Health Environ, 2024, 4(1): 229-236
DOI: 10.25082/HE.2023.01.005

RESEARCH ARTICLE

Determination of some heavy metals and physicochemical properties in contaminated soils of open waste dumpsite in Awka, Anambra State

Ogochukwu J. Okakpu[1*] **Patrice A. C. Okoye**[1] **Theresa U. Onuegbu**[1]

[1] Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University, Awka, Nigeria

Correspondence to: Ogochukwu J. Okakpu, Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University, Awka, Nigeria;
E-mail: ezevictor54@yahoo.com

Received: November 4, 2023;
Accepted: January 11, 2024;
Published: January 15, 2024.

Citation: Okakpu OJ, Okoye PAC and Onuegbu. Determination of some heavy metals and physicochemical properties in contaminated soils of open waste dumpsite in Awka, Anambra State. *Health Environ*, 2024, **4**(1): 229-236.
https://doi.org/10.25082/HE.2023.01.005

Copyright: © 2024 Okakpu *et al*. This is an open access article distributed under the terms of the Creative Commons Attribution-Noncommercial 4.0 International License, which permits all non-commercial use, distribution, and reproduction in any medium, provided the original author and source are credited.

Abstract: The current study was designed for the assessment of cadmium, chromium, lead, nickel, zinc and manganese and some physicochemical properties of soils collected from an open dumpsite in Awka, Nigeria. Soil samples at the depth (0-20 cm) were randomly collected at the dump field and were analyzed for physicochemical parameters and heavy metals using standard analytical methods. The results show that the main dumpsite had a high sand content (91.48% $\pm$ 0.26%) with a low silt 4.07% $\pm$ 0.03% and clay 4.65% $\pm$ 0.00%. The pH of the dumpsite soils was 6.07 $\pm$ 0.04 which is an acidic pH. Organic matter (%) and organic carbon (%) were 3.84 $\pm$ 0.06 and 2.23 $\pm$ 0.04 respectively. The EC (μS cm^{-1}) was 476.9 $\pm$ 0.00 while the ECEC (cmol/kg) 18.93 $\pm$ 0.04. The bulk density (g cm^{-3}) was 1.32 $\pm$ 0.00 and the porosity (%) of the dump soil was 41.40 $\pm$ 0.00. Total metal concentrations of Cd, Cr, Pb, Ni, Zn and Mn were also analyzed and the concentrations of the heavy metals at dumpsitewas obtained (28.35 $\pm$ 0.21 to 149.10 $\pm$ 0.01 mg/kg). Metal contamination at dumpsite was in the order of Mn $>$ Zn $>$ Pb $>$ Cd $>$ Cr $>$ Ni. The study evidently indicates the presence of heavy metal contamination in the dumpsite even though some of them fell below the critical permissible concentration level. However, it is their accumulation and persistence in the soils of the dump site that may be a cause of concern for their surrounding environment and organisms.

