

Assessment of heavy metals contamination in groundwater samples from a reclaimed dumpsite at independence layout Annexe, Enugu, Nigeria

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Abstract

An open solid waste dumpsite was reclaimed lately for residential purposes and metropolitan expansion at Independence Layout Annexe, Enugu, Nigeria. Residents of the area were constrained to access groundwater through hand dug wells despite the health risk effects and consequences. Sequel to this menace/risk, this study was aimed at assessing Heavy Metals Contamination in Groundwater Samples from a Reclaimed Dumpsite in the area. The water samples were collected during the wet and dry seasons, at intervals of six months for two years to ascertain any contamination of the groundwater within the neighbourhood. The heavy metals of the groundwater were measured using Atomic Absorption Spectroscopy and the results were compared with the permissible limit of World Health Organization (WHO). Using Statistical Package for the Social Sciences (SPSS 23), Analysis of Variance (ANOVA) was carried out to determine the statistically significant difference in the concentration of heavy metals in the different water samples at 95% confidence level. The results of water analyses indicated that the samples were laden with Dissolved Solids, high in Nickel, Chromium, and Lead in dry season, while Cadmium was high in both seasons. Cobalt was relatively high in the wet season. The report signals that the groundwater within the study area is polluted and may aggravate human health risks in the neighbourhood. Therefore, appropriate treatment of the water is required before consumption.

Keywords: Heavy Metals; Contamination; Groundwater; Reclaimed Dumpsite; Solid Waste

1. Introduction

Municipal solid waste disposal constitutes a serious concern globally, especially in developing and least developed countries where large scale poverty is evident, and population growth/explosion combines with ineffective and under-funded governments to preclude the efficient management of wastes. Municipal Solid Wastes pose environmental and public health hazards all over the world [1]. The sound management of waste is necessary in every community, and this is a significant challenge in most developing and least developed nations.

Dumpsite is a widespread land meant or designed for deposition of waste and unwanted materials from households, industries, institutions or environment, and is generally open or covered with soil layer, with or without liner at the bottom [2]. Landfills and open dumps have been pinpointed and recognized as one of the key perils to groundwater resources. Waste placed in landfills or open dumps are subjected to ground water flow or infiltration from precipitation. Leachate generated from landfill or open dump sites tends to affect surface water quality through surface runoff and ground water quality in the adjacent areas through infiltration and percolation into the subsoil.

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Groundwater resource all over the world is under threat due to contaminant load introduced into it through urbanization, industrialization, agriculture and exploitation of natural resources [3]. Groundwater contamination, typically resulting from the activities of industrialization, urbanization, agriculture etc., has evolved over time due to flagrant disregard for environmental considerations. The effect of leachate on ground water and other water resources has attracted a lot of attention because of its overwhelming environmental significance in recent times. Leachate transportation and migration from waste dump sites or landfills and the release of pollutants from sediments constitute a high risk to groundwater resource if not adequately managed. Related works done in/around dumpsites include: [4, 5, 6, 7, 8, 9, 10, 11, and 12] etc.

Contamination of groundwater from landfills or open dump sites largely results from leaking "Leachate" – water that has filtrated and percolated through waste and gathered several ions in solution. Present-day sanitary landfills have clay and plastic (geo-membrane) barricades/barriers beneath the waste, as well as leachate collection and management techniques to intercept and impede leakage of leachate. Older landfills in Asia, Europe and North America as well as majority of the landfills and dump sites in the developing countries today, especially Nigeria and the study area in particular have no barriers and allow the seepage and filtration of leachate into groundwater.

The study site is mainly a grassland with a flat terrain. Vegetation is lush in areas that have not been altered by anthropogenic activities. There is a dumpsite under reclamation at the S/Eastern portion of the site. The N/Eastern and N/Western portions of the site are used for cultivation of crops. There is a building under construction with a well beside it, located at the entrance of the study area from the main access road at the S/Eastern portion of the site. The site is located within Ugwuaji in the outskirts of Enugu metropolis. It served as an open dump for waste from 1992 – 2019 when its usage for disposal and management of municipal solid waste was discontinued. The site was an un-engineered landfill site which was far below the required standards for disposal and management of solid wastes globally. Presently, the site is designated as Independence Layout Annex by the State Government, and it is undergoing some road constructions and development of buildings for residential purposes.

Following the reclamation of the dumpsite, studies linking the groundwater of the reclaimed site to heavy metals contamination are lacking. Thus, this study was poised to assess the groundwater resource and ascertain if there is any form of contamination by heavy metals after discontinuation of the site as a dumpsite. The objectives of the study were to (1) To measure the heavy metals concentration in the water samples and compare with WHO standards, and (2) compare values of the heavy metal load with WHO standards. The study evaluated heavy metals contamination in the groundwater so as to establish any risks posed to human health, animals or plants in the study area. Groundwater in the study area is essentially used for consumption, and other domestic purposes. Heavy metals content will certainly have a negative effect on its suitability for the intended use.

