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Assessment of the Effects of Gosa Dumpsite on Soil, Water, and Air Quality in Abuja Municipal Area Council, Nigeria

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ABSTRACT

Open dumpsites remain a major environmental challenge in developing nations. This study assessed physicochemical properties, heavy metal concentrations, and ambient air pollutants around the Gosa dumpsite in Abuja, Nigeria. Soil samples (n=9 + control) were analyzed for texture, organic carbon, cation exchange capacity, and heavy metals (Zn, Cu, Mn, Pb). Water samples (n=3) were tested for major ions, pH, conductivity, and organic load indices. Air pollutants ($PM_{2.5}$, PM_{10}, CO, H_2S, VOCs) were quantified. Results revealed sandy loam soils with low organic carbon (0.2–0.3%) and moderate cation exchange capacity (12–13 cmol/kg). Heavy metals occurred at low–moderate levels, while water samples showed significant contamination exceeding WHO/NESREA limits. Air quality was degraded, with NH_3, SO_2, NO_2, $PM_{2.5}$, and PM_{10} surpassing permissible thresholds. Findings highlight risks of groundwater pollution, reduced agricultural productivity, and public health hazards. Proper waste management, groundwater protection, and soil fertility restoration are recommended.

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Waste management, dumpsite pollution, heavy metals, soil degradation, air quality, Abuja.

INTRODUCTION

Rapid industrialization and urbanization have accelerated the generation of large volumes of waste, creating significant environmental and health challenges worldwide (Emmanuel-Akerele & Peter, 2020). Poor waste management practices particularly indiscriminate solid waste disposal is among the most pressing issues, especially in developing nations where infrastructure and resources are limited (Byamba-Ochir & Tugjjav, 2019; Kundiri *et al*., 2017). Nigeria exemplifies this situation, with several open dumpsites posing environmental and public health risks. The Gosa dumpsite in Abuja is a notable example, where poor waste disposal practices have introduced pollutants, including heavy metals, into the surrounding environment (Ebisintei *et al.,* 2015; Magaji, 2012).

Gosa dump site is located in Gosa community on Musa Yar'Adua way close to Dr. Nnamdi Azikiwe international Airport, Abuja the dump site is about 4 kilometers off the Airport Road and about 10 kilometers from the Abuja central District. Previous studies in Nigeria and other developing regions confirm that dumpsites contribute to soil degradation, groundwater contamination, and air pollution. However, limited site-specific evidence exists for Gosa, necessitating this study.

STATEMENT OF THE RESEARCH PROBLEM

Solid waste disposal remains a pressing environmental concern in Abuja, Federal Capital Territory (FCT), where the proliferation of open dumpsites particularly the Gosa dumpsite has become a major ecological challenge. Poor waste management practices at this site have been linked to land degradation, water pollution, and air pollution (Nnaji *et al.,* 2016). The dumpsite contributes to soil deterioration and reduced vegetation cover (Ameh, 2022). In addition, soils around such sites often exhibit elevated levels of pH, total dissolved solids, and heavy metals such as lead (Pb), copper (Cu), nickel (Ni), and zinc (Zn). This contamination results largely from the co-disposal of hazardous substances, including industrial residues, incinerator ash, mining wastes, batteries, paints, and dyes (Tripathi & Misra, 2022). These pollutants threaten soil fertility, ecosystem integrity, animal health, and human well-being. Alterations in soil physicochemical properties also disrupt plant

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metabolism and hinder vegetation growth (Iyebor *et al.,* 2020).

STUDY AREA

1.1 Location and Size

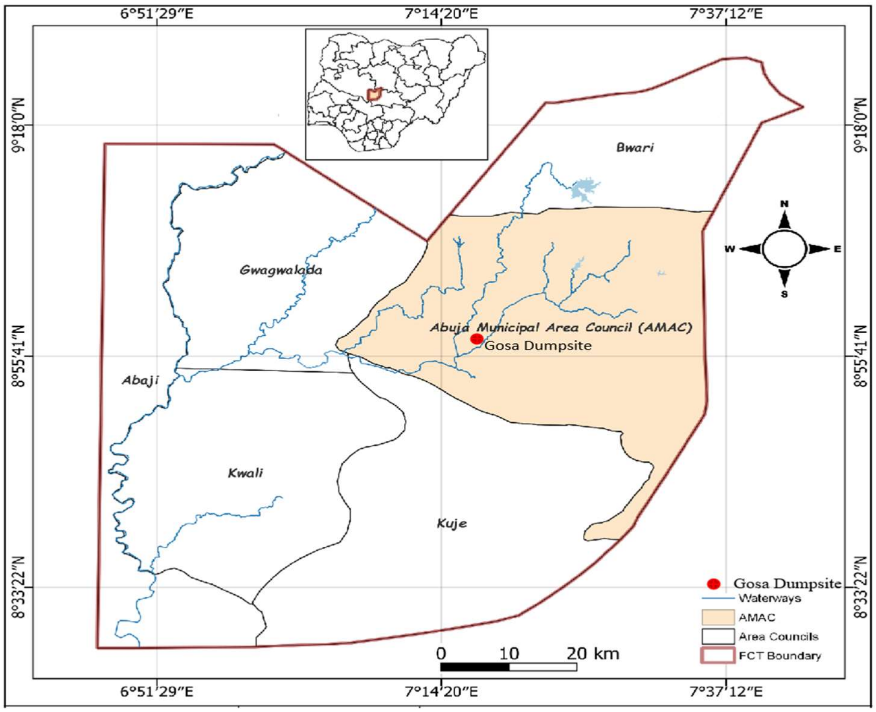

Figure 1.1: FCT showing Gosa dumpsite in AMAC, FCT, Abuja, Nigeria

LITERATURE REVIEW

CONCEPTUAL REVIEW

Waste as a Concept

Waste is broadly understood as unwanted, unusable, or discarded materials that arise from human activities. It encompasses all substances, objects, and by-products that the generator no longer considers useful and thus intends to dispose of. According to the World Health Organization, waste refers to materials that are not the primary product for which a process is intended, and which the generator has no further use of in terms of production, transformation, or consumption (World Health Organization, 2020). Waste management therefore covers the collection, transportation, treatment, recycling, and final disposal of such materials to minimize their negative environmental and health impacts.

Solid waste, in particular, has been classified into several categories based on its origin and characteristics. Chavan, Patel, and Deshmukh (2018) identified municipal, domestic, commercial, industrial, mining, agricultural, and construction wastes as the major sources of solid waste in urban areas. More recently, Hredoy, Rahman, and Das (2022) emphasized that modern waste streams also include electronic waste, biomedical waste, and hazardous industrial residues, which pose complex management challenges.