Keywords: heavy metals, contamination, physicochemical properties, dumpsite soil

1 Introduction

Soil is a highly dynamic, ecologically complex and diverse living entity that is formed as a result of various biological and climatological interactions with the earth's bedrock [1–3]. Soil pollution is a phenomenon characterized by the loss of the structural and biological properties of the soil layers as a result of numerous human and natural factors [2–5]. Nearly all human activities generate waste, and the way in which this is handled, stored, collected and disposed of, can pose risks to the environment and to public health [3–6]. As urbanization increases and human population grows, there is a need to manage the waste produced from human activities and this has led to the creation of dumpsites. Dumpsites are waste depositing land areas where uncontrolled waste disposal activities occur in such a way that the environment is not protected from the detrimental effect that arises from these activities [4]. Several fluxes of waste and cover materials from different sources end up at these dumpsites and due to the heterogeneity and complexity of wastes, these dumpsites contain a variety of contaminants which can pollute the soil of the area. The ecological balance of any ecosystem gets affected due to the widespread contamination of the soil [2]. According to Awka History & Facts *Encyclopedia Britannica* [5], it is listed that Awka the capital city of Anambra State, Nigeria is located at 199.1km (123.7mi), by road directly north of Port Harcourt in the Centre of densely populated Igbo heartland in south-east, Nigeria. The city has an estimated population of 301,657 as of the 2006 Nigerian census and over 2.5million as of 2018 estimate. In Anambra State, solid wastes are handled by the Anambra State Ministry of Environment (ANSEPA). The Ministry has allocated an extent of land at Agu-awka for disposal of these solid wastes collected from Awka town and its environs. Awka as both industrialized and non-industrialized city, the refuse generated within the city comprise largely of degradable materials from markets, offices, hospitals and households such as garbage, plastics, textiles, stationeries, sludge from sewage, dead animals, ashes, wood, food and farm waste products and some other non-degradable materials such as metallic materials from damaged vehicle parts, electronics, computers, cans, oil, used batteries, painting waste etc. are also disposed in the same way as the other non-metallic materials, thereby constituting a source of metal contamination in the soil. Open dumps are generally unsanitary and constitute stinking places in which disease-carrying vermin such as rats, cockroaches and flies proliferate [6–10]. Methane and other gases are released into the surrounding air as microorganisms decompose the solid wastes and fires and smokes from practicing open burnt system pollute the air and other numerous volatiles. Liquids that ooze and seep through the solid waste heap ultimately reach the soil, surface water and ground water. Hazardous materials such as heavy metals, pesticides and hydrocarbons that are dissolved in this liquid often contaminate soil and water [7]. Nevertheless, 8. Aralu et al. (2022) [8] suggested that continuous disposal of wastes on soil may lead to increase in heavy metals in the soil and surface water that would be hostile to deep feeding plants. Accumulation of heavy metals can also degrade soil quality, reduce crop yield and the quality of agricultural products, and thus negatively impact the health of humans, animals and the ecosystem at large [9]. Small life forms may consume harmful chemicals, accumulate and pass them up the food chain to larger animals leading to morbidity and increased mortality rates of organisms. Human exposure to pollution is believed to be more intense now than any other time in human existence [10, 11].

The increasing awareness of the potential hazards of large-scale contamination of the environment with heavy metals arising from rapid unplanned industrial, agricultural and human domestic activities or practices such as unlawful wastes disposal system and order anthropogenic sources which introduces these heavy metals into soils has highlighted the need for continuous monitoring of the concentration levels and its evaluation. The physicochemical properties of the soil are also one of the important factor playing roles in soil development and revitalization [12]. Since these contaminants affect the environmental qualities in and around such open dumpsites, monitoring of soil qualities especially heavy metal content in dumpsite becomes necessary which can facilitate to recommend suitable remedial measures [13] hence this study intends to determine the contents of cadmium, chromium, lead, nickel, zinc and manganese and the physicochemical properties of the soil of the dump field in Awka area in view of interpreting its suitability for crop production.

2 Methods and materials

2.1 Study area

The present study was performed in one of the major refuse waste dumpsites in Awka city (6^{o}13'30"N and 7^{o}06'0"E) of Anambra state, Nigeria. The study site is Agu-Awka waste dumping site. The dumpsite contains mixtures of both organic and inorganic waste materials such as food wastes, papers, cardboards, metals, engine oils, tins, glass, ceramics, battery wastes, textile rags, plastics, sewage night-soils and other miscellaneous materials such as bricks, ash, fine dust, rubber and wood wastes. These wastes have been dumped and allowed to accumulate for years. Figure 1 and 2 shows the map of Awka indicating the geographical locations of the sampling areas.