2. Methodology

The water samples were collected during the wet and dry seasons, at intervals of six months for two years to ascertain any contamination of the groundwater within the neighbourhood. The heavy metals of the groundwater were measured using Atomic Absorption Spectroscopy (AAS) and the results were compared with the permissible limit of World Health Organization (WHO). Using Statistical Package for the Social Sciences (SPSS 23), Analysis of Variance (ANOVA) was carried out to determine the statistically significant difference in the concentration of heavy metals in the water samples at significant level of 0.05.

3. Results and Discussion

The result of heavy metals measurement in the water samples during the wet and dry seasons, is shown in Table 1. The mean values were compared with WHO permissible limits for both seasons. The result of the Analysis of Variance (ANOVA) carried out to determine the significant difference between the means of the variables is shown in Table 2.

Table 1 Heavy Metals in the Water Samples

HEAVY METALS		YEAR 1		YEAR II		WHO STD.	UNIT
		WET	DRY	WET	DRY		
1.	Ag	0.0001	0.003	0.0002	0.005	0.05	Mg/l
2.	Cd	0.17	0.020	0.16	0.025	0.003	Mg/l
3.	Pb	0.009	0.12	0.001	0.17	0.01	Mg/l
4.	Cr	0.022	0.307	0.02	0.44	0.05	Mg/l
5.	Ni	0.001	0.009	0.03	2.66	0.1	Mg/l
6.	Co	0.038	0.034	0.035	0.003	0.01	Mg/l
7.	Fe	0.280	0.177	0.19	0.167	1.00	Mg/l
8.	Zn	0.586	0.61	0.735	0.845	3.00	Mg/l

Table 2 ANOVA of the Parameter Values collected during both Dry and Wet Seasons

		Sum Squares	of Df	Mean Square	F	Sig.
Concentration of Silver in the water	Between Groups	0.002	2	0.001	923.824	0.001
	Within Groups	0.000	2	0.000		
	Total	0.002	4			
Concentration of Cadmium in the water	Between Groups	0.027	2	0.013	430.315	0.002
	Within Groups	0.000	2	0.000		
	Total	0.027	4			
Concentration of Lead in the water	Between Groups	0.023	2	0.011	17.925	0.053
	Within Groups	0.001	2	0.001		
	Total	0.024	4			
Concentration of Chromium in the water	Between Groups	0.147	2	0.073	16.251	0.058
	Within Groups	0.009	2	0.005		
	Total	0.156	4			
Concentration of Nickel in the water	Between Groups	1.989	2	0.995	0.593	0.628
	Within Groups	3.357	2	1.679		
	Total	5.346	4			
Concentration of Cobalt in the water	Between Groups	0.001	2	0.000	1.173	0.460
	Within Groups	0.000	2	0.000		
	Total	0.001	4			

Concentration of Iron in the water	Between Groups	0.511	2	0.256	124.756	0.008
	Within Groups	0.004	2	0.002		
	Total	0.516	4			
Concentration of Zinc in the water	Between Groups	4.259	2	2.129	110.004	0.009
	Within Groups	0.039	2	0.019		
	Total	4.297	4			

3.1. Silver (Ag)

From Table 1, it can be seen that the mean concentration of Silver (dry season- 0.0004mg/l, wet season- 0.00015mg/l) fell below the WHO permissible limit of 0.05mg/l. A closer examination of both seasons showed an increase in the Ag value during dry season, which could be as a result of evaporation of fluids. This result is in agreement with the research carried out by Michaela *et al* [7] at a dumpsite area in Onitsha, South East, Nigeria. Result from Table 2, showed that at significant level of 0.05, there was statistically significant difference in the concentration of Silver in the different water samples with P-value of 0.001.

3.2. Cadmium (Cd)

Cd was observed from Table 1 to be high, as the mean concentrations for both dry and wet seasons were higher than the WHO admissible limit of 0.003mg/l. This implies that the water is polluted with Cd during both seasons. It indicates that the water is unsafe for human consumption. A closer examination of the measured values of both seasons showed that Cd increased in concentration during the dry season. This could be attributed to fluids evaporation, due to increased temperature, during the dry season. This result is in harmony with the study done by Ojekunle *et al* [13] where level of Cd contamination was above permissible limit and posed serious potential ecological risk. It is also in harmony with the research carried out by Ogbuene *et al* [14] at Ugwuaji dumpsite area of Enugu, Nigeria where Cd was detected to be one of the major contaminants of the soil, and the study emphasized that oxides of some elements such as Cd penetrate and contaminate the soil, surface and ground water through leaching processes.