Waste Management as a Concept

Waste management refers to the systematic administration of activities related to the handling of waste from its generation to its final disposal, with the goal of protecting human health, the environment, and ensuring resource efficiency. The World Health Organization

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(2020) defines waste management as the collection, transport, processing, recycling, and disposal of waste materials in a way that minimizes risks to health and the environment. Similarly, the United Nations Environment Programme (2021) describes waste management as an integrated system of controlling the generation, storage, collection, transfer, processing, and disposal of waste in a manner that is consistent with the best principles of public health, economics, engineering, and environmental sustainability. In the Nigerian context, the National Environmental Standards and Regulations Enforcement Agency (NESREA) define waste management as a process of ensuring that waste is handled in compliance with national environmental regulations to protect ecosystems and human settlements (National Environmental Standards and Regulations Enforcement Agency, 2020).

EFFECT OF DUMPSITE ON SOIL QUALITY

Shehu-Alimi et al. (2020) investigated the physicochemical and heavy metals characteristics of soils from three major dumpsites in Ilorin Metropolis, North Central Nigeria. Soil samples were collected from Ita-Amodu, Sawmill Garage, and Kuntu areas and analyzed for pH, electrical conductivity, temperature, sulphates, chlorides, nitrates, moisture content, organic matter, and heavy metals including cadmium (Cd), lead (Pb), zinc (Zn), iron (Fe), and copper (Cu). The study revealed pH values of 7.1, 7.2, and 6.8, and organic matter contents of 0.95%, 0.73%, and 1.14% respectively. Moisture contents ranged between 2.89% and 3.93%. The chloride contents varied from 31.76 mg/L to 91.63 mg/L, while nitrates were between 0.06–0.23 mg/L. Heavy metal analysis showed the presence of cadmium (0.048–0.62 mg/L), lead (0.056–0.07 mg/L), zinc (0.009–0.066 mg/L), copper (0.028–0.031 mg/L), and iron (0.190–0.62 mg/L). The results indicate moderate contamination and possible risks to soil quality.

EFFECTS OF DUMPSITE ON WATER QUALITY

Ferreira, Aderibigbe, and colleagues (2023) investigated groundwater quality in boreholes and wells around the Olusosun dumpsite one of Lagos's largest municipal waste sites. Methodology: the authors collected representative borehole and well samples and analyzed a suite of physicochemical parameters (pH, electrical conductivity, TDS, major ions), heavy metals, and microbial indicators using standard laboratory methods; results were compared with WHO drinking-water limits and local standards. Findings: several parameters including electrical conductivity, total dissolved solids and selected heavy metals were elevated in wells closest to the dumpsite, and microbial contamination was frequently detected, indicating leachate influence and risk to potable groundwater.

EFFECTS OF DUMPSITES ON AIR QUALITY

Open dumpsites and uncontrolled/poorly managed landfills are important local sources of air pollution. Key emissions include particulate matter ($PM_{2.5}$/PM_{10}), gases produced by anaerobic decomposition (methane, CO_2), odorous and toxic trace gases (H_2S, NH_3, VOCs such as benzene and formaldehyde), combustion products when waste burns (CO, PM, NO_x, SO_x, VOCs), heavy metals associated with fugitive dust, and emerging contaminants (PFAS) found in landfill gas. These emissions degrade local air quality, cause acute and chronic respiratory and other health impacts for nearby communities and workers, and can create episodic high-exposure events during landfill fire (*Atmosphere* **2024)**, *15*(4), 410; ***https://doi.org/10.3390/atmos15040410***

RESEARCH METHODOLOGY

This study is anchored on the principle of hypothesis-testing research design. The design aimed at testing objective theory postulated in the form of research hypothesis, to ascertain the level of chemical parameters and heavy metal properties in the water, soil and plants in the study area. This design was adopted to draw conclusions in the premise of deductive theory.

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This study relied on numerical dataset which is most suitable for quantitative analysis. Physicochemical and heavy metals values in the water (ground and surface), soil (top and sub) and plant samples constitutes the numerical data. The dataset is measured on a ratio scale (microgram/liter and kg/l) as obtained from the laboratory analysis.

The study relied solely on primarily sourced data. Samples of groundwater, soil, and plant were collected afresh and subjected to laboratory analysis for biophysical, chemical and heavy metal concentration. The originality of the dataset is subject to the fact that the data were generated and not sourced from existing archives.

Soil Sampling: Nine points + control, analyzed for particle size, organic carbon, cation exchange capacity, and heavy metals.

Water Sampling: Three points, tested for pH, conductivity, hardness, chloride, sulphate, BOD, COD, and heavy metals.

Air Quality Monitoring: $PM_{2.5}$, PM_{10}, CO, H_2S, VOCs measured at varying distances from dumpsite. Air quality analysis was conducted around the Gosa dumpsite to determine the concentration of major atmospheric pollutants produced from the decomposition and burning of municipal solid waste. The parameters measured include Carbon monoxide (CO), Nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), Ammonia (NH_3), Methane (CH_4), and Particulate Matter ($PM_{2.5}$ and PM_{10}).

The study adopted both the descriptive and inferential statistical methods of data analysis. The descriptive statistics includes both mean and standard deviation of the derived data obtained from the laboratory analysis, while Anova statistics, student t-test and correlation constituted the inferential statistics adopted in this study to provide meaningful inferences on the study hypothesis. The data analysis commensurate to the study objects.

RESULTS AND DISCUSSION;

Air Quality Result Table

Parameter	At Dumpsite (A)	500m Away (B)	1000m Away (C)	WHO Standard
CO (ppm)	8.5	5.2	2.1	9 ppm
NO_2 (ppm)	0.08	0.05	0.02	0.04 ppm
SO_2 (ppm)	0.06	0.04	0.01	0.02 ppm
NH_3 (ppm)	1.20	0.75	0.30	0.20 ppm
CH_4 (%)	3.5	2.1	0.8	Not specified
$PM_{2.5}$ (µg/m³)	55	40	22	25 µg/m³
PM_{10} (µg/m³)	120	85	50	50 µg/m³

Air: Pollutant concentrations highest at dumpsite, decreasing with distance. NH_3, SO_2, NO_2, $PM_{2.5}$, PM_{10} exceeded WHO limits.

