Assessment of the quality of borehole water collected around unlined solid waste dumpsite within Awka metropolis

Abstract

Groundwater is an important natural resource that is essential to man and other living things. However, it can become polluted resulting from natural and anthropogenic conditions. The quality of selected groundwater samples collected from boreholes around abandoned and active dumpsites in Awka metropolis, Nigeria between January and March 2023, was assessed using water quality index (WQI) method. The samples were analyzed for their physico-chemical properties and some selected heavy metals using atomic absorption spectroscopy. The results of the physico-chemical analysis showed that the mean pH ranged from 5.75 – 6.71 in January as compared to 5.92 – 6.98 in February and 5.94 – 6.84 in March indicating slight acidity. Calcium and magnesium content ranged from 8 – 20mg/l of Ca^{2+} and 96 – 314 mg/l of Mg^{2+} ion. The concentration of heavy metals in the samples were all seen to be within the standard limits for potable water (Fe (0.057 – 2.384 ppm), Cu(0.00 – 0.185 ppm) except for mercury, lead and cadmium(Hg (0.00 – 0.248 ppm), Pb (0.00 – 0.051 ppm), Cd (0.006 – 0.39 ppm) for the month of February whereas heavy metal concentration for the month of March ranged from Fe (1.432 – 2.908 ppm), Cu (0.00 – 0.008 ppm), Hg (0.00 – 0.016 ppm), Pb (0.00 – 0.003 ppm), Cd (0.00 – 0.01ppm). Pollution Index of the sampled borehole water from the different locations shows that some were potable and can be consumed without treatment. The study shows that solid wastes contribute to the level of contamination caused by Heavy metals and some physico-chemical parameters in groundwater matrix.

Keywords: Unlined dumpsite, Water quality index, Sustainability, Portable water.

Introduction

Waste is produced everywhere and is a natural by-product of human activities. Solid waste is an undesirable or worthless material that is produced in a specific region by a combination of commercial, industrial, and residential activities. It can be divided into categories based on where it came from (household, industrial, commercial, construction, or institutional), what's inside of it (organic material, glass, metal, plastic, paper, etc.), or the danger it poses (toxic, non-toxin, flammable, radioactive, infectious etc). Several chemical and biological processes convert waste in landfills to organic and inorganic compounds in the gas/liquid phases, resulting in the generation of landfill gas (LFG) and land-fill leachate (Afolayan *et al*., 2012).Ogwueleke (2009) estimated that only 20.8% of the solid waste produced by communities was disposed of through suitable landfill sites, and 10.7% of such waste was burnt in his study of solid waste management in Port-Harcourt, Nigeria. When harmful waste from landfills seep into the soil through raindrops and infiltrates into groundwater sources, especially wells and boreholes, the water body becomes contaminated and unusable for domestic and other purposes (Eni *et al.,* 2014).The primary source of ground water pollution is leachate, a liquid that results from the interaction of solid waste and water. Leachate alters the inorganic, organic, physical, and biological characteristics of the water quality (Ali, 2012).In a 2015 study in Ado-Ekiti, Ekiti State, 37% of water samples from 300 groundwater sources (wells and boreholes) tested positive for Escherichia coli (E. coli) (Olowe *et al.*, 2015).Dumpsite and landfill leachates could be a significant threat to groundwater quality, in addition to industrial and agricultural activities (Egbi*et al.,* 2017), particularly in the absence of groundwater quality monitoring. According to a study, 58% of waste in developing nations like Nigeria is discarded carelessly, and 52% of solid waste contains organic waste (Dladla *et al.*, 2016).It has been widely reported, though, that leachates from landfills for non-hazardous waste may also contain complex organic compounds, chlorinated hydrocarbons, and metals at concentrations that endanger both surface and groundwater. Numerous studies on the effects of dumpsite leachate on the surface and groundwater have been conducted over time (Simon and Ogunlowo, 2022).A regular feature in Awka is the high heaps of refuse dumps that emit a repulsive odour resulting from decomposing organic and agricultural waste. These heaps serve as both visual pollution and a breeding ground or sink for microorganisms that spread disease. The interaction of population, wealth, and technology are the primary causes of pollution and other forms of environmental degradation in any community (Nduka *et al.*,2006).Urban groundwater in Nigeria especially urban cities like Awka, Anambra State must be continuously monitored to determine its quality status, especially in areas near landfills or other indiscriminate disposal sites. The public and community health workers will use this as a guide when making action plans. The aim of the study is to assess the quality of underground water collected around unlined dumpsites in Awka metropolis, determine physicochemical properties of water samples from boreholes around selected dumpsites, determine the concentration of heavy metals in water samples from boreholes around the selected dumpsites using Atomic Absorption Spectrophotomoter (AAS), determine the risk indices of the pollutants in the water samples.