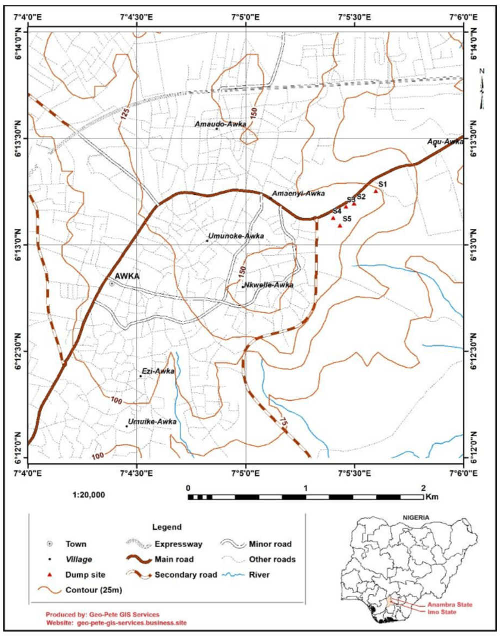

Figure 1 Map of the study site

Figure 2 Plate 1: picture of the study sites

2.2 Soil sampling

The soil samples after removing the overlying wastes were collected from refuse dump site at Agu-Awka at the depths of 0–20 cm using soil spade and shovel. At site for sampling, five sub-sites soil as shown on the map above were taken for the purpose of random sampling and pooled together to obtain a composite sample. Wastes, nylons, plastics and stones were manually sorted out and removed to some extent. They were bagged and transported home. The soil was air dried for eight days, ground and sieved through a 2 mm sieve. These were stored in well labeled polythene bags and taken to the laboratory for analysis.

2.3 Physicochemical analysis

Physicochemical properties such as bulk density, porosity, particle size (% sand, % silt and % clay), pH, effective cation exchange capacity (ECEC) electrical conductivity, organic matter, and organic carbon were analyzed. The pH and electrical conductivity were measured in a soil suspension (1:10 w/v dilution) by pH meter (Hannah 1100) and conductivity meter (AEMax India 976), respectively. Bulk density and porosity was calculated following [14–16]. The organic carbon and organic matter were determined based on the Walkley-Black method [17]. The cation exchange capacity (CEC) of soil, and Exchangeable acidity (EA) were determined by titration method [18]. The effective cation exchange capacity (ECEC) was calculated as the total exchangeable bases plus exchangeable acidity [18]. Particle size was determined using the method developed by collaborative study of cation exchange capacity of peat minerals [19].

2.4 Heavy metal analysis

Total metal concentrations of heavy metals such as Cd, Cr, Ni, Zn and Mn were analyzed. For heavy metal analysis, 2 g of the sieved soil sample was accurately weighed and digested with 15 ml of Aqua regia (mixture of concentrated HCl and HNO_3 acids in the ratio 3:1, kermel and JHD Analar grade) for two hours. The solution was filtered with Whatman No 1 filter paper and made up to 50 mL. The filtrates were analyzed for heavy metals (Cd, Cr, Pb, Ni, Zn and Mn) using atomic absorption spectrophotometer, AAS (FS240AA). Procedural blanks and internal standards were also used where appropriate.

2.5 Data treatment

For the interpretation of the data, the results are presented as mean value $\pm$ standard deviation and analyzed by analysis of variance (ANOVA) using SPSS software package version 23 and Microsoft Office Excel-2016.

3 Results and discussion

3.1 Physicochemical properties of the soil

Soil quality can be monitored by a set of measurable attributes termed indicators. These indicators can be broadly grouped as physical and chemical indicators and one can assess overall soil quality by measuring changes in these indicators [20, 21]. In the present study, various physicochemical properties of the refuse dump soil was evaluated.

The physicochemical properties of the dumpsite soil are presented in Table 1. The pH of the dumpsite soil is 6.07 $\pm$ 0.04 this result indicated that the dumpsite soil is acidic in nature. Additionally, the pH range of the soil in this present study is in agreement with the reports of other studies whose soil pH in water ranged from 4.89 $\pm$ 0.05 to 7.60 $\pm$ 0.01 in dumpsites [18]. On the other hand, the moderately acidic soil from the site may tend to have an increased micronutrient

Table 1 Physicochemical properties of the dumpsite soils

Soil properties	Site (AGD)
pH	6.07 ± 0.04
EC (μScm^{-1})	476.9 ± 0.00
Bulk Density (gcm^{-3})	1.32 ± 0.00
Porosity (%)	41.40 ± 0.00
ECEC (cmol/kg)	18.93 ± 0.04
Organic matter (%)	3.84 ± 0.06
Organic carbon (%)	2.23 ± 0.04
Sand (%)	91.48 ± 0.26
Silt (%)	4.07 ± 0.03
Clay (%)	4.65 ± 0.00