Meanwhile, the result of the statistical analysis in Table 2 showed that with a p-value of 0.002, there is statistically significant difference in the concentration of Cd in the different water samples.

3.3. Lead (Pb)

The result from Table 1 indicated that the mean concentration value of Pb in dry season (0.145mg/l) was above WHO permissible limit of 0.01mg/l. Whereas, in wet season, the mean value of 0.005mg/l was seen to be within WHO permissible limit. This implies that the water is contaminated with Pb during the dry season, hence unsafe for human consumption. The increase in Pb concentration during the dry season may be as a result of fluids evaporation or discharge into the water body from anthropogenic activities. Presence of Pb is a signal of the degree of toxicity of groundwater, hence portends grave environmental peril or danger to living organisms and the soil. This is also in agreement with the study done by Ojekunle *et al* [13] in which Pb was detected to be above WHO permissible limit. Pb was also detected by Ogbuene *et al* [14] as a significant contaminant to soil and groundwater in Ugwuaji dumpsite area.

The result also showed from Table 2 that with P-value of 0.053, there is no statistically significant difference in the mean concentration of Pb in the samples.

3.4. Chromium (Cr)

From Table 1, it was observed that the mean concentration of Cr in dry season (with value 0.3735mg/l) was above WHO permissible limit of 0.05mg/l. In the wet season, the mean concentration of 0.012mg/l was within the permissible limit. This implies that the water is contaminated with Cr mostly in dry seasons, which could be as result of evaporation of fluids. Asibor *et al* [4] detected Cr near a municipal solid waste dumpsite in Delta State, Nigeria.

However, at significant level of 0.05, the result from Table 2 showed that with p-value of 0.058, there is no statistically significant difference in the concentration of Cr in the water samples.

3.5. Nickel (Ni)

Nickel, from Table 1, exhibited a mean concentration of 1.3345mg/l in dry season which was above WHO permissible limit of 0.1mg/l. Whereas, the mean concentration of Ni in wet season (0.0155mg/l) was within the permissible limit of WHO. This indicates that the contamination of the water body with Nickel is associated with the dry season possibly as a result of evaporation. This is in conformity with the research work undertaken by Asibor *et al* [4] where it was recorded that the heavy metals fell within the guiding/regulatory limits of the country, apart from a few clusters of Ni in which they were noted to be a little above the regulatory limit. This makes the water unsafe for human consumption. However, from Table 2, with P-value of 0.628, result indicated that there is no statistically significant difference in the concentration of Ni in the water samples.

3.6. Cobalt (Co)

Table 1 indicated that the mean concentration of Cobalt in dry season (0.0035mg/l) was seen to be within the WHO permissible limit of 0.010mg/l. In the wet season, the concentration of Cobalt was 0.0365mg/l which is higher than the permissible limit. This implies that the water is contaminated with cobalt during wet season which may be due to run-off. Result from Table 2 showed that with p-value of 0.460, there is no statistically significant difference in the concentration of Cobalt in the water samples.

3.7. Iron (Fe)

Table 1 indicated that the mean concentration of Fe for both dry and wet seasons respectively (dry-0.172mg/l and wet-0.235) fell within the WHO permissible limit of 1.0mg/l. This finding is in harmony with the study done by Asibor *et al* [4] where the level of Fe was found to be within WHO limits. Ogbuene *et al* [14] also detected and recorded the presence of Fe in leachate samples collected from different locations in Ugwuaji dumpsite area of Enugu, Nigeria. Result from table 2, showed that at significant level of 0.05, there was statistically significant difference in the concentration of Fe in the different water samples with P-value of 0.008.

3.8. Zinc (Zn)

Result from Table 1 showed that the mean concentrations of Zn for both dry and wet seasons (dry- 0.7275mg/l, wet-0.6605mg/l) were below the WHO permissible limit of 3.0mg/l. The result obtained for Zn is in agreement with the work done by Kanownic and Policht-Latawiec [15] where Zn was recorded to be within admissible regulatory limits in a municipal landfill site.

With P-value of 0.009 as indicated in Table 2, there is statistically significant difference in the concentration of Zn in the water samples.

4. Conclusion

The laboratory report revealed that the water samples are fraught with dissolved solids high in Cadmium, Nickel, Chromium, Cobalt, and Lead. The concentration levels of the analyzed metals indicate pollution.