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SPATIAL DISTRIBUTION OF PHYSICOCHEMICAL AND HEAVY METALS CONCENTRATIONS IN THE SOIL AND WATER AROUND THE DUMP SITE

Spatial distribution of physicochemical concentrations in the Soil

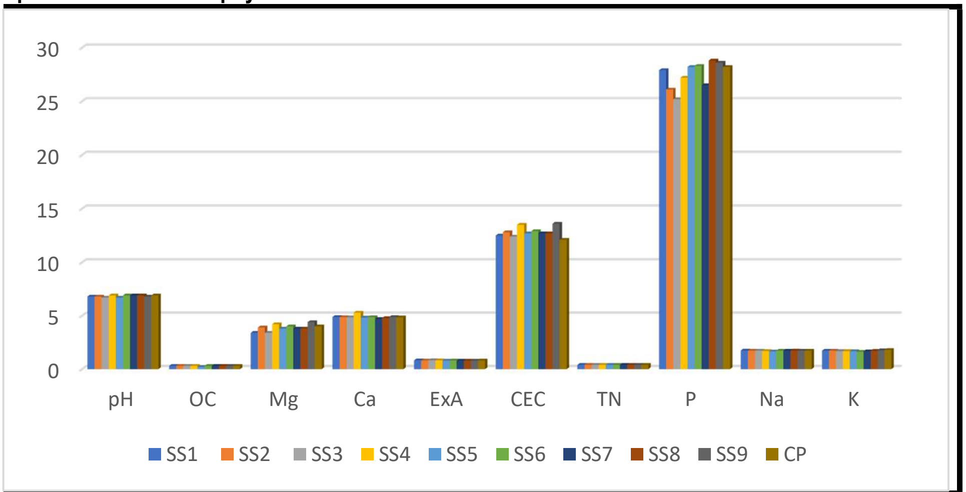

Figure 4.1: Spatial analysis of physicochemical concentrations in the Soil

Spatial distribution of Heavy metals concentrations in the Soil

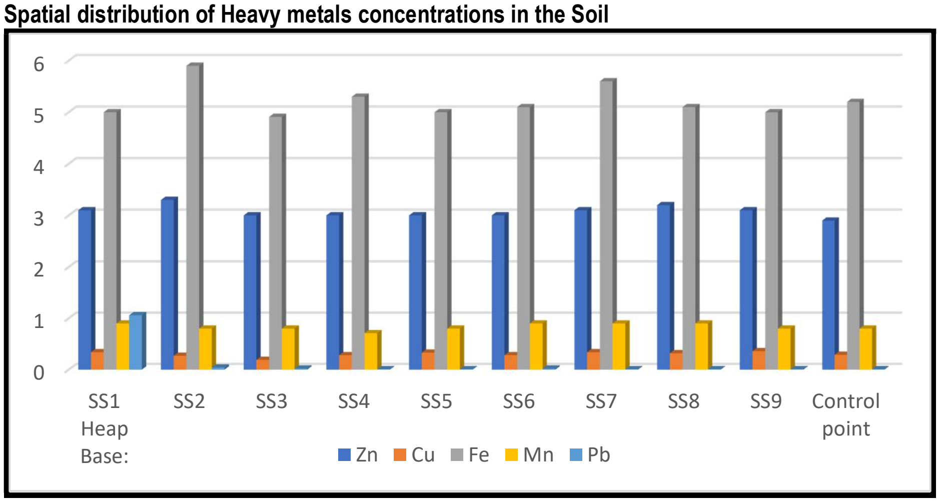

Figure 4.2: Spatial analysis of Heavy metals concentrations in the Soil

Comparative analysis of Heavy metals in Soils between the field results with the set standards.

Parameter	Gosa	**NESREA**	**FAO**
Zn	3.1	5.0	3.0
Cu	0.3	1.5	0.1
Fe	5.21	2.0	0.3
Mn	0.83	-	0.2
Pb	0.84	0.1	0.05

Source: Field survey, (2026)

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The results of the heavy metal analysis in Gosa soils (Table 1.3) reveal widespread contamination when benchmarked against NESREA and FAO permissible standards. Although zinc (3.1 mg/L) falls below the NESREA threshold (5.0 mg/L), it slightly exceeds FAO's agricultural limit (3.0 mg/L), indicating a potential risk of gradual soil accumulation and eventual crop uptake. Copper (0.3 mg/L) is within NESREA's permissible concentration (1.5 mg/L) but surpasses FAO's guideline (0.1 mg/L) by threefold, highlighting the likelihood of long-term phytotoxicity and soil quality impairment if irrigation continues with contaminated water. The most striking result is iron (5.21 mg/L), which greatly exceeds both NESREA (2.0 mg/L) and FAO (0.3 mg/L) limits, signifying severe contamination and posing risks of iron overload in crops and adverse health outcomes in consumers. Likewise, manganese (0.83 mg/L) is more than four times FAO's permissible limit (0.2 mg/L), while lead (0.84 mg/L) surpasses both NESREA (0.1 mg/L) and FAO (0.05 mg/L) thresholds by wide margins, raising immediate concerns about toxicological impacts on humans, livestock, and soil ecology.

THE POTENTIAL ECOLOGICAL AND HEALTH RISKS ASSOCIATED WITH THE OBSERVED LEVELS OF PHYSICOCHEMICAL PARAMETERS AND HEAVY METALS IN THE STUDY AREA.

The analysis of heavy metals in the Gosa site reveals concentrations that exceed several national and international standards, raising serious ecological and public health concerns. Zinc was detected at 3.1 mg/L, slightly above the FAO irrigation threshold of 3.0 mg/L but within NESREA's permissible limit of 5.0 mg/L. Although zinc is an essential micronutrient for plants and humans, the World Health Organization (WHO, 2021) notes that long-term exposure to elevated concentrations can cause soil accumulation and eventual phytotoxicity. Crops irrigated with such water may show reduced yields and nutritional quality, while in humans, chronic exposure could impair immune function and cause gastrointestinal disturbances.

Copper levels were recorded at 0.3 mg/L, which falls within NESREA's permissible limit of 1.5 mg/L but is three times higher than the FAO recommended guideline of 0.1 mg/L. The WHO (2021) guidelines for drinking water quality set an upper safe limit of 2.0 mg/L, suggesting that immediate health risks may be low. However, in irrigation contexts, such accumulation can negatively affect seed germination, microbial balance, and soil fertility. Over time, excessive copper in soils may reduce crop yields, while in human populations, high copper ingestion has been linked to liver and kidney damage as well as gastrointestinal irritation in sensitive groups.

Iron was found at 5.21 mg/L, far exceeding NESREA (2.0 mg/L), FAO (0.3 mg/L), and WHO (2021) standards, which set a maximum acceptable concentration of 0.3 mg/L in drinking water. Elevated iron levels present a dual ecological and health threat. In soils, they can cause hardpan formation, restrict root aeration, and induce toxicity in crops such as rice and leafy vegetables. From a human health perspective, long-term iron ingestion can lead to hemochromatosis, a disorder associated with liver, pancreas, and heart damage, while also affecting water aesthetics by imparting unpleasant taste, odor, and discoloration.

Manganese concentration at 0.83 mg/L also surpasses the FAO irrigation guideline (0.2 mg/L) and exceeds the WHO (2021) drinking water guideline of 0.4 mg/L. Manganese accumulation in soils can reduce phosphorus availability and impair photosynthesis, lowering crop productivity and soil quality. In human populations, chronic exposure to elevated manganese is associated with neurological disorders, including manganism, a Parkinson's-like condition. Children are particularly vulnerable to neurodevelopmental effects, making this parameter especially concerning in the Gosa context.

