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A Study on Single Extraction Technique of Some Selected Heavy Metals in the Soils of Abuja Metropolis, Nigeria

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Abstract

Toxicity of metals in the soils has been a great environmental menace for decades. Toxicity of ions in Abuja soils at soil depth of 15cm was investigated using a single extraction analytical technique. Flame atomic absorption spectrometer was used for instrumental analysis. Single extraction ionic mobility sequence in urban soil samples is as follows: Zn>Cu>Fe>Al>Mn>>As>Ni>Pb>Cd>Cr. Mobility sequence in sub-urban soils is Zn>Cu>Fe>Al>Mn>>As>Ni>Pb>Cd>Cr and the sequence in Asokoro Forest soils (control) is Zn>Cu>Mn>Al>Fe>As>Ni>Cr>Cd>Pb. Zn ion has the highest mobility/bioavailability which indicates that Abuja metropolis could be sitting on Zn deposits. High mobility of Zn portends danger to plants and environment, as Zn toxicity hinders photosynthesis in plants thereby increasing the amount of CO_2 *in the atmosphere which increases climate change subsequently. The study of metals toxicity in the environment will assist environmentalists and government policy makers in making decisions on how to tackle this menace. Abuja environment stakeholders should as a matter of urgency develop technical and legal frameworks to control the rise in metal build up in the metropolis.*

Keywords: Abuja, Toxicity, Metals, Single extraction and Ions.

INTRODUCTION

Urban soils are soils of urban and environments intensively disturbed by human activity and that demonstrates a remarkably spatial heterogeneity (Dominique *et al*, 2021). Urban soils are essentially under strong human influence and also exerting a strong effect on human health, plants and soil organisms and on water infiltration (Pouyat *et al*., 2019). Atmospheric deposition reflected by high heavy metal concentration in urban dust is one of the main sources of heavy metal accumulation in urban soils (*Jin et al*., 2019).

The worst part about heavy metals is that once they build up in the body, they can cause irreversible damage and the effect of heavy metals can range from subtle symptoms to serious diseases (Griffin, 2020). Studies establishing close association between exposure to heavy metals and cancer epidemiology in sub-Saharan Africa are increasing (Kim *et al*., 2015). Several

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health hazards have been associated with the consumption of high doses of heavy metals, and these hazards include but are not limited to; diarrhea, nausea, abdominal pain, nervous system disorder, kidney and diabetes diseases (Magaji and Mallo, 2020).

Soil is a fragile resource, since its health depends on physical conditions, environmental context, and the interlacing of inevitable natural processes (including extreme weather conditions: constant strong wind, heavy rain, floods, etc.), in relation to the intensity of human interventions, e.g. urbanization, industrialization, and local contamination (Cecchini *et al*., 2019). Soil is a dynamic, environmental matrix, assuring necessary support to any form of life on Earth and needing strict protection regulations (Brevik *et al*., 2015). Soil quality is intended as "the capacity of a soil to function, within land use and ecosystem boundaries, to sustain biological productivity, maintain environmental quality, and promote plant, animal, and human health (Salvati *et al*., 2018).

The concern over soil contamination by heavy metals started primarily from health risks, for instance Cu can cause health problems such as anemia, liver and kidney damage, stomach and intestinal irritation (Abdulrashid *et al*, 2017).According to World Health Organisation (WHO), long-term exposure to arsenic is mainly related to increased risks of skin cancer and some other cancers, as well as other skin lesions such as hyperkeratosis and pigmentation changes (WHO, 2018). Soil pollution assessment is common in recent times because of the wide range of health issues streaming from soil and plant relationship, soil and soil organism relationship, ecological degradation and environmental impact assessment issues (Tan *et al*., 2020).

Apart from the health hazards of metals to humans and animals, they also could cause phytotoxicity in plants. Zn phytotoxicity for instance, includes the disruption of photosynthesis in plants which could increase the amount of CO_2 in the atmosphere. This study intends to emphasize on this issue in order to contribute to the natural solution to climate change.

MATERIALS AND METHODS

Sampling Method

Grab sampling method was used at 34 sampling points in Abuja metropolis to collect soil samples, which were selected from several locations in the metropolis in mid-July of the year of collection. Abuja soils were classified into urban, sub-urban and Asokoro forest soils (control) in this work. Soils were dug at depths of 15 cm using a plastic shovel and collected in polythene bags. Collected samples were taken immediately to a laboratory immediately for air drying.