Note: OM: Organic matter; OC: Organic carbon; AGD: Agu-Awka dumpsite

solubility and mobility as well as increased heavy metal concentration in the soil [18]. The electrical conductivity of the dumpsite soil sample is 476.9 $\pm$ 0.00 μS cm^{-1}. This result may be attributed to the presence of ions in the dumpsite soil. It can also be due to the disposal of metallic scraps at the dumpsite. However, this indicates that there are movement of charge particles which is a good indicator for the growth of plants [22]. The dump site soil recorded its bulk density to be 1.32 $\pm$ 0.00 g cm^{-3}. This finding is consistent with the report of [16, 17] who noted that a low bulk density could be due to the continuous addition of soil organic carbon which decrease the soil bulk density. However, it should be noted that high bulk density can reduce the root length and limits the root penetration in dump soil [23–25]. With respect to the porosity of the dumpsite soil sample in this study, the result showed that the dumpsite soil has its porosity to be 41.40% $\pm$ 0.00%. This soil porosity at the dump-site location may be associated with the addition of soil organic matter from decomposition of the municipal waste. On the other hand, result of this study revealed that soil from the dump site had the ECEC value of 18.93 $\pm$ 0.04 cmol/kg. The ECEC status of dump soils was slightly below 20 cmol/kg regarded as being suitable for crop production [24–27]. The organic matter in the soil samples was 3.84% $\pm$ 0.06%. The dump soils contain high amount of organic matter. This can be attributed mainly to the presences of many organic waste residues which add more organic matter after their decay. And organic carbon in the dump site soil under investigation in this study was 2.23% $\pm$ 0.04%. The moderately high amount of organic carbon of the refuse dump soils is an indication of presence of degradable and compostable wastes [16, 18]. Furthermore, the particle size of the soil which plays an important role in plant species establishment and development and also influences physical parameters of soil, the soil particle size was evaluated for the study site based on the amount of sand, silt and clay in a soil. The refuse dump soil had much wastes on it hence its decomposition impacted hugely on the particle sizes. In this study, the dumpsite had a high sand content of 91.48% $\pm$ 0.26%, with a low silt content of 4.07% $\pm$ 0.03% and clay 4.65 $\pm$ 0.00% content. This result is similar with the report of Moorberg and Crouse (2017) [18] and Dalal and Moloney (2000) [25]. In addition, [26] concluded that the decomposition of municipal waste of soil micro-organisms significantly impacts on the texture and particle sizes of the underlying soils.

3.2 Heavy metal concentrations

The concentration of cadmium in the soil sample from dumpsite was 48.67 $\pm$ 0.10 mg/kg. This value is higher than the natural limits of 0.01- 3.0 mg/kg in soil as given by Sahrawat and Narteh (2002) [27] and Shehu-Alimi et al. (2020) [28]. This value is also above the maximum tolerable level proposed for agricultural soil. Cadmium is a poisonous heavy metal that can occur as a waste product from industrial workplaces. The high levels could be attributed to the availability of cadmium materials from sludges, cadmium batteries or metal scraps and metal plating, plastic stabilizers, PVC materials, coatings and motor oils and pesticides which leached into the underlying soil [16].

The concentrations of Cr in the dump soil were 37.35 $\pm$ 0.21 mg/kg. This value obtained is lower than the critical permissible level which is 50 mg/kg for soil recommended for agriculture by Sahrawat and Narteh (2002) [27] and Shehu-Alimi et al. (2020) [28]. Sources of Cr in the soils could be due to waste consisting of lead-chromium batteries, coloured polythene bags, discarded plastic materials and empty paint containers [18, 29–31].

The level of Pb found in the dumpsite soil was 121.07 $\pm$ 0.04 mg/kg. This value was lower than the value [28] with upper limit of 300 mg/kg but falls within the maximum tolerable levels proposed for agricultural soil and 90-400 mg/kg set by world health organization [36] and National Environment Protection council of Australia [37]. This is in agreement with the results obtained from a similar study [32] for dumpsites soil within Ikot-Ekpene in Akwa- Ibom state, Nigeria. The presence of Pb at the study site can be attributable to the disposal of waste materials containing batteries, food packaging material, PVC materials, automobile exhaust fumes, engine oil spillages, combustion using diesels, sewage effluents, runoff of wastes, atmospheric depositions, accumulation of solid waste and its combustion and insecticides.

