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Macro-faunal diversity of a contaminated dumpsite in ibadan, Nigeria

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ABSTRACT
Landfilling affects soil macro-fauna, which are important in soil fertility. The effects of landfilling practices on macro-faunal abundance and diversity at Aba-Eku landfill, Ibadan, Nigeria were investigated. Dumpsite and control soils were sampled bimonthly from April-August, 2010. Macro-fauna were extracted via Tullgren funnel and classified accordingly. Shannon-Weiner and Simpson's dominance were used for analysis. 928 macro-fauna; (605: dumpsite; 323: control) in three phyla: mollusca, arthropoda and annelida were observed. On the dumpsite, this comprised ten orders; with molluscan order Stylommatophora (51.7%) dominating vegetated portions of the dumpsite. The remainder were arthropod orders; including isoptera (14.7%), isopoda (8.1%) and coleoptera (7.9%). Thirteen families including Porcellionidae (8.1%) were also observed. Some organisms observed on the dump site included *Porcellio scaber* (8.1%) and *Aspavia armigera* (2%). Arthropods (77.1%) dominated the control. Ten orders including coleoptera (21.98%) and isoptera (19.2%) were observed. This comprised ten families including the Iulidae (15.2%). The dumpsite (2.174) showed a higher diversity than control (1.645); while the control had higher dominance (0.84) than the dumpsite (0.593). Molluscsan dominance suggests tolerance to heavy metal contamination from metal wastes disposed. Coleopteran dominance on the control may be associated with the presence of the grasses - *Tridax procumbens* and *Panicum maximum*.

Introduction

Solid wastes are composed of various components, some of which are not biodegradable. Hence, they constitute a nuisance to the environment. Historically, landfills have been the most common methods of organized waste disposal and remain so in many places around the world (Daskalopoulous, 1998). One of the most perceptible problems associated with landfilling practices, is the direct impact of pollutant accumulation in soil, with particular emphasis on heavy metal contamination (Biswas *et al*, 2010). Batteries for instance, were reported by Richard and Woodbury (1993) to contribute up to 66% of the total lead content in US landfills even after 80% of the battery wastes had been recovered from the landfills. In addition, iron and steel scrap dumped in municipal solid waste landfills may be potential sources of iron (Ademoroti, 1980; Al-Yaqout, 2003). The disposal of these wastes will ultimately impact the soil and several studies have reported elevated heavy metal content in soils of dumpsites (Benka Coker and Bafor, 1999; Anikwe and Nwobodo, 2002). Leachate is a liquid formed from the percolation of rain water through the disposed wastes. The dissolution of contaminants such as heavy metals in the leachate can pose serious pollution problems. Another potential environmental risk is also linked with the production and migration of gases such as methane and carbon dioxide from the wastes during landfilling and decomposition activities (Chan *et al*, 1991).

The accumulation of solid wastes on land affects the quality of the terrestrial environment, which in turn affects soil organisms. Soil biodiversity reflects the mix of living organisms in the soil. The capacity of the soil to function as a vital living and dynamic system is referred to as soil health; and the biological diversity along with the health of the soil is a key component of overall ecological resilience. The macro-fauna are organisms that range in size between 2 - 20mm in length. They are the most diverse group of animals and include the annelids and arthropods amongst others. The importance of soil macro-fauna to the promotion of tropical soil fertility has been stressed in various reviews (Fragoso *et al*., 1993; Garnier-Sillam and Harry, 1995; Nash and Whitford, 1995; Lavelle *et al*., 1997). The distribution and stabilization of organic matter, the genesis of soil structure (macroaggregates), humification, the improvement of drainage and aeration, and the increase in exchangeable cations have all been demonstated in soils modified by termites (order: isoptera; phylum: arthropoda) and earthworms (phylum: annelida) - (Mulongoy and Bedoret, 1989; Lavelle *et al*., 1992). Furthermore, soil macro-fauna can significantly affect the distribution of soil organic matter in the soil profile by litter fragmentation and its' mixing with mineral soil, thus, indirectly affecting soil micro-flora (Lavelle *et al*. 1997). Earthworms, termites, leaf cutter ants are the more readily accessible and potentially manageable 'ecosystem engineers'. Earthworms and termites not only ingest large amounts of litter and soil, but also actively move around in soil and thereby play a major regulatory role in the dynamics of litter, soil organic matter and soil nutrients. Leaf cutter ants have been shown to decrease deep soil resistance to penetration and increase deep soil fertility (Mulongoy and Bedoret, 1989).

