Heavy Metal Contamination and Risk Assessment of Borehole Water within a Landfill in the Nnewi Metropolis

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ABSTRACT

Borehole water has been used as a vital source of water for many communities. The pollution of these boreholes by heavy metals using unlined solid waste dumpsites has posed a significant risk to the populace living around the dumpsite. This study investigates the environmental impact of heavy metals on borehole water within the vicinity of an unlined dumpsite in the Nnewi metropolis. The upstream and downstream samples (16 each) were collected in wet and dry seasons. The heavy metal analysis was performed using the methods of the American Public Health Association (APHA) under the required conditions. The quality of the boreholes was assessed using the World Health Organisation (WHO) acceptable limits for drinking water. The risk assessment was estimated for carcinogenic and non-carcinogenic risks using ingestion and dermal routes. The results show that the borehole water was contaminated with heavy metals through leachate infiltration, which exceeded the WHO permissible limits for drinking water at both locations and seasons. The upstream borehole samples were more contaminated than the downstream samples for both seasons, due to their proximity to the pollution source. The hazard indices of the ingestion and dermal routes showed that the borehole water poses serious cancer and non-cancer health risks for both locations. The results revealed that children are more susceptible to cancer and non-carcinogenic health threats than adults for both locations and seasons. The pollution indices of borehole water for wet season (9.028 and 5.728) and dry season (7.107 and 5.328) for upstream and downstream samples respectively, were polluted and the pollution was higher in the wet season. The borehole water samples were unsuitable for drinking water and should be treated before use.

Keywords: Heavy metals; Borehole; Contamination; Health risk; Pollution; Ground water

INTRODUCTION

Groundwater has always been a major source of water for the residents of Nnewi in Anambra State. The populace normally depends on groundwater for drinking and other domestic purposes. Groundwater quality can be altered because of human activities, which can change the physicochemical characteristics of the water [1]. Human activities such as unsanitary landfills, poor soakaway systems and indiscriminate dumping of refuse can have negative consequences on the quality of the underground water. Unsanitary landfills are the most common waste disposal practise used in Anambra State, Nigeria.

The increase in population growth, urbanisation and industrialisation has also increased the volume of waste generated in Anambra state. Poor allocations for waste management have negatively impacted waste management activities [2]. This method of waste practice has led to environmental pollution, which can pose a severe health risk to the populace. The unregulated leachates coming from this unlined dumpsite tend to infiltrate the soil and thereby pollute the soil and groundwater due to the migration of pollutants.

Leachates from these dumpsites according to researchers constitute a major source of heavy metal pollution to the groundwater and its environment. Wastes such as electronic products, paint waste and automobile batteries deposited in the refuse dump, tend to increase the volume of heavy metals in dumpsites, which can be toxic to the environment. Open burning of wastes using unlined dumpsite is a common practise usually done to reduce the quantity of waste. The by-products left after the burning can pose a risk to the underground water and public health.

Heavy metals are adsorbed into soils and water bodies, which when exposed to the human body, results in a severe threat to human health [3-6]. Recently, the contamination and potential risk of underground water have been investigated. Some heavy metals such as Pb and Hg, are toxic and can induce cancer in the human body when they exceed their threshold limits. Exposure to heavy metal toxicity can cause brain damage, dermatitis, anaemia and death in humans.

Health-associated risks caused by the use of unlined dumpsites call for a complete assessment of the effect of unlined waste dumpsites on the environment. Many researchers have reported groundwater pollution through leachates from dumpsites. However, few studies have been conducted on heavy metal pollution of underground water from landfill leachates in the Nnewi metropolis. The previous studies on the underground water quality in Nnewi only focused on the levels of heavy metals and pollution indices of the water and did not evaluate the risk assessment involved in the use of the water by the residents.