Materials And Methods

Study Area

Awka is the capital of Anambra State South East Nigeria and it is one of the busiest town in Anambra State. According to the last census of 2006, the city has a population of 301657(NBS, 2007). Due to the high influx of people into the city, thus rapid increase in population growth, industrialization, medical facilities, education and commercial centres. It is obvious this increase will resultantly lead to increased generation of municipal solid waste and consequently create a huge environmental management problem.

Equipment used: The equipments used for this research includes: Mercury thermometer**,** Conductivity meter (Model: DDS-307)**,** Atomic absorption spectrophotometer (Model: AA240)**,** UV spectrophotometer (Model: PD303)**,** Air Compressor (Gardner Denver, Model: 1207PH180-

379.E), Water bath (Adarsh Technology, Model: Iso-9001), Digital weighing balance (Mettler Toledo, Model: AB-265), Fume cupboard (Shanghai Lida, Model: A028528), Acetylene gas, Volumetric flasks, pH meter (Model: H1991300)andHDPE bottles.

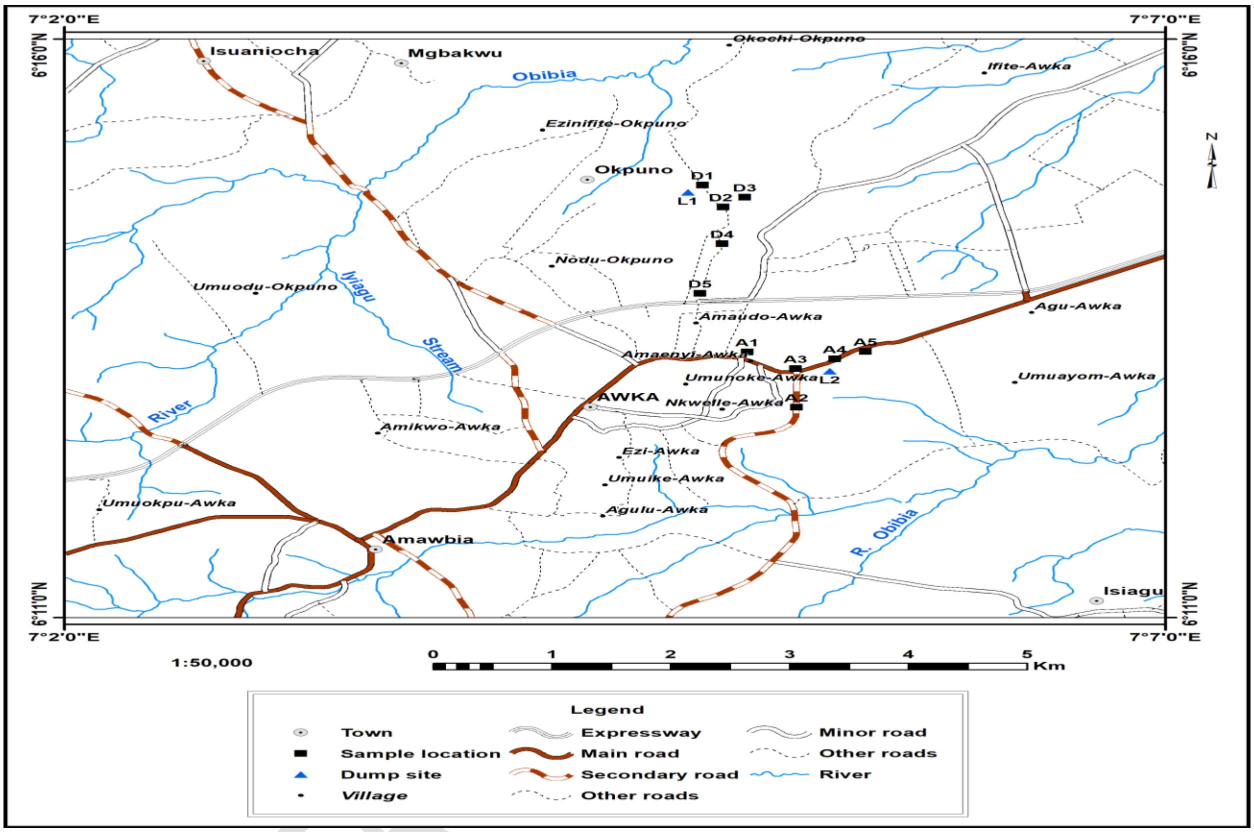

Fig 1: map of sampling location

Reagent used: The reagents used in this research include:Sodium hydroxide solution, Kovak reagent, Potassium dichromate, Hydrogen peroxide, Silver nitrate, EDTA (Ethylene diamine tetraacetic acid), Distilled water, Methyl red, Murixide indicator, Dichloromethane, Acetonitrile, Bromothymol blue indicator, Hydrochloric acid, Sulphuric acid, Nitric acid, Bromocresol indicator

Sampling and Sample Treatment

Sampling was done monthly from January to March 2023. The sampling was conducted at the upstream location which is within the dumpsite and downstream locations which is far away from the dumpsite for the both sampling locations of Awka using Global Positioning System

(GPS). The control sample was collected at 10km away from the abandoned dumpsites and 12km from the in-use dumpsites**.**

Determination of some physico-chemical properties

Determination of pH