CONCLUSION

The study revealed that the soils in the study area are generally slightly acidic to neutral, with moderate cation exchange capacity and adequate levels of essential macronutrients such as calcium, magnesium, potassium, and phosphorus, indicating that the

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soils are reasonably fertile but limited by low organic carbon and organic matter content. Soil physical properties such as texture, bulk density, and moisture content suggest moderate suitability for crop cultivation, although organic amendments are needed to enhance water retention, aeration, and biological activity. Heavy metal analysis showed that zinc, copper, iron, and manganese were within acceptable limits, but lead concentrations were elevated at specific points, particularly around the heap base, raising localized environmental and health concerns.

Overall, the findings imply that while the soils are suitable for agricultural use, their long-term sustainability depends on improved organic matter management and careful monitoring of heavy metal accumulation to prevent ecological and public health risks.

RECOMMENDATIONS

Based on the findings and conclusion of the study, the following recommendations are considered appropriate:

1. The soils are moderately acidic (pH 6.7–6.9) with low organic carbon (0.2–0.3%). To improve fertility and enhance microbial activity, farmers should adopt organic amendments (manure, compost, crop residues) and lime application where necessary to sustain neutral soil reaction for optimum nutrient availability.
2. Pollutant concentrations are highest at the dumpsite and decrease with distance. This suggests that improved waste management strategies are necessary to reduce environmental and health risks associated with the dumpsite
3. Exchangeable bases (Ca^{2+}, Mg^{2+}, K^+, Na^+) and phosphorus were within acceptable ranges but showed spatial variations. Site-specific fertilizer application and precision nutrient management should be encouraged instead of blanket fertilizer use, ensuring balanced supply of macronutrients and preventing localized deficiencies.
4. Cation exchange capacity (12.1–13.6 cmol/kg) was moderate, suggesting soils have limited buffering capacity. This calls for regular soil testing and tailored fertilization to avoid nutrient leaching. Incorporating leguminous cover crops could also improve nitrogen supply and boost soil nutrient retention.
5. Levels of Zn, Cu, Fe, and Mn were within safe limits, but traces of lead (Pb up to 1.06 mg/kg at SS1) were detected. Regular monitoring of heavy metals in soils, irrigation water, and crops is necessary to avoid long-term accumulation in the food chain. Phytoremediation using tolerant plant species may also help mitigate risks in hotspot areas.
6. Since both physicochemical properties and heavy metal concentrations show spatial variation across sampled sites, site-specific soil management is strongly recommended. Precision agriculture tools and farmer training on sustainable irrigation practices can enhance soil health and productivity while reducing environmental risks.

REFERENCES

Abah, S. O., & Ohimain, E. I. (2021). Assessment of Dumpsite Rehabilitation Potential Using the Integrated. *World Applied Sciences Journal*, *8*(4), 436–442.

Abdulrahman, A. I., & Yusuf, A. (2023). Heavy metal levels in soils around dumpsites and control points in Sokoto, Northwestern Nigeria. *Environmental Earth Sciences, 82*(7), 195. https://doi.org/10.1007/s12665-023-11245-5

Aboyeji, O. S., & Eigbadon, I. A. (2020). Heavy metals assessment in soils and vegetables from selected dumpsites in Lagos, Nigeria. *Environmental Monitoring and Assessment, 192*(6), 382. https://doi.org/10.1007/s10661-020-08358-9

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Adebara S. A., Afolayan A., Omajali D. I., & Olatunji A. A. (2016). Assessment of the Effects of Solid Waste Dumpsite on Groundwater in Osogbo and Ede Metropolis Osun State, Nigeria. *Journal of Engineering Technologies and Management Research, 3*(2), 1–21.

Adeolu, A. T., Adaikpoh, E. O., & Ogunleye, O. O. (2023). Assessment of groundwater contamination from municipal solid waste dumpsites in Lagos, Nigeria. *Environmental Monitoring and Assessment, 195*(8), 1034. https://doi.org/10.1007/s10661-023-11456-9

Adeolu, A. T., Adaikpoh, E. O., & Ogunleye, O. O. (2023). Assessment of groundwater contamination from municipal solid waste dumpsites in Lagos, Nigeria. *Environmental Monitoring and Assessment, 195*(8), 1034. https://doi.org/10.1007/s10661-023-11456-9

Adewumi, I. (2022). *Industrial waste management practices in Nigeria: Challenges and opportunities.* Journal of Environmental Science and Policy, 15(3), 44–58.

Adewumi, I. K., Okareh, O. T., & Akinbile, C. O. (2021). Sustainable waste management in developing countries: A review of practices, challenges, and opportunities. *Environmental Challenges, 4,* 100138. https://doi.org/10.1016/j.envc.2021.100138

Adewumi, I. K., Okareh, O. T., & Akinbile, C. O. (2021). Waste-to-resource opportunities: A pathway to circular economy and sustainable waste management in developing countries. *Environmental Challenges, 5,* 100291. https://doi.org/10.1016/j.envc.2021.100291

Ajayi, T. A. (2023). Spatial variability of soil properties around municipal dumpsites in southwestern Nigeria. *Environmental Research and Public Health, 20*(15), 6789. https://doi.org/10.3390/ijerph20156789

Akintola, O. O., Adeyemi, G. O., Olokeogun, O. S., & Bodede, I. A. (2021). Impact of Wastes on Some Properties of Soil around an Active Dumpsite in Ibadan, Southwestern Nigeria. *Journal of Bioresource Management*, *8*(3), 27–40. https://doi.org/10.35691/JBM.1202.0193

Ameh, E. G. (2022). Metal uptake efficacy and phytoremediation potential of plants grown around soil dumpsites in Anyigba, Kogi State, Nigeria. *International Journal of Science Global Sustainability*, *8*(2).

Aralu, C. C., et al. (2024). Seasonal variations of risks associated with potentially toxic elements near Awka dumpsite. ScienceDirect.

Arogundade, J., & Aurelius, O. (2023). Toxicity Characteristics Leaching Procedure of Wastes dumped in some parts of Federal Capital Territory Abuja, North Central Nigeria. *Yanbu Journal of Engineering and Science*, *20*(1), 61–66. https://doi.org/10.53370/001c.74005

Asare, A. B., Kusi, J., & Mensah, R. (2023). Soil fertility and contamination in Ghanaian urban agricultural soils near waste sites. *Journal of Environmental Quality, 52*(4), 900–913. https://doi.org/10.2134/jeq2022.08.0310

Ayoola, O. J. (2022). An assessment of the heavy metals concentration of Gosa landfill and Mpape dumpsite in Abuja Municipal Area Council, Federal Capital Territory, Nigeria. *African Journal of Geography and Environmental Management.*

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. (1989). *United Nations Treaty Series, 1673,* 57. Retrieved from https://www.basel.int

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Sustainable Procurement, Environmental and Social Standards Enhancement Centre of Excellence, ATBU, Bauchi
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Basel Convention Secretariat. (2022). *Overview of hazardous wastes and their management*. United Nations Environment Programme. Retrieved from https://www.basel.int

Byamba-Ochir, M., and Tugjjav, O. (2019). Microbiological contamination and content of heavy metals in unlined landfill sites of Ulaanbaatar. *International Journal of Scientific Reports*, *5*(8), 73–82. https://doi.org/10.3389/fenvs.2021.604216

Chavan, A., Patel, D., & Deshmukh, R. (2018). Municipal solid waste generation and management: Current status and challenges. *International Journal of Environment and Waste Management, 22*(2), 147–165. https://doi.org/10.1504/IJEWM.2018.100167.