Sample Area

Abuja metropolis is an area comprising of Abuja city and its environs between the coordinates of Longitude 9.07^{o}N and Latitude 7.40^{o}E (Orisakwe *et al*., 2017). Asokoro forest is which is part of Abuja metropolis, is considered to be an unexploited land which is not used for farming or any significant anthropological activities as of the time of carrying out this work.

Sample Preparation

Samples were pretreated for clean up before analysis. They were first air dried at room temperature in the laboratory for 2 weeks after collection and sieved with 100mm mesh one after the other to get a uniform mass. The dried samples were taken to oven after the oven temperature was set at 65°C for 16 hours each according to Mehlich, (1978). The oven dry method was employed to take care of any microbial activity that might have taken place during the 2 weeks of air drying in the laboratory.

Single Extraction

This extraction method shows a relatively fast, cheap and simple way to assess mobility of trace elements in contaminated soils. Putting into consideration, the objectives of the extraction methods, water, less concentrated salts solutions or even stronger reagents like Ethylene diamine tetra acetic acid (EDTA) as Ammonium EDTA are used according to Oliveira, (2012).

Fractions are operationally defined by means used to separate them and the mobile fraction is equivalent to available fraction which shows potential availability of trace elements in soil. Reagents used in this extraction method were of analytical grade which included; CH_3COOH, NH_3 and EDTA. 0.05mol/L ammonium-EDTA extraction solution was prepared as an ammonium salt solution by adding in a fume cupboard 146.12 ±0.05mL of ammonium-EDTA free acid to 800±20 mL distilled water and by partially dissolving and stirring in 130±5mL of concentrated ammonia solution until all the EDTA was dissolved .The obtained solution was filtered (with20μm filter paper) and diluted with water to 9.0±0.5L. The pH was adjusted to 7.0±0.05 by addition of a few drops of HCl. Finally the solution was diluted with distilled water to 10±0.1L, well mixed and then stored in a stoppered polythene bottle. 0.43mol/L CH_3COOH extracting solution was prepared by adding 250±2mL of distilled glacial CH_3COOH in a fume cupboard to about 5L of distilled water to 10mL volume, well mixed and then stored in a stoppered polythene container. 20mL of a 0.05mol/L ammonium-EDTA solution was added to 2.00g of soil sample. The suspension was shaken for 1 hour in a reciprocal shaker. Centrifugation at 3500 revolution per minute for 10 minutes was carried out. Solution was decanted and filtered; the supernatant was kept in a 50mL polythene bottle for instrumental analysis according to Cappuyns, (2012).

Note: After measuring the pH, the CH_3COOH extracts were added to the pH< 2. The EDTA extracts were not acidified prior to analysis to prevent precipitation of EDTA with concentrated HNO_3 to bring the salts at very low pH according to Oliveira, (2012).

RESULTS AND DISCUSSION

Results of single extractions of ions in both urban and sub-urban soils with Asokoro Forest soil as control are as outlined in the following tables.

Table1. Mean Total Single Extraction Results in Urban, Sub-urban and Asokoro Forest

Ions Sampling Zones	Depth (cm)	Pb	Cd	Fe	Ni	Zn	Al	Mn	Cu	Cr	As
Urban Soils 15cm	15	0.24±0.01	0.34±0.01	33.66±0.01	3.80±0.01	136.21±0.21	20.12±0.21	18.73±0.00	89.12±0.03	0.81±0.01	7.13±0.00
Sub-Urban Soils		0.27±0.01	0.14±0.01	17.44±0.57	1.13±0.01	91.52±0.02	14.63±0.01	13.31±0.01	86.95±0.01	0.09±0.01	4.82±0.00
Asokoro Forest(Control)		0.00±0.00	0.00±0.00	0.28±0.00	0.02±0.00	2.49±0.01	0.31±0.01	0.31±0.01	1.73±0.01	0.00±0.01	0.16±0.01

