Agr. Foo. Nat. Res. J. Volume 3, Issue 1, Page 113 - 121

ISSN: 3043-5420

Agriculture, Food and Natural Resources Journal

The Official Journal of the Faculty of Agriculture, Nnamdi Azikiwe University, Nigeria

Journal homepage: https://journals.unizik.edu.ng/afnrj

Agriculture, Food & Natural Resources Journal (AFNRJ)

Original Article

Impact of waste dumps on soil and groundwater quality in Owerri, Southeastern Nigeria

OPEN ACCESS

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DOI: https://www.doi.org/10.5281/zenodo.13932188

Editor: *Dr Onyekachi Chukwu, Nnamdi Azikiwe University, NIGERIA*

Received: *January 5, 2024*
Accepted: *March 21, 2024*
Available online: *March 31, 2024*

Peer-review: *Externally peer-reviewed*

Conflict of Interest: The authors have no conflicts of interest to declare

Financial Disclosure: *The authors declared that this study has received no financial support*

ABSTRACT

This study evaluated the soil physico-chemical properties and concentration of heavy metals (lead and chromium) and their influence on the soil and groundwater quality due to waste dumps in Owerri, Southeastern Nigeria. Four profile pits of about 180 cm depth were dug, one each at the polluted and control sites, from which soil samples were collected and analysed. Also, water samples proximate to the dumpsite (5 m) were collected, and control samples about 300 m away from the dumpsite were collected. Soil data were subjected to analysis of variance, and significant means were separated using the least significant difference ($p \geq 0.05$), while water samples were compared with local and international standards. The results obtained showed that the soils studied were dominated by sand (>80%). Soils from the polluted site had a higher soil pH (>6), whereas the unpolluted sites had a pH (<6.24). Soil organic matter, % total nitrogen, total exchangeable bases, bulk density, and electrical conductivity were higher in the Nekede polluted site (>180μS/cm) and least in the Nekede control site of Owerri. The control soil showed higher % silt content; % porosity, moisture content, and heavy metal concentration in the polluted soils were significantly higher than the control soils. This indicates a higher deterioration of both soil and water in the environment; thus, water pre-treatment before domestic or industrial use and remediation of the polluted soils before agricultural activities are recommended.

KEYWORDS: *Ground water pollution, Physicochemical properties, Waste dumps, Soil pollution*

INTRODUCTION

Soil pollution by heavy metal is a significant environmental problem worldwide (Kuang *et al.*, 2024; Zhou *et al.*, 2022). In particular, heavy metal pollution of surface soils due to intense industrialization and urbanization has become a serious concern in many developing countries (Ali *et al.*, 2019). Large areas of land can be contaminated by heavy metals released from smelted waste incinerators, industrial waste water, and from the application of sludge or municipal compost, pesticides and fertilizers (Xiao *et al.*, 2023). Irrespective of their sources in the soil, accumulation of heavy metal can degrade soil quality reduce crop yield and the quality of agriculture products, and thus negatively impact the health of humans, animals and the eco-system (Alengebawy *et al.*, 2021). The rapid industrialization and urbanization over the past three decades has brought significant environmental problems to people, including wide spread water pollution, photochemical smog, soil

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and sediment pollution. Also, surface and underground water contamination has become one of the main sources of health related problems (Babuji *et al.,* 2023; Li *et al.,* 2022).

According to the World Health Organization (WHO) and United Nations International Children Emergency Fund (UNICEF), estimated 502,000 deaths were caused by inadequate drinking water, 280,000 by inadequate sanitation, and 297,000 by inadequate hand hygiene (Hutton & Chase, 2017). Some 60% of all infant mortality worldwide is linked to infections and water related. Drinking and bathing in polluted water are the most common routes for the spread of diseases with symptoms like abdominal pain, hair loss, numbness in hands, loss of appetite, eye infections, irritation of skin and fever (Rehman, 2019). The dumping of domestic and municipal waste although considered as less effective to cause diseases in human body but is hazardous to human health, since the dumping of industrial and municipal wastage for a long time in the same place produced a liquid leachate which diffuses through the soil and affects the ground water. There is a pressing need to assess the distributions of heavy metals in the surface soils, which serve as an important sink, to understand the overall status of heavy metal pollution and the associated ecological risk in the region.

Waste dumpsites are notorious for their potential to leach toxic substances into the surrounding soil and groundwater, posing serious risks to ecosystems and human populations (Szulc *et al.,* 2024). Lead and chromium are particularly of concern due to their toxicity and persistence in the environment (Ahmed *et al.,* 2020). Lead, often found in batteries, paints, and plumbing materials, can cause severe health issues including neurological and developmental disorders (Olufemi *et al.,* 2022). Chromium, commonly used in industrial processes such as electroplating and leather tanning, can exist in several oxidation states, with hexavalent chromium being highly toxic and carcinogenic (Sazakli, 2024).