Ebisintei, S., Ojo, E., & Ihekweme, G. (2015). Soil Degradation Resulting from Migration of Ion Leachate in Gosa Dumpsite, Abuja, Nigeria. *International Journal of Innovation and Scientific Research*, *16*(2), 326–340.

Emmanuel, J. E., Nnawuike, A. J., Michael. N.O., Kelechi, I. S., Kelechi, O.J., Chinecherem, U. K., & Chukwuebuka, A. D. (2020). Assessment of Physicochemical Characteristics and Heavy Metal Concentration in Soils and Plants in Selected Refuse Dumpsites within Nkwerre L.G.A., of Imo State, Southeast Nigeria. *South Asian Research Journal of Natural Products*, *3*(3), 26–36.

Emmanuel-Akerele, H. A., & Peter, F. I. (2020). Microbial and Physico-Chemical Assessment of Soil and Water Around Waste Dump Sites in Lagos. *International Journal of Applied Biology*, *5*(1), 73–82.

Environmental Literacy Council. (2025). *What are landfills? A deep dive into waste management's final frontier*. Retrieved from Environmental Literacy Council website.

Environmental Protection Agency. (2018). *Waste Classification - List of Waste & Determining if Waste is Hazardous or Non-hazardous* (Issue 5).

European Commission (2021). Guidance on classification of waste according to EWC-Stat categories. *Eurostat*, *2150/2002*(2), 82.

European Commission. (2022). *Waste framework directive (Directive 2008/98/EC as amended).* Retrieved from https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive

European Environment Agency. (2022). *Construction and demolition waste: challenges and opportunities in a circular economy*. EEA Report.

European Union. (1999). *Council Directive 1999/31/EC on the landfill of waste* (Landfill Directive). Amended by Directive (EU) 2018/850 (2020).

Ferreira, C. S., *et al.* (2023). Groundwater quality in the vicinity of a dumpsite in Lagos. ScienceDirect.

Food and Agriculture Organization. (2021). *Managing agricultural waste for sustainable food systems*. FAO.

Forti, V., Balde, C. P., & Kuehr, R. (2022). *The Global E-waste Monitor 2022*. United Nations Institute for Training and Research (UNITAR).

Forti, V., Baldé, C. P., Kuehr, R., & Bel, G. (2020). *The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential*. United Nations University, ITU & ISWA.

Ganiyu, A. R. (2024). Heavy metal hotspots in soils around municipal dumpsites in Nigeria: Implications for land use. *Environmental Pollution, 339*, 122471. https://doi.org/10.1016/j.envpol.2023.122471

Gupta, L., & Rani, S. (2016). Leachate characterization and evaluating its impact on groundwater quality in the vicinity of landfill site area. *Journal of Environmental Science, Toxicology and Food Technology*, *8*(10), 01–07.

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https://doi.org/10.9790/ 2402-081030107

Gyabaah, F. A., Osei, R., & Boateng, K. (2024). Sandy soil textures and waste site contamination in West Africa. *African Journal of Environmental Science and Technology, 18*(1), 15–27. https://doi.org/10.5897/AJEST2023.3201

Hong, Y., Zhu, Z., Liao, W., Yan, Z., Feng, C., & Xu, D. (2023). Freshwater Water-Quality Criteria for Chloride and Guidance for the Revision of the Water-Quality Standard in China. *International Journal of Environmental Research and Public Health*, *20*(4), 2875. https://doi.org/10.3390/ijerph20042875

Hredoy, M. J., Rahman, M. S., & Das, S. (2022). Challenges and prospects of solid waste management in developing countries: A case of South Asia. *Journal of Environmental Management, 310,* 114760. https://doi.org/10.1016/j.jenvman.2022.114760

Hredoy, M., Rahman, A., & Das, S. C. (2022). Emerging challenges of solid waste management in developing countries: A review. *Waste Management & Research, 40*(7), 861–874. https://doi.org/10.1177/0734242X221093876

Hredoy, R. H., Siddique, M. A. B., Akbor, M. A., Shaikh, M. A. A., & Rahman, M. M. (2022). Impacts of Landfill Leachate on the Surrounding Environment: A Case Study on Amin Bazar Landfill, Dhaka (Bangladesh). *Soil Systems*, *6*(4), 1–16. https://doi.org/10.3390/soilsystems6040090

Institute for Environmental Research and Education. (2025). *What are landfills*. Retrieved from IERE website.

International Atomic Energy Agency. (2022). *Radioactive waste management*. IAEA.

Iwuoha, G. N., Okechukwu, P. E., & Nwankwo, C. J. (2021). Heavy metal concentrations in soils around municipal solid waste dumpsites in Aba, Southeastern Nigeria. *Applied Water Science, 11*(5), 120. https://doi.org/10.1007/s13201-021-01406-0

Iyebor, E. W., Ngah, S. A., Abam, T. K. S., Ubong, I., & Ule, O. (2020). Assessment of Heavy Metals in Soil around Leaking Underground Petroleum Facilities in Rivers State. *International Journal of Scientific and Technical Research in Engineering*, *5*(2), 12–27.

Jain, P., Kim, H., and Townsend, T. G. (2005). Heavy metal content in soil reclaimed from a municipal solid waste landfill. *Waste Management*, *25*(1), 25–35. https://doi.org/10.1016/j.wasman.2004.08.009

James, L. (2016). Waste Classification. *Royal Society of Chemistry, Environmental Chemistry Group*, *12*, 23–24.

Joseph Omeiza, A., Hammed Adeniyi, L., & Mohammed Shettima, N. (2023). Investigation of groundwater vulnerability to open dumpsites and its potential risk using electrical resistivity and water analysis. *Heliyon*, *9*(2), e13265. https://doi.org/10.1016/j.heliyon.2023.e13265

Kundiri, A. M., Umdagas, B. A., & Oumarou, M. B. (2017). Characterization of Leachate Contaminants from Waste Dumpsites in Maiduguri, Borno State. *Arid Zone Journal of Engineering, Technology and Environment*, *13*(1), 140–148.

Lohfa, T. R., Gotep, J. G., Olasehinde, G. I., & Musa, J. J. (2019). Speciation study of cadmium and zinc in water and soil samples obtained at the vicinity of abattoir, Bukuru and Busa-Buji dumpsites in Jos Metropolis. Journal of Applied Sciences and Environmental Management, 23(3), 467–472. https://doi.org/10.4314/jasem.v23i3.17

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Sustainable Procurement, Environmental and Social Standards Enhancement Centre of Excellence, ATBU, Bauchi
© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved.