Soil characteristics may change owing to disturbances caused by solid waste disposal. This may result in land pollution, evidenced by the elevated levels of heavy metals, hydrocarbons and other compounds in the soil. Species richness may be reduced due to metal pollution (Nahmani *et al*, 2003) and this indirectly alters species interaction (Grzes, 2009). This in turn creates an imbalance in fauna and flora residing in and on

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the soil, thus adversely affecting the environment. Soil fauna respond to many different environmental variables and can indicate environmental stress through changes in species or community structure (Hågvar 1994; Van Straalen 1998; Niklas, 2003).

The Aba-Eku landfill site is a poorly managed dumpsite located in Ona-Ara local government area of Ibadan, South-Western Nigeria (Fig. 1). Changes in soil faunal abundance and diversity can indicate environmental stress. As the macro-fauna constitute the most diverse group of soil fauna, there is therefore a need to study the impact of human activities via landfilling practices on the abundance and diversity of soil macro-fauna on the Aba- eku dumpsite. The specific objectives were therefore to:

- To determine how landfill practices affect the abundance and diversity of soil macro- fauna on the dumpsite,
- To determine how landfilling practices affect the physico-chemical parameters of the soils of the dumpsite.

Materials and Methods

Study area:

The Aba Eku municipal solid waste landfill is located at km 13 along Akanran- Ijebu Igbo road in Ona Ara Local Government, Ibadan South West, Nigeria. It has been a dumpsite since 1994 but was closed in 1996 to allow for upgrading to sanitary landfill status which was not achieved. It was however re-opened to the public for dumping of refuse in 1999. It has since then been used for Municipal Solid Waste disposal from public and private waste management operators (Aluko 2001). The map of the study area is shown in Fig 1.

Demarcation of the study area

Landfill: The area of the landfill receiving wastes was measured with a measuring tape and pegged with suitable landmarks. This area formed a rectangular plot of 250m by 200m. Two-thirds of this demarcated area, besides serving as a receptacle for the wastes disposed, is also covered with vegetation; while the remaining one-third is bare ground but receives the greater proportion of the wastes dumped in the landfill (Plate 1).

Control: A rectangular plot of similar size as the demarcated landfill area (250m by 200m) was delineated approximately 350m away from the landfill and pegged with suitable landmarks. This served as the control. The control site is highly vegetated with bushes surrounding the dwelling places (Plate 2).

Sampling and sampling period

Sampling was carried out bi-monthly between April and August 2010. Sampling dates (labelled SD 1-8 respectively) were: 28th of April 2010; 12th of May 2010; 28th of May 2010; 9th of June 2010; 24th of June 2010; 8th of July 2010; 28th of July 2010; and 10th of August 2010. A quadrat of 0.5m x 0.5m was thrown randomly eighteen times each within the marked areas of the dumpsite and control respectively; and surface soil samples were collected using a spade. A total of 36 soil samples (i.e. 18 each from the dumpsite and control site) were collected each sampling day; while two hundred and eighty eight (288) samples were collected over the entire sampling period.

For the dumpsite, twelve quadrats were thrown randomly on the vegetated portions of the dumpsite (which comprised two-thirds of the demarcated area of the dumpsite), while six quadrats were thrown on the active fill area of the dumpsite (i.e. the remaining one third of the demarcated area of the dumpsite). This was done to provide some information on the spatial variation of organisms within the dumpsite. This made a total of eighteen quadrats for the dump site. Surface soil samples from each quadrat were collected using a spade and transferred into labeled polythene bags and taken to the laboratory for the extraction of the soil macro fauna. Soil macro-fauna were extracted according to the procedure for extraction of macro-fauna given by Lasebikan (1974), as described below. Macro-fauna observed on the soil surface during sampling with a quadrat were also collected and transferred into specimen bottles containing 70% alcohol.