The study focused on analyzing the concentration levels of these heavy metals content in soils and groundwater samples collected from different locations around waste dumpsites in Owerri, Southeastern Nigeria. By comparing these concentrations with established safety standards and guidelines, the research aims to determine the extent of contamination and its potential impact on soil and groundwater quality. The results are also helpful for the management of environment in areas undergoing fast industrial transformation. There has been works on the soil and water quality by different authors in Owerri but there are scanty existing literatures on the soil and groundwater quality in the research areas. Hence, this justifies this project work. The findings of this study will provide valuable insights into the environmental and public health risks associated with waste dumps in Owerri, and will inform strategies for better waste management and pollution mitigation. Through a comprehensive assessment of the contamination levels and their effects, this research seeks to contribute to the broader effort of ensuring environmental sustainability and public health safety in urban areas.

MATERIALS AND METHODS

Location of the Study Area

The study was conducted in Owerri West Local Government Area where the dumpsites were located- Nekede and Orogwe dumpsites. The study sites lie between latitudes 5º28' N and 5º32' N and longitudes 7º1' E and 6º58' E, soils of the area are formed from Coastal Plain Sands (Ihem *et al.,* 2015). It has a humid tropical climate with annual rainfall ranging from 1500mm to 2250mm with temperature ranging of 26ºC to 31ºCand relative humidity of 75% to 87% (Ihem *et al.,* 2015). The vegetation is tropical rain forest (secondary forest). Nekede dumpsite is the main municipal waste dump in the Owerri City and has existed for more than 25 years, it is bordered to the north by the Otamiri River which transects towards Rivers State. Also, Orogwe dumpsite is a waste dump for both automobile and domestic waste which has existed for more than 10 years. The major economic activities in both study sites are farming, trading, hunting and automobile works.

Data collection and Analysis

Four profile pits of about 180cm depth were dug: two at the polluted sites and the other two at a control site (unpolluted sites) about 300 meters away from the polluted sites. A total of 20 samples were collected. Concentration of heavy metals at the various locations were determined using the atomic absorption spectrophotometer (AAS) (APHA, 2005). Alkalinity was determined using titrimetric methods as described in APHA (2005). The data were subjected to the Analysis of Variance (ANOVA), the Least Significant Difference (LSD) method of mean separation to determine the level of significance of parameters at 5% probability with Gen Stat Statistical Package Edition 4. Data were also subjected to correlation and regression analysis and was presented in tables and graphs. Also data from water analysis was compared with (WHO, 2006).

Results

Results of Soil Heavy Metals Concentration

Lead concentration (Figure 3) ranged between 1.55mg/kg and 1.6mg/kg in (polluted) and 1.21mg/kg to 1.14mg/kg in (unpolluted) Nekede and Orogwe sites. The mean concentration of Chromium (Figure 3) was 0.99 and 1.03mg/kg in (polluted) and 0.77 to 1.14mg/kg in (unpolluted) the Nekede and Orogwe sites respectively. Cr concentration was higher in Orogwe and least in Nekede control sites. Figure 3 shows the concentration of the heavy metals (Pb and Cr) analyzed in the studied soils

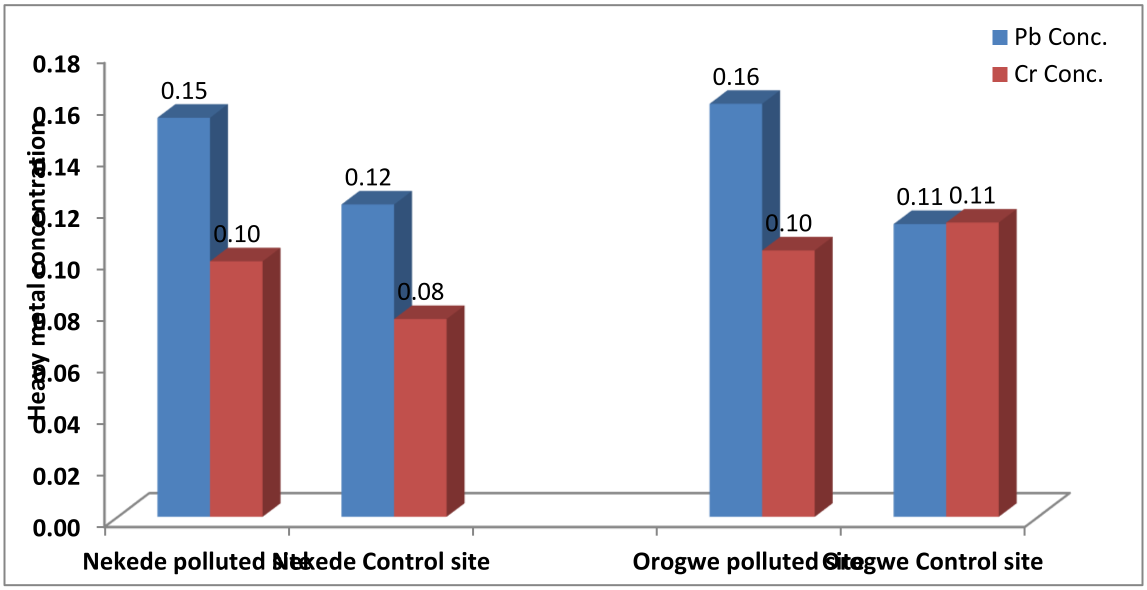

Figure 3: Concentration of heavy metals in the study sites

Relationship between Pb and Cr with soil physical properties

Lead had no significant relationship with sand (r = -0.0417), and clay (r = -0.1132), silt (r = 0.2343), moisture content (r = 0.2080) and bulk density (r = 0.2590) at 5% probability level. Also chromium concentration does not relate significantly with clay (r = -0.4372), moisture content (r = -0.1022) and silt content (r = -0.0016), sand content and bulk density. Table 3 shows relationship between Pb and Cr with some selected soil physical properties.