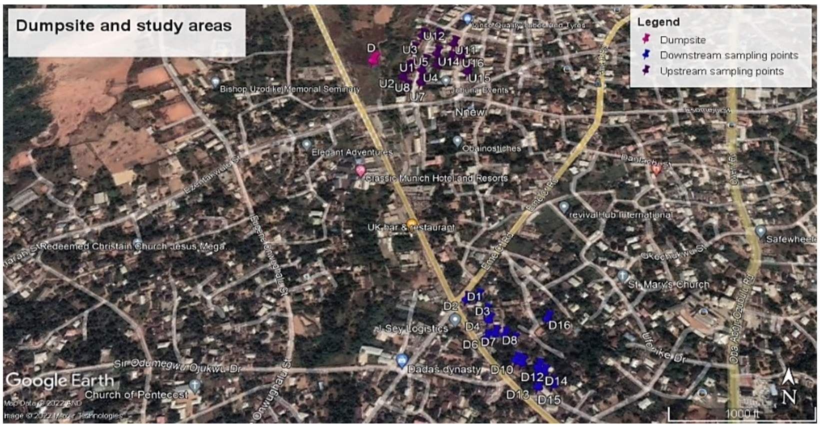
Therefore, in this research work, the impact of solid waste leachates on heavy metal contamination of groundwater quality was studied around the okpunoeze dumpsite in the nnewi metropolis [7]. Cancer and non-cancer health risks were also estimated using dermal and ingestion routes on the populace. The metal pollution index of the borehole water was also determined. The findings of this work will be a valuable tool for policy makers on better ways to prevent underground water pollution using improved waste disposal methods.

MATERIALS AND METHODS

Sampling area

The sampling area Figure 1 is located around the okpunoeze otolo dumpsite in nnewi, anambra state. Nnewi is located within the tropical rainforest region of Nigeria. Nnewi is a major town in anambra state known for its manufacturing activities, which has led to the rapid growth of the city. Open dumpsites are the predominant waste disposal method practised in the area [8]. The dumping site is located at the following latitude of 6°00’43.4”N and longitude of 6°54’28.2”E. Two distinct seasons are observed, dry and wet. Nnewi has an annual rainfall of about 2000 mm. Wastes disposed of in the landfill are predominantly solid waste from industries, hospitals, markets, workshops and households, which are located around the dumpsite.

Figure 1. Map of sampling areas. **Note:** Dumpsite; Downstream sampling points; Upstream sampling points.



The nnewi metropolis lies beneath nanka formation, consisting of loose and friable sands. The lithology of the area is composed of sandstones, which are porous and allow for infiltrating leachates into the aquiferous system. The average depth to the water table in the study area is about 110 m and the average static water level is 120 m.

Sampling of borehole water samples

Borehole water samples (16 each) were collected during the morning hours (9 am- 10 am) from the upstream and downstream locations for 4 months (May 2018-August 2018) for the wet season, and 3 months (december 2018-february 2019) in the dry season. The downstream samples were collected 685 m-935 m away from the upstream samples, which are located around the dumpsite. Properly washed and rinsed glass sample bottles were used for sample collection from the selected locations [9]. The sampled borehole water was homogenised to form a composite sample. Acidification of the samples was done with 10% HNO_3. The water samples were brought in an ice chest, before being stored at 4°C in the refrigerator.

Chemicals and reagents

All chemicals used were of high analytical reagent grade, which were purchased from Sigma-Aldrich, USA.

Sample preparation and heavy metal analysis

The heavy metal analyses of the samples were carried out using standard methods. 100 ml of the borehole water samples were transferred into a 250 ml glass beaker. Concentrated HNO_3 (6 ml) was added and it was heated using a hot plate until the volume was reduced to 20 ml. The mixture was allowed to cool and filtered. It was made up to the 100 ml mark using deionized water [10]. The samples were aspirated into the oxidizing air-acetylene flame using an agilent 240-FS atomic absorption spectrophotometer. The sensitivity for 1% absorption was observed after the samples were aspirated. The heavy metal analysis was analysed for Nickel (Ni), Iron (Fe), Cadmium (Cd), Chromium (Cr), Lead (Pb), Arsenic (As), Cobalt (Co), Manganese (Mn), Zinc (Zn) and Copper (Cu).