Fractions of ions in single extraction Ions mobility in Abuja urban soils in the decreasing order:
Zn>Cu>Fe>Al>Mn>>As>Ni>Cr>Cd>Pb
Ions mobility in sub- urban soils in decreasing order:
Zn>Cu>Fe>Al>Mn>>As>Ni>Pb>Cd>Cr

Ions mobility in Asokoro forest soils (control) in decreasing order:
Zn>Cu>Mn>Al>Fe>As>Ni>>Cr>Cd>Pb

Total mean fraction of Pb ions extracted from urban soils is 0.225±0.007, which is lower than that of sub-urban soils which is 0.27±0.008. Moderate amount of Pb ions concentration for both urban and sub urban soils could be due to efficient extraction of Pb ions in NH_4-EDTA as it forms Pb-EDTA complexes; this conforms to the findings of Nair and Varghese, (2020). Total mean fraction of Cd ions in urban soils is 0.335±0.007 while that of sub-urban soils is 0.135±0.007. Low concentration of Cd ions from reaction with NH_4-EDTA could be due to buffering effect of soil-solid phase, as this does not affect Cd ion absorption as it forms Cd-EDTA complex; this is in conformity with the findings of Custos *et al*., (2014). Moreover, the total mean fraction of Fe ions is 33.66±0.014 in urban soils which is higher than that of sub urban soils which is 17.44±0.565. High total mean fraction of Fe ions in NH_4-EDTA extraction could be due to efficient extraction ability of EDTA for Fe ion in solid phase as it forms Fe-EDTA complex; this conforms to the findings of Chiumiento *et al*., (2015). Total mean fraction of Ni ions in urban soils is 3.80±0.007 which is lower than that of sub urban soils which is 17.44±0.565. High total mean fraction of Ni ions could be due to efficient extraction of Ni ion by NH_4-EDTA agent in soil samples especially when pH is considered as a factor here, as Ni complexes with EDTA to form Ni-EDTA; this conforms to the findings of Zhu *et al*., (2018).

Total mean fraction of Zn ions in urban soils is 136.21±0.021 which is higher than that of sub urban soils of 91.515±0.021. High total men fraction of Zn ions in reaction with NH_4-EDTA could be due to strong affinity of EDTA to Zn ion as a chelating agent as it readily forms Zn-EDTA complex: this is in conformity with the findings of Hosseinpur and Motaghian, (2014). But Zn phytotoxicity disrupts plant photosynthesis which increases the amount of CO_2 in the atmosphere according to the findings of Vassilev *et al*., (2011) who concluded that "excess Zn triggers disturbances in the waters relations which affect photosynthesis, namely stomatal conductance and therefore plant growth". Total mean fraction of Al ions in urban soils is 20.115±0.021 which is higher than that of sub-urban soils which is 17.63±0.021. High total mean fraction of Al ions in reaction could be due to efficient absorption of Al ion by EDTA, as it forms Al-EDTA complex: this conforms to the findings of Zhao *et al*., (2018). Mn ions have a total mean total fraction of 18.73±0.042 which is higher than that of sub urban soils with a value of 13.305±0.007. Moderate concentration of Mn ions in reaction with NH_4-EDTA could be due to easier leaching of Mn ion by NH_4-EDTA from soil samples to form Mn-EDTA complex: this conforms to the findings of Zhang *et al*., (2018). Cu ions have a total mean fraction of 89.12±0.028 which is higher than that of sub-urban soils which is 86.95±0.028. Very high concentration of Cu ion could be due to NH_4-EDTA as an extracting and chelating agent ability to remove Cu ions efficiently from soil samples to form Cu-EDTA complex: this conforms to the findings of Cappuyns, (2012).

Cr ions have a total mean fraction of 0.825±0.007 in urban soil samples which is higher than that of sub-urban soils which is 0.085±0.007. Low mean concentration of Cr ions from reaction with NH_4-EDTA could be due to forms, oxidation states of Cr ion and soil properties: this conforms to the findings of Lesniewska *et al*., (2017). Total mean fraction of As ions in urban soil samples is 7.125±0.001 which is higher than that of sub-urban soil samples which is 4.815±0.02. Moderate concentration of As ions in samples could be due to less affinity of EDTA to As ion to form As-EDTA complex: this conforms to the findings of Gonzaga *et al*., (2012). Therefore, based on the above results, it could be observed that Zn ions have the highest mobility in Abuja soil samples extraction. Heavy metals phytotoxicity, like Zn phytotoxicity can be detrimental to the environment as it disrupts the process of photosynthesis in plants.