Table 3: Relationship between Pb and Cr with soil physical properties (N = 20)

Soil Physical Property	Pb	Cr
Sand	-0.0417ns	0.3307ns
Silt	0.2343ns	-0.0016ns
Clay	-0.1132ns	-0.4372ns
MC	0.2080ns	-0.1022ns
BD	0.2590ns	0.2979ns

Where, ns = not significant, MC= Moisture content, BD= Bulk density, Pb= Lead, Cr= chromium.

Relationship between Pb and Cr with soil chemical properties

Lead concentration had no significant relationship with calcium (r = -0.1781) and TEB (r = -0.1902), whereas it was positively correlated with %BS (r = 0.2194), EC(r = 0.3222), OM (r = 0.2810) and pH (water) (r = 0.0443). However, Lead related significantly negatively with ECEC (r = -0.4887) and significantly positively with %TN (r = 0.6620) at a 5% probability level. Similarly, chromium had no significant relationship with Ca (r = -0.3850), TEB (r = -0.1886), %BS (r = 0.2644), %TN (r = 0.3738), EC (r = 0.0307) and pH (water)(r= 0.2218)) but significantly negative with ECEC (r = -0.4357) and significantly positive with OM (r = 0.4543) at 5% probability level.

Table 4: Relationship between Pb and Cr with soil chemical properties (N = 20)

Soil chemical properties	Pb	Cr
%BS	0.2194ns	0.2644ns
TN	0.6620*	0.3738ns
Ca	-0.1781ns	-0.3850ns
ECEC	-0.4887*	-0.4357*
EC	0.3222ns	0.0307ns
OM	0.2810ns	0.4543*
TEB	-0.1902ns	-0.1886ns
pH in Water	0.0443ns	0.2218ns

Where, %BS=%Base Saturation, TN= Total Nitrogen, Ca=Calcium, ECEC=Effective cation Exchange Capacity, EC=Electrical conductivity,OM=Organic matter, TEB=Total Exchangeable Bases, Pb=Lead , Cr= Chromium, *= significant at 0.05 probability level, ns = not significant

Water Physiochemical Parameters

From figure 4 below, alkalinity values for water sample ranged from 8 – 12mg/l in (polluted) and 16mg/l in (unpolluted) water samples from the Nekede and Orogwe sites. Alkalinity levels in the control sites is higher than the polluted sites. The ranges for pH from figure 4 varied between 6.08 and 6.54 in water samples from (polluted) and 5.92 to 6.96 in (unpolluted) water samples from Nekede and Orogwe sites. The value of temperature for water samples from polluted sites was 29ºC, while it ranged from 27 to 28ºC for (unpolluted) samples from Orgowe and Nekede sites. Turbidity in water is caused by suspended particles or colloidal materials that obstruct light transmission through the water (WHO, 2011). From figure 4, turbidity of the polluted sites ranged between 1 to 3 NTU, it ranged between 2 and 5 NTU in (unpolluted) Nekede and Orogwe samples. The values of Biological Oxygen Demand (BOD), varied within 1.15mg/l to 1.93mg/l in water samples from (unpolluted), whereas it ranged within 1.42mg/l to 2.20mg/l in (polluted) Orogwe and Nekede sites respectively. The BOD of the water samples from the polluted sites was lower than those from the unpolluted sites. The COD values of water samples ranged between 2.88 to 4.83 mg/l in water samples from (unpolluted) and 3.5to 5.5mg/l in water samples from (polluted) Nekede and Orogwe sites. Values of COD in the polluted sites are higher than those obtainable in the unpolluted sites. Dissolved oxygen values of the water samples. Water samples had DO values of 4.05mg/l to 5.03mg/l in (polluted) and 4.03 to 5.5mg/l in (unpolluted) water samples from Nekede and Orogwe sites. DO in the water samples from control sites were higher than that from the polluted sites.