Lymer, J. (2016). Waste classification. *Environmental Chemistry Group*, *12*(12), 23–24.

Magaji, J. Y. (2012a). Effects of Waste Dump on the Quality of Plants Cultivated Around Mpape Dumpsite FCT Abuja, Nigeria. *Ethiopian Journal of Environmental Studies and Management*, *5*(4), 567–573. https://doi.org/10.4314/ejesm.v5i4.s17

Magaji, J. Y. & Mallo. I. I. Y. (2020). An assessment of the vertical movement of heavy metals in the soils of Mpape Dumpsite, Federal Capital Territory, Abuja, Nigeria. *Australian Journal of Science and Technology*, *4*(3), 326–332.

Magaji, J. Y. (2020). Evaluation of Mpape landfill standard in FCT Abuja, Nigeria. *International Journal of Scientific and Research Publications*, 10(6), 589–596.

Magaji, J. Y., & Jenkwe, E. D. (2019). An assessment of soil contamination in and around Mpape dumpsite, Federal Capital Territory (FCT), Abuja, Nigeria. *Global Journal of Earth and Environmental Science*, 5(3), 73–81.)

Makuleke, E. M., & Ngole-Jeme, V. M. (2020). Solid waste management in developing countries: A focus on sustainability and circular economy. *Sustainability, 12*(24), 10505. https://doi.org/10.3390/su122410505

Makuleke, L. J., & Ngole-Jeme, V. M. (2020). Environmental and health risks associated with mine waste in South Africa. *Environmental Geochemistry and Health, 42*(7), 2053–2069. https://doi.org/10.1007/s10653-019-00483-3

Makuleke, M., & Ngole-Jeme, V. M. (2020). Waste management in Africa: Trends, challenges, and opportunities. *Waste Management & Research, 38(9),* 1042–1050. https://doi.org/10.1177/0734242X20937328

Manea, D. N., Ienciu, A. A., Ştef, R., Şmuleac, I. L., Gergen, I. I., & Nica, D. V. (2020). Health Risk Assessment of Dietary Heavy Metals Intake from Fruits and Vegetables Grown in Selected Old Mining Areas. A Case Study: The Banat Area of Southern Carpathians. *International Journal of Environmental Research and Public Health*, *17*(14), 5172. https://doi.org/10.3390/ijerph17145172

Mekonnen, B., Alemayehu, E., & Leta, S. (2020). Impact of solid waste dumpsite on surrounding soil and river water quality in Tepi Town, Southwest Ethiopia. Journal of Environmental and Public Health, 2020, Article 5157046. https://doi.org/10.1155/2020/5157046

Mekonnen, B., Haddis, A., & Zeine, W. (2020b). Assessment of the Effect of Solid Waste Dump Site on Surrounding Soil and River Water Quality in Tepi Town, Southwest Ethiopia. *Journal of Environmental and Public Health, 2020*. https://doi.org/10.1155/2020/5157046

Mensah, E., & Boateng, S. (2022). Heavy metal accumulation in dumpsite soils and comparison with international safety thresholds in Kumasi, Ghana. *Environmental Challenges, 8*, 100574. https://doi.org/10.1016/j.envc.2022.100574

Michael C. O. (2014). Effects of Waste Dumps on Stream Water Quality in Rural Areas of Southern Nigeria. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, *8*(2), 82–88. https://doi.org/10.9790/2402-08228288

Mohammed, S. A., & Olalekan, R. M. (2022). Industrial waste management practices and challenges in developing countries: A review. *Environmental Research and Public Health, 19*(4), 2345.

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https://doi.org/10.3390/ijerph19042345

National Environmental Standards and Regulations Enforcement Agency. (2020). *National environmental regulations: Waste management guidelines.* Federal Republic of Nigeria. https://nesrea.gov.ng

Nava, V., Patelli, M., Bonomi, T., Stefania, G. A., Zanotti, C., Fumagalli, L., Soler, V., Rotiroti, M., & Leoni, B. (2020). Chloride Balance in Freshwater System of a Highly Anthropized Subalpine Area: Load and Source Quantification Through a Watershed Approach. *Water Resources Research*, *56*(1). https://doi.org/10.1029/2019WR026024

Nazir, M. I., Sundan, S., Fayaz, S., Dar, M. A., & Raju, J. (2014). the Effect of Dumping Site Leachate on Groundwater Quality-a Case Study of Srinagar City, India. *International Journal of Civil, Structural, Environmental and Infrastructure Engineering*, *4*(1), 1–8.

Neina, D. (2019). The Role of Soil pH in Plant Nutrition and Soil Remediation. *Applied and Environmental Soil Science*, *2019*, 1–9. https://doi.org/10.1155/2019/5794869

Nihalani, S. A., Behede, S. N., & Meeruty, A. R. (2022). Groundwater quality assessment in proximity to solid waste dumpsite at Uruli Devachi in Pune, Maharashtra. *Water Science and Technology*, *85*(11), 3331–3342. https://doi.org/10.2166/wst.2022.172

Nnaji, J. C., and Chukwu, E. (2020). Ecological Risk Assessment of Heavy Metals in Soils from Dumpsites within Umuahia, Nigeria. *Communication in Physical Sciences*, *5*(2), 124–135.

Nwankwoala, H. O., & Ngah, S. A. (2022). Groundwater quality variability around municipal waste dumpsites in Port Harcourt, Nigeria. *Hydrogeology Journal, 30*(6), 1921–1934. https://doi.org/10.1007/s10040-022-02547-1

Nnaji, J. C., Chukwu, E., Obasi, I. A., Nnachi, E. E., Igwe, O. E., Obasi, N. A. P., Tripathi, A., Misra, D. R., Olatunji, O. M., Horsfall, J. T., Sunmonu, L. A., Olafisoye, E. R. R., Adagunodo, T. A., Alagbe, O. A., Gupta, L., Rani, S., Ogu, G., O. Ojiego, B., Bello, Z., … & Tuncan, A. (2016). Impact of solid waste disposal on groundwater quality near Gazipur dumping. *International Journal of Environment*, *5*(1), 15–22. https://doi.org/10.9734/bjast/2014/12964

Nwankwoala, H. O., & Ngah, S. A. (2022). Groundwater quality variability around municipal waste dumpsites in Port Harcourt, Nigeria. *Hydrogeology Journal, 30*(6), 1921–1934. https://doi.org/10.1007/s10040-022-02547-1

Ndubueze, C. O., et al. (2026). *Recent trends in air quality around municipal dumpsites in southeastern Nigeria* (preprint).