The pH measurement was carried out using (APHA, 2005). Distilled water was used to rinse the electrodes and blot dry. The pH electrodes were rinsed in a small beaker with a portion of the sample. a large amount of water sample was put in a small beaker to allow the tips of the electrodes to be immersed to a depth of about 2cm. From the side and bottom of the beaker the electrodes was at least 1cm away. The temperature adjustment dial was done accordingly. The pH meter was turn on and the pH sample was recorded

Determination of Electrical Conductivity

The analysis was conducted according to the guidelines of (APHA, 2005). The electrical conductivity meter, model DDS-307 was used for the analysis. The conductivity cell was rinsed with at least three portions of the water sample. The temperature of the sample was then adjusted to 20 ± 0.1^{O}C. The conductivity cell containing the electrodes was immersed in a sufficient volume of the sample. The conductivity meter was turned on and the conductivity of the sample was recorded.

Determination of Total Solids

Total solids is the term applied to the material residue left in the vessel after evaporation of the water sample and its subsequent drying in an oven at a temperature of 103- 105^{o}C. Total solids include total suspended solids and total dissolved solids (APHA, 2005). 50ml of water samples was measured into a pre-weighed dish and evaporated to dryness at 103^{o}C on a steam bath. The residue was dried in an oven for about an hour at 103-105^{o}C, then cooled in a desiccators, and the weight was recorded. Other physicochemical properties were analyzed using specific model.

Results and Discussion

Table 1: Mean concentration of Physico-chemical properties and heavy metals of the borehole water from the abandoned site from January -March 2023

Parameters	**January**	**Control**	**February**	**Control**	**March**	**Control**	**WHO**
Temperature	25.6000	23	28.8000	29.5	29.8000	30.3	28^{o}C
pH	6.0800	5.7	6.3820	6.36	6.4660	6.63	8.5
Turbidity	0.1500	0.20	.3000	0.20	.8600	1.40	5
Conductivity	176.6000	120	94.1500	73.89	160.4000	160	500