The level of Ni found in the dumpsite soil was 28.35 $\pm$ 0.21 mg/kg. Nickel was found to be below the critical permissible concentration of 50mg/kg [27, 28] and within the range of 2-200 mg/kg [33]. Comparing the result for Nickel with WHO maximum allowable limit for nickel in soil, the sample collected is below the limit (50mg/kg) [34, 35]. Furthermore, the concentration of Ni at the location could be as a result municipal waste, sewage sludge, nickel-cadmium batteries, and fertilizers being disposed at the refuse site [36–41].

The concentration of zinc in the dump site soil sample is 131.92 $\pm$ 0.03 mg/kg. Comparing the results for zinc with WHO maximum allowable limit of 300 mg/kg. The sample is below the allowable limit [34, 35]. Presence of Zn within the dumpsite could be attributed to disposal of heavy metal substances which includes presence of dry cells and the burning of electronic waste [37]. It could also be due to high usage of various types of pesticides, degradable chemicals and fertilizers [38, 42–45]. Although the concentration of Zn was within the permissible concentration limit, it may however, be a threat to human health if ingested in large quantities.

The concentration of manganese in the soil sample is 149.10 $\pm$ 0.01 mg/kg. Comparing the WHO maximum allowable limit for manganese which is 2000 mg/kg with the results of sample tested for manganese, it shows that the sample is below the WHO limit [36, 46–50]. Mn at the location could be as a result municipal waste, sewage sludge, degradable chemicals and fertilizers being disposed. The total metal concentrations of heavy metals have been given in Table 2 and Figure 3.

Table 2 Total metal concentrations (mg/kg) of heavy metals at study site

Heavy metals	Site (AGD)
Cadmium	48.67 ± 0.10
Chromium	37.35 ± 0.21
Lead	121.07 ± 0.04
Nickel	28.35 ± 0.21
Zinc	131.92 ± 0.03
Manganese	149.10 ± 0.01

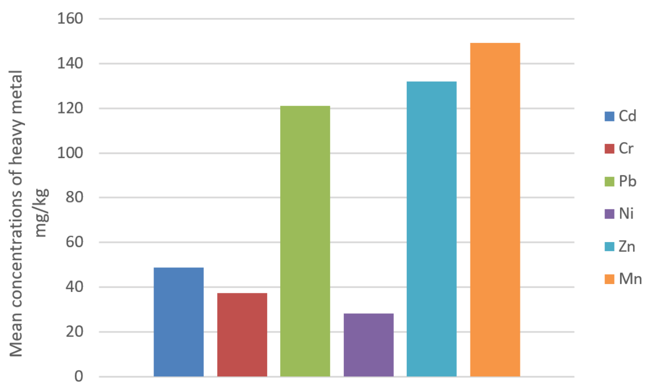

Figure 3 Mean concentrations of heavy metals in the dumpsite soil

4 Conclusion

This study indicates the level of contamination at the municipal waste dumpsites. The studied dumpsites are contaminated with heavy metals. The availability of these heavy metals in the studied site could be attributed generally to human activities and lack of waste management. On the cause of this research, I found out that the waste materials being generated around Awka metropolis after collection are being dumped on this site. This leads to substantial accumulation of these waste products which causes huge environmental pollution. Furthermore, from the results in Table 2, it was seen that there are presence of heavy metals in the dump site soil, even though some of them fell below the critical permissible concentration level. However, it seems that their accumulation and persistence in the soils of the dump site may lead to increased enormous pollution of the soil and possible uptake by any nearby plants. Therefore, it is pertinent to evaluate the contamination levels of dumpsites in our cities from time to time especially those sites used for vegetable production for the use of soils from dump site for crop production, particularly vegetables, should not be encouraged. Also, continuous buildup may lead to serious ineffective soil quality, degradation of environment and soil ecosystem at large.

Author contributions

OJO: visualization, conceptualization, methodology, and writing- original draft preparation; PAC: reviewing, supervision and editing, data curation; TUO: investigation, software, and validation.

Conflict of interest

No potential conflict of interest was reported by the author(s).

