb, 0.29 PPM for Eu, 0.17 PPM for V, 0.2 PPM for Ni, 0.03 PPM for Cr and 0.07 PPM for Zn.

All the trace elements detected in the current work were less than the values for trace element contents of termiteria soil reported by Semhi et al. [18], in which (Sr = 1163, Ba = 122.7, V = 133.2, Ni = 63.4, Cr = 152.3, Zn = 80.4, Cu = 50.8, Zr = 526.5, Rb = 29.1, Eu = 0.7 and Yb = 1.55) µg/g.

Some trace elements are essential for the well-being of both plants and animals. For instance, Zn is essential in plants for production of auxins, activities in enzymes, protein synthesis, regulation and consumption of sugar, formation of chlorophyll and root development. Cu functions as catalyst in photosynthesis, respiration, enzyme systems, metabolism of carbohydrates and protein, in flavoring fruits and storage ability [10]. Similarly, it has been on record that some of the trace elements such as Zn, Se, Cu, to mention a few, are essential for maintaining the metabolism of human body below certain concentration threshold, above which they are poisonous [19].

Table 1. Minerals identified in *Termitera* (T) and 10 meter (10 m) adjacent soils in the study area (Maiha)

Minerals	Compound name	Chemical formula	Crystal system	Maiha East				Maiha West			
				T^r	T^d	$10m^r$	$10m^d$	T^r	T^d	$10m^r$	$10m^d$
Brucite	Magnesium hydroxide	$Mg\ (OH_2)$	Hexagonal	-	-	-	*	-	-	-	-
Covellite	Copper Sulfide	CuS	Hexagonal	-	-	-	*	-	-	-	-
Dickite	Aluminum Silicate Hydroxide	$Al_2\ Si_2O_5(OH)$	Monoclinic	-	-	-	-	*	-	-	-
Dolomite	Calcium Magnesium Carbonate	$Ca._{1.13}Mg_{0.87}\ (CO_3)_2$	Rhombohedral	-	-	-	-	-	-	*	-
Greenalite	Iron Silicate Hydroxide	$Fe_3Si_2O_5(OH)_4$	Hexagonal	-	-	-	-	-	*	-	-
Ellite	Potassium Aluminum Silicate Hydroxide	$(K,H_3O)Al_2Si_3AlO_{10}(OH)_2$	Monoclinic	-	-	-	-	-	*	-	-
Montmorillonite	Sodium magnesium Aluminum Silicate Hydroxide Hydrate	$Na_{0.3}(Al,Mg)_2 4H_2O(Si_{3.1}Al_{0.9})O_{10}(OH)_2$	Hexagonal	*	-	*	-	-	-	-	-
Muscovite-3T	Potassium, Aluminum, Silicate hydroxide	$(K, Na)(Al, Mg, Fe)_2Si_4 O_{10}(OH)_2.4H_2O$	Hexagonal	-	*	-	-	-	-	-	-
Microcline	Potassium Aluminum Silicate	$K\ Al\ Si_3O_8$	Anorthic	-	*	-	-	-	-	*	*
Orthoclase	Potassium Aluminum Silicate	$K(Al, Fe)\ Si_2O_8$	Monoclinic	-	-	-	-	*	-	-	-
Phillipsite	Potassium Sodium Calcium Iron Aluminum Silicate hydrate	$K\ Na\ Ca\ Fe\ Al\ Si_{6.39}H_2O$	Orthorhombic	*	-	-	-	-	-	-	-
Quartz	Silicon oxide	SiO_2	Hexagonal	*	*	*	*	*	*	*	*
Rutile	Titanium oxide	TiO_2	Tetragonal	-	-	*	-	*	*	-	-