Acidity	38.4000	14	39.2000	20	20.4000	22	100
Alkalinity	22.2500	37.5	45.5000	50	22.5000	15	100
TDS	55.4000	66	88.4000	130	60.2000	68	500
Chloride	170.4000	100	43.8000	25	105.6000	103	250
Total Hard	189.6000	150	200.0000	250	66.4000	64	500
Calcium Hard	122.0000	90	79.6000	18	20.0000	24	100
Magnesium Hard	67.6000	60	157.2000	232	46.4000	40	100
TSS	1.5720	1.36	1.1720	0.86	1.4360	2.45	30
DO 1	47.2000	38.6	18.4400	19.1	43.5340	49.27	7.5
BOD	93.2000	82	151.6000	154	154.5600	207.4	6
COD	198.4000	160	158.8000	208	204.0000	240	10
Fe	0.2588	0.163	0.4652	0.021	2.0078	0.198	3
Cu	0.0632	0.002	0.0220	0.015	0.0150	0.005	2.000
Hg	0.0376	0.001	0.0222	0.003	0.0226	0.004	0.006
Pb	0.0198	0.002	0.0070	0.001	0.0068	0.001	0.010
Cd	0.0217	0.008	0.0118	0.002	0.0066	0.003	0.003

Table 2: Mean concentration of Physico-chemical properties and heavy metals of the borehole water from the in-use dumpsite from January -March 2023

Parameters	January	Control	February	Control	March	Control	WHO
Temperature	23.6000	23	28.9000	29.5	29.4000	30.3	28°C
pH	6.3400	5.7	6.5960	6.36	6.4300	6.63	8.5
Turbidity	0.1120	0.20	0.3560	0.20	1.1600	1.40	5
Conductivity	135.4000	120	86.0940	73.89	94.0000	160	500
Acidity	28.4000	14	54.4000	20	59.2000	22	100
Alkalinity	36.0000	37.5	39.5000	50	17.5000	15	100
TDS	188.6000	66	68.8000	130	76.0000	68	500
Chloride	138.4000	100	75.6000	25	88.4000	103	250
Total Hard	169.2000	150	235.2000	250	81.6000	64	500
Calcium Hard	101.2000	90	10.8000	18	27.6000	24	100
Magnesium Hard	68.0000	60	224.4000	232	54.0000	40	100
TSS	0.8600	1.36	1.4820	0.86	1.2300	2.45	30
DO 1	52.6200	38.6	18.8200	19.1	44.4360	49.27	7.5
BOD	104.4600	82	143.6800	154	185.8800	207.4	6
COD	275.2000	160	171.2000	208	188.0000	240	10
Fe	1.0182	0.163	1.8102	0.021	2.6460	0.198	3
Cu	0.0132	0.002	0.0334	0.015	0.0334	0.005	2.000
Hg	0.0444	0.001	0.0442	0.003	0.0512	0.004	0.006

Pb	0.0244	0.002	0.0232	0.001	0.0182	0.001	0.010
Cd	0.0522	0.008	0.0320	0.002	0.0142	0.003	0.003

Physicochemical parameters

Water quality is an essential aspect of human life, and it is crucial to ensure that the water we consume meets certain standards to protect human health. The World Health Organization (WHO) has set guidelines for the quality of drinking water to ensure that it is safe for human consumption (World Health Organization, 2011 and 2017). The dataset parameters can be used to determine the quality of the water sample and check whether it meets the WHO guidelines.

The result contains measurements of various parameters for a water sample, including temperature, water appearance, color, taste, dissolved solids, suspended solids, pH, dissolved oxygen, alkalinity, acidity, hardness, chloride, Chemical oxygen demand, calcium, magnesium, etc. The result of water samples from eleven locations shown in Table 1 and 2, were analyzed for physiochemical parameters and heavy metals.

pH

pH was between 5.55 to 6.71 in the month of January as compared to the month of February with pH range of 5.92 to 6.98, and also in the month of march, the pH range is between 5.90 to 6.84. In general, the pH range for all samples collected is slightly acidic across all samples and can be recommended for consumption according to WHO standard. The pH level can alter the physiological and biochemical processes of aquatic organisms, such as respiration, metabolism, enzyme activity, and ion regulation, which can affect their behavior, health, and survival. For example, acidic water with a low pH level can lead to acidosis in fish, which can affect their behavior, growth, and mortality. Similarly, alkaline water with a high pH level can cause alkalosis, which can also impact fish physiology and mortality (Cao et al., 2015; Banaee et al., 2012).Moreover, pH can also influence the efficacy and performance of water treatment processes, such as coagulation, disinfection, and membrane filtration (Jiang et al., 2019). The pH level affects the chemical and physical properties of water, such as the charge and size of particles, which can affect their removal and treatment efficiency