References

[1] Sing D, Sing CF. Impact of Direct Soil Exposures from Airborne Dust and Geophagy on Human Health. International Journal of Environmental Research and Public Health. 2010, 7(3): 1205-1223. https://doi.org/10.3390/ijerph7031205

[2] Zaware SG. Environmental impact assessment on soil pollution issue about human health. International Research Journal of Environment Sciences. 2014, 3: 78-81.

[3] Okeke DO, Ifemeje JC, Eze VC. Determination of the levels of heavy metals and physicochemical properties of borehole water within selected mining sites in Ebonyi state, Nigeria. International Journal of Chemical and Biological Sciences. 2021, 3(2): 5-10. https://doi.org/10.33545/26646765.2021.v3.i2a.28

[4] Eze VC, Okeke DO, et al. Assessment of vanadium pollution and ecological risk in some selected waste dumpsites in Southeastern Nigeria. Health and Environment. 2022, 3(1): 169-175. https://doi.org/10.25082/he.2022.01.004

[5] Zhu D, Asnani PU, Zurbrugg C, et al. Improving Municipal Solid Waste Management in India. The World Bank, 2007. https://doi.org/10.1596/978-0-8213-7361-3

[6] Nagajyoti PC, Lee KD, Sreekanth TVM. Heavy metals, occurrence and toxicity for plants: a review. Environmental Chemistry Letters. 2010, 8(3): 199-216. https://doi.org/10.1007/s10311-010-0297-8

[7] Aralu CC, Okoye PAC, Abugu HO, et al. Toxicity and distribution of polycyclic aromatic hydrocarbons in leachates from an unlined dumpsite in Nnewi, Nigeria. International Journal of Environmental Analytical Chemistry. Published online November 2, 2022: 1-12. https://doi.org/10.1080/03067319.2022.2140415

[8] Aralu CC, Okoye PAC, Abugu HO, et al. Pollution and water quality index of boreholes within unlined waste dumpsite in Nnewi, Nigeria. Discover Water. 2022, 2(1). https://doi.org/10.1007/s43832-022-00023-9

[9] Awka. History & Facts. Encyclopedia Britannica. Map Showing Port Harcourt And Awka with Distance Indicator, 2021. https://www.Globalfeed.com

[10] Bellebaum J. Between the Herring Gull Larusargentatus and the Bulldozer: Black- headed Gull Larusridibundus feeding sites on a Refuse Dump. OrnisFennica. 2005, 82: 166-171.

[11] Adelekan BA, Alawode AO. Contributions of refuse dumps to heavy metal concentrations in soil profile and groundwater in Ibadan, Nigeria. Journal of Applied Biosciences. 2011, 40: 7227-2737.

[12] Anikwe M. Long term effect of municipal waste disposal on soil properties and productivity of sites used for urban agriculture in Abakaliki, Nigeria. Bioresource Technology. 2002, 83(3): 241-250. https://doi.org/10.1016/s0960-8524(01)00154-7

[13] Adelekan BA, Abegunde KD. Heavy metals contamination of soil and groundwater at automobile mechanic villages in Ibadan, Nigeria. International Journal of the Physical Sciences. 2011, 6(5): 1045-1058.

[14] Schell LM, Gallo MV, Denham M, et al. Effects of Pollution on Human Growth and Development: An Introduction. Journal of PHYSIOLOGICAL ANTHROPOLOGY. 2006, 25(1): 103-112. https://doi.org/10.2114/jpa2.25.103

[15] Oluwayiose O, Akinsete S, Ana G, et al. Soil Contamination by Refined Crude Oil Using Lumbricus terrestris as Toxicity Indicator at a Petroleum Product Depot, Ibadan, Nigeria. British Journal of Applied Science & Technology. 2015, 9(1): 37-46. https://doi.org/10.9734/bjast/2015/17923

[16] Gairola SU, Soni P. Role of soil physical properties in ecological succession of restored mine land – A case study, International Journal of Environmental Sciences. 2010, 1(4): 475-480.

[17] Biswas AK, Kumar S, Babu SS, et al. Studies on environmental quality in and around municipal solid waste dumpsite. Resources, Conservation and Recycling. 2010, 55(2): 129-134. https://doi.org/10.1016/j.resconrec.2010.08.003

[18] Moorberg CJ, Crouse DA. Soil laboratory manual. USDA, Soil taxonomy classification, 2017.