A standard solution containing 1000 ppm of 2% HNO_3 was used to prepare the spiking experiments and calibration standards. Two working standards for each heavy metal were prepared from these standards. A standard calibration curve was obtained by running a prepared standard solution of each heavy metal.

RESULTS AND DISCUSSION

The heavy metal parameters of the borehole water samples were shown in Table 1. The borehole samples showed different levels of heavy metal characteristics in both study areas. The values of the mean heavy metal parameters were compared with WHO standard limits.

Table 1. Heavy metal levels in the borehole water.

Metals	Wet season				Dry season			
	Upstream		Downstream		Upstream		Downstream	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Zn	1.38–1.58	1.478 ± 0.08	1.14–1.37	1.245 ± 0.09	1.18–1.31	1.23 ± 0.07	1.12–1.24	1.187 ± 0.06
As	0.01–0.02	0.013 ± 0.01	0.00–0.01	0.008 ± 0.00	0.01–0.01	0.01 ± 0.00	0.00–0.01	0.007 ± 0.00
Pb	0.00–0.02	0.018 ± 0.00	0.00–0.02	0.01 ± 0.01	0.01–0.02	0.013 ± 0.01	0.00–0.01	0.007 ± 0.00
Fe	0.28–0.36	0.308 ± 0.04	0.22–0.25	0.235 ± 0.01	0.24–0.31	0.267 ± 0.04	0.17–0.24	0.207 ± 0.04
Ni	0.04–0.07	0.05 ± 0.02	0.00–0.04	0.023 ± 0.02	0.05–0.06	0.053 ± 0.01	0.03–0.05	0.037 ± 0.01
Mn	0.37–0.45	0.4 ± 0.04	0.10–0.34	0.265 ± 0.11	0.32–0.38	0.347 ± 0.03	0.22–0.33	0.277 ± 0.06
Cr	0.03–0.05	0.043 ± 0.01	0.01–0.04	0.03 ± 0.01	0.03–0.04	0.033 ± 0.01	0.01–0.03	0.023 ± 0.01
Co	0.03–0.05	0.04 ± 0.01	0.02–0.04	0.03 ± 0.01	0.03–0.04	0.037 ± 0.01	0.02–0.03	0.023 ± 0.01
Cd	0.00–0.01	0.005 ± 0.00	0.00–0.01	0.003 ± 0.00	0.00–0.01	0.003 ± 0.00	0.00–0.01	0.003 ± 0.00
Cu	0.37–0.48	0.433 ± 0.05	0.32–0.48	0.383 ± 0.07	0.41–0.47	0.443 ± 0.03	0.28–0.37	0.32 ± 0.05

The mean concentration of Zn ranged from 1.23 mg/l-1.478 mg/l for upstream samples for both seasons. In the downstream samples, the mean values ranged from 1.187 mg/l–1.245 mg/l for both seasons. The Zn values for the upstream sample were higher than the downstream values, possibly due to infiltration of the leachates from the dumpsite, which were closer to the upstream locations. The Zn levels were below the WHO permissible limit (3 mg/l) for drinking water. The values were lower than 1.79 mg/l and 10.8 mg/l which were reported. The Zn values obtained from this study were higher than the values obtained.

The As values for both seasons ranged from 0.01 mg/l-0.013 mg/l for the upstream samples, while the downstream samples ranged from 0.007 mg/l-0.008 mg/l for both seasons. The As values in the upstream samples were equal to or greater than the WHO maximum allowable limit of 0.01 mg/l for both seasons. Higher values of arsenic higher than the study samples were reported. The values of As reported in this study were similar.

The mean values of Pb in the upstream location ranged from 0.013 mg/l-0.018 mg/l for both seasons, while the downstream values ranged from 0.01 mg/l-0.007 mg/l. The values were equal to or greater than the WHO threshold limit of 0.01 mg/l, except for the downstream value in the dry season, which was lower than the WHO limit. The high values of Pb could be attributed to the disposal of lead batteries, pipes, and paints at the refuse dump. The values obtained from this study were similar. High values of Pb higher than this study was obtained.