Chemical Oxygen Demand

Chemical oxygen demand (COD) is a measure of the number of organic pollutants present in water, and it is an important parameter for determining the pollution level of water(APHA, 2017). The COD value for the samples in the dataset ranges from 64 to 480 mg/l in January, while in the month of February it ranges within 96 to 250 mg/l and also in the month of March, it ranges within 160 to 207 mg/l. This indicates that the water samples are considered safe as compared to WHO recommendation of COD value less than 4275.00 mg/l for drinking water (WHO, 2011). Therefore, the dataset's water samples are unsuitable for human consumption.

The presence of dissolved solids can affect the taste and odor of water and adversely affect the growth and reproduction of aquatic organisms (Chapman, 2006).

Dissolved Oxygen

Dissolved oxygen in the month of January ranges from 29.6 mg/l to 64.6 mg/l while in February, it ranges from 5.2 mg/l to 23.0 mg/l and in the month of March, it ranges from 29.40 mg/l to 52.42 mg/l with the lowest range in the month of March. Dissolved oxygen is an important parameter that indicates the amount of oxygen present in water(Kemp and Dodds, 2002). The dissolved oxygen value for all the samples is above the range of 1.4-2.4 mg/l, which is acceptable as per the WHO guidelines. The DO level is affected by several factors such as temperature, pH, and the presence of organic matter. Low DO levels can cause stress or mortality in aquatic organisms (USEPA, 2006).

Turbidity

The turbidity of the water samples collected was shown to reveal the highest degree of clarity in the month of February in the range of 0.2 to 0.5 NTU. All the water samples are fit for consumption as they show good clarity across the three month.

Alkalinity

Alkalinity is the measure of the water's ability to neutralize acids, while the acidity is the measure of the water's ability to neutralize bases (APHA, 2017), caused by the presence of bicarbonate, carbonate, and hydroxide ions in water and it is an essential parameter for determining the suitability of water for human consumption (USEPA, 2016). The avarage alkalinity values in the dataset are within the recommended range of 30-50 mg/l (WHO, 2011).Alkalinity can buffer pH changes and prevent the water from becoming too acidic or basic, which was positively correlated with pH, as shown by the higher alkalinity in samples with a higher pH. Acidity, on the other hand, refers to the presence of hydrogen ions in water and can lead to lower pH values. In the given dataset, acidity was measured as mg/l and ranged from 0.14 to 0.15 mg/l. Acidity was negatively correlated with pH, as shown by the higher acidity in samples with a lower pH.

Hardness

Hardness is a measure of the amount of dissolved calcium and magnesium in water. High levels of hardness can cause scaling and build-up in water distribution systems and appliances, as well as interfere with the effectiveness of soaps and detergents (USEPA, 2009). Hardness was positively correlated with calcium and magnesium levels, as shown by the higher hardness in samples with higher calcium and magnesium levels.The hardness of water can affect its suitability for various purposes such as drinking, industrial use, and irrigation (Khan et al., 2015).The concentration of calcium is within 54 to 160 mg/l in January, which is above the permissible range of 75 mg/l. The magnesium concentration in the water is between 34 to110 mg/l also in January, which is also above the safe limits (>30 mg/l). In February, the concentration of calcium decrease drastically within the range of 8 mg/l to 80 mg/l while that of magnesium is between the range 96 mg/l to 314 mg/l. In respect to magnesium content, the water is not considered safe for drinking. Whereas in march, the concentration of both calcium and magnesium were at a minimal range as compared to previous months and therefore the water is considered safe for drinking.