*Key: r = Rainy Season, d = Dry Season, __ = Absents, * = Present*

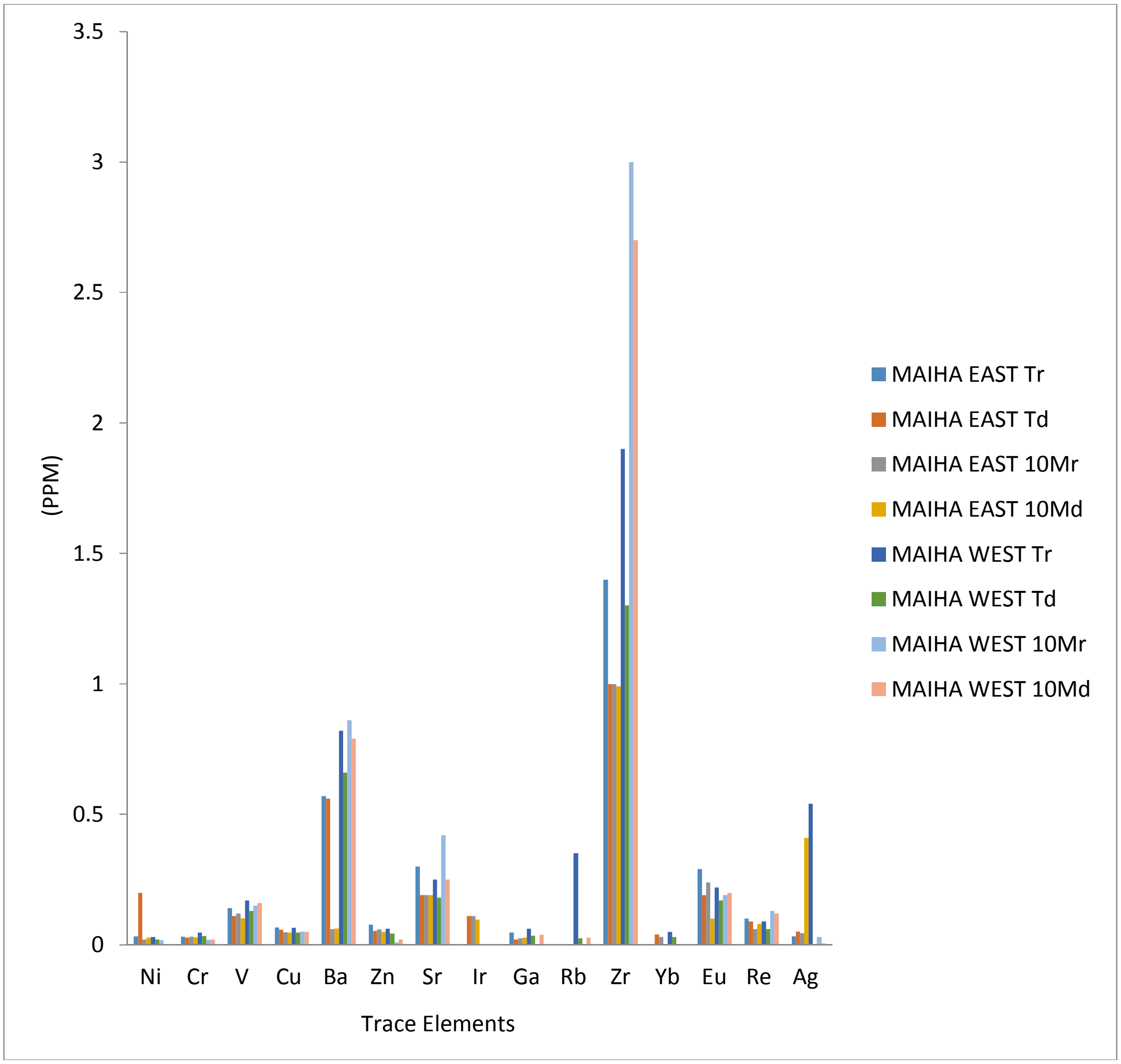

Fig. 1. Elemental composition of *Termiteria* (T) and ten meter (10 M) soils in the study area (Maiha) during rainy (r) and dry (d) seasons

Single factor analysis of variance (ANOVA) was used in testing for variation between termiteria samples and ten meter adjacent soil samples for both dry and rainy seasons. $P < 0.05$ indicates lack of significant differences between the aforementioned parameters.

4. CONCLUSION

The results of this work carried out to assess minerals and trace element contents of termiteria and ten meter adjacent soils during dry and rainy seasons indicated, Presence of thirteen different minerals in the samples analyzed by XRD. The minerals wee; quartz microcline, rutile, montmorillonite, brucite, covellite, dickite, dolomite, greenalite, elite, muscovite-3T, orthoclase and phillipsite and fifteen trace elements which were detected in the samples analyzed by XRF, these include; Zr, Ba, Ag, Sr, Rb, Eu, Ni, V, Re, Ir, Zn, Ga, Cu, Yb and Termiteria can serve as a tool for preliminary mineral exploration and a direct source of some important trace elements for geophagic individuals. On the hand, the danger posed by associated trace elements and over consumption of the essential ones beyond their threshold concentrations are major health risk.

ANOVA treatments of the data from this work showed that the contents of the termiteria soils distributed up to ten meters away from the termiteria.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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