Fig. 1: Map of Ona Ara local Government showing the Aba-Eku Landfill site

Source: Department of Geography, University of Ibadan, Ibadan.

Plate 1: Aba-Eku landfill

Plate 2: The control site

Extraction, preservation and identification of soil macro fauna

Soil samples were carefully homogenized by mixing, and transferred into a Tullgren funnel into which specimen bottles containing 70% alcohol were attached. In addition, soil samples that could not be contained within the Tullgren funnel were searched manually for macro-fauna with the aid of a magnifying glass and a pair of forceps. The macro-fauna found were transferred into specimen bottles containing 70% alcohol (Lasebikan, 1974). The soil fauna collected on the sites as well as those extracted in the laboratory were preserved in 70%

Alcohol for proper identification. They were identified at the Department of Zoology, University of Ibadan, Ibadan.

Analysis of physico-chemical parameters: temperature, pH and moisture content

For the purpose of analysis only, dumpsite soils from both vegetated and active fill areas were bulked together and regarded as one sample for each sampling day. Soil temperature was determined *in situ* with the use of mercury in glass thermometer. Soil pH was taken according to the method given by ASTM (1995). Soil moisture content was determined according to the method given by Odu *et al*, (1986). It was analyzed based on the difference between the soil weight on collection and dry weight after oven drying.

Soil nitrogen, phosphorus, potassium and organic matter analysis

These were analysed at the Nigerian Institute of Science laboratory Technology (NISLT), Samonda, Ibadan.

Heavy metal analysis in the soil

The heavy metals analyzed were: iron, copper, nickel, lead, zinc and cadmium. For heavy metal analysis, soil samples collected bimonthly were bulked together to form one representative sample per month. The sample for April was however represented by only one sampling period (April 28th, 2010). Soil samples were processed according to the method described by ISO, (1995). After processing, samples were analysed for the above parameters using a Perkin Elmer Analyzer AA200 Atomic Absorption Spectrophotometer at the Multi disciplinary Central Research Laboratory, University of Ibadan, Ibadan, Nigeria.

Statistical analysis

Shannon-Weiner and Simpson's dominance indices were used to analyze macro-faunal data; while the data for the physico-chemical parameters obtained from both the dumpsite and control site was subjected to a t - test analysis to check for significant differences between the physico-chemical parameters of both sites.

Results

Soil biodiversity

Abundance and distribution of macrofauna

A sum total of 928 soil macrofauna from three phyla and eleven orders were encountered during the study period. This comprised 605 macro-fauna from the landfill and 323 from the control site (Table 1). The macro-fauna obtained from both sites belong to three phyla - Mollusca, Annelida and Arthropoda. On the landfill/dumpsite, molluscs had the highest abundance at 51.7%, this was closely followed by the arthropods with 45.5%; while annelids had the least abundance at 2.8% (Figure 2a). On the control site arthropods dominated the faunal abundance at 77.1%; 14.6% were molluscs, while 8.4% were annelids (Figure 2b). The mean difference between both sites was not significant (t-test, p, 0.05). Molluscs identified on both the dumpsite and control belonged to the order: stylommatophora; while annelids on the control site belonged to the order neoligochaeta. Annelids of the dumpsite were unidentified (Table 1).

Members of the phylum arthropoda found on the dumpsite comprised the following orders with their respective abundance; Isoptera (14.7%), Isopoda (8.1%), Coleoptera (7.9%), Arachnida (1.3%), Hymenoptera (0.8%), Diptera (0.7%), Orthoptera (0.5%), Chilopoda (0.2%), Diplopoda (0.2%) (Table 1). Isopterans found on the dumpsite were not identified to genus or species level. However, the isopods found belong to the family - Porcellionidae and were represented by the species - *Porcellio scaber*. Only 34 of the 48 coleopterans found on the dump site could be identified to species level. The identified coleopterans comprised five species belonging to four families. Some of these include the Tenrebrionidae (species: *Gonocephalum simplex*); the Pentatomidae (species: *Aspavia armigera*) and the Coccinelidae (species: *Oryctes nasicomus*) Table 2.