Other Physicochemical Parameters

Suspended solids can affect the clarity of water and can have negative impacts on aquatic organisms (Reynolds et al., 2002).Manganese is a naturally occurring element that can be found in water sources, and its levels can indicate the presence of other metals and minerals in the water, as high levels of manganese can affect the taste and odor of water, and can also stain plumbing fixtures and laundry (USEPA, 201; ATSDR, 2012). The parameters can be used to determine the suitability of water for human consumption, and the WHO guidelines can be used as a reference for comparison. The dataset highlights the importance of monitoring water quality and ensuring that the water we consume meets certain standards to protect human health. The data can be used to determine the suitability of a particular water source for various purposes such as drinking, industrial use, and irrigation. The parameters can also be used to monitor changes in water quality over time and to develop strategies for water management and conservation (Foster and Hirata, 2019).

Table 3: Pollution index of water from the abandoned and in-use dumpsites from January - March 2023

Parameters	**Stations**	**January 2023**		**February 2023**		**March 2023**		**WHO**
		ABD	**INU**	**ABD**	**INU**	**ABD**	**INU**	
Fe (ppm)	Point A	0.360	3.900	0.497	4.810	5.070	7.813	0.3
	Point B	0.490	3.520	1.907	6.663	7.180	7.790	0.3
	Point C	1.700	3.617	2.560	5.233	7.233	9.490	0.3

	Point D	0.450	2.653	2.383	7.000	7.547	9.250	0.3
	Point E	1.313	3.280	0.407	6.463	6.433	9.757	0.3
	ΣMPI	**4.313**	**16.97**	**7.754**	**30.169**	**33.463**	**44.100**	
	Control	0.543		0.070		0.660		0.3
Cu (ppm)	Point A	0.093	0.008	0.006	0.010	0.007	0.024	2.0
	Point B	0.027	0.005	0.011	0.027	0.009	0.021	2.0
	Point C	0.010	0.004	0.007	0.009	0.006	0.007	2.0
	Point D	0.016	0.009	0.023	0.022	0.007	0.014	2.0
	Point E	0.014	0.008	0.010	0.016	0.010	0.018	2.0
	ΣMPI	**0.160**	**0.034**	**0.057**	**0.084**	**0.039**	**0.084**	
	Control	0.001		0.008		0.003	2.0	
Hg (ppm)	Point A	3.667	13.667	2.500	4.167	2.000	12.333	0.006
	Point B	8.500	12.500	5.167	14.167	7.000	5.667	0.006
	Point C	10.500	3.667	3.667	5.333	2.333	14.000	0.006
	Point D	3.500	4.167	4.333	4.667	4.000	6.333	0.006
	Point E	5.167	3.000	2.833	8.500	3.500	4.333	0.006
	ΣMPI	**31.334**	**37.001**	**18.500**	**36.834**	**18.833**	**42.666**	
	Control	0.167		0.500		0.667		0.006
Pb (ppm)	Point A	2.600	3.800	0.700	2.600	0.400	2.400	0.01
	Point B	2.000	1.500	1.000	4.100	0.700	1.800	0.01
	Point C	1.200	1.700	0.600	2.100	0.500	1.700	0.01

	Point D	1.500	2.000	0.700	1.200	0.800	2.000	0.01
	Point E	2.600	3.200	0.500	1.600	1.000	1.200	0.01
	ΣMPI	**9.900**	**12.200**	**3.500**	**11.600**	**3.400**	**9.100**	
	Control	0.200		0.100		0.100		0.01
Cd (ppm)	Point A	6.667	29.000	2.000	9.000	1.667	3.667	0.003
	Point B	10.333	23.667	3.667	21.000	3.333	6.667	0.003
	Point C	8.667	6.000	2.667	8.000	1.333	6.333	0.003
	Point D	3.333	11.333	5.000	10.000	2.667	4.333	0.003
	Point E	7.000	17.000	6.333	5.333	2.000	2.667	0.003
	ΣMPI	**36.000**	**87.000**	**19.667**	**53.333**	**11.000**	**23.667**	
	Control	2.667		0.667		1.000		0.003

ABD = Abandoned dumpsite INU = In-Use dumpsite

Discussion of the table above

The metal pollution index values for the following heavy metals Fe, Hg, Pb, Cd were seen to be above 1.0 ppm (**MPI**> 1.0). This indicates that the water samples from this boreholes were polluted therefore, the consumption of contaminated borehole water will likely cause obvious health effects because the greater the Pollution index value, the greater the probability of the hazard risk on human body (Girl and Singh, 2015).From the MPI values above, copper (Cu) is seen to be below 1.0ppm (MPI < 1.0). As a result the borehole water sample had no copper pollution. However, it fell below the W.H.O permissible limit of 2 ppm or 2 mg/L which shows that the water has low amount of copper, this could be attributed to predominant activities within the vicinity of the boreholes around the unlined abandoned and In-use dumpsites.