The Fe values for the upstream values ranged from 0.267 mg/l-0.308 mg/l for both seasons, while the downstream values ranged from 0.207 mg/l-0.237 mg/l respectively, which were above the permissible limit of 0.30 mg/l. The mean value for the upstream samples during the wet season was the only mean value that exceeded the WHO permissible limits. High values of Fe in water can be attributed to the oxidation of metal wastes in the dumpsites. The upstream samples were higher than the downstream samples for both seasons.

The mean values of Ni for the upstream samples for both seasons ranged from 0.05 mg/l-0.053 mg/l. The downstream samples ranged from 0.023 mg/l- 0.037 mg/l for both locations. The values were lower than the threshold limit of 0.07 mg/l for both locations in both seasons. The upstream location values were higher than the downstream locations for both seasons. The Ni values in this study were similar. The Ni values from this study were higher than the reported work.

The mean values of Mn for the upstream samples ranged from 0.347 mg/l-0.4 mg/l, while they ranged from 0.265 mg/l-0.277 mg/l for the downstream samples for both seasons. The upstream sample value in the wet season was the only Mn value equal to the WHO threshold, while the rest were within the limit. The values from this study were higher than the obtained value and were lower than the values.

The mean values of Cr for the upstream samples ranged from 0.033 mg/l-0.043 mg/l, while the downstream values ranged from 0.023 mg/l-0.03 mg/l for both seasons. These values were below the permissible limit of the WHO. The values in this study were similar. The mean values of chromium obtained in this study were lower than the results obtained.

The mean values of Co for the upstream samples for both seasons ranged from 0.03 mg/l-0.04 mg/l, while the downstream sample values ranged from 0.023 mg/l-0.03 mg/l. These values were lower than the results obtained.

The mean values for Cd ranged from 0.003 mg/l-0.005 mg/l for the upstream samples and 0.003 mg/l for the downstream samples for both seasons. The Cd values were either equal to or greater than the threshold limit by the WHO for both locations and seasons. Cadmium could be linked with the dispersal of heavy metals produced from electronic wastes disposed of in the dumpsite. Similar values of Cd were reported. The values were higher than the reported work and lower than obtained work.

The mean values for Cu in the upstream sample ranged from 0.443 mg/l-0.443 mg/l for both seasons, while they ranged from 0.32 mg/l-0.383 mg/l in the downstream samples in both seasons. These values were below the WHO permissible limits of 2 mg/l. The values were higher than the values obtained and lower than the value obtained.

The order of maximum concentrations followed this order for the wet season: Zn>Cu>Mn>Fe>Ni>Cr>Co>Pb>As> Cd for the upstream samples, and Zn>Cu>Mn>Fe>Cr>Co>Ni>Pb>As>Cd for the downstream samples. The dry season followed this order: Zn>Co>Mn>Fe>Ni>Co>Cr>Pb>As>Cd for the upstream samples and Zn>Co>Mn>Fe> Ni>Cr>Co>As>Pb>Cd for the downstream samples.

The correlation values of the heavy metal parameters for the borehole water samples indicated a strong positive correlation between upstream and downstream samples during the wet season and dry season [11,12]. The correlation study values between the wet and dry season upstream values and downstream values showed a strong positive linear relationship. The strong correlation observed in the study areas indicates that the pollution is of a similar source. The pollutant source was linked to anthropogenic activities such as the discharge of leachates from the unlined dumpsite. The p-values are all less than 0.05 ($p<0.05$), which implies that the heavy metal characteristics are significant, and are dependent on the extent of accumulation of pollutants in the borehole water samples in both seasons.

Therefore, the study suggests that the levels of heavy metals obtained were attributed to leachate percolation through the unlined refuse dump. The upstream sample's results were predominantly higher than the results of the downstream samples for both locations and seasons. This is due to the infiltration of pollutants from the leachates because of its proximity to the dumpsite.