This phenomenon can increase the amount of CO2 in the atmosphere (CO2 being a raw material for photosynthesis in plants). Large amount of CO2 in the atmosphere will increase global warming which will give rise to climate change in Abuja Metropolis.

CONCLUSION

Metal mobility in urban soil samples is found in the decreasing order; Zn>Cu>Fe>Al>Mn>>As>Ni>Cr>Cd>Pb. Mobility in sub-urban soil samples is; Zn>Cu>Fe>Al>Mn>>As>Ni>Pb>Cd>Cr. Mobility in Asokoro forest soils samples is Zn>Cu>Mn>Al>Fe>As>Ni>Cr>Cd>Pb. Metal mobility in both urban and sub-urban soils in single extraction was found to be higher than in Asokoro Forest soil samples, indicating higher anthropogenic activities in Abuja urban and suburban areas than in Asokoro Forest. Zn and Cu were discovered to be the metals with the highest mobility in single extraction. Pb, Cd, Ni, Zn, Al, Mn, Cu and Cr have concentration within regulatory authorities' limits. Fe and As have no available standard from regulatory authorities.

Metals under study (Pb, Cd, Fe, Ni, Zn, Al, Mn, Cu, Cr and As) were found to be within the limits of regulatory authorities. Zn phytotoxicity disrupts plant photosynthesis among other things, which increases the amount of CO_2 in the atmosphere thereby increasing global warming and by implication, Abuja Metropolis is in danger of the consequences of rapid climate change. Regulatory authorities should give more attention to periodic environmental risk assessment of Abuja soils in order to checkmate the rising metal build up in the metropolis.

Stakeholders should endeavor to contain the high amount of Zn in Abuja soils in order to protect plants from its toxicity which can increase climate change in Abuja and its environs. Public enlightenment should be employed to promote advocacy for the control of metals in the environment Periodic environmental risk assessment should be conducted across urban and sub-urban centers in Abuja metropolis. Policy makers should as matter of urgency, formulate policies geared towards safeguarding green zones in particular and Abuja ecosystem in general. A further study should be carried out on all the metals obtainable in soils in order to have a further understanding of metals mobility/bioavailability in Abuja soil

REFERENCES

Abdulrashid, L. Yaro, A. and Isah, A. (2017). Heavy metals contamination in urban Soils of Nigerian roads: a review. *International Journal of Innovative Bioscience Research*, 5(3): 1-12.

Brevik, E. C., Cerdà, A., Mataix-Solera, J., Pereg, L., Quinton, J. N., Six, J. and Van Oost, K. (2015). The interdisciplinary nature of soil. *Soil,* 1(2015): 117–129.

Cappuyns, V. (2012). A critical evaluation of single extraction from the SMT programmes to determine trace element mobility in sediments. *Applied and Environmental Soil Science*, 11(2012): 2371-2382.

Cecchini, M., Zambon, I., Pontrandolfi, A., Turco, R., Colantoni, A., Mavrakis, A. and Salvati, I., (2019). Urban sprawl and development. *Journal of Geography*, 2019(84): 237–255.

Chiuniento, F., D'Aloise, A., Marchegiani, F. and Meki, V. (2015). Determination of EDTA in feed and premix formulations by HPLC-DAD. *Food Chemistry*, 175(2015), 452-456.

Custos, J., Moyne, C., Trillion, T. and Starkemen, C. (2014). Contribution of Cd-EDTA complexes to Cadmium uptake by maize: a modeling approach. *Plant and Soil*, (2014), 374-497.

Dominique, S., Franco, A., Gusheppe, C., Cocco, S., Cappo, V. and Adamo, P.(2021). Heavy metal load and effects on biochemical properties in urban soils of a medium sized city, Ancona, Italy. *Environmental Geochemistry and Health, 6*(202): 456-463.

Gonzaga, M. I. S., Ma, L. Q., Pachuca, E. P. and des Santos, W. M.(2012). Predicting Arsenic bioavailability to hyper accumulates *Pterivitta* in Arsenic-contaminated soils. *International Journal of Phytoremediation*, 14(2012), 939-949.

