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Assessment of Heavy Metals Contamination on Soil Faunal Diversity in Selected Local Governments Areas of Jigawa State, Nigeria

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Abstract
Heavy metal pollution in soils constitutes a highly complex disruption of ecological equilibrium because some are essential trace elements that become toxic when present beyond a certain concentration. The aim of this research is to assess the level of heavy metals contamination on soil faunal diversity in Dutse and Hadejia Jigawa State-Nigeria. The study employed multistage sampling techniques using 20cm² quadrants thrown at random. A modified Baermann's funnel method of extraction was used to extract the soil fauna from the soil samples and the specimens were properly examined for identification under compound microscope. The collected soil samples were digested using concentrated HNO_3 and HCl. The digested samples were analyzed for heavy metals using Atomic Absorption Spectrophotometer. The result revealed that a total of 275 individuals and 13 species, belonging to 5 classes and 4 phyla were identified from both study areas. Ants, termites, millipedes, earthworms and snails (Cornu aspersum) were found in both Dutse and Hadejia. However, Beetles, wax worms, roundworms, burrowing nematodes and snails (Achantina fulica) were found only in samples from Hadejia. There was no significant variation in abundance of most soil fauna ($p > 0.05$) extracted across the study sites, except for dung beetle, millipedes, earthworm and roundworm. It also suggested a positive relationship between heavy metals and soil fauna density ($r \geq 0.76$), that is, the mean density of soil fauna increased proportionally with increasing heavy metal concentration. Further study should be conducted to check whether the soil fauna possibly resisted or adapt to the effect of the heavy metal or the concentration in the soil or inside the organisms is insignificant to have a negative effect on their diversity.

Keywords: Soil fauna, Heavy metals, Contamination, Diversity, Dutse, Hadejia.

INTRODUCTION
Soils become contaminated by the accumulation of heavy metals and metalloids through emissions from the rapidly expanding industrial areas, mine tailings, disposal of high metal wastes, leaded gasoline and paints, land application of fertilizers, animal manures, sewage sludge, pesticides, wastewater irrigation, coal combustion residues, spillage of petrochemicals, and atmospheric deposition (Khan *et al.*, 2008; Wang *et al.*, 2010). Soil communities are among the most species-rich compartments of terrestrial ecosystems. It consists of a complex mixture of particulate materials derived from abiotic parent minerals, living biota and particulate organic detritus and humus substances. The interactions between

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soil fauna are numerous, complex and varied. Microfauna includes small Collembola and mites, nematodes and protozoa, among others, that generally live in the soil-water film and feed on microflora, plant roots, other microfauna and sometimes larger organisms. Soil macrofauna groups include organisms like earthworms, millipedes, centipedes, ants, Coleoptera (adults and larvae), Isopoda, spiders, slugs, snails, termites, Dermaptera, Lepidoptera larvae and Diptera larvae (Wallwork 1970; Michael *et al.,* 1979).

Heavy metals are naturally present in the soil, anthropogenic and geologic activities increase the concentration of these elements to certain amounts that are very harmful to both plants and animals (Chibuike and Obiora 2014). Heavy-metal-contaminated soil may transfer pollutants to further levels of the trophic chain, i.e plants, animals and humans, or it may constitute a source of secondary pollution of air and water, therefore, impacting humans directly, without passing through the trophic chain. As opposed to air or water, the soil cleaning process is very slow. Excessive quantities of heavy metals pose a significant threat to plants and humans as well as to soil fauna. Invertebrates are sensitive to changes in soil conditions, and may be considered invaluable indicators of soil disruptions (Ruslan and Butovsky, 2011).

Several heavy metals, such as copper, zinc and iron, are essential for the physiological functioning of living organisms, but they all become toxic at high concentrations. The toxicity of a metal depends on the metal itself, the total concentration, the availability of the metal to the organism, and the organism itself. Depending on the organism and the metal, different modes of action are recognized (Kabata-Pendias and Pendias 2001).

Heavy metals, represented mainly by cadmium, lead, arsenic, and mercury, are playing unknown physiological functions in living organisms (Ali *et al.,* 2013). It is clear that heavy metals in soil are very toxic to humans, plants and animals, as well as microbes, even at low concentrations (Giller *et al.,* 2009). Previous studies have shown that traffic pollution can cause significant accumulation of certain heavy metals such as Pb, Cd, Zn and Cu in roadsides soils, primarily resulting from vehicle emissions, and mechanical abrasion and normal wear and tear (George *et al.,* 2013). The aim of the study was to assess the level of heavy metals contamination on soil fauna diversity with a view to determine the abundance of extracted soil fauna, the diversity of soil fauna within the study areas based on seasonal variation and the relationship between heavy metals and soil fauna diversity.