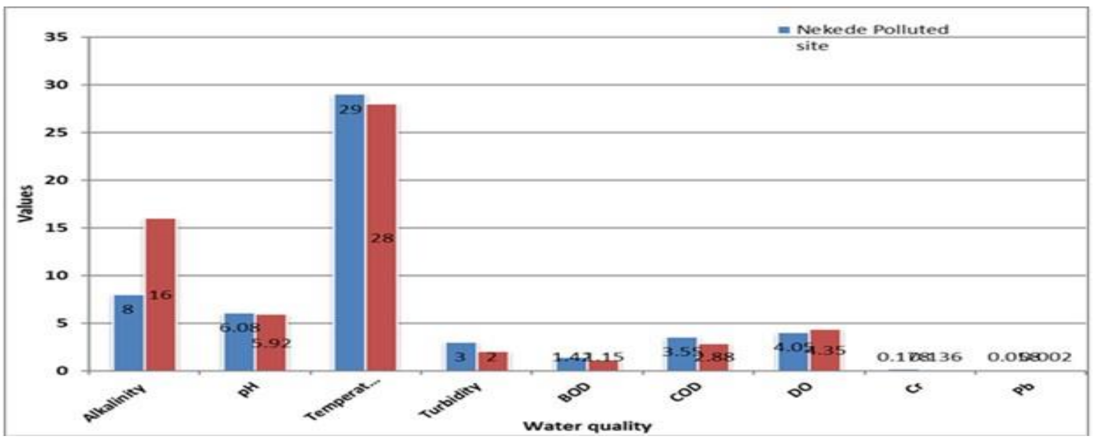

Figure 4 shows the results of the water physiochemical parameters

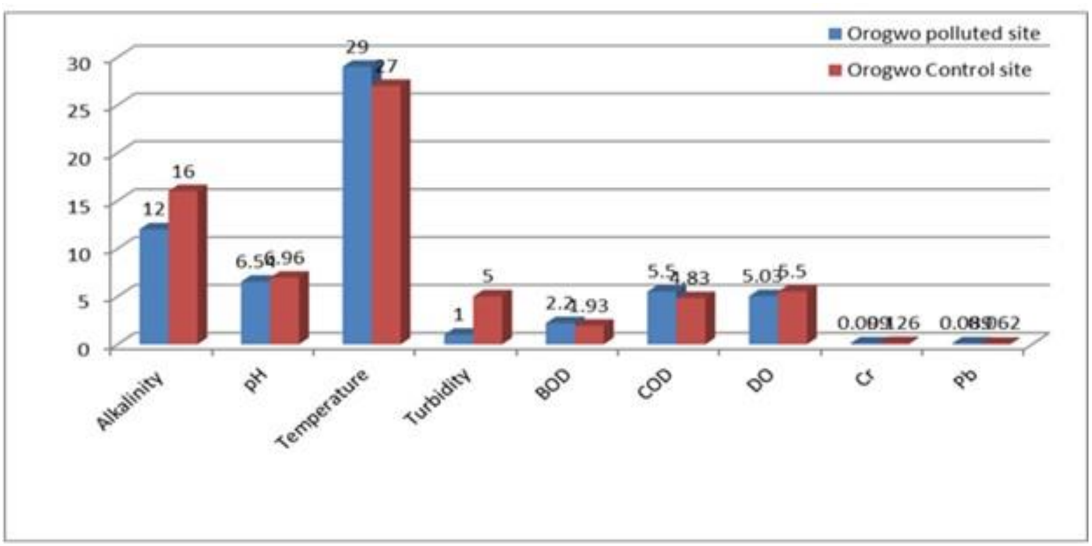

Figure 4: Concentration of physiochemical properties of water samples

Water Heavy Metal (Pb and Cr) Concentration

The lead concentration of the water samples examined had 0.058 to 0.089mg/l in (polluted) and 0.002 to 0.062mg/l in (unpolluted) water samples from Nekede and Orogwe sites. Lead content was highest in Orogwe polluted sample (0.089mg/l) and least value was obtained in the water sample from Nekede control site with 0.002mg/l. Chromium concentration in the water samples ranged from 0.178 to 0.099mg/l in (polluted) and 0.136 to 0.126mg/l in (unpolluted) water samples from Nekede and Orogwe sites.

Discussion

From the results, it was observed that Nekede polluted site had higher sand value than Orogwe polluted site. There was no significant difference observed at 5% probability level. Orogwe polluted site had a higher clay content. There was no significant difference observed at 5% probability level. This contradicts the findings of Zhang et al. (2024) who opined that the increase in heavy metal ion concentration leads to the decrease in liquid limit, plastic index, and clay content. There was significant difference in silt content in the control sites at 5% probability level. This agrees with the study of Zhang et al. (2024), which reveal that as the concentration of heavy metals in contaminated soil rises, there is a concurrent decrease in the silt content. The results of the soils in the study sites according to Ihem *et al.* (2015) were sandy (> 80%). The textural class using the USDA textural triangle showed the predominance of loamy sand except in Nekede polluted site being sand. Soil texture is an inherent attribute of the soil and may not be influenced by pollution *(*Ihem *et al.* 2015). High silt content of the control sites may result in slower hydrocarbon and water intake, and higher water holding capacity. The bulk densities of the polluted sites were higher than the control sites. This could be attributed to increased organic matter deposition and decomposition (Crnobrna *et al.,* 2022). From Table 1, Percentage porosity varied significantly in the control site. This was as a result of the sandiness of soils as influenced by parent material of the areas.The increase in moisture content of the control sites could relate to the sealing and crushing effects of silt which causes high water impermeability and holding capacity.

The mean soil pH values ranged between 6.68, and 6.06 (polluted), 6.24 and 5.80 (unpolluted) for Nekede and Orogwe sites. The type of materials deposited at the sites may have influenced the pH of the sites. This pH range is good for the growth of a wide range of plant as only at about pH values below 4.2 would H^+ stop or reverse cation uptake by roots (Penn & Camberato, 2019). The major effect of this pH ranges will include: reduction in nutrient supply increased concentration of metal ions in solution especially Aluminium, Copper and Manganese which may be toxic while nitrogen fixation by legumes maybe reduced except *Rhizobium* strains which is tolerant (Dorraji *et al.,* 2011). These pH values indicate that the soil sample were slightly acidic (FAO, 2004). Increased concentration of metal ions in solution especially Aluminium, Copper and Manganese which may be toxic while nitrogen fixation by legumes may be reduced except Rhizobium strain is tolerant Dorraji *et al*. (2011).