[19] Al-Shammary AAG, Kouzani AZ, Saeed TR, et al. Evaluation of a novel electromechanical system for measuring soil bulk density. Biosystems Engineering. 2019, 179: 140-154.
https://doi.org/10.1016/j.biosystemseng.2019.01.007

[20] Aralu CC, Okoye PAC, Abugu HO, et al. Characterization, sources, and risk assessment of PAHs in borehole water from the vicinity of an unlined dumpsite in Awka, Nigeria. Scientific Reports. 2023, 13(1).
https://doi.org/10.1038/s41598-023-36691-3

[21] Aralu CC, Okoye PAC, Abugu HO, et al. Potentially toxic element contamination and risk assessment of borehole water within a landfill in the Nnewi metropolis. Health and Environment. 2023, 4(1): 186-197.
https://doi.org/10.25082/he.2023.01.001

[22] Agbeshie AA, Adjei R, Anokye J, et al. Municipal waste dumpsite: Impact on soil properties and heavy metal concentrations, Sunyani, Ghana. Scientific African. 2020, 8: e00390.
https://doi.org/10.1016/j.sciaf.2020.e00390

[23] Walkley A, Black Ia. An Examination of the Degtjareff Method for Determining Soil Organic Matter, and A Proposed Modification of The Chromic Acid Titration Method. Soil Science. 1934, 37(1): 29-38.
https://doi.org/10.1097/00010694-193401000-00003

[24] Tautua A, Bamidele Mw, Onigbinde, et al. Assessment of some heavy metals and physicochemical properties in surface soils of municipal open waste dumpsite in Yenagoa, Nigeria. African Journal of Environmental Science and Technology. 2014, 8(1): 41-47.
https://doi.org/10.5897/ajest2013.1621

[25] Thorpe VA. Collaborative Study of the Cation Exchange Capacity of Peat Materials. Journal of AOAC INTERNATIONAL. 1973, 56(1): 154-157.
https://doi.org/10.1093/jaoac/56.1.154

[26] Dalal RC, Moloney D. Sustainability indicators of soil health and biodiversity, In Management for sustainable ecosystems, ed. P. Hale, A. Petrie, D. Moloney, and P. Sattler. Brisbane: Centre for Conservation Biology, University of Queensland. 2000, 101–108.

[27] Sahrawat KL, Narteh LT. A fertility index for submerged rice soils. Communications in Soil Science and Plant Analysis. 2002, 33(1-2): 229-236.
https://doi.org/10.1081/css-120002389

[28] Shehu-Alimi E, Esosa I, Ganiyu BA, et al. Physicochemical and Heavy Metals Characteristics of Soil from Three Major Dumpsites in Ilorin Metrpolis, North Central Nigeria. Journal of Applied Sciences and Environmental Management. 2020, 24(5): 767-771.
https://doi.org/10.4314/jasem.v24i5.6

[29] Rai AK, Paul B, Singh G. A study on the bulk density and its effect on the growth of selected grasses in coal mine overburden dumps, Jharkhand, India, International Journal of Environmental Sciences. 2010, 1(4): 677-684.

[30] FAO. A Framework for Land Evaluation. FAO Bulletin 32, FAO/UNESCO, France, 1976.

[31] Okonkwo NE, Odemelam S, Ano O. Levels of toxic elements in soils of abandoned waste dump site. African journal of Biotechnology. 2016, 5(13):1241-1244

[32] Obianefo F, Agbagwa I, Tanee FBG. Physicochemical Characteristics of Soil from Selected Solid Waste Dump Sites in Port Harcourt, Rivers State, Nigeria. Journal of Applied Sciences and Environmental Management. 2017, 21(6): 1153.
https://doi.org/10.4314/jasem.v21i6.27

[33] MAFF (Ministry of Agriculture, Fisheries and Food) and Welch Office Agriculture Department (1992). Code of Good Agriculture Practice for the Protection of Soil. Draft Consultation Document, MAFF, London.

[34] EC (Council of the European Communities). Directive 86278 EECN on the Protection of the Environment and in Particular of the soil when Sewage Sludge is used EEC. Brussels, 1986.