The findings of this study reveal and signal pollution with respect to the groundwater of the study area and the aforementioned heavy metals, and may exacerbate human health risks in the neighborhood as the filtration and permeation of pollutants already in the soil increases, especially during the wet season. Statistical analyses of the heavy metals showed that there was statistically significant difference in the concentration of Cd, Ag, Fe, and Zn in the water samples, while that of Cr, Co, Pb and Zn were not statistically significantly different. The indiscriminate and haphazard disposal of some hazardous wastes such as electrical/electronic wastes, batteries, and construction wastes has given rise to the increased presence of heavy metals in waste dumpsites. Many of these wastes are disposed of in the dumpsite without adequate treatment or management, coupled with the fact that the dumpsite is an un-engineered land fill. Leachates produced from such dumpsites are laden with traces of heavy metals, which eventually infiltrate into the subsoil, and contaminate groundwater.

Compliance with ethical standards

Disclosure of conflict of interest

The author declared no potential conflicts of interest.

References

- [1] Bassey IU, Brooks AA, Asikong BE, Andy IE. Environmental and public health aspects of solid waste management at the lemna dumpsite in Calabar, Cross River State, Nigeria. *International Journal of tropical disease and health*. 2015; 10(3):1-13.
- [2] Igboama WN, Hammed OS, Fatoba JO, Aroyehun, MT, Ehiabhili JC. Review article on impact of groundwater contamination due to dumpsites using geophysical and physiochemical methods. *Applied water science*. 2022; 12(6): 30.
- [3] Ravindra K, Mor S. E-waste generation and management practices in Chandigarh, India and economic evaluation for sustainable recycling. *Journal of cleaner production*. 2019; (221):286-294.
- [4] Asibor G, Edjere O, Ebighe D. Leachate characterization and assessment of surface and groundwater qualities near municipal solid waste dumpsite at Okuvo, Delta State, Nigeria. *Ethiopian journal of environmental studies and management*. 2016; 9(4):523-533.
- [5] Bullough F, Fenech C, Bridle H. advances in water quality monitoring of inorganics: current trends. *Journal of water resource and protection*. 2013; 5(4):40.
- [6] Ketata M, Gueddari M, Bouhlila R. Suitability assessment of shallow and deep ground waters for drinking and irrigation use in the El Khairat aquifer, Enfidha, Tunisian Sahel. *Environmental earth sciences*. 2012; 65(1):313-330.
- [7] Michaela EI, Odohb AO, Chukwurac EI, Bend MG. Heavy metal and microbial load properties of dumpsite leachate: case study of Onitsha dumpsite, South-East, Nigeria. *J Toxicol anal*. 2018; 1(1):6.
- [8] Sarr A, Ndoye S, Djanni ALT, Faye S. assessment of groundwater quality for drinking and irrigation uses in the Samba Dia area, Central West Senegal'. *Journal of water resource and protection*. 2023; 15(4):130-148.
- [9] Stanly R, Yasala S, Oliver DH, Nair NC, Emperumal K, Subash A. Hydrochemical appraisal of groundwater quality for drinking and irrigation: a case study in parts of southwest coast of Tamil Nadu, India. *Applied water science*. 2021; (11):1-20.
- [10] Udoh AC, Chinwuko AI, Onwuemesi AG, Anakwuba EK, Oyonga AO, Usman AO. Impact of solid waste on groundwater quality in selected dumpsites in Akwa Ibom State, Nigeria using resistivity and hydrochemical data. *Bulletin of the mineral research and exploration*. 2021; 164(164):231-249.
- [11] Ugwuanyi MC, Ibuot JC, Obiora DN. Hydrogeophysical study of aquifer characteristics in some parts of Nsukka and Igbo-Eze South Local Government Areas of Enugu State, Nigeria. *International journal of physical sciences*. 2015; 10(15):425-435.
- [12] Vidović M. Assessment of the trophic status by monitoring of reservoir's water quality. *Journal of water resource and protection*. 2015; (7):1-13.
- [13] Ojekunle OZ, Ojekunle OV, Adeyemi AA, Taiwo AG, Sangowusi OR, Taiwo AM, Adekitan AA. Evaluation of surface water quality indices and ecological risk assessment for heavy metals in scrap yard neighbourhood. *SpringerPlus*. 2016; (5):1-16.
- [14] Ogbuene EB, Odinkonigbo UL, Nebo AN, Ghasi NC, Aloh OG, Odoms IC. Open solid waste leachate output and monthly rainfall variation in Ugwuaji, Enugu, Nigeria. *International journal of development and sustainability*. 2018; 7(3):986 – 992.
- [15] Kanownik W, Policht-Latawiec A. Impact of municipal landfill site on water quality in the włosanka stream. *Journal of ecological engineering*. 2016; (17):57-64.