Nekede polluted site had higher organic matter content which according to FAO (2004) was high. This correlates with the high industrial and municipal waste deposition on the area which increased microbial activities and increased rate of decomposition since composition of organic refuse was high. This observation is in line with the findings of Redko *et al.* (2024) who reported that dumpsites have significantly higher pH regime and soil organic matter as compared to the control soil. High organic matter according to Vasilachi *et al.* (2023) in soils is conducive for heavy metal chelation formation. Furthermore, Nekede polluted site recorded a higher value while Nekede control site recorded this least value. This could be due to increase in organic matter content of the site since nitrogen is a component of organic carbon (Ihem *et al*., 2015). The values are low according to the ratings of FAO (2004). Calcium values were low according to the ratings of FAO (2004). This could be attributed to the parent material (Coastal plain sand), high rainfall and leaching which has washed away the basic cations (Ihem *et al*., 2015). This affected the Total exchangeable bases content of the studied sites adversely. This was due to the sandy nature of the soils and high rainfall and intense leaching (Ihem *et al.* 2015). This observation contradicts the findings of Domingues *et al.* (2020) who got a higher pH which enhanced the high presence of basic cations in the unpolluted sites.

Total exchangeable acidity contents could be as a result of the type of waste deposited on the soil which could be highly acidic and thus, influence positively the concentration of acidic cations (H^+ and Al^{3+}) on the soil. This may be compounded by high rainfall and intense leaching which may have washed away basic actions from the soils and acidic nature of the parent material of the studied soils (Ihem *et al.* 2015). ECEC result reflects the nature of the materials deposited at the site. This finding contradicts those of Ghorbani et al. (2024) who stated that ECEC increases with increase in organic matter content of soils. The mean percentage base saturation (%BS) of the studied soils could be as a result of high microbial activity and decomposition within the favourable pH range obtained. Contrastingly, Johan et al. (2021) found that base saturation and microbial activities increase with decreasing soil acidity. Percentage base saturation in the studied soils were generally low according to FAO (2004) soil fertility ratings. The increase in the EC is relatable to factors such as soil salinity, soil texture, cation exchange capacity, etc. Soils with higher organic matter content retain much higher positively charged ions. The presence of these ions in the moisture filled pores will enhance soil electric conductivity (Zhang et al., 2024).

The lead concentration values were lower than EC upper limit of 300mg/kg and the maximum tolerable levels proposed for agricultural soils, 90 to 400mg/kg set by WHO (1993) soil fertility ratings. This observation is in line with the findings of Umo and Etim (2013). High concentration of Lead in the polluted sites could be as a result of sources from automobile exhaust fumes, dry cell batteries, sewage effluents and runoff of waste on the soil (Kumar et al., 2020). The mean concentration of Chromium (Figure 3) was higher in Orogwe and least in Nekede control sites. High concentration level in Orogwe control site could be due to its close proximity to a maternity in the area which may have disposed some sources of chromium on the soil such as lead-chromium batteries, coloured polythene bags, discarded plastic materials and empty paint containers. Lead had no significant relationship with sand. This implies that an increase in silt content, moisture content and bulk density will not influence the concentration of Pb concentration in the studied soils. Also chromium concentration does not relate significantly with clay and silt content sand content and bulk density. This shows that as sand content and bulk density, silt, clay and moisture contents will not affect Cr concentration in the studied soils.

Lead concentration had no significant relationship with calcium whereas it was positively correlated with %BS, OM, and pH (water). This indicates that an increase in calcium and TEB will reduce lead concentration, while an increase in organic matter, EC, %BS, and pH(water) will not influence Lead concentration. However, Lead related significantly negatively with ECEC and significantly positively with %TN at a 5% probability level. This implies that an increase in ECEC will cause a significant decrease in Pb concentration, while an increase in %TN will bring a corresponding increase in Pb in the soil. This is because %TN is a component of Organic carbon and thus will increase with increase in Organic carbon content (Ihem *et al.*, 2015) and as such enhances metal chelation formation. Similarly, chromium had no significant relationship with Ca, TEB, %BS, %TN, EC, and pH (water), but significantly negative with ECEC and significantly positive with OM at 5% probability level. This shows that an increase in the ECEC will cause a significant decrease in chromium concentration, while an increase in OM will cause a significant increase in chromium concentration. This is because heavy metals are associated with organic matter, adsorbed onto Fe/Mn oxides or complexes with hydroxides, sulphides and carbonates (Bielski & Czaplicka, 2023).

Alkalinity levels in the control sites was higher than the polluted sites. This indicates less pollution of ground water in the control sites compared to the polluted sites which may have been influenced by leachate high concentration and contamination of ground water by salts. Since alkalinity in water samples has the potential to alter the ability of other pollutants to cause toxicity (Guney et al., 2021). Thus, this implies that water samples from control sites are safer for consumption than the polluted sites. However, the alkalinity levels of water samples from both studied sites were below the ranges of 80 to 120mg/l WHO (2006).