MATERIALS AND METHODS

Study Area

The research was conducted at Dutse and Hadejia Local Governments Areas, situated in the northwestern part of the country between latitudes 11.00°N to 13.00°N and longitudes 8.00°E to 10.15°E in Jigawa State as presented on Figure 1. The study areas have average annual temperature of 26.6°C with average rainfall of 681mm. The major agricultural activities are farming, fishing and animal rearing.

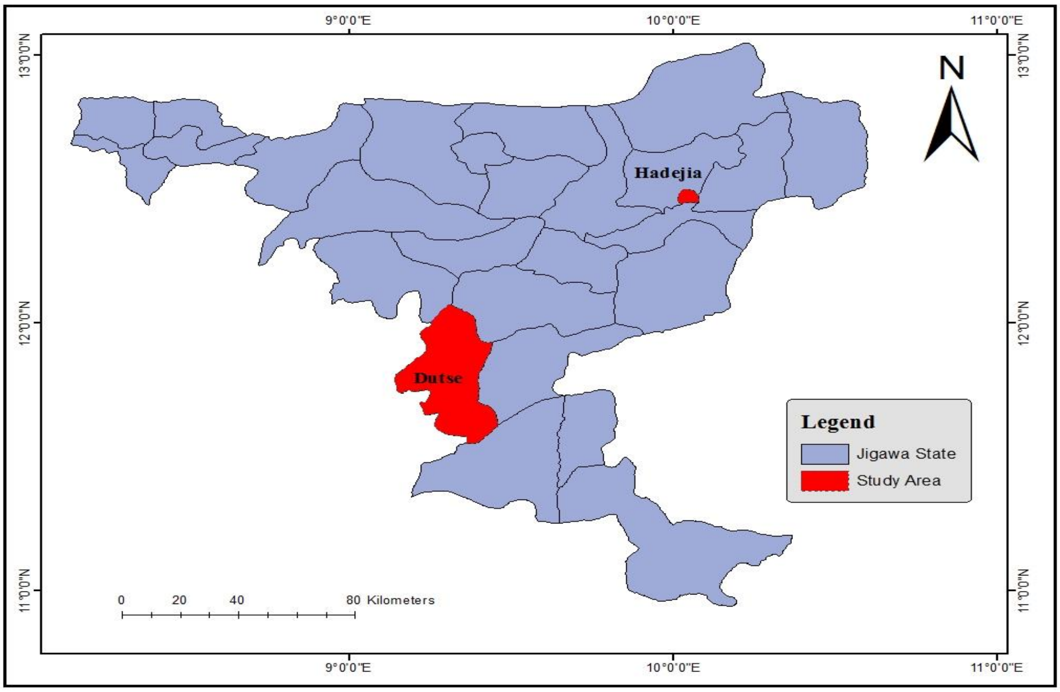

Figure 1: Map of the study areas obtained from GIS Laboratory

Sampling Technique: The study employed multistage sampling techniques using 20 cm^2 quadrant thrown at random. Auger was pressed down to the soil to collect samples from the top to 10 cm depth because, according to Mosadoluwa *et al.* (2000), about 90% of soil fauna lives in the top cultivated areas. Each sample was carefully pushed out with peg from the auger into a polythene bag, tied properly to prevent desiccation and spilling out before reaching the laboratory.

Extraction Procedure: A modified Baermann's funnel method of extraction was used to extract the soil fauna from the soil samples. After extraction, the soil fauna was poured into a beaker, sorted and counted under a dissecting microscope and hand lens and preserved in ethanol. The specimens were properly examined for identification under compound microscope. The soil fauna was identified from Phylum, class down to species level by using keys and illustrations provided in (Nuria *et al.*, 2008; Felicity, 2013).

Analysis of Heavy Metals: The collected soil samples were air dried and sieve in a 2 mm mesh. 5 g of the sieved soil samples was mixed with 25 mL of extractant (3 m L of concentrated HNO_3 and 1 mL of concentrated HCl) for digestion. The digested samples were analyzed for heavy metals using Atomic Absorption Spectrophotometer (PerkinElmer PinAAcle 900 H Model).

Statistical Analysis

Data obtained were subjected to SPSS statistical software for analysis. Pearson correlation was used to determine the relationship between heavy metals contamination and soil fauna diversity. Descriptive statistic of mean was used to determine the effect of heavy metals on soil fauna. Analysis of variance was used to compare the mean values of heavy metals and soil fauna diversity parameters.