Of the arthropods found dominating the control site, the coleopterans were the most abundant at 22%, followed by the isoptera 19.2%, diplopoda 15.2%, isopoda 7.7 %, Hymenoptera 6.5%, Arachnida 1.2%, Chilopoda 0.6% and orthoptera 0.3% (Table 1). Most of the coleopterans found on the control site were identified to species level. Of the 71 coleopterans found, the Pentatomidae (species: *Aspavia armigera*) and to a lesser extent the Chrysomidae (represented by the species: *Diacantha rubrocastenea*) dominated the group (Table 2). The variation in faunal abundance over the study period for the dumpsite and control site is presented in Figs. 3a and 3b; while Fig. 4 shows the spatial variation in faunal abundance and diversity for the dumpsite (i.e. the vegetated and active fill areas of the dumpsite). Molluscs were found mainly on the vegetated portions of the dumpsite and to a lesser extent on the active fill areas of the dumpsite (Fig. 4).

Shannon Weiner indices showed a higher diversity of orders of macro-fauna on the dumpsite (2.174) compared to the control (1.645); and a slightly higher diversity of species (1.259) compared to the control (1.250). The control site however showed a greater diversity of families (1.162) compared to the control (1.370). Simpsons' index showed a higher dominance of macro-faunal orders (0.84), families (0.84) and species (0.80) on the control site than the dumpsite (0.593; 0.765; 0.714) respectively (Table 3).

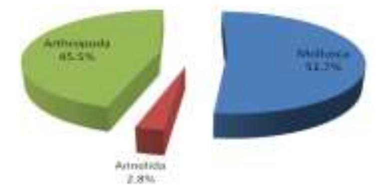

Figure 2a: A pie chart showing the percentage abundance of Phyla obtained on the dumpsite

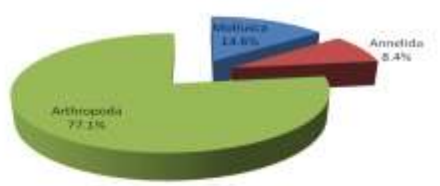

Figure 2b: A pie chart showing the percentage abundance of Phyla obtained on the control site

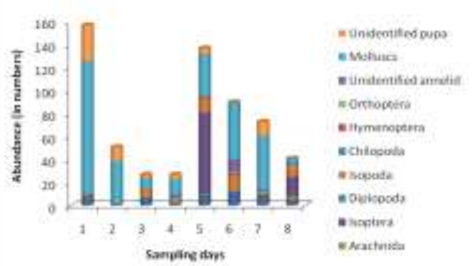

Figure 3a: Macrofauna abundance observed over the study period (dumpsite)

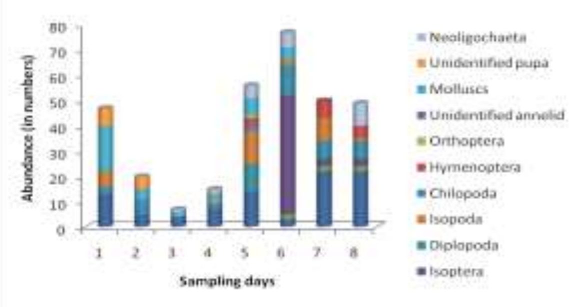

Figure 3b: Macrofauna abundance observed over the study period (control site).

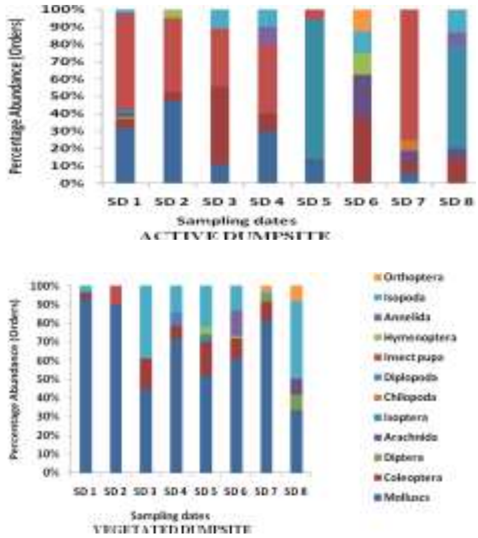

Fig. 4: Spatial distribution of organism groups found on the dump site

Physico-chemical parameters of soils of both sites

General parameters: Temperature, pH and moisture content

The temperature range obtained in the soil over the study period was between 27°C to 41.7°C on the dumpsite site with a mean of 32.31°C, while the temperature on control site ranged from 28.2°C to 43°C, with a mean of 31.84°C. The mean difference between the dumpsite and the control was not significant at p, 0.05. Soil pH in the dump site ranged from 7.04 to 8.07, with a mean value of 7.65; while the pH on the control site ranged from 5.68 to 7.74 (i.e. acidic to slightly basic) with a mean of 6.84. The variation in pH between both sites was not significant. Mean difference between pH on dumpsite and control was not significant at p, 0.05. The moisture content in the landfill ranged from 6.8% to 36.6%, with a mean value of 17.60%; while the control site had moisture content of between 3.3% and 18.2%, with a mean value of 9.07%. The mean difference between the dumpsite and control was not significant at p, 0.05 (Table 4).

Macro- nutrient and organic matter content of the soil

Nitrogen concentration values on the dumpsite ranged from 0.29 % to 0.34 %, with a mean value of 0.31 %; while the control ranged from 0.01 % to 0.10%, with a mean of 0.07%. Mean differences between dumpsite and control was significant at p, 0.05. Phosphorus concentration value on the dumpsite ranged from 230.03 µg/ g to 456.18 µg/ g, with a mean value of 334.65 µg/ g ; while the control concentration ranged from 17.97 µg/ g to 212.41 µg/ g, with a mean value of 82.605 µg/ g. Mean differences between the dumpsite and control was significant at p, 0.05. Potassium concentration value on the dumpsite ranged from 2,47 µg/ g to 3,67 µg/ g, with a mean value of 3090 µg/ g ; while the concentration of the control ranged from 18.9 µg/ g to 44.2 µg/ g, with a mean value of 27.55 µg/ g. The mean difference between the dumpsite and control was significant at p, 0.05. The organic matter concentration value on the dumpsite ranged from 5.173 % to 5.803 %, with a mean value of 5.5; while the concentration on the control ranged from 0.175 % to 5.783%, with a mean value of 2.358 %. Mean difference between dumpsite and control was significant at p, 0.05 (Table 4).

Heavy metal content of the soil

Iron concentration on the dumpsite ranged from 550 mg/ L to 640 mg/L, with a mean value of 586.2 mg/L; while the concentration on the control ranged from 175.16 mg/ l to 333.8 mg/L, with a mean of 267.29 mg/L . Mean difference between the dumpsite and control was significant at p, 0.05. Copper concentration obtained from the dumpsite ranged from 5.05 mg/L to 6.79 mg/L, with a mean value of 5.66 mg/L; while the control ranged from 0.24 mg/L to 0.61 mg/L, with a mean vale of 0.35 mg/L. Mean difference between the copper concentration on dumpsite and control was significant at p, 0.05. Nickel concentration obtained from the dumpsite ranged from 0.96 mg/L to 5.06 mg/L, with a mean of 2.16 mg/L; while nickel concentration on the control ranged from 0.14 mg/L to 0.22 mg/L, with a mean value of 0.18 mg/L. Mean difference between dumpsite and control concentration was significant at p, 0.05 (Table 4).

The lead concentration on the dumpsite ranged from 9.02 mg/L to 23.76 mg/L, with a mean value of 13.39 mg/L; while concentration on control ranged from 0.08 mg/L to 1.71 mg/L, with a mean value of 0.57 mg/L. Mean difference between dumpsite and control concentration of lead was significant at p, 0.05. Zinc concentration obtained from the dumpsite ranged from 1.51 mg/L to 3.78 mg/L, with a mean value of 2.56 mg/L; while concentration on control ranged from 0 mg/ l to 0.09 mg/L, with a mean value of 0.02 mg/L. The mean difference between dumpsite and control zinc concentration was significant at p, 0.05. Cadmium concentration obtained from the dumpsite ranged from 0.18 mg/ l to 0.30 mg/L, with a mean value of 0.23 mg/L; while concentration on control value was 0 mg/L. The mean difference between the dumpsite and control was significant at p, 0.05 (Table 4).

Discussion

Abundance and diversity of soil macrofauna

Soil animal density of the dumpsite was 605 compared to the control's 323, with the dumpsite showing a higher diversity as indicated by the Shannon-Wiener diversity index (Tables 1, 3 & 4). Similar results were obtained by Chan *et al.*, (1997) in their study on the influence of landfill factors on plants and soil fauna. Soil animal density was higher on the landfill sites than the reference sites, indicating that landfill soil can support a diverse fauna which can play an active role in the food web, compared with the reference sites. The macro-fauna obtained from the dumpsite in our study belong to the phyla: annelida, arthropoda, and mollusca; with the phylum mollusca having the highest abundance at 51.7% (Table 1; Figs 2a & 2b). The molluscs can be used as bio-indicators for heavy metal pollution because they have the capacity to bio-accumulate heavy metals especially lead (Ologhobo *et al*, 2008). This might explain their ability to thrive well on the Aba-Eku dumpsite, which is already known to be contaminated with heavy metals (Oni, 2010), and this was also supported by the results of this study (Table 4). Their herbivorous feeding habits probably explain their relatively increased abundance on the vegetated portions of the dumpsite (Fig. 4).

The order - isoptera was more abundant on the dumpsite compared to the control site (Table 1). Isopterans (e.g. termites) feed mainly on dead plant materials and humus; one of the major constituents of solid wastes found on the dumpsite (Oni, 2010). Their abundance on the control site is likely due to the availability of food sources such as cellulose containing plant material as well as their ability to feed on soil. Isopterans are important in the formation of burrows which help to improve soil aeration and water flux. Their excavation activity serves to improve water infiltration, offers new paths for root penetration, and may serve as penetration paths for other surface invertebrates (Ruitz *et al*., 2008). Isopods were also abundant on the dumpsite, indicative of their tolerance to the attendant level of soil pollution. Migliorini *et al*., (2004) reported that isopods were able to bio-accumulate lead and this could be dangerous to higher consumers in the trophic network. The reduced abundance of annelids (earthworms) on the dumpsite compared to the control (Table 1; Figs 2a & 2b) may be due to the fact that the pH range of the control site (Table 4) was more conducive to the presence of earthworms, which are known to thrive at an optimum pH range of 6-7 (Yusnaini *et al*., 2004). pH affects the optimum development of earthworm (Labrador, 1996). However, pollution by heavy metals may also be a contributory factor as earthworms have been found to be scarce or absent in metal contaminated areas (Lukkari *et al*., 2005). The control soil was enriched with coleopterans known for their herbivorous feeding habit (Ewuim, 2004). This must have accounted for their higher abundance on the control site (Table 1) distinguished from the dumpsite by its more abundant and luxuriant vegetative cover (Plates 1 & 2). Recent studies indicated that Coleopterans are more abundant in areas where there are grasses such as *Tridax procumbens* and *Panicum maximum* in abundance (Ewuim, 2004). *Tridax procumbens* and *Panicum maximum* were the abundant floral species found on the control site. This probably explains the abundance of coleopterans on the control site.

Soil physico- chemical parameters

The results of the t-test reveal that there was no significant difference in mean pH and temperature (Table 4). The effect of treatment of waste and landfilling practices might have resulted in the alkaline pH of the dumpsite (Table 4). Furthermore, Usha and Babyshakila, (2009) reported that chemicals such as sodium carbonate, sodium chloride and other compounds of chloride causes soil alkalization resulting in increased soil pH. These chloride based compounds can be found as part of the constituents of landfill leachate that penetrates into the soil (Chimenos *et al*., 1999).

The temperature ranges during the sampling period seemed to favour the growth of isopterans which are known depth dwellers. They were obtained very close to the soil surface during the period of sampling; this may be due to the averagely mild temperature. The increased moisture content of the dumpsite may be as a result of moisture addition to the soil by leachate infiltration into the soil. Jordan *et al*., (1999) observed that slight increases in soil moisture had significant effect on the abundance of macro-fauna. This may account for the higher abundance of soil fauna obtained from the dumpsite. The macro-nutrient (nitrogen, phosphorus, potassium and organic matter content) were significantly higher on the dumpsite than the control (Table 4). Soil nutrients and organic matter contained in decomposed wastes affects soil productivity (Anikwe & Nwobodo, 2002), which in turn impacts on the flora and fauna found in the soil. Specifically, the disposal of unsorted municipal wastes may lead to changes in soil physical and chemical characteristics such as the loading of soil and water with nutrients such as nitrates (Anikwe & Nwobodo, 2002).

The organic matter content of the two sites was significant (t-test, p, 0.05). The penetration of leachate effluent into the soil may have accounted for the adverse effect on the physico-chemical parameters of the soil (Rani and Singaram, 1996; Usha and Babyshakila, 2009). The heavy metals (iron, lead, copper, nickel, zinc and cadmium) also showed a significant (t-test, p, 0.05) increase in levels on the dumpsite than the control (Table 4). The high concentration of heavy metals on the dumpsite could be attributed to the disposal of solid wastes on the site which over time biodegrade and adds their metallic content to the soil. Metals and metal containing wastes are known to constitute a significant proportion of the wastes dumped at the site – about 25% (Oni, 2010). Majority of heavy metals are toxic to living organisms and when retained in the soil, interfere with biochemical processes and alter the ecological balance (Nwuche and Ugoji, 2008). These heavy metals do not biodegrade rather they bioaccumulate and this may have adverse effects on the biodiversity of the area if the organisms do not develop a mechanism of adaptation to it. Isopterans seemed to be tolerant of the metal concentration on the dumpsite. They were probably favored in their abundance by co-existing with the molluscs which have the capacity to bioaccumulate metals. They were however also abundant on the control although found to a lesser extent.

Conclusion / recommendations

The present findings indicate that soils of the Aba-Eku landfill contain toxic constituents' particularly heavy metals which may affect leachate emanating from the dumpsite. It elicited changes in the diversity of macro-fauna found on the landfill. Leachate generation at the study site is therefore of primary health concern because there is no proper treatment system for it. The abundance of molluscs on the dumpsite is also an indication of the site being polluted with heavy metals. They were mainly found within the vegetated parts of the dumpsite due to their herbivorous feeding habits. Molluscs have the ability to bioaccumulate metals, especially lead; and thus, can be used as a bioindicator of environmental stress. This however has implications for organisms higher up the trophic level. These findings suggest that bioremediation strategies need to be considered for the Aba-Eku dumpsite.

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Table 1: Abundance and percentage of orders observed from both sites

	Dumpsite		Control	
Phylum / Orders	No	%	No	%
ARTHROPODA: Diplopoda (millipede)	1	0.2	49	15.2
Arachnida (spider)	8	1.3	4	1.2
Isopoda (woodlice)	49	8.1	25	7.7
Diptera (housefly larva)	4	0.7	0	0
Coleoptera (beetle)	48	7.9	71	22
Chilopoda (centipede)	1	0.2	2	0.6
Hymenoptera (ants)	5	0.8	21	6.5
Orthoptera (longhorned grasshopper)	3	0.5	1	0.3
Isoptera (termite)	89	14.7	62	19.2
Unidentified pupa	67	11.1	14	4.3
MOLLUSCA: Stylommatophora (snail)	313	51.7	47	14.6
ANNELIDA: Neoligochaeta (earthworm)	0	0	27	8.4
Unclassified annelid (earthworm)	17	2.8	0	0
Total	605	100	323	100

Table 2: Classification and abundance of some of the identified macro-fauna from both sites

Phylum	Class	Order	Family	Genus	Sp.	DS	CS
Arthropoda	Myriapoda	Diplopoda	Iulidae	*Spirostrepsis*	*asinensis*	1	49
		Chilopoda*	Geophilidae	*Geophilomorph*	*sp*	1	0
	Arachnida	Aranea	Araneidae	*Cyclosa*	*conica*	8	4
	Malacostraca	Isopoda	Porcellionidae	*Porcellio*	*scaber*	49	25
	Insecta	Diptera	Stratiomyidae	*Hermetia*	*pennicornia*	4	0
		Coleoptera*	Carabidae	*Distichus*	*simplex*	0	8
			Scarabeidae	-	-	4	3
				Aulaserica	*sp*	0	4
				Onthophagus	*mocquerysi*	0	8
			Tenebrionidae	*Opatrinus*	*ovalis*	0	2
				Gonocephalum	*simplex*	6	0
			Coccinelidae	*Oryctes*	*nasicomus*	4	0
			Pentatomidae	*Aspavia*	*armigera*	12	30
			Chrysomidae	*Diacantha*	*rubrocastenea*	8	14
				Asbecesta	*sp*	4	0
			Lagridae	*Lagria*	*villoss*	0	2
		Hymenoptera	Formicidae			5	21
		Orthoptera	Tettigonidae			3	1
Unidentifd.						496	152
Total						605	323

*Only some members of these orders could be identified; members of unlisted orders were unable to be identified to genus and/ or species level

Table 3: Results of the diversity indices for the sites

	Dumpsite	Control
Diversity (Shannon-Weiner)		
Orders*	2.174	1.645
Families*	1.162	1.370
Species*	1.259	1.250
Dominance (Simpsons' index)		
Orders*	0.593	0.840
Families*	0.765	0.838
Species*	0.714	0.804

Only distinctly identified orders, families and species were used for computation

Table 4: Summary of the physico-chemical parameters obtained from the dump site and control

PHYSICO-CHEMICAL PARAMETERS	RANGE DUMP SITE	MEAN ± SEM DUMP SITE	RANGE CONTROL	MEAN ± SEM CONTROL	SIG. (p. 0.05)
pH	7.03-9.45	7.66 ± 0.05	5.85-8.24	6.84 ± 0.09	N.S
Temperature (^oC)	28.30-41.70	32.58 ± 1.65	28.70- 43.00	31.85 ± 1.36	N.S
Moisture Content (%)	6.80-36.60	17.61 ± 1.51	3.0-18.2	9.09 ± 1.23	N.S
% Nitrogen	0.285-0.344	0.312 ± 0.02	0.01-0.10	0.07 ± 0.03	Sig.
Phosphorus (μg/ g)	314.57-456.18	369.52 ± 43.85	17.97-65.17	39.34 ± 13.81	Sig.
Potassium (μg/ g)	2470-3670	3090.00 ± 321.70	18.90-44.20	27.55 ± 5.72	Sig.
% Organic matter	5.17-5.80	5.47 ± 0.18	0.18-1.78	1.22 ± 0.52	Sig.
Iron (mg/kg)	550.00-640.40	586.20 ± 20.47	175.16-333.80	267.30 ± 33.27	Sig.
Copper (mg/kg)	5.02-6.79	5.65 ± 0.40	0.24-0.61	0.35 ± 0.09	Sig.
Nickel (mg/kg)	0.96-5.06	2.16 ± 0.98	0.14-0.22	0.18 ± 0.02	Sig.
Lead (mg/kg)	9.02-23.76	13.39 ± 3.48	0.08-1.71	0.57 ± 0.38	Sig.
Zinc (mg/kg)	1.51-3.78	2.55 ± 0.48	0.00-0.09	0.02 ± 0.02	Sig.
Cadmium(mg/kg)	0.18-0.30	0.23 ± 0.03	0.00	0.00	Sig.