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Comparative Analysis of Termiteria and Surrounding Soil Properties in the University of Agriculture, Makurdi, Nigeria

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ABSTRACT

Variations in the properties of termitaria and their surrounding soil properties within the University of Agriculture Makurdi were investigated using routine soil analysis protocol. Parameters such as texture, pH, cationic exchange capacity (CEC), organic carbon (OC), available phosphorus (AP) and total nitrogen (TN) were determined alongside with the elemental (Cu, Mn, Zn, Fe, Cd, Pb, Na, K, Ca, Mg and Al) analysis. There were clear disparity in the texture (clay content), pH level, AP and TN within the mound and in the environs. Similarly, elemental analysis shows significant variability of the elements among sites ranging from 0.02-196 mg/kg and 0.01-172 mg/kg for the termitaria and surrounding soils, respectively. The predominant analyte is Al, which is the most abundant element in the earth crust. The results show that trace elements such as Mn and Fe, are significantly higher in the termite mounds compared to the surrounding soils. Therefore, we recommended that farming should be carried out very close to the termitaria soils since these elements were essential to plants and animals.

Keywords: AAS, Heavy metals, Makurdi, Soils, Termites

INTRODUCTION

Termites are eusocial insects that live in colonies composed of individuals from more than one generation (Dawes, 2010). Termite's colonies are composed of reproductive pair (king and queen) and their offsprings of thousands of non reproductive individuals. This group is divided into workers and soldiers, the workers perform most of the task including foraging and repairing the mounds while the soldiers are responsible for the defense of the kingdom, soldiers fight to defend their territory and to protect every member of the family. Taxonomically, termites belong to the order of the Isopteran, phylum: Arthropoda, class insecta, kingdom: Animalia and six families are distinguished as follows: *Mastotermitidae, Kalotermitidae, Termopsidae, Hodotermitidae, Rhinotermitidae, and Termitidae* (Krohmer, 2004).

The kalotermitidae, termopsidae and rhinotermitidae species live within wood, while the others live inside the soil matrix in nests that are better described as diffuse gallery system. Some of the termitidae build very architecturally complex nests, albeit completely subterranean. Others, while keeping intricate gallery system inside the soil, still build mounds (Fig. 1) emerging from the soil surface. Termitaria can also shelter other organisms or are important nutrients hot-spots for plants and their associated fauna. Therefore, it has a high ecological role which cannot be disregarded.

Generally, termites are affected by the environment where they live when inflicting physical and chemical changes in the plant-litter-soil system. They do so through nesting sheeting, farraginous, and several modes of feeding behavior. These activities influence to a great extent the local soil biota (Radojevic *et al*, 2005). Termites can transform clay, k-feldspars into kaollinite, use it as a cementing agent during mound construction and synthesize organo-metal complexes (Adekayode *et al*, 2009). Arshad (1981), studied the chemical properties of the mound soil built by macrotermites in East Africa, he concluded that mounds are built of subsoil which is not affected in its chemical properties by the termites. Peterson (2010) reports that in certain areas of leveling of termitaria, there is a formation of slicks spots (alkali affected patches). These slick spots are as a result of termitaria leveling that occurs only in areas with saline ground water. Jouquet (2005) reported that microhabitats are created by termites which are favourable for the development and sustenance of symbiotic micro-organisms, providing them with optimum security from predators and other interferences, minimum or loss extreme fluctuations of wetting and drying cycles, as well as abundant and accessible nutrients. Also, termite's effects resulted in decreased productivity of dominant shrub and changed the composition of spring annual plant community. Kaschuk *et al* (2006) reported termites activity in relation to grassland soil attributes.

Fig. 1: Typical Termitaria Soil Within the Study Areas

In tropical savannas, trees associated with termites' colonies remained green throughout the year due to the sustenance of water from termite colonies well into the dry season (Turner, 2006). African farmers also collect termite mound soils and apply to cropped fields as it can be rich in available nitrogen, total phosphorus and organic carbon than adjacent soil (lopez-Hernandez *et al*, 2001).