RESULTS

Abundance and Diversity of Soil Fauna Extracted within Dutse and Hadejia

The result presented in Table 1 revealed that, a total of 275 individuals and 13 species, belonging to 5 classes and 4 phyla were identified from the two study areas. Ants, termites, millipedes, earthworms and snails (*Cornu aspersum*) were found in both Dutse and Hadejia. However, Beetles, wax worms, roundworms, burrowing nematodes and snails (*Achantina fulica*) were only sampled in Hadejia.

Table 1: Percentage Composition of soil fauna extracted within Dutse and Hadejia

Phylum/Class	Species	Dutse			Hadejia			Both Sites		
		Dry	Wet	Total	Dry	Wet	Total	Dry	Wet	Total
Arthropods										
Insecta	Ants (*Formicidae*)	5	22	27	45	40	85	50	62	112
Insecta	Beetles (*Coleoptera*)	0	0	0	6	13	19	6	13	19
Insecta	Beetles (*Larvae*)	0	0	0	1	8	9	1	8	9
Insecta	Dung beetle (*Scarabeidae*)	0	0	0	3	0	3	3	0	3
Insecta	S&beetle (*Omophronnitidum*)	0	0	0	9	0	9	9	0	9
Insecta	Termites (*Isoptera*)	0	5	5	13	5	18	13	10	23
Insecta	Wax worms (*Galleriinae*)	0	0	0	2	7	9	2	7	9
Myriapods	Millipedes (*Diplopoda*)	0	9	9	2	15	17	2	24	26
Annelids										
Oligochaeta	Earthworms (*Lumbricina*)	0	4	4	0	11	11	0	15	15
Mollusc										
Gastropod	Snails (*Cornuaspersum*)	2	2	4	1	14	15	3	16	19
Gastropod	Snails (*Achantin afulica*)	0	0	0	4	6	10	4	6	10
Nematodes										
Secernentea	Roundworms (*Enoplea*)	0	0	0	0	8	8	0	8	8
Secernentea	Burrowing nematodes (*Radopholussimilis*)	0	0	0	7	6	13	7	6	13
Total number of individuals		**7**	**42**	**49**	**93**	**133**	**226**	**100**	**175**	**27**

Table 2: Correlation between heavy metal concentrations (As, Cd, Cu, Fe, Pb) and soil fauna mean density

Heavy metal	N	Correlation coefficient (r)	P-value
As	4	0.76	0.24
Cd	4	0.23	0.77
Cu	4	0.51	0.49
Fe	4	0.40	0.60
Pb	4	0.65	0.35

Key: *As: Arsenic, Cd: Cadmium, Cu: Copper, Fe: Iron, Pb: Lead*

DISCUSSION

As depicted in Table 1 that arthropods especially ants were the most frequently occurring species across the study sites during both dry and wet seasons. However, nematodes especially roundworms were found to be the less frequently occurring species across the two study sites. This could be due to the idea that macro arthropods such as insects and myriapods differ from their smaller relatives in that; they may have direct effects on soil structure. Furthermore, frequent occurrence of soil nematode generally decreases with increasing depth and distance from plants, as many soil nematodes are largely concentrated in the rhizosphere.

The present research confirmed the findings of Russell *et al.* (1985) who found that up to 70% of the bacterial- and fungal feeding nematodes in the 4-5% of the total soil that was rhizosphere. Similarly, (Griffiths and Caul, 1993), found that nematodes migrated to packets of decomposing grass residues, where there were considerable amounts of labile substrates and microbial food sources. In addition, nematodes also move and occur vertically in soils toward plant roots, but distance moved is dependent on species, soil temperature, soil type, and soil moisture. In deserts, nematodes are associated with plant roots to depths of 15 m as are mites and other biota (Diana *et al.,* 1989). However, it was discovered that nematode (*Halicephalus mephisto*) was recently recovered from soils 3 km deep (Borgonie *et al.,* 2011).