Obasi, I. A., Nnachi, E. E., Igwe, O. E., & Obasi, N. P. (2017). Evaluation of pollution status of heavy metals in the groundwater system around open dumpsites in Abakaliki urban, Southeastern Nigeria. *African Journal of Environmental Science and Technology*, *9*(7), 600–609. https://doi.org/10.5897/ajest2015.1780

Odubanjo et al. (2024) — Multi-city $PM_{2.5}$ monitoring in Nigeria

Ogbuehi, H. C., Onuh, M. O., & Christo, I. E. (2021). Effect of dumpsite organic manure soil on growth, nutrient content, and yield of Curcuma longa L.(turmeric) in Owerri, Imo State. *GSC Advanced Research and Reviews*, *8*(1), 140–148. https://doi.org/ 10.30574/gscarr.2021.8.1.0147

Ogunmodede, A. M., Adeola, O. A., & Adedeji, T. A. (2022). Assessment of heavy metal contamination in soils of municipal dumpsites in Ibadan, Nigeria. *Environmental Monitoring*

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and Assessment, 194(9), 632. https://doi.org/ 10.1007/s10661-022-10125-2

Ogunmodede, O. T., Ajayi, O. O., Onifade, A. K., Ojo, A. A., & Onosanya, A. A. (2014). Seasonal Variation of Microbial Population and Heavy Metal Characteristics of Dumpsite Soil in Ado Ekiti City. *International Journal of Applied Research and Technology*, *3*(5), 118–124.

Ohwoghere–Asuma, O., & Aweto, K. E. (2013). Leachate Characterization and Assessment of Groundwater and Surface Water Qualities Near Municipal Solid Waste Dump Site in Effurun, Delta State, Nigeria. *Journal of Environment and Earth Science, 3*(9), 126–134.

Ojiego, B. O., Ilo, O. P., Okolo, J. C., Igborgbor, J. C., Ishaku, T., Abdullai, I., GAdzama, M., & Bolorunduro, P. (2022). Concentrations of heavy metals in soil samples from dumpsites located at Kuje and Kwali area councils, Abuja, Nigeria. *Journal of Materials and Environmental Sciences*, *13*(9), 1037–1046.

Ojiego, B., Madu, J., Ilo, O., Odoh, J., Audu, E., Ishaku, S., Abdullahi, S., Gadzama, I., Bolorunduro, P., Ella, E., & Gideon, I. (2022). Heavy Metal Tolerance of Bacterial Isolates from Solid Waste dumping sites in Abuja, Nigeria. *International Journal of Environment*, *1* (1), 9–19.

Ojo, A. A., Talabi, A. O., Afolagboye, L. O., & Popoola, K. (2022). Evaluation of the Impacts of Dumpsite Leachate on Groundwater Quality in Omuooke-Ekiti, Southwestern Nigeria. *International Journal of Scientific and Research Publications (IJSRP)*, *12*(06), 137–148. https://doi.org/10.29322/IJSRP.12.06.2022.p12615

Okeke, P. (2014). Impact of Solid Waste on Physico-Chemical Properties of Ferrealsol in Owerri, Nigeria. *African Research Review*, *8*(3), 116. https://doi.org/10.4314/ afrrev.v8i3.10

Okafor, E. C., et al. (2024). *Comparative assessment of air quality around engineered and non-engineered dumpsites in Lagos State*. Environmental Quality Management.

Oladipo, A. A., Ojo, A. O., & Akinyemi, O. D. (2022). Environmental impact of abattoir waste discharge on water and soil quality in Ado-Ekiti, Nigeria. Environmental Health Insights, 16, 1–12. https://doi.org/10.1177/11786302221084494

Sawyerr, H. O., Adeoluwa, S. A., & Ajayi, S. O. (2017). Impact of dumpsites on the quality of soil and groundwater in satellite towns of the Federal Capital Territory, Abuja, Nigeria. Environmental Research Journal, 11(1), 1– 8.

Oladipo, O. O., Ilesanmi, T. M., & Olaleye, A. C. (2022). Environmental Impact of Abattoir Waste Discharge on the Quality of Water Body and Soil in Ado-Ekiti, Ekiti State. *Asian Journal of Biotechnology and Bioresource Technology*, *April*, 1–6. https://doi.org/10.9734/ajb2t/2022/v8i230120

Olayiwola, H. A., Abudulawal, L., Adewuyi, G. A., & Azeez, M. O. (2017). Heavy Metal Contents in Soil and Plants at Dumpsites: A Case Study of Awotan and Ajakanga Dumpsite Ibadan, Oyo State, Nigeria. *Journal of Environment and Earth Science*, *7*(4), 11–24.

Osazee, O. J., Obayagbona, O. N., & Daniel, E. O. (2017). Microbiological and physicochemical analyses of top soils obtained from four municipal waste dumpsites in Benin City, Nigeria. *International Journal of Microbiology and Mycology*, *1*(1), 2309–4796.

Osei, K., & Darko, P. (2021). Groundwater contamination risks from municipal solid waste disposal sites in Ghana. *Water, Air, & Soil Pollution, 232* (11), 456. https://doi.org/ 10.1007/s11270-021-05365-7

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© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved.

Osei, K., Boadi, S., & Anokye, J. (2021). Heavy metal accumulation in soils and crops around dumpsites in Kumasi, Ghana. *Environmental Science and Pollution Research, 28*(20), 25874–25885. https://doi.org/10.1007/s11356-020-12198-3

Oshoma, C. E., Igbeta, B., & Omonigho, S. E. (2017). Analysis of microbiological and physicochemical properties of topsoil from municipal dumpsites in Benin City. *Journal of Applied Sciences and Environmental Management*, *21*(5), 985. https://doi.org/10.4314/jasem.v21i5.28

Popego, T., Dikinya, O., & Gaobotse, G. (2019b). Impact of dumpsites on the quality of soil and groundwater in satellite towns of the Federal Capital Territory, Abuja, Nigeria. *African Journal of Soil Science*, *7*(1), 15–22. https://doi.org/10.5696/2156-9614-7.14.15

Preventionweb (UNDRR). (2025). *Landfilling: Understanding disaster risk*. UN Office for Disaster Risk Reduction website.

Rabah, A., Ijah, U., Manga, S., & Ibrahim, M. (2008). Assessment of Physico-chemical and Microbiological qualities of Abattoir Wastewater in Sokoto. *Nigerian Journal of Basic and Applied Sciences*, *16*(2), 149–154.

Regional/port studies 2024–2025 (Port Harcourt, Bonny Island, Kuje): various peer-reviewed and technical reports. (Wjarr, MedCrave Online, ijaem.net)

Sawyerr, H. O., Adeolu, A. T., Afolabi, A. S., Salami, O. O., & Badmos, B. K. (2017). Impact of dumpsites on the quality of soil and groundwater in satellite towns of the Federal Capital Territory, Abuja, Nigeria. *Journal of Health and Pollution*, *7*(14), 15–22. https://doi.org/10.5696/2156-9614-7.14.15

Schmidt, W. P., Haider, I., Hussain, M., Safdar, M., Mustafa, F., Massey, T., Angelo, G., Williams, M., Gower, R., Hasan, Z., Sharma Waddington, H., Anjum, N., & Biran, A. (2022). The effect of improving solid waste collection on waste disposal behaviour and exposure to environmental risk factors in urban low-income communities in Pakistan. *Tropical Medicine and International Health*, *27*(7), 606–618. https://doi.org/10.1111/tmi.13787.