Griffin, R. M. (2020). Heavy metal poisoning. *Journal of Natural and Applied Sciences*, 20(10), 451-462.

Hosseinpur, A. A. and Motaghian, H. (2014). Evaluation of many chemical extractants from assessment of Zn and Pb uptake by beans in polluted soils. *Journal of Soil Science and Plant Nutrition*, 15(1): 236-2

Jin, Y., O'Connor, D., Ok, Y. S., Tseng, D. C. W. and Hou, D. (2019). Assessment of sources of heavy metals in soil and dust of children's park in Beijing using GIS and multivariate statistical analysis. *Environmental International*, 124(2019): 320-328.

Kim, H. S., Kim, Y. J. and Seo, Y. R. (2015). An overview of carcinogenic heavy metal: molecular toxicity mechanism and prevention. *Journal of Cancer Prevention,* 20(4): 232-240.

Lesniewska, B., Gantarska, M. and Godlewska-Zykiewkz, B. (2017). Selective separation of Chromium species from soils by single-step extraction methods. *Water, Air and Soil Pollution*, 228(2017), 274-287.

Magaji, J. and Mallo, I. I. Y. (2020). An assessment of the vertical movement of heavy metals in the soils of Mpape dumpsites, Federal Capital Territory, Abuja, Nigeria. *Australian Journal of Science and Technology*, 46(3): 4450-4462.

Mehlich A.(1979). New extractant for soil test evaluation of phosphorus, potassium, magnesium, calcium, sodium, manganese and zinc. Community Soil Science and Plant Analysis, 1978, 9(6), 477-492.

Nair, N. M. and Varghese, G. K. (2020). Optimisation of parameters for the extraction of Pb from laterite oil using EDTA. *SN Applied Science*, 2(2020), 1344-1356.

Oliveira, H. (2012). Chromium as an environmental pollutant insight on induced plant toxicity. *Journal of Botany*, 12(3), 123-132.

Orisakwe, I., Nuofor, O., Noku, C. and Ezodigboth, U. (2017). On the analysis of the changes in the temperatures over Abuja, Nigeria. *Journal of Physical Sciences and Environmental Studies*, 3(2017): 8-17.

Pouyat, R. V., Doi, S. D., Brown, S., Schwarz, K., Shaw, R. E., Sshavez, K., Trammel, T. L. and Yeskwal, S. I. D. (2020). Urban soils, forest and rangeland soils of the United States under changing conditions. In: Soil usage. 124-144, Springer, Cham, USA.

Salvati, L., Zambon, I., Chelli, F. M. and Serra, P. (2018). Do spatial patterns of urbanization and land consumption reflect different socioeconomic contexts in Europe? *Science of the Total Environment,* 625(2018): 722–730.

Tan, K., Wang, H., Chen, L., Du, Q., and Pen, C. (2020). Estimation of the spatial distribution of heavy metals in agricultural soils using airborne hyper spatial imaging and random forest. *Journal of Hazardous Materials*, 382(2020): 987-893.

Vassilev, A., Nikolova, A., Koleva, l. and Lidon, F. |(2011|). Effects of excess Zn on growth and photosynthetic performance of young bean plants. J*ournal of Phytology*, 3(6), 58-62.

World Health Organisation, WHO. (2018). Lead poisoning and health. Downloaded from www.who.org

Zhang, C., Wang, S., Cao, Z. and Zheng, H. (2018). A novel process for the separation and recovery of value-added metals from Manganese-Silver ores by EDTA/EDTA-2Na and Thiosulfate. *Hydrometallurgy*, 178(2018), 256-263.

Zhao, Z. H., Liu, G. H., Liu, Q. S., Huang, C., Li, H., & Wu, C. S. (2018). Distribution characteristics and seasonal variation of soil nutrients in the Mun river Basin, Thailand. *International Journal of Environmental Research & Public Health*, 15(2018), 18-25.

Zhu, G., Jiang, G., Li, J. and Ma, Y. (2018). Toxicity thresholds based on EDTA extractable Nickel and Barley roots elevation in Chinese soils. *International Journal of Environmental Research and Public Health*, 15(4), 669-678.