The pH values of water samples from Orogwe polluted and control sites fall within the permissible limits of 6.5 to 8.5 for drinking by WHO (2006), for irrigation while pH values of water samples from Nekede polluted and control sites fall below the permissible limits of WHO (2006) showing slight acidity. This could be as a result of the acidic nature of leachate that may have found its way into the ground water. However, water samples from Orogwe were slightly alkaline, whereas those from Nekede were slightly acidic according to WHO (2004). This could be as a result of the acidic nature of leachate that may have found its way into the ground water. High pH values may also affect the solubility and bioavailability of other substances (heavy metals) in water (EPA, 2003). This indicates toxic pollution of water (Zhu et al., 2023).Values of temperature values were above WHO (2006) standard of 5^{o}C for domestic water. This indicates the presence of foreign bodies in the water samples (van der Wielen et al., 2023). High water temperature enhances the growth of microorganisms and causes problems related to taste, odour and colour (WHO, 2011).Turbidity in water is caused by suspended particles or colloidal materials that obstructs light transmission through the water (WHO, 2011). From figure 4, turbidity values noticed may be caused by inorganic matter or a combination of the two in the water samples (Nawaz et al., 2023). High turbidity levels though does not have any direct health implications according to WHO (2006), but may interfere with water treatment, staining of clothes and household fittings (Afuye *et al.*, 2015). The turbidity values of the water samples estimated were within the permissible limit of 5 NTU according to WHO (2006) standard. The values of Biological Oxygen demand (BOD), varied. The BOD of the water samples from the polluted was lower than those from the unpolluted sites. This indicates that there was a higher microbial population in the water samples from the polluted sites and thus, will result in a higher depletion of dissolved oxygen in water which could create an aerobic condition and hence, cause the death of aerobic aquatic organisms (Chapra *et al.*, 2021). However, the values of the water samples were within the permissible limits of 5 - 6mg/l of WHO (2006). Lower BOD in water samples suggest that the water samples are fit for drinking and irrigation. The COD values in the polluted sites were higher than those obtainable in the unpolluted sites. This could be as a result of surface runoff into water bodies and thus indicates presence of toxic materials and microorganisms in the water samples (Lemessa et al., 2023). The COD values in the polluted sites was higher than the permissible limit set by WHO (2006). Dissolved oxygen values of the water samples. The values of the DO in the water samples indicates that water samples from the control sites are fit for irrigation and other agricultural activities according to Adekunle *et al.* (2007), who opined that higher values greater than 0.5mg/l of dissolved oxygen in water samples show their stability for irrigation and other agricultural purposes. These values of dissolved oxygen of the water samples are lower than the limits set by the WHO (2006). The lead concentration of the water samples obtained could be as a result of toxic waste, coming perhaps from disposed battery cells, used aerosol cans and other materials with a certain degree of toxicity (Akinbile and Yusuff, 2011). This observation is in agreement with the findings of Okoro *et al.* (2014). Chromium concentration in the water samples were higher than the standard set by WHO (2006) for drinking. High concentration of heavy metals has been reported to negatively affect crop growth and can cause varying levels of ailments which are heavy metal associated, such as liver and kidney diseases, damage to bone marrow and cancer (Abd Elnabi *et al.*, 2023; Vasilachi *et al.*, 2023).

REFERENCES

Abd Elnabi, M. K., Elkaliny, N. E., Elyazied, M. M., Azab, S. H., Elkhalifa, S. A., Elmasry, S., Mouhamed, M. S., Shalamesh, E. M., Alhorieny, N. A., Abd Elaty, A. E., Elgendy, I. M., Etman, A. E., Saad, K. E., Tsigkou, K., Ali, S. S., Kornaros, M., & Mahmoud, Y. A.-G. . (2023). Toxicity of heavy metals and recent advances in their removal: A review. *Toxics*, *11*(7), 580. https://doi.org/10.3390/toxics11070580

Adekunle,I., Adetunji, M.T., Gbadebo, A.M., and Banjo, O.P. (2007) Assessment of groundwater quality in a typical rural settlement in southwest Nigeria. International Journal of Environmental Research and Public health (IJERPH) 4(4), 307-318.

Afuye, G.G., Oloruntade, A.J., Mogaji, K.O. (2015). Ground Water Quality Assessment in Akoko Southeast Area of Ondo State, Nigeria. *International Journal of Science and Technology*. Vol 5, 9: 51-58.

Ahmed, M. F., Mokhtar, M. B., Alam, L., Mohamed, C. A. R., & Ta, G. C. (2020). Investigating the status of cadmium, chromium and lead in the drinking water supply chain to ensure drinking water quality in Malaysia. *Water*, *12*(10), 2653. https://doi.org/10.3390/w1210265.

Akinbile C.O. and Yusoff, M.S. (2011). Environmental impact of leachate pollution on groundwater supplies in Akure, Nigeria. International Journal of Environmental Science and Development 2(1): 81-86.