The most frequently occurring soil fauna species obtained at the two study sites were ants with a total of 112 across study sites which constitute 40.7% of all soil fauna. Millipedes and termites were the second in abundance after ants with a total number of 26 (9.5%) and 23 (8.4%) respectively. However, species with the lowest abundance were waxworms, sand beetles, beetles' larvae, roundworms and dung beetles. This could be due to the fact that, the soil food webs are linked to aboveground systems, making trophic analyses much more complicated than in either subsystem alone (David *et al.,* 2004; Vander Putten *et al*., 2013). Even permanent resident organisms of the soil may be adapted to life at various depths in the soil. It was reported that populations of ants are equally numerous, about one-third of the animal biomass of the Amazonian rain forest is composed entirely of ants and termites, with each hectare containing in excess of 8 million ants and 1 million termites (Holldobler and Wilson, 1990). In addition, Hanis *et al.* (2001) reported that termites are highly successful, constituting up to 75% of the insect biomass and 10% of all terrestrial animal biomass in the tropics. Although termites are mainly tropical in distribution, they occur in temperate zones also. The macrofauna have the ability to create their own spaces through their burrowing activities, and like the megafauna, they can have large influences on gross soil structure (Lavelle and Spain, 2001; Van Vliet and Hendrix, 2004).

The results presented on Table 2 suggest a positive relationship between heavy metals and soil fauna density, that is, the mean density of soil fauna increased proportionally with increasing heavy metal concentration. However, the relationship was not statistically significant ($p > 0.05$). The analysed metals content in the studied soils correlated with the abundance and the diversity of the soil fauna. These results suggest that the total bioactivity, richness and diversity of soil organisms increased with increasing heavy metal concentrations because microorganisms differ in their sensitivity to heavy metal toxicity.

In contrary to the present study, heavy metals strongly reduced the numbers and species diversity of the soil organisms (Butovsky 2011). This could be due to the idea that, elevated levels of heavy metals in soils had significant impacts on the population size and overall activity of the soil organisms. Several studies, depending on the isolation-based techniques used, have revealed that heavy metal contamination gave rise to shifts in soil organism populations (Gingell *et al.,* 1976; Barkay *et al.,* 1985; Roane and Kellogg, 1996).

CONCLUSION

The research revealed that, a total of 275 soil fauna were extracted at the two study sites where ants, millipedes and termites occurred more frequently (40.7%, 9.5% and 8.4%) across study sites respectively. However, the less frequently occurring species were waxworms, sand beetles, beetles' larvae, roundworms and dung beetles. The research discovered that 13 species, belonging to 5 classes and 4 phyla were extracted from both study areas across dry and rainy seasons, in which about 100 soil fauna were sampled in the dry season, and 175 in the wet season. However, Hadejia had significantly higher densities of ants, beetles, termites, waxworms, snails and borrowing nematodes compared to Dutse in both dry and rainy seasons. The research also established a positive relationship between heavy metals and soil fauna density, whereby; the mean density of soil fauna increased proportionally with increasing heavy metal concentration.

RECOMMENDATION

The research discovered a positive relationship between heavy metals and soil fauna density across the study sites, as such, further research should be carried out to check whether the soil fauna possibly resisted or adapt to the effect of the heavy metal or the concentration in the soil or inside the organisms is insignificant to have a negative effect on their diversity, because soil microorganisms must display extensive physiological adaptivity considering the space and time variability of soils, selection pressure resulting from metal status in soils probably provides an impetus for the adaptation of physiological pathways in soil microorganisms.

REFERENCES

Ali, T., A. & Wainwright, M. (2013). Metal accumulation by phanerochacte chrysosporium. *Pakistan Journal of Pharmacology,* **12,** (2), 1-18.

Bert Holldobler, E. & Wilson, O. (1990). The Ants. *Harvard University Press.*

Borgonie, G., Garcia-Moyano, A., Litthauer, D., Bert, W., Bester, A., Van Heerden, E., Moller, C., Erasmus, M. & Onstott, T., C. (2011). Nematoda from the terrestrial deep subsurface of South Africa. *Nature.* 474, 79-82.

Chibuike, G., U. & Obiora, S., C. (2014). Heavy metal polluted soils, effect on plants and bioremediation methods. *Hindawi Publishing Corporation. Journal of Applied and Environmental Soil Science*. 14(*12):*708-752.

David, A., Wardle, R., D., Bardgett, J., N., Klironomos, H., S. & Wim, H., V. (2004). Ecological linkages between aboveground and belowground biota. *Science Journals AAAS.* 304(*5677*), 1629-1633.

Diana, W., Freckman, R. & Virginia, A. (1989). Plant-Feeding Nematodes in Deep-Rooting Desert Ecosystems. *Ecological Society of America (esa).* 70(*6*): 1665-1678.

Felicity, C. (2013). Identifying with soil fauna. *Global soil biodiversity initiative.*

George, E., Rolf, S. & John, R. (2013). Method of Soil, Plant and Water Analysis 3rd Ed. *A manual for the West Asian and North African Region. International Center for Agricultural Research in the Dry Areas (ICARDA)*. 65 -78.