Among termites, the genus macortermes in Africa had been identified to have most spectacular effects on the soil as they build large mounds which can be about 12 to 18 meters in diameter and up to 7 meters high (Mitchell, 2002). The underlying philosophy of the University of Agriculture Makurdi is that the average Nigerian farmer should have easy access to the fruits of scientific agriculture. This means that the University scientific community must work on the key practical problems of village farmers. Therefore, characterization of physiochemical properties of both the termitaria and its surrounding soils within the University community is very important as indices for educating the local farmers. Since Students Industrial Work Experience Scheme (SIWES) is usually carried out within the University soils especially those in the College of Agronomy.

MATERIALS AND METHODS

Sampling

Soil samples (10g) were taken within the co-ordinates of the University of Agriculture Makurdi {from south core (ST), the north core (NT) and another located in the central part of the university community (MT)}. The termiteria were randomly selected and seven samples were collected from each termiterium, two from each mound and five from their surroundings making a total number of twenty one samples in all. Sampling was done between 7^{th}-11^{th} April 2014, and the analysis was carried out over four weeks within the month of May 2014. Soil samples were collected from different positions at 10, 20, 30, 40, and 50 meters away from the termiteria, each 10 meter location was labeled SS1-5, NS1-5 and MS1-5 accordingly. Where SS, NS, MS are: south core surrounding soil, north core surrounding soil and middle core surrounding soils respectively.

Method

About 2.0g of air-dried soil sample was weighed into a 150mL beaker and 20mL of concentrated HNO_3 was added to it and well covered with a glass lid, this mixture was allowed to stand for one hour before the careful addition of 15mL of concentrated $HClO_4$ acid. It was placed on an electric hot plate to digest at 200 - 250°C until the mixture turned yellowish in colour in about an hour. The digest was dissolved in 0.1M HCl and filtered into a 250mL volumetric flask and made up to mark with deionised water used three times in rinsing the digestion container (Radojevic *et al,* 2005). Finally, the elements were determined by Atomic Absorption Spectrophotometer (AAS). Analytical grade salts of the metals to be analyzed were obtained from Zayo International, Jos, Nigeria, and standard solutions of the salts were prepared for a calibration curve. Their concentrations were determined from the standard curve (Glen *et al,* 1973). Calculation: If X = mg of Cu, Fe, Mn, Zn etc are obtained from the standard curve.

$$\mathrm{Cu\ (mg.Kg^{-1})} = \frac{\mathrm{X\ (mg)\ \ x\ \ solution\ vol.(mL)\ x\ 10^3}}{\mathrm{Aliquot\ (mL)\ \ x\ \ Sample\ wt\ (g)}}$$

Soil pH

10g of <2mm sieved air-dried soil sample was weighed into 25mL beaker, and 20 mL of distilled water was gradually added. This suspension was allowed to stand for 30 minutes and later stirred thoroughly with a glass stirring rod. The glass electrodes were inserted into the suspension to take the pH measurement (Glen *et al, 1973*). Similar procedure was repeated for pH in 0.01M $CaCl_2$ by adding 20mL of 0.01M $CaCl_2$ solution (Charman *et al*, 2000).

RESULTS AND DISCUSSION

The percentage average particle size distributions of the termitaria soil samples were 70.8%, 12.4% and 16.8% for sand, silt and clay, respectively. While the surrounding soil contains 80.9%, 12.8% and 6.21% for sand, silt and clay, respectively. Generally, the clay content of the termitaria soil was about three times higher than the surrounding soils clay, while the sand and silt were slightly lower in the termitaria soil. Termite mounds have the capacity of enriching the soil with clay, because termites except in rare cases select clay particles for their numerous activities, this characteristic has greatly affected the concentration and availability of soil nutrients in the anthill (Huldo and McDowell, 2004).

The termitaria soil pH is lower compared to surroundings in both aqueous and calcium chloride solution as shown in Table 1. The solubility metals investigated depends squarely on pH than on redox potentials (Evans, 2003). The difference between the pH in the mound and surrounding is caused by the accumulation of calcium carbonate in mounds, while the decrease in pH is associated with high organic matter content in mounds. The pH values obtained was in agreement with literature values, as the presence of termites in the soil may bring about an increase in pH of the soil according to Marais (1989). Their gut is formed by the five compartments that presents rising gradient to pH of up to 12.5 and different status of oxygen and hydrogen (Huldo and McDowell, 2004). The high pH in termite gut is also necessary for the breaking down of soil particles; kaollinite becomes less crystalline after passing through termite guts due to high pH.

CEC is pH dependent, it is greatly affected by pH, and it is lower when the soil is acidic and highest when alkaline. Porosity also affects the soil CEC because the more porous the soil, the more easily electricity is conducted. The CEC of the termitaria soil sample (6.5cmol/kg) was slightly higher than the surrounding soils (6.3cmol/kg) and hence high clay content could be responsible for this charge due to its colloidal nature (see Table 1). Clay carries negative charge that easily attracts anions that are readily exchangeable and clay soil acts as a giant magnet (Krohmer, 2004).

Table 1: Concentration of some selected soil properties at the sampling point.

Sampling Point	Soil Properties					
					pH	
	CEC (cmol/kg)	OC (g/kg)	AP (g/kg)	TN (mg/kg)	H_2O	$CaCl_2$
Termiteria	6.5	5.2	7.6	0.7	6.5	5.7
Surrounding	6.3	5.9	5.9	0.5	6.5	5.9

The organic carbon (OC), total nitrogen (TN) and available phosphorus (AP) of the soils investigated were also presented in table 1. The AN and TP of termitaria soil were higher compared to surroundings in all the sample areas. However, the OC of termitaria soil investigated is lower compared to surrounding. The consumption of humus by soil-feeding termites and accumulation of N_2 in termite biomass and its subsequent release into the system upon death is also thought to be a considerable input to N_2 and P into the system. Similarly, termites that feed on dead wood, litter, and grass also facilitate the cycling of mineral elements and the formation of humus (Sileshi *et al., 2010*). Roland (1993) reported that termite excrement and fecal is rich in N_2, nitrate levels fluctuate widely depending on the season or rainfall, this could be responsible for the higher N_2 level in the study area as indicated in Table 1. Phosphorus (P) level in soil can affect the availability of P, especially if it has been built over the years and the P fixing capacity is satisfied (at soil pH of < 7.0). However, desorption of phosphates in the soil causes availability of P in the soil to increase. In a similar study, soil samples collected from top, middle and bottom of termite mounds and from the adjacent areas revealed a greater content of K, P, Mg, OC and lowered pH (Kaschuk *et al*, 2006).

Table 2: Average concentration (mg/kg) of available elements and exchangeable bases in soils.

Sampling points	Elements										
								Exchangeable bases			
	Cu	Mn	Zn	Fe	Cd	Pb	Al	Na	K	Mg	Ca
Termitaria	1.3	76	1.8	21	0.1	8.3	160	0.3	0.2	1.1	3.5
Surrounding	0.8	64	1.5	15	0.002	7.4	157	0.2	0.4	0.7	2.2

The termitaria accounts for elevated concentrations of important nutrients such as Nitrogen, potassium, phosphorus, magnesium and calcium. The mean concentrations of exchangeable bases are presented in table 2 and the data obtained were higher in the termitaria as compared to surrounding soils except K. The result was in agreement with the literatures even though, mean concentration of K was a little higher in the surrounding soils (Krohmer, 2004; Sianme, 2005; Ackerman *et al*, 2007; Sileshi *et al.,* 2010). Termite mounds are habitat of high socio-economic importance, the termiteria is richer in minerals like Ca, Mg, K, Na and also the accumulation of all these bases increases the pH value of the soil (Joseph *et al.,* 2012).

Table 3 presents the mean value and standard deviation of elements estimated in each samples at various locations. The result revealed that Al was the highest among the metals (Cu, Mn, Zn, Fe, Cd, Pb, Al) determined while Cd was the least in both termitaria and surrounding soils. The high value of Al may be connected to its most abundance in the earth crust of about 7 percent (Ackerman *et al*., 2007). The low value of Cd in the soil sample could be attributed reduced level of anthropogenic activities except farming only. The results obtained were in agreement with literature values as they state that termite mounds are richer in minerals (Joseph, 2012).

Table 3: Mean and Standard Deviation of Available Elements (mg/kg) at each Sampling Points.

Location Code	**Cu**	**Mn**	**Zn**	**Fe**	**Cd**	**Pb**	**Al**
ST	1.58±4.8	75.3± 4.8	1.26± 0.2	22.6± 0.2	0.25± 0.01	9.36± 0.2	196± 1
SS	1.35± 0.1	61.2± 3.7	1.41± 0.3	20.1± 2.0	0.01± 0.1	8.09± 0.6	172± 1
NT	0.84± 0.4	29.8± 1.2	1.18± 0.3	21.4± 0.5	ND	8.07± 0.1	101±3
NS	0.68± 0.2	52.4± 6.1	1.04± 0.4	14.1± 1.6	0.01± 0.1	7.47± 0.7	139± 1
MT	1.44± 0.2	122± 8	3.06± 2.7	17.4± 2.6	0.02± 0.1	7.51± 0.2	183±3
MS	0.42± 0.1	79.3± 1.0	2.06± 2.3	10.3± 1.5	0.03± 0.1	6.59± 0.4	160± 2

ND: below the detection limit.

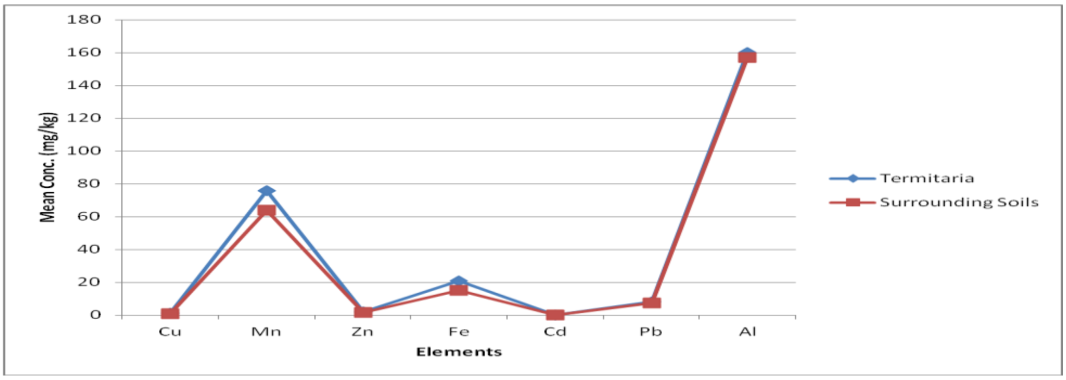

Fig. 2: Average Concentrations of Elements in the Termitaria and Surrounding Soils

Al has the highest concentration with its cumulative in both termitaria and the surroundings soils in the order Al > Mn > Fe > Pb. Similarly, Cu and Zn are present at very low concentrations while Cd is almost not detected in some cases as shown in Fig. 2. Also, the essential elements to living organisms (such as Mn and Fe) were mostly altered to higher concentrations compared to its surroundings (see Fig. 2). There is a clear disparity between the termite influenced soil and the surrounding soils with good agreement across all samples with about 80% difference, the 20% that disagrees with this result could be due to some extreme conditions. As termites embark in search of moisture, they bring a considerable amount of mineral material to the surface to include in their nests, potentially altering soil properties at the surface (Huldo and McDowell, 2004).

CONCLUSION

This work clearly shows that there are variations between the chemical properties of the termite mound and the surrounding soils. These variations are caused by certain ecosystem services provided by termites, such as bioturbation and soil formation, nutrient transportation and cycling, litter decomposition, soil animal and microbial diversity, amendment and remediation. Therefore, the bye-products which is the reworked soil, is a geo-concentration compared to its surrounding soil. Also, the essential elements to plants and living organisms (such as Mn and Fe) were mostly altered to higher concentrations compared to its surroundings.

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