Scutarașu, E. C., & Trincă, L. C. (2023). Heavy Metals in Foods and Beverages: Global Situation, Health Risks and Reduction Methods. *Foods*, *12*(18), 3340. https://doi.org/10.3390/ foods12183340.

Seidu, K., Muhammad, I. D., & Ozigis, I. I. (2021). Characterization of Gosa Municipal Solid Wastes at Abuja, Nigeria. *FUOYE Journal of Engineering and Technology*, *6*(1), 72–76. https://doi.org/10.46792/fuoyejet.v6i1.559.

Shehu-Alimi, E., Esosa, I., Ganiyu, B. A., Olanrewaju, S., & Daniel, O. (2020). Physicochemical and Heavy Metals Characteristics of Soil from Three Major Dumpsites in Ilorin Metrpolis, North Central Nigeria. *Journal of Applied Sciences and Environmental Management*, *24*(5), 767–771. https://doi.org/10.4314/jasem.v24i5.6

Singh, R., & Kumar, A. (2024). Hydrogeochemical impacts of leachate from solid waste landfills on groundwater quality in India. *Environmental Geochemistry and Health, 46*(2), 643–660. https://doi.org/10.1007/s10653-023-01667-2

Srivastava, S. K., et al. (2023). Impact of leachate percolation on groundwater near Bandhwari landfill. Springer.

Tautua, A., Bamidele, M. W., Onigbinde, A. O., & Ere, D. (2014). Assessment of some heavy metals and physicochemical properties in

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© 2026. Faculty of Technology Education. ATBU Bauchi. All rights reserved.

surface soils of municipal open waste dumpsite in Yenagoa, Nigeria. *African Journal of Environmental Science and Technology*, *8*(1), 41–47. https://doi.org/10.5897/AJEST2013.1621.

Tripathi, A., & Misra, D. R. (2022). A study of physico-chemical properties and heavy metals in contaminated soils of municipal waste dumpsites at Allahabad, India. *International Journal of Environmental Sciences*, *2*(4), 2034–2042. https://doi.org/10.6088/ijes.00202030087

Ukpong, E. C., Antigha, R. E., & Moses, E. O. (2013). Assessment of Heavy Metals Content in Soils qnd Plants Around Waste Dumpsites in Uyo Metropolis, Akwa Ibom State. *The International Journal of Engineering and Sciences*, *2*(7), 75–86.

United Nation Economic Commission for Europe. (2021). *Waste Classification and Inventory System in South Caucasus*. 1–15.

United Nations Economic and Social Commission for Asia and the Pacific. (2022). Chapter 8 Types of wastes. *United Nations ESCAP Library*, 170–194.

United Nations Economic Commission for Europe. (2021). *Classification of waste streams and waste management practices.* Geneva: UNECE. Retrieved from https://unece.org/environment-policy

United Nations Economic Commission for Europe. (2021). *Water and health: Preventing pollution from liquid waste*. UNECE Publications. Retrieved from https://unece.org

United Nations Environment Programme. (2021). *Basel convention on the control of transboundary movements of hazardous wastes and their disposal: Status and updates.* Nairobi: UNEP. Retrieved from https://www.basel.int

United Nations Environment Programme. (2021). *From pollution to solution: A global assessment of marine litter and plastic pollution*. UNEP.

United Nations Environment Programme. (2021). *From pollution to solution: A global assessment of marine litter and plastic pollution*. UNEP. Retrieved from https://www.unep.org

United Nations Environment Programme. (2021). *Global waste management outlook 2.* Nairobi: UNEP. https://www.unep.org/resources/report/global-waste-management -outlook-2

United Nations. (2016). *Landfilling*. United Nations Environmental Indicators: Waste. United Nations Statistics Division.

United States Environmental Protection Agency. (2023). *Types of hazardous waste*. U.S. EPA.

Uzoigwe, C. & Agwa, K. (2012). Microbiological quality of water collected from boreholes sited near refuse dumpsites in Port Harcourt, Nigeria. *African Journal of Biotechnology*, *11*(13), 3135–3139. https://doi.org/10.5897/ajb10.2664

Vegi, S., Reddy, P., & Kumar, V. (2024). Sandy-loam soils and leachate migration risks near urban dumpsites in India. *Waste Management, 168*, 34–45. https://doi.org/10.1016/j.wasman.2023.10.019

Vegi, S., Reddy, P., & Kumar, V. (2024). Sandy-loam soils and leachate migration risks near urban dumpsites in India. *Waste Management, 168*, 34–45. https://doi.org/10.1016/j .wasman.2023.10.019.

WHO. (2009). *Hardness in Drinking-water: Background document for development of WHO Guidelines for Drinking-water Quality. WHO Press, World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland*.

World Health Organization (WHO). (2021). *Guidelines for drinking-water quality* (4th ed., incorporating 1st

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Sustainable Procurement, Environmental and Social Standards Enhancement Centre of Excellence, ATBU, Bauchi
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addendum). Geneva: WHO. https://www.who.int/publications/i/item/9789241549950

World Health Organization (WHO). (2021). *Guidelines for drinking-water quality* (4th ed., incorporating 1st addendum). Geneva: WHO. https://www.who. int/publications/i/item/9789241549950

World Health Organization. (2020). *Health-care waste: Key facts.* Geneva: WHO. Retrieved from https://www.who.int/news-room/fact-sheets/detail/health-care-waste

World Health Organization. (2020). *Safe management of wastes from health-care activities (2nd ed.).* Geneva: WHO Press. https://www.who.int/publications/i/item/ 9789241548564

World Health Organization. (2022). *Safe management of wastes from health-care activities* (2nd ed.). WHO Press.

World Health Organization. (2022). *Safe management of wastes from health-care activities: A summary*. WHO Press. Retrieved from https://www.who.int

Wambebe et al. (2020) — Urban PM trends in Abuja

Yahaya, T. O., Abdulganiyu, Y., Salisu, T. F., Abdulazeez, A., Izuafa, A., Sanni, S. A. & Ahmadu, A. I. (2022). Characterization and risk evaluation of water samples collected from boreholes situated around a dumpsite in Obalende, Lagos, Nigeria. *Ruhuna Journal of Science*, *13*(1), 41. https://doi.org/10.4038/rjs.v13i1.114

Zhang, L., Xu, C., & Li, Y. (2021). Agricultural waste management and its environmental impacts: A global review. *Journal of Environmental Management, 295*, 113067. https://doi.org/10.1016/j.jenvman.2021.113067

Zhou, J., Wang, H., & Liu, Y. (2022). Health risk assessment of heavy metals in soils surrounding urban dumpsites in Eastern China. *Science of the Total Environment, 833*, 155125. https://doi.org/10.1016/j.scitotenv.2022.155125

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