CONCLUSION

The results of the study area showed that the upstream and downstream boreholes were contaminated with different concentrations of heavy metals through the infiltration of the leachates from the unlined dumpsite. The results revealed that Cd was above the WHO limit across both locations. The Mn and Fe values for the upstream samples in the wet season were above the WHO permissible limit. The As mean values in the upstream samples in both seasons were above the WHO limit. The Pb values were above the WHO threshold limit, except for the downstream sample values in the dry season. The overall results obtained showed that both borehole water samples do not meet the WHO standard for drinking water. The upstream sample's heavy metal levels were greater than that of the downstream samples, because of leachate infiltration linked to their proximity to the dumpsite. The wet season concentrations were higher than those during the dry season because of the runoff of leachates from the unlined dumpsite. Carcinogenic and non-carcinogenic risks through ingestion and dermal contact with heavy metals pose serious health-related risks to the population, of which children are more vulnerable than adults. The pollution indices showed that the borehole water samples were polluted and should be treated before use. Routine monitoring of the borehole water around the dumpsite area should be encouraged to curtail health-related risks from exposure to heavy metal toxicity. The government should adopt an efficient waste management system that involves constructing sanitary dumpsite that will prevent leachate infiltration from the environment.

AUTHORS CONTRIBUTIONS

All authors have read and approved the manuscript. CCA: Writing- Original draft preparation, Conceptualization, Methodology; PAC: Reviewing and Editing, Data curation; HOA: Investigation, Supervision and Validation; VCE:

Methodology, Data curation, Software; HOC: Visualization, Conceptualization. The final manuscript was read and approved by all authors.

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DATA AVAILABILITY STATEMENT

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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CONFLICTS OF INTEREST

No potential conflict of interest is reported by the authors.

REFERENCES

1. Alam R, et al. Assessment of surface water quality around a landfill using multivariate statistical method, sylhet, bangladesh. Environ Nanot Monit Manage. 2021;15:100422.

2. Ubechu BO, et al. Assessment of physicochemical characteristics of groundwater around an unlined landfill in aba, southeastern nigeria. J Res Environ Earth Sci. 2021;7:76-82.

3. Aralu CC, et al. Polycyclic aromatic hydrocarbons in soil situated around solid waste dumpsite in awka, nigeria. Tox Rev. 2023;42:122-131.

4. Aralu CC, et al. Impact of solid waste leachates on soil and edible plants within unlined dumpsite in awka, anambra state. Amer J Chem. 2020;10:11-18.

5. Aralu CC, et al. Assessment of heavy metals levels in soil and vegetables in the vicinity of unlined waste dumpsite in nnewi, anambra state nigeria. J Chem Soc Niger. 2020;45:687-696.

6. Aralu CC, et al. Toxicity and distribution of polycyclic aromatic hydrocarbons in leachates from an unlined dumpsite in nnewi, nigeria. Int J Environ Anal Chem. 2022;83:121-126.

7. Laniyan TA, et al. Health risk assessment of heavy metal pollution in groundwater around an exposed dumpsite in southwestern nigeria. J Heal Pollut. 2019;9:191210.

8. Egbueri JC. Assessment of the quality of groundwaters proximal to dumpsites in awka and nnewi metropolises: A comparative approach. Int J Energy Water Res. 2018;2:33-48.

9. Aralu CC, et al. Pollution and water quality index of boreholes within unlined waste dumpsite in nnewi, nigeria. Discov Wat. 2022;2:14.

10. Deng Y, et al. Spatial distribution and risk assessment of heavy metals in contaminated paddy fields-a case study in xiangtan city, southern china. Ecotoxic Environ Saf. 2019;171:281-289.

11. Eze VC, et al. 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. Int J Environ Anal Chem. 2022;102:3722-3743.

12. Okeke DO, et al. Determination of the levels of heavy metals and physicochemical properties of borehole water within selected mining sites in ebonyi state, nigeria. Int J Chem Biol Sci. 2022;3:5-10.