Summary

Waste management problem is usually a regular feature with growing cities where rapid industrialization and lack of sanitary landfill form a major environmental nuisance, which constitutes health hazards in residential and industrial areas.

This work assessed the quality of 11 selected borehole waters around abandoned unlined dumpsite and in –use unlined dumpsite in Awka for their physicochemical parameters and heavy metals for a period of three months which spanned (Jan to March, 2023), following standard water sampling and analysis procedures and the results were compared with WHO standard for potable water. The results of the mean distribution across the month studied, revealed that pH values of the in – use dumpsites were more acid that of the abandoned and the control area. They were seen to range between 6.7, 6.5 and 5.7 for the in-use, abandoned and the control areas respectively, this is not within the allowable specification of WHO for potable drinking water. The conductivity of the studied samples spanned from (120 to 205μS/cm) for the abandoned, in-use, and the control areas with the highest value recorded for the in-use dumpsites although they were all seen to be within the WHO standards for potable water. The acidity and alkalinity values were all seen to be within the WHO permissible limit of 100 mg/L. Regard less of this fact, the samples from the in-use dumpsites recorded higher values for both parameters. This trend continued for other physicochemical parameters except for chloride where the abandoned dumpsites recorded higher values than the in-use dumpsites and control, although that there were all within the WHO limits of 250 mg/L for potable water.

The following heavy metals Fe, Cu, Hg, Pb, and Cd were analyzed for in the 11 samples of the abandoned, in-use dumpsites and the control area borehole waters. All the metals recorded mean higher concentration than the WHO permissible limits except for copper (Cu). Also the mean concentrations of the in-use dumpsites boreholes samples were seen to be higher that the abandoned dumpsites and the control area. Pollution of borehole water samples due to effect of distance from the unlined dumpsite to the boreholes was seen from the value recorded from both the abandoned and in-use dumpsite when compared to the control area. The effect was not significant statistically.

Conclusion

Assessment of water quality is an important tool for determining pollution levels in the environment. The heavy metals analyzed yielded varying results for different water samples. The pollution indicators were discovered to vary by location and sample. The results from the various parameters of the studied borehole waters were largely outside the WHO limit.

According to this study, borehole and waters in Awka are unfit for drinking and domestic use since their contamination indexes exceed 1.0. Similarly, physicochemical indices including DO and BOD were over the WHO guideline. These discoveries call for the purification of borehole in Awka metropolis before usage. Proper monitoring should be effected on the study area by the regulatory bodies in Awka metropolis.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1. none

2. none

References

Afolayan, O. S., Ogundele, F. O and Omotayo, A. (2012).Comparative analysis of the effect of closed and operational landfills in groundwater quality in Solous, Lagos, Nigeria. *Journal of Applied Technology in Environmental Sanitation*, 2(1): 67-76

Ali, F.A. (2012). Groundwater Pollution Threats of Solid Waste Disposal in Urban Kano, Nigeria: Evaluation and Protection Strategies. Doctoral dissertation, The University of Manchester. Pp 1-27.

APHA, American Public Health Association (2005); Methods for the examination of water and waste water, 21st Edition, U. S. A. 2130B-2320B.

APHA. (2017). Standard methods for the examination of water and wastewater, 23rd Edition, Washington, DC. Pp148-176.

ATSDR. (2012). Agency for Toxic Substance and Disease Registry. (2010). Public Health Statement. August 1995.Accessed 12-09. US Department of Health and Human Services. Agency for Toxic Substances and Disease Registry, 28 -30.