Giller, E., Ken, A., Ernst, W. & Steve, P., M. (2009). Heavy metals and soil microbes. *Soil Biology and Biochemistry*. 41(*10*): 2031-2037.

Griffiths, B.S. & Caul, S. (1993). Migration of bacterial-feeding nematodes, but not protozoa, to decomposing grass residues. *Biology and fertility of soils.* 15, 201-207.

Hanis, Aiman, J., Tiong, I.Y. & Abu Hassan, A. (2010). Diversity of Termite Species in Teluk Bahang Forest Park, Penang Island. 7th *IMT-GT UNINET and 3rd Joint international PSU-UNS Conferences, Prince* of Songkla University, Hat Yai, Thailand 78, 150.

Hazrat, A., Ezzat, K. & Muhammad, A., S. (2013). Phytoremediation of heavy metals concepts and applications. *Chemoshere.* 91(*7*): 869-881.

Kabata, P. & Pendias, H. (2001). *Trace Metals in Soils and Plants*: CRC Press, Boca Raton, Fla, USA, 2nd edition.

Khan, A., S., Cao, Q., Zheng, Y., M., Huang, Y., Z. & Zhu, Y., G. (2008). Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. *Journal of Environmental Pollution.* 152(*65*): 686–692.

Lavella, P. & Spain, A. (2001). Soil Ecology Dordrecht. The Netherlands, Kluwer Academic Publisher.

Lucia, S., Cornalis, A., Van Gestel, M., Annamaria, R. & Giulia, M. (2012). Soil invertebrate as bioindicators of urban quality soil. *Book Environmental Pollution*. 161: 57-63.

Michael, J., Swift, H., O. Jonathan, W., M. & Anderson, J., M. (1979). Decomposition in terrestrial ecosystems, 5.

Mosadoluwa, A., B. & Amin, O. (2000). Abundance and Diversity of Soil Mites of Fragmented Habitats in Biosphere Reserve in Southern Nigeria. *Peseqiusa Agropecuaria Brasileira*. 35, 2121-2128

Nuria, R., Patrick, L. & Juan, J. (2008). Soil Macrofauna Field Manual. Food and Agriculture Organization (FAO Consultant) of the United Nations Rome.

Roane, T., M. & Kellogg, S., T. (1996). Characterization of bacterial communities in heavy metal contaminated soils. *Canadian journal of microbiology*. 42(6): 593-603.

Ruslan, O. & Butovsky, R. (2011). Heavy metals in Carabids (Coleoptera, Carabidae). *ZooKeys*. 215.

Russell, E., I., Trofymow, J., A., Elaine, R., Ingham, D. & Coleman, C. (1985). Interactions of Bacteria, Fungi, and their Nematode Grazer: Effects on Nutrient Cycling and Plant Growth. *Ecological Society of America (esa)*. 55(*1*) 119-140.

Sally, M., Gingell, R., Campell, M. & Martin, H. (1976). The effect of zinc, lead and cadmium pollution on the leaf surface microflora. *Environmental Pollution*. 11(*1*): 25-37.

Tamar, B., Susan, C., Tripp, B. & Olson, H. (1985). Effect of metal-rich sewage sludge application on the bacterial communities of grasslands. *Applied and Environmental Microbiology*. 49(*2*): 333-337.

Van Vliet, P., C., Beare, J., M., Coleman, C., D. & Hendrix, P., F. (2004). Effect of enchytraeids (Annelida: Oligochaeta) on soil carbon and nitrogen dynamics in laboratory incubations. *Applied Soil Ecology*. 25(*2*): 147-160.

Vander, P., D., Corbisier, P., Diels, L., Terry, A., S. & Banuelos, E. (2013). The role of bacteria in the phytoremediation of heavy metals. *Phytoremediation of Contaminated Soil and Water*. Eds., 265–281, Boca Raton, Fla, USA

Wallwork, J., A. (1970). Ecology of soil animals 283. *Publisher: McGraw-Hill, London*.

Wang, A., S., Angle, J., S., Chaney, R., L., Delorme, T., A., & Reeves, R., D., (2010). Soil pH effects on uptake of Cd and Zn by Thlaspi caerulescens, *Plant and Soil*, **281**, (1-2), 325–337.

Yi, L., Hong, Y., Wang, D. & Zhu, Y. (2007). Determination of free heavy metal ion concentrations in soils around a cadmium rich zinc deposit. *Geo-chemical Journal*. 41(*4*): 235–240.