Alengebawy, A., Abdelkhalek, S. T., Qureshi, S. R., & Wang, M.-Q. (2021). Heavy metals and pesticides toxicity in agricultural soil and plants: Ecological risks and human health implications. *Toxics*, *9*(3), 42. https://doi.org/10.3390/toxics9030042

Ali, H., Khan, E., & Ilahi, I. (2019). Environmental chemistry and ecotoxicology of hazardous heavy metals: Environmental persistence, toxicity, and bioaccumulation. *Journal of Chemistry*, *2019*, 1–14. https://doi.org/10.1155/2019/6730305

APHA. (2005). Standard Methods for the Examination of Water and Waste Water, 21st ed. American Public Blakie and Son, Glasgow. p. 368.

Babuji, P., Thirumalaisamy, S., Duraisamy, K., & Periyasamy, G. (2023). Human health risks due to exposure to water pollution: A review. *Water*, *15*(14), 2532. https://doi.org/10.3390/w15142532

Bielski, A., & Czaplicka, A. (2023). Heavy metals in post-exploitation reservoirs—the Bagry Lake case study (Poland). *Applied Sciences*, *13*(10), 5884–5884. https://doi.org/10.3390/app13105884

Chapra, S. C., Camacho, L. A., & McBride, G. B. (2021). Impact of global warming on dissolved oxygen and BOD assimilative capacity of the world's rivers: Modeling analysis. *Water*, *13*(17), 2408. https://doi.org/10.3390/w13172408

Crnobrna, B., Llanqui, I. B., Cardenas, A. D., & Panduro Pisco, G. (2022). Relationships between organic matter and bulk density in amazonian peatland soils. *Sustainability*, *14*(19), 12070. https://doi.org/10.3390/su141912070

Domingues, R. R., Sánchez-Monedero, M. A., Spokas, K. A., Melo, L. C. A., Trugilho, P. F., Valenciano, M. N., & Silva, C. A. (2020). Enhancing cation exchange capacity of weathered soils using biochar: Feedstock, pyrolysis conditions and addition rate. *Agronomy*, *10*(6), 824. https://doi.org/10.3390/agronomy10060824

Dorraji S.S., Golchin A., Ahmadi S. (2010): The effects of hydrophilic polymer and soil salinity on corn growth in sandy and loamy soils. *Clean – Soil, Air, Water*, **38**: 584–591.

Environmental Protection Agency (EPA), 2003. Drinking Water Infrastructural Needs Survey, Factsheet 816F05014. www.eoa.gov.safewater/needssurvey/pdf2003

Food and Agricultural Organization (2004) A provisional methodology for Land degradation assessment FAO, Rome. In Idoga (2013) Soil degradation assessment of the university of Agriculture Markurdi. PAT 9 (2) 126-135.

Ghorbani, M., Amirahmadi, E., Bernas, J., &Konvalina, P. (2024). Testing biochar's ability to moderate extremely acidic soils in tea-growing areas. *Agronomy*, *14*(3), 533–533. https://doi.org/10.3390/agronomy14030533

Guney, M., Akimzhanova, Z., Kumisbek, A., Kismelyeva, S., Guney, A., Karaca, F., &Inglezakis, V. (2021). Assessment of distribution of potentially toxic elements in different environmental media impacted by a former chlor-alkali plant. *Sustainability*, *13*(24), 13829. https://doi.org/10.3390/su132413829

Hutton, G., & Chase, C. (2017). *Water supply, sanitation, and hygiene* (C. N. Mock, R. Nugent, O. Kobusingye, & K. R. Smith, Eds.). PubMed; The International Bank for Reconstruction and Development / The World Bank. https://www.ncbi.nlm.nih.gov/books/NBK525207/#

Ihem, E.E., Osuji, G. E., Onweremadu, E.U., Uzoho, B.U., Nkwopara, U.N., Ahukemere, C.M. Onwudike, S.O., Ndukwu, B.N., Osisi, A.S., Okoli, N.H., (2015). Variability In Selected Properties Of Crude Oil-Polluted Soils Of Izombe,,Nprthem Niger Delta, Nigeria. Agriculture, Forestry AndFisheris. Special Issue Environment And Applied Sciecnce Management On A Changing Global Climate. Vol 4, No. 3 -1. Pp: 29 -33.

Johan, P. D., Ahmed, O. H., Omar, L., & Hasbullah, N. A. (2021). Phosphorus transformation in soils following co-application of charcoal and wood ash. *Agronomy*, *11*(10), 2010. https://doi.org/10.3390/agronomy11102010

Kuang, Y., Chen, X., & Zhu, C. (2024). Characteristics of soil heavy metal pollution and health risks in chenzhou city. *Processes*, *12*(3), 623–623. https://doi.org/10.3390/pr12030623

Kumar, A., Kumar, A., M. M.s., C.-P., Chaturvedi, A. K., Shabnam, A. A., Subrahmanyam, G., Mondal, R., Gupta, D. K., Malyan, S. K., Kumar, S. S., A. Khan, S., & Yadav, K. K. (2020). Lead toxicity: Health hazards, influence on food chain, and sustainable remediation approaches. *International Journal of Environmental Research and Public Health*, *17*(7), 2179. https://doi.org/10.3390/ijerph17072179

Lemessa, F., Simane, B., Seyoum, A., &Gebresenbet, G. (2023). Assessment of the impact of industrial wastewater on the water quality of rivers around the Bole Lemi Industrial Park (BLIP), Ethiopia. *Sustainability*, *15*(5), 4290–4290. https://doi.org/10.3390/su15054290

Li, J., Sun, C., Chen, W., Zhang, Q., Zhou, S., Lin, R., & Wang, Y. (2022). Groundwater quality and associated human health risk in a typical Basin of the Eastern Chinese Loess Plateau. *Water*, *14*(9), 1371–1371. https://doi.org/10.3390/w14091371

Nawaz, R., Nasim, I., Irfan, A., Islam, A., Naeem, A., Ghani, N., Irshad, M. A., Latif, M., Nisa, B. U., & Ullah, R. (2023). Water quality index and human health risk assessment of drinking water in selected urban areas of a Mega City. *Toxics*, *11*(7), 577. https://doi.org/10.3390/toxics11070577

Olufemi, A. C., Mji, A., &Mukhola, M. S. (2022). Potential health risks of lead exposure from early life through later life: Implications for public health education. *International Journal of Environmental Research and Public Health*, *19*(23), 16006. https://doi.org/10.3390/ijerph192316006

Penn, C. J., &Camberato, J. J. (2019). A critical review on soil chemical processes that control how soil pH affects phosphorus availability to plants. *Agriculture*, *9*(6), 120. https://doi.org/10.3390/agriculture9060120

Redko, V., Wolska, L., Olkowska, E., Tankiewicz, M., & Cieszyńska-Semenowicz, M. (2024). Long-Term polyethylene (bio)degradation in landfill: Environmental and human health implications from comprehensive analysis. *Molecules*, *29*(11), 2499. https://doi.org/10.3390/molecules29112499

Rehman, F. U. (2019). Polluted water borne diseases: Symptoms, causes, treatment and prevention. *Journal of Medicinal and Chemical Sciences*, *6*(4). https://doi.org/10.26655/jmchemsci.2019.6.4

Sazakli, E. (2024). Human health effects of oral exposure to chromium: A systematic review of the epidemiological evidence. *International Journal of Environmental Research and Public Health/International Journal of Environmental Research and Public Health*, *21*(4), 406–406. https://doi.org/10.3390/ijerph21040406

Szulc, J., Okrasa, M., Nowak, A., Ryngajłło, M., Nizioł, J., Kuźniar, A., Ruman, T., &Gutarowska, B. (2024). Uncontrolled post-industrial landfill—source of metals, potential toxic compounds, dust, and pathogens in environment—a case study. *Molecules/Molecules Online/Molecules Annual*, *29*(7), 1496–1496. https://doi.org/10.3390/molecules29071496

Umoh S,D and Etim EE (2013). Determination of heavy metals content from dumpsites within Ikot Ekpene, Akwa Ibom State, Nigeria. *International Journal of Engineering Science*, 2(2):123-129.

van der Wielen, P. W. J. J., Dignum, M., Donocik, A., & Prest, E. I. (2023). Influence of temperature on growth of four different opportunistic pathogens in drinking water biofilms. *Microorganisms*, *11*(6), 1574. https://doi.org/10.3390/microorganisms11061574

Vasilachi, I. C., Stoleru, V., & Gavrilescu, M. (2023). Analysis of heavy metal impacts on cereal crop growth and development in contaminated soils. *Agriculture*, *13*(10), 1983. https://doi.org/10.3390/agriculture13101983

WHO (2004). Guidelines for drinking water quality: 3rd edn. Vol. 1 recommendation, Geneva. Pp 515.

WHO (2011).Guidelines for drinking water quality. Acceptability aspects: taste, odor and appearance. 4th Ed. 1:

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

WHO, 2006. Guidelines for Drinking water Quality: First Addendum to Third edition. World Health Organization, Geneva, 515.

Xiao, D., Li, H., Wang, Y., Wen, G., & Wang, C. (2023). Distribution characteristics of typical heavy metals in sludge from wastewater plants in Jiangsu Province (China) and their potential risks. *Urban Water Management*, *15*(2), 313–313. https://doi.org/10.3390/w15020313

Zhang, G., Liu, T., Li, H., Wang, Z., Huang, X., Yi, X., & Yan, D. (2024). Experimental Study on the Effects of Heavy Metal Pollution on Soil Physical Properties and Microstructure Evolution. *Applied Sciences*, *14*(5), 2022–2022. https://doi.org/10.3390/app14052022

Zhou, H., Ouyang, T., Guo, Y., Peng, S., He, C., & Zhu, Z. (2022). Assessment of soil heavy metal pollution and its ecological risk for city parks, vicinity of a landfill, and an industrial area within Guangzhou, South China. *Applied Sciences*, *12*(18), 9345. https://doi.org/10.3390/app12189345

Zhu, Q., Ji, J., Tang, X., Wang, C., & Sun, H. (2023). Bioavailability assessment of heavy metals and organic pollutants in water and soil using DGT: A review. *Applied Sciences*, *13*(17), 9760–9760. https://doi.org/10.3390/app13179760