Cao, J., Chen, J., Xie, L., Wang, J., Feng, C., and Song, J. (2015). Protective properties of sesamin against fluoride-induced oxidative stress and apoptosis in kidney of carp (Cyprinus carpio) via JNK signaling pathway. *Aquat. Toxicol*. 16(7): 180–190.

Chapmam, D. (2006).Determination of Heavy metals in Industrial Harbor Water by GC MS.*International Journal o f environmental Research*, 2(9): 2175-2188.

Dladla, I., Machete, F and Shale, K. (2016). A review of factors associated with indiscriminate dumping of waste in eleven African countries. *African Journal of Science, Technology, Innovation and Development*, 8(56): 475–481.

Egbi, C.D., Akiti, T.T., Osae, S., Dampare, S.B., Abass, G and Adomako, D. (2017). Assessment of groundwater quality by unsaturated zone study due to migration of leachate from Abloradjei waste disposal site, Ghana. *Appl Water Sci.*, 2 (7):845–859

Eni, M. (2011).Use of geographical information system and Water Quality Index to assess groundwater quality in El Khairat Deep Aquifer (Enfidha, Tunisian Sahel).*Iran J Energy Environ* 2(2):133–144.

Foster, S., Hirata, R., Eichholz, M., and Alam, F-M. (2022). Urban Self-Supply from Groundwater-An Analysis of Management Aspects and Policy Needs. *Water* 14(4):575-581

Jiang, A., Asaolu, S. and Ipinmoroti, K. (2019). Effect of leaching on heavy metals concentration in some dumpsites. *African Journal of Environmental Science and Technology*, 4(8): 495-499.

Kemp, R.K. and Dodds, J.E. (2002). Source apportionment of heavy metals in dumpsite in the urban atmosphere: A comparison of three methods. *Environ. Sci. Technol*. 3(7): 1873–1881.

Ogwueleka, O. (2009). Municipal solid waste management in Port Harcourt, Nigeria: Obstacles and prospects. *Management of Environmental quality*, 15(4): 38-39.

Olowe, B.M., Oluyege, J.O and Famurewa, O. (2015). Prevalence of waterborne diseases and microbial assessment of drinking water quality in Ado-Ekiti and its Environs, Southwestern, Nigeria.*Br Microbiol Res J*, 12(2):1–13.

Nduka, J.K., Orish, E.O., Linus, Obi Ezenweke, .L.O. and Abiakam, .C.A. (2006). Archives of *Environmental and Occupational Health*, 61(5):1-10.

Reynold, F., Seng, C., Azan, A. and Tahir, M. (2002). Possible source and pattern distribution of heavy metals content in urban soil at Kuala Terengganu Town Centre. *The Malaysian Journal of Analytical Sciences*, 10(12): 458-467.

Simon, C.E and Ogunlowo,O. O. (2022). Assessment of Leachate Pollution Potential of Unlined Landfill Using Leachate Pollution Index (LPI), Nigeria. *British Journal of Multidisciplinary and Advanced Studies*: Engineering and Technology, 3(2):67-76

USEPA, (2016). Test methods for evaluating Solid Waste, SW –846, 3rd Edition (USEPA, Office of solid Waste and Emergency Response, Washington, DC, November). pp 200-206.

USEPA, (2006). United States Environmental Protection Agency. Guidelines for physicochemical analysis [EPA Report]. (EPA/630/P-03/001F). Washington, DC: U.S. Environmental Protection Agency, Risk Assessment Forum. pp 196-208.

USEPA, (2009). Screening For Environmental Hazards at Sites with Contaminated Soil and Groundwater, Hazard Evaluation and Emergency Response. pp 208-216.

World Health Organization, (WHO). (2011). Guidelines for Drinking Water Quality, 4thedition. WHO Press. Geneva, Switzerland. pp 222-230

Nduka, J.K., Orish, E.O., Linus, Obi Ezenweke, .L.O. and Abiakam, .C.A. (2006). Archives of *Environmental and Occupational Health*, 61(5):1-10.

Simon, C.E and Ogunlowo,O. O. (2022). Assessment of Leachate Pollution Potential of Unlined Landfill Using Leachate Pollution Index (LPI), Nigeria. *British Journal of Multