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Presence of metals in farmland edible termites in Mazabuka District, Zambia

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Edible termites have played an important role in the history of human nutrition due to their nutritional value. Despite their nutritional body content, it is known that during their termitarium construction, termites accumulate metals in their bodies. This study examined the heavy metal content in selected edible termites for food safety. The household survey was carried out in 8 camps of Magoye and Stateland farming blocks in Mazabuka district. The study was done to determine human activities in the farmlands. A structured questionnaire was used to collect data via one-on-one interview. A total of 362 respondents participated and their farmland activities included; mixed farming, agrochemical usage, transportation, milling, mining and termite harvesting. Composite samples of selected edible soldier termites and the nest soil were analysed for the presence of Cu, Co, Pb, Mn, Ni, Zn, Fe using atomic absorption spectrophotometer. Results in nest soil showed all analysed metals, with Mn having the highest mean 6.65±1.73 mg/L and sampled termites showed presence of all heavy metals except Ni and Co, with Fe having the highest mean value of 5.38±4.75 mg/L. ANOVA revealed a significant difference with *P*<0.05 in Co, Mn, Zn, Ni in nest soil and no significant difference in sampled termites. There was no significant Pearson correlation between heavy metals in soil and edible termites, suggesting an active regulation of metals by termites.

Keywords: Edible insects, entomophagy, termitarium, Magoye, Zambia.

INTRODUCTION

Entomophagy which is the consumption of insects, has globally increased over the years due to the demand for protein and increase in population, projected to reach 9.7 billion by 2050 (Murefu et al., 2019). According to Van Huis et al. (2013), “It is estimated that insects form part of the traditional diets of at least two billion people” and more than 2000 edible insect have been listed in the world list (Jongema, 2015). A total of 470 species have been recorded to be consumed in Africa (Kelemu et al., 2015). Termites as edible insects have played an important role as a source of food across continents like Africa, Asia and Latin America due to their positive

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impact in human nutrition (Idowu et al., 2014). The study by Netshifhefhe et al. (2018) in the three local municipalities of the Vhembe district in the Limpopo province in South Africa showed that the majority of the respondents (97.96%) grew up eating termites as they were reported to enhance health, ease digestion and good for breastfeeding mothers. Apart from termites being edible insects, they are also considered as crucial members of the soil ecosystem (Ghaly and Edwards, 2011). They improve agricultural land, help regenerate degraded land and tree establishment, shelter other organisms, medicinal usages, rituals, serve as bio-indicators of metals in the environment and termite mounds are owned by individual and form part of their inheritance when they die (Denloye et al., 2015; Nkunika et al., 2013).

Studies on nutrient analysis have shown that termites are high in nutritional values as they are a good source of protein, fats, fibre, key vitamins, and minerals (Fombong and Kinyuru, 2018; Ntukuyoh et al., 2012). Termites feed on rotting organic matter of soil, plant parts, wood and also unintentionally ingest contaminated plants/debris thereby concentrating heavy metals in the process (Butt et al., 2018; Van der Fels-Klerx et al., 2018). It has therefore been established that termites would serve as a media for heavy metals pick-up due to their feeding on soil as well as termitarium construction and in the process accumulate metals in their bodies (Denloye et al., 2015; Musa et al., 2014). In addition the range and source of difference in mineral content within and between species remains largely unknown (Verspoor et al., 2020). Literature reviews show that most of the studies on edible insects, are on nutritional composition, and studies on the safety of the edible insects as regards to heavy metals are still limited, especially in Africa (Imathiu, 2020; Murefu et al., 2019). The limited knowledge may continue to hinder the promotion of edible insects and consumption in some ethnical groups. Other studies have suggested that the promotion of edible insects can be achieved by ensuring food safety (Van der Fels-Klerx et al., 2018). Masindi and Muedi (2018) stated that "heavy metals are known to occur naturally but anthropogenic activities introduce them in large quantities in different environmental compartments". Omwoma et al. (2014) in their study concluded that addition of nitrogenous fertilizers, herbicides and sewage sludge by anthropogenic activities in the River Kuywa had a positive impact on the levels of this heavy metal (Cd, Cr, Pb). Mohammed et al. (2011) also reported that heavy metals are released in the environment due to human activities. For example, Idowu et al. (2014) concluded that higher levels Cr^{2+} and Zn^{2+} in termites from farmland could have been as a result of residues of pesticide.

The present study aimed at determining human activities and their effect on the farmland termites in the study area as well as examining heavy metals namely Cu, Fe, Zn, Pb, Mn, Ni in the farmland edible termites in relation to the surrounding.

MATERIALS AND METHODS

Description of the study site

The study was conducted in Magoye and Stateland farming blocks in Mazabuka district, Southern province of Zambia. Magoye is located at latitude 16° 14' 1'' South and longitude 27° 36' 33'' East, Stateland is located at latitude 15° 58' 19'' South and longitude 27° 52' 32'' East. These study areas are located in Agro-ecological region II. The region has the favourable agro-ecological conditions in regards to rainfall, soil quality (Siegel, 2008) and 80% of the land in the district is used for agriculture purposes (Kasali, 2001). The mean annual rainfall is 800-1000 mm extending from mid-November to the end of March, although there is a single rainfall peak in December (Kenneth et al., 1967; Petrik et al., 2016). The temperatures are high prior to start of rains between September and November, with maximum temperatures ranging from 30-35°C. The main vegetation type found in this district is Munga, Miombo, Mopane woodlands and open savanna grasslands. Bantu speaking Tonga people occupy the area, and their main occupation is farming. In terms of household food security, maize, sugarcane, cotton, sorghum, wheat, soybean, groundnut, beans with fruits like bananas, citrus fruits and guavas are grown (Siegel, 2008; Livelihood, 2014; Kasali, 2001).

The farmland household survey was carried out in the eight farming camps namely; Nkonkola, Chivuna, Munjile A and B, Ngwezi A and B, Dumba and Oliver. Figure 1 shows the study site where the study was conducted.

Farmland household survey

The local names of termites in Tonga (common language spoken by respondents) are called 'Inswa, Selele, Machenya, Chuulu' and these were used in the questionnaire due to their familiarity with the respondents. Information about demographic characteristics was obtained which included; the age, gender, period of stay in the area and the level of education. The survey investigated land owned, food crops grown, livestock kept, control of weed, pest and disease. On edible insect awareness and management, the survey mainly investigated; knowledge of edible insects, beneficial elements of termites, capture, preparation and consumption of termites. The survey also focused on possible sources of heavy metals in these farmlands.

The target population were farmers aged 15 years and above. The age limit was arrived at with an assumption that those people have more understanding about farming. Respondents were purposively sampled via agriculture extension officers and camp chairpersons and camps purposively selected based on agriculture activities. Based on the 2020 Mazabuka district farmer register for the two farm blocks where the survey was conducted, there was a total population size of 17581.

Therefore, statistically the sample size of respondents in Mazabuka districts was determined as described by Cochran (1977):

$$n = N \times \frac{\frac{Z^2 \times p \times (1-p)}{e^2}}{\left[N - 1 + \frac{Z^2 \times p \times (1-p)}{e^2}\right]}$$

Where z = standard normal deviate at 95% confidence interval = 1.96; p = the estimated proportion of an attribute present in the

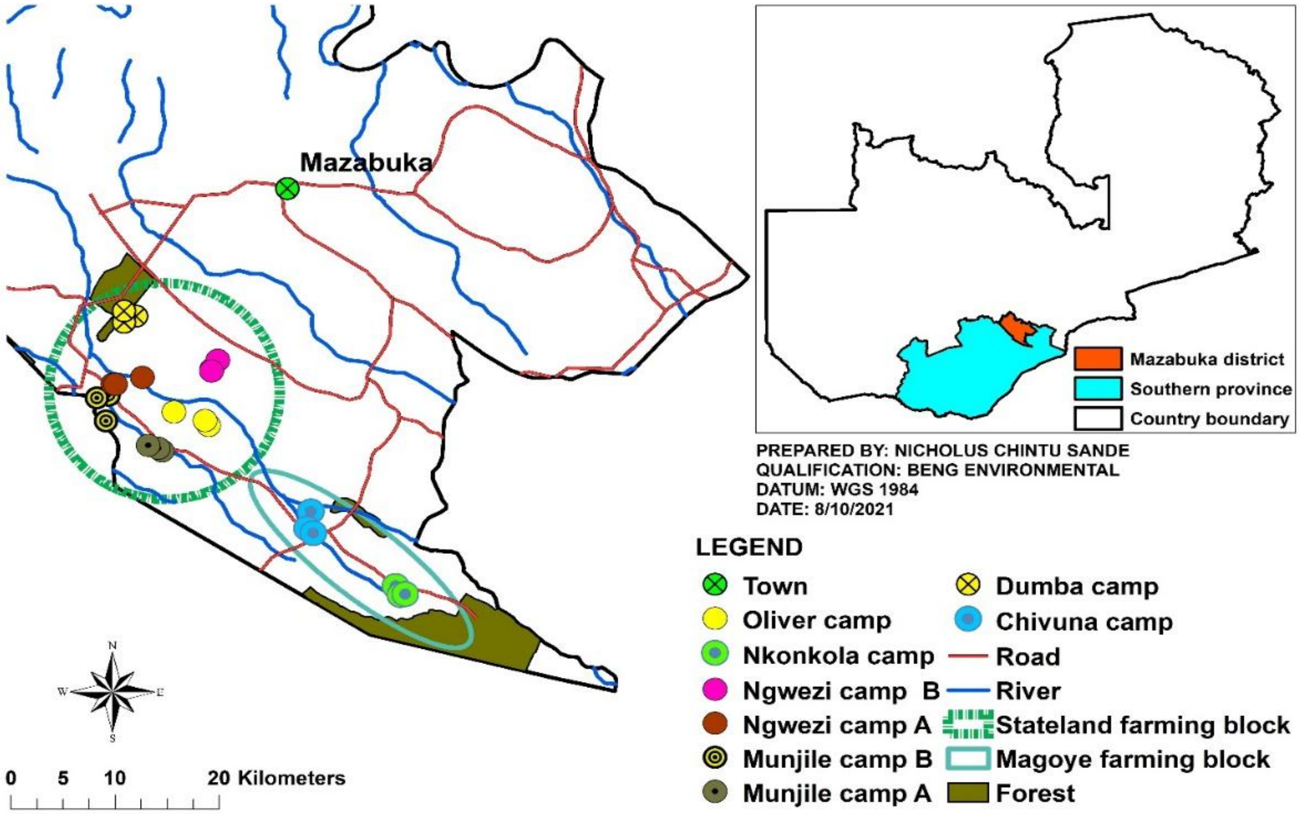

Figure 1. Map showing the study sites.

sample population (uncertain) (0.5 or 50%); e = allowed standard error = 0.05 and N = population Size 7581 and n= sample size.

Thus, given

$$n= 17581 \times \frac{\frac{1.96^2 x\ 0.5x\ (1\text{-}0.5)}{0.05^2}}{\left[17581\text{-}1+ \frac{1.96^2 x0.5\ x\ (1\text{-}0.5)}{0.05^2}\right]} = 375.97$$

The final sample size was calculated as follows:

$$\mathrm{nf} = \frac{\mathrm{n}}{1 + (\frac{\mathrm{n}}{\mathrm{N}})}$$

This gives $\mathrm{nf} = \frac{375.67}{1+(\frac{375.67}{17581})}$

Therefore nf = 368.30 ~ 368. Therefore, out of the 2 farming blocks the target population of approximately 368 was anticipated to be sampled, instead 362 were sampled. A semi-structured questionnaire was administered to the respondents from each structured household.

Sample collection

A randomized complete block design (RCBD) with interactions was used as camps served as blocks, while the selected sampling points served as treatments. Each treatment was replicated three times to reduce variability in results of the heavy metals of the treatments. Termites' collection was carried out by excavation through the mounds or nests in decaying wood and termites were collected using forceps. Termite samples were preserved in Pyrex bottles and 500 ml falcon tubes containing 70% ethanol solution and while others were oven dried at 50^0C for 3 h. Dried termite samples were packaged and sealed in air tight polythene bags prior to analysis in order to prevent spoilage and stored in the refrigerator at a temperature of 25 ± 2^0C. Also, soil samples were collected randomly at a depth of 20 cm from selected termite mounds/nests and subsequently analysed for heavy metals respectively.

Termite identification

Edible termites of the solider caste samples preserved in 70% ethanol were identified to genera at Tropical Disease Research Centre Insect Laboratory. Salient morphological characters used in the identification included the presence or absence of compound eyes, mandiles, shape of pronotum, fontanelle and labrum. A key to the termite genera based on the soldier caste (Mitchell, 1980) was used for this purpose.

Preparation of samples and experimental analysis

Dried edible termite samples weighing 0.2 g was digested in a mixture of supra pure grade 30 ml nitric acid and 5 ml perchloric acid. The mixture was then heated to dryness until brown fumes disappeared and cooled to room temperature (24^0C). Digests were topped up to volume with distilled water. The digest solution was then filtered in 100-ml beakers using 125 mm Whatman filter paper

No.1 (Wambua, 2015). Digests were analysed for metal contents using PinAAcle 500 flame atomic absorption spectrophotometer.

Soil samples weighing .0 g were pulverised and sieved (using 2.0-mm wire mesh), placed in a beaker and digested in 40 ml of Aqua regia (mixture of 30 ml hydrochloric acid and 10 ml nitric acid). The mixture was then heated for 20 min at 105^{0}C on a hotplate. Afterwards, digest was topped up to a volume with distilled water and reheated for 10 minutes to complete digestion. Cooling of the digest at room temperature was done and the digested solutions were filtered into 100-ml beakers using 125 mm Whatman filter paper No.1 (Ahmadi Doabi et al*.,* 2019). Laboratory sample analysis was conducted from the Copperbelt University, School of Mines and Mineral Sciences Department and samples were transported in air-tight polythene bags.

Bioaccumulation factor

Bioaccumulation Factor (BAF) was determined in order to understand the soil to termite transfer mode of heavy metals. The BAF is the ratio of the substance concentration in the animal's body and the substance in the environment. It is considered bioaccumulation when metal concentrations in organisms are larger than the concentrations of the environment. Thus, for values ≥ 1, bioaccumulation is accepted. The BAF is described by the following formula:

BAF = Organism metal concentration / Soil metal concentration

Where organism and soil metal concentration represent the heavy metal concentrations in the termites and soils, respectively (Souto et al*.,* 2019).

Statistical analysis

Data entry management and preliminary summaries were done on MS Excel spreadsheet and Epi Info v7.1 (Center for diseases Control and Prevention, 2020). The means, median, ranges, standard deviations and Pearson correlation of the data collected were determined. Experimental treatment significant differences ($\alpha < 0.05$) were determined using analysis of variance (ANOVA). All statistical analyses were performed using SPSS v21 version software programme.

RESULTS AND DISCUSSION

Demographic information

A total of 331 participants had lived in the study farms for 1-85 years, followed by three individuals who only lived for months and lastly a total of 28 respondents could not account for the years or months they had lived on the study farms. As regards ownership of land recorded among farmers respondents; 45.9% had <5 ha, followed by 31.5% with 2-5 ha, 13% with 1 ha and below while 9.7% said they did not know their land size. Table 1 summarises the demographic information obtained, based on the variables; age, gender and the level of education.

Table 1 indicates that the study was dominated more by males (62%) compared to females (38%) and out of the 362 respondents, the majority of them were above 30 years. This concurs with the finding of Eifediyi et al*.* (2014). Most of the respondents attended primary school (36%) and junior secondary (35%), with only a few having achieved tertiary level (3%). The three major crops grown in the farmlands were maize (98.6%), groundnuts (84.0%) and sweet potatoes (66.9%). This is in agreement with the work of Livelihood (2014) on Tonga people. Other crops grown included; Sorghum (15.2%), Vegetables (55.2%), Cassava (17.4%), Cotton (27.1%) and Cowpeas (26.2%).

Less than 10% accounted for sugar cane, soya beans, beans, sun hemp and sunflower. However, for livestock, farmers reared goats, cattle, sheep and poultry. Some respondents engaged in other non-agriculture activities, which accounted for less than 10%; transportation (3%), mining (1.1%), industries (2.2%) and milling (1.1%). The minority of farmers that were knowledgeable on sources of heavy metals reported; atmospheric decomposition (18.8%), agriculture (8.6%), waste disposal (6.4%), mining activities (5.0%) and industry (3.3%). These confirm the study by Adelekan and Abegunde (2011) on heavy metal accumulation routes. A 2x2 chi-square test of independence between the two groups, education levels and usage of pesticides revealed a strong significant relationship ($X^2 = 24.171$; D.F. = 5; p = 0.000), indicating that education had an effect on the use of pesticides as observed by Eifediyi et al. (2014). There was a significant relationship between the size of land and use of pesticides ($X^2 = 10.671$; D.F. = 3; p = 0.014). This could imply that the bigger the land, the more the respondents used chemical products to control insect pests. It was concluded that human activities were influenced by literacy levels, size of land and incidence of pest and diseases on the farmlands.

Control of weed, pests and diseases

As highlighted by El-Barasi et al*.* (2018) and Yêyinou Loko et al., (2017), respondents in this study also acknowledged that crops and livestock are mostly susceptible to pests and diseases and control methods include; chemical (61.3%), biological (52.8%), integrated pest management (40.3%). Only (39.0%) were formally trained on how to control pests and diseases. The mostly used pesticide is insecticides (85.1%), herbicides (53.3%), fungicides (3.6%) and rodenticides (1.7%). To maintain soil fertility conditions in the area, farmer participants use fertilizers (98.3%), crop rotation (77.3%), tillage (50.8%) and intercropping (37.6%). When it came to how often they meet experts for consultation, the farmers said "most often" (8.6%), "sometimes" (57.5%) and "never" (34.0%). This study concurs with that of Atafar et al. (2010) where farmers consumed a lot of fertilizer without any evaluation of land requirement by experts. These anthropogenic activities suggests sources of heavy metals in the soil and observation of these

Table 1. Demographic information per camp.

Variable	Camp								Frequency	Cumulative percent
	Munjile B	Munjile A	Dumba	Ngwezi A	Ngwezi B	Chivuna	Nkonkola	Oliver		
Sample size	27	26	47	35	40	76	69	42	362	100
Gender										
Male	15	18	32	16	28	52	38	26	225	62.15
Female	12	8	15	19	12	24	31	16	137	37.85
Age										
15-20	1	1	1	0	2	0	0	1	6	1.66
21-25	1	1	1	2	3	5	6	3	22	6.08
26-30	5	24	6	5	3	9	11	3	66	18.23
<30	20	0	39	28	32	62	52	35	268	74.03
Level of education										
Non	2	2	2	1	1	4	7	0	19	5.25
Primary	6	10	20	10	8	31	29	18	132	36.46
Junior Secondary	16	9	16	18	16	25	20	9	129	35.64
Senior Secondary	1	5	7	6	12	15	10	13	69	19.06
Tertiary	2	0	2	0	2	1	3	2	12	3.31
Don't know	0	0	0	0	1	0	0	0	1	0.28

activities in agriculture land corroborates the finding of Ahmadi Doabi et al. (2019) and Hossen et al. (2015) that human activities results in Zn, Cu, Ni and Fe accumulation in the agricultural fields.

Edible insects' awareness and management

The information on edible insects was obtained focusing on; consumption, preparation, beneficial elements of termites and control of pestiferous termites. The respondents described alates and soldier termites (99.7%), flying ants (85.9%), caterpillars (84.5%), grasshoppers (83.1%), crickets (63.3%), stink bugs (62.7%) and long-horned beetles (4.1%) as edible insects, in the farmlands with *Macrotermes* genera of termites predominately being eaten as food and feed, with a frequency percentage (94.2%) as shown in Figure 2. The findings of this study are in line with those of Verspoor et al. (2020). Soldiers and alates were used as both food and feed. Collection methods of termites by respondents were similar to those reviewed by Alamu et al. (2013); which included hand picking, digging of soil, and luring of alates into water traps. Preparation and preservations methods by respondents were similar to those reported by Ayieko et al. (2010) and Melgar-Lalanne et al., (2019). The most common preservative method used include; salting and making them into powdered form for children's porridge or relish and as protein for animal feed. The beneficial elements of termites and their mounds were in line with those reported by Daniel and Getu (2015).

Termite infestations were experienced by respondents in the farmlands who reported that termites in their fields fed on dead wood, soil and live plant materials such as maize, groundnuts, sugarcane and fruit trees being the most affected. Dao et al. (2020) in his study pointed out that *Macrotermes* spp were the most economically important termite pests. Overall, 64.4% respondents used chemical control to reduce termite infestations in their farmlands. Other control strategies used, were good nursery management (40.3%), protection of tree seedlings (32.6%), crop rotation (66.9%), providing alternative sources of food (39.8%), avoiding planting susceptible species to termites (13.8%) and maintaining soil organic matter (16.3%). Indigenous user-friendly methods include; crop rotation, wood ash, botanicals, cow dung, urine, physical removal of the queen and directing water off into an ant hill as reported by Logan et al. (1990) and Nkunika et al. (2013).

Accumulation of heavy metals in termites and soil

Heavy metal mean concentrations in the termite samples and heavy metals limits are summarized in Table 3. Zn, Fe, Pb, Mn and Cu were detected at various concentrations in all the termite samples except Co and Ni. Heavy metal concentration ranges were between 0.103 - 10.851 mg/L for Fe, 0.018 - 4.530 mg/L for Mn, 0.052 - 0.868 mg/L for Zn, 0.0678 - 0.272 mg/L for Cu and 0.012 - 0.038 mg/L for Pb. Fe was observed to have

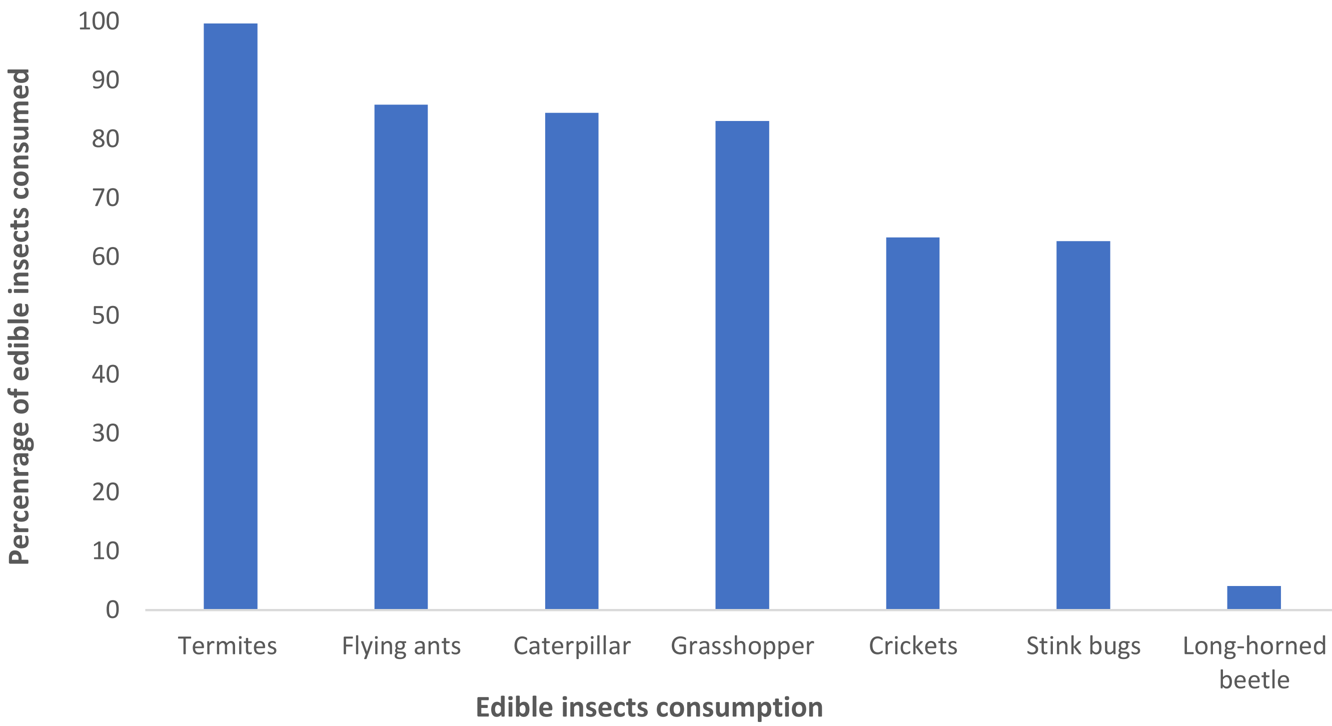

Figure 2. Edible insects consumed by respondents.

Table 2. Specimen genera per camp.

Genera	Magoye Block						Stateland Block																	
	Nkonkola			Chivuna			Dumba			Ngwezi A			Ngwezi B			Munjile A			Munjile B			Oliver		
Macrotermes	1	2	3				1	2							3									
Odontotermes					2	3				1	2	3		2						2	3	1	2	3
Pseudacathotermes					1				3				1			1		3						
Microtermes																			1					
Amitermes																	2							

the highest mean concentration of 5.38±4.75 mg/L. This concurs with Banjo et al*.* (2006), Eneji et al*.* (2015) and Sirimungkararat et al. (2010), thus insects are rich in mineral content copper, zinc especially iron. Based on this, eating of insects can be considered as an alternative of minerals to fight problems of zinc and iron deficiency in developing countries and provide essential micronutrients (Poma et al., 2016). Similarly, Ni was not detected by Denloye et al. (2015) in soldier caste in Lagos, Nigeria while Fe 5.12 was in the same range as those of this study from Chivuna and Oliver camps. One way analysis of variance (ANOVA) at ($p < 0.05$) showed no significant difference in farmland harvested edible termites from the study camps. Some studies described an active regulation of zinc in insects (Diener et al*.*, 2015). Heavy metals in termites were within the internationally accepted concentration levels; hence, the results suggest that further studies be conducted in other agro-ecological regions. Table 2 shows the identified genera per camp site.

In nest soil sample, Cu, Co, Pb, Mn, Zn, Ni, Fe were detected with Mn having the highest mean of 6.65±1.73 mg/L which supports the findings of Eneji et al*.* (2015). One way (ANOVA) revealed a significant difference in Cobalt (0.000), Manganese (0.000), Zinc (0.007) and Nickel (0.012). The least significance difference in Zn among camp sites from the study area suggests agricultural activities such as fertilizer application (Idowu et al*.*, 2014; Lin et al*.*, 2017). Table 4 summarizes the mean concentration and standard deviation of heavy metals nest soil samples analysed and the heavy metals limit in food. The significance levels of heavy metals in soil implies that; even if there is a case of human activities having an effect on the accumulation of heavy

Table 3. Heavy metals mean (X̄ ±SD) in edible termites per camp (mg/L).

Metal	Camp								Heavy metals limits (mg/kg)
	Munjile B	Munjile A	Dumba	Ngwezi A	Ngwezi B	Chivuna	Nkonkola	Oliver	
Cu	0.18±0.04	0.16±0.09	0.08±0.14	0.16±0.07	0.09±0.01	0.14±0.02	0.14±0.06	0.16±0.07	20-50
Co	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	1.0
Pb	0.03±0.00	0.02±0.01	0.02±0.00	0.02±0.00	0.02±0.00	0.02±0.00	0.02±0.01	0.02±0.00	2.0
Mn	1.90±1.00	2.14±2.23	0.00±0.00	1.23±1.46	0.01±0.02	1.37±0.83	2.22±1.37	1.33±1.34	NS
Zn	0.36±0.09	0.45±0.39	0.06±0.01	0.27±0.12	0.27±0.35	0.34±0.12	0.53±0.25	0.27±0.11	100
Ni	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	2.1
Fe	3.68±1.97	3.14±2.81	0.17±0.07	1.18±1.09	0.26±0.11	5.19±4.87	4.59±2.28	5.38±4.75	100

Limits in food.
Source: Anani and Olomukoro (2019); FAO and WHO (2002); and Kapungwe et al. (2013).

Table 4. Heavy metals mean (X̄±SD) in soil per camp (mg/L).

Metal	Site								Heavy metals limits (mg/kg)
	Munjile B	Munjile A	Dumba	Ngwezi A	Ngwezi B	Chivuna	Nkonkola	Oliver	
Cu	0.09±0.05	0.07±0.03	0.08±0.02	0.12±0.05	0.15±0.05	0.16±0.08	0.09±0.00	0.16±0.04	130-140
Co	0.04±0.05	0.00±0.01	<0.01	0.01±0.01	0.01±0.02	0.11±0.05	0.17±0.06	0.03±0.91	240
Pb	0.76±1.28	<0.01	0.15±0.02	0.19±0.10	0.29±0.09	<0.01	0.01±0.16	0.19±0.09	450-300
Mn	2.63±0.65	1.87±0.49	1.96±0.79	2.53±0.22	3.23±0.53	2.47±0.54	6.65±1.73	2.88±0.41	NS
Zn	1.20±1.68	0.23±0.11	1.17±0.30	2.74±1.13	2.85±1.67	0.24±0.07	0.54±0.38	2.97±0.76	200
Ni	0.10±0.08	0.02±0.02	0.03±0.04	0.08±0.04	0.07±0.02	0.17±0.11	0.22±0.07	0.09±0.25	50-75
Fe	3.08±1.34	1.25±0.67	3.05±0.59	3.49±0.76	4.26±0.46	3.34±0.65	4.79±3.03	4.03±0.62	21000

Limits in soil.
Source: Krishna and Govil (2007); Kapungwe et al. (2013); and Wambua (2015).

metals in soil, the levels are not yet directly connected to the levels in the termites of the study area.

Bioaccumulation factor

Soil to insect bioaccumulation factor were analysed and the data was recorded in Table 5. The data obtained in this study revealed that bioaccumulation factor, that is, the ratio of the amount of metal in the body compared to that in the soil varied among the different metal elements with iron having the highest bioaccumulation factor of 12.05 at Munjile A in *Amitermes.* The BF for copper ranged from 0.47 to 5.13, 0.01 to 0.51 for lead, 0.00 to 3.49 for manganese, 0.03 to 6.58 for zinc and 0.03 to 12.05 for iron. This is in support of work done by Zhuang et al*.* (2009) on cotton leaf worm caterpillar (Spodoptera litura larva). Since all the termite samples showed that concentration of cobalt and nickel was below the detectable level of the instrument of 0.01 ppm under study, there was no bioaccumulation factor that was performed for levels of nickel and cobalt. This applied to other soil and termites samples that were below the detectable limits in different metal elements. Findings of this study on accumulation variation complements those of Butt et al*.* (2018); as metal accumulation in insects depends on a range of factors including their age, sex, physiology, and genetics. Also, Idowu et al*.* (2014) research concluded that some species of termites have lower tendency to accumulate heavy metals. Banjo et al*.* (2010) on larvae of *Rhynchophorus phoenicis* (beetle) and *Anapleptes trifasciata* (beetle) found substantial amount of nickel, lead, cadmium, zinc, sodium in the insects. Diener et al*.* (2015) showed accumulation of cadmium with a range of 2.32.and 2.94, lead remained below its initial concentration in feed and zinc decreased from 0.97 to 0.39, when black soldier fly *H. illucens* feed was spiked with cadmium, lead and zinc contaminated chicken feed.

Correlation between heavy metals in soil and heavy metals in termites

Pearson correlation showed no significant correlations (*P*>0.05) between heavy metals in soil and edible termites, which is suggestive of termites having a very low tendency to accumulate heavy metals from the soil

Table 5. Bioaccumulation factor.

Camp	Genera	BF_{Cu}	BF_{Pb}	BF_{Mn}	BF_{Zn}	BF_{Fe}
	Microtermes	0.95	0.01	0.37	0.08	0.47
Munjile B	*Odontotermes*	2.80	0.51	0.95	1.54	1.54
	Odontotermes	3.76	<0.01	0.86	2.21	2.23
	Pseudacathotermes	1.79	<0.01	0.06	0.35	0.21
Munjile A	*Amitermes*	5.13	<0.01	3.49	6.58	12.05
	Pseudacathotermes	1.13	<0.01	0.83	1.17	2.06
	Macrotermes	0.64	0.13	<0.01	0.04	0.03
Dumba	*Macrotermes*	1.68	0.17	0.01	0.06	0.10
	Pseudacathotermes	0.98	0.15	<0.01	0.06	0.05
	Odontotermes	1.38	0.07	1.03	0.10	0.52
Ngwezi A	*Odontotermes*	2.18	0.27	0.35	0.16	0.53
	Odontotermes	0.87	0.10	0.00	0.06	<0.01
	Pseudacathotermes	1.85	<0.01	0.94	2.27	3.20
Chivuna	*Odontotermes*	0.57	<0.01	0.32	0.98	0.64
	Macrotermes	0.93	<0.01	0.42	1.16	0.84
	Macrotermes	2.04	<0.01	0.58	1.66	2.50
Nkonkola	*Macrotermes*	1.17	0.48	0.09	0.25	0.49
	Macrotermes	1.04	<0.01	0.43	2.54	0.81
	Odontotermes	1.97	0.21	0.28	0.12	3.21
Oliver	*Odontotermes*	0.98	0.15	1.03	0.14	0.64
	Odontotermes	0.47	0.08	0.13	0.04	0.57
	Pseudacathotermes	0.47	0.05	<0.01	0.15	0.10
Ngwezi B	*Odontotermes*	0.47	0.08	<0.01	0.03	0.06
	Macrotermes	1.00	0.10	0.01	0.04	0.03

as well as active regulation of metals within the insect body (Idowu et al., 2014). This is also in line with the findings of Denloye et al. (2015) about varying relationship between the presence of heavy metals in termite species and their nests.

Conclusion

The present study indicated that farmers in the study area were involved in conducting human activities that would suggest an increase in soil heavy metals, although there is no direct link yet to the termites of the study area. The most common anthropogenic activity was fertilization activity, pesticides and herbicide application. Education levels and land size showed to have had an effect on the farmers in Magoye and Stateland on pesticide application. This study also revealed that edible insects among farmers in the study area were well known and natural methods of termite management were on the ground. Results from the study showed that there was a significant difference in heavy metals concentration in soil and there was no significant difference in heavy metals concentrations in termites. Furthermore, the bioaccumulation factors among termites differed; others were high accumulators while others were low accumulators. There was no Pearson correlation between heavy metals in soil and heavy metals in termites from the study area. Overall, the results from experiments of toxic elements show that the levels of these heavy metals in the edible termite samples investigated were within the internationally accepted concentration level such as the USEPA, European Union regulation and WHO/FAO. The results suggest the need for further studies in other ecological regions of Zambia.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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