[35] Chessed G, Sakiyo DC, Yako AB. Concentration of Heavy Metals in Soil around Dumpsites in Jimeta and Ngurore, Adamawa State, Nigeria. NIGERIAN ANNALS OF PURE AND APPLIED SCIENCES. 2019, 1: 105-112.
https://doi.org/10.46912/napas.33

[36] World Health Organization (WHO). Standard maxima for metals in Agricultural soils, 1993.

[37] National Environment Protection Council of Australia (NEPCA). Limits of Heavy metals in soils, 2010.
https://www.newzealand.govt.nz

[38] Eze VC, Enyoh CE, Ndife CT. Soil Cationic Relationships, Structural and Fertility Assessment Within Selected Active Dumpsites in Nigeria. Chemistry Africa. 2020, 4(1): 127-136.
https://doi.org/10.1007/s42250-020-00194-9

[39] Eze VC, Onwukeme V, Enyoh CE. Pollution status, ecological and human health risks of heavy metals in soil from some selected active dumpsites in Southeastern, Nigeria using energy dispersive X-ray spectrometer. International Journal of Environmental Analytical Chemistry. 2020, 102(16): 3722-3743.
https://doi.org/10.1080/03067319.2020.1772778

[40] Umoh SD, Etim EE. Determination Of Heavy Metal Contents From Dumpsites Within Ikot Ekpene, Akwa Ibom State, Nigeria Using Atomic Absorption Spectrophotometer. The International Journal of Engineering and Science (IJES), 2013, 2(2): 123-129.

[41] Bowen HJM. The Environmental Chemistry of Elements. Academic Press London.1979, 212-246.

[42] Ogunlana R, Korode AI, Ajibade ZF. Assessing the level of heavy metals concentration in soil around transformer at Akoko community of OndoState, Nigeria. Journal of Applied Sciences and Environmental Management. 2021, 24(12): 2183-2189.
https://doi.org/10.4314/jasem.v24i12.26

[43] Chiroma Tm, Ebewele R O, Hymore Fk. Comparative assessment of heavy metal levels in soil, vegetables and urban grey waste water used for irrigation in Yola and Kano. International Refereed Journal of Engineering and Science. 2014, 3(2): 1-9.

[44] Akanchise T, Boakye S, Borquaye LS, et al. Distribution of heavy metals in soils from abandoned dump sites in Kumasi, Ghana. Scientific African. 2020, 10: e00614.
https://doi.org/10.1016/j.sciaf.2020.e00614

[45] Twumasi P, Tandoh MA, Borbi MA, et al. Assessment of the levels of cadmium and lead in soil and vegetable samples from selected dumpsites in the Kumasi Metropolis of Ghana, 2016.

[46] Addis W, Abebaw A. Determination of heavy metal concentration in soils used for cultivation of Allium sativum L. (garlic) in East Gojjam Zone, Amhara Region, Ethiopia. Pashikanti S, ed. Cogent Chemistry. 2017, 3(1): 1419422.
https://doi.org/10.1080/23312009.2017.1419422

[47] Okeke DO, Ifemeje JC. Levels of heavy metals in soils and food crops cultivated within selected mining sites in Ebonyi State, Nigeria. Health and Environment. 2021, 2(1): 84-95.
https://doi.org/10.25082/he.2021.01.003

[48] Onwukeme VI, Eze VC. Identification of heavy metals source within selected active dumpsites in southeastern Nigeria. Environmental Analysis Health and Toxicology. 2021, 36(2): e2021008.
https://doi.org/10.5620/eaht.2021008

[49] Eze VC, Onwukeme VI, Ogbuagu JO, et al. Toxicity and risk evaluation of polychlorinated biphenyls in River Otamiri, Imo State. Scientific African. 2023, 22: e01983.
https://doi.org/10.1016/j.sciaf.2023.e01983

[50] Eze VC, Onwukeme VI, Ogbuagu JO. Concentration, toxicity, and health risk assessment of polychlorinated biphenyls (PCBs) in top soils around Nekede auto-mechanic village, Imo State. Arabian Journal of Geosciences. 2024, 17(1).
https://doi.org/10.1007/s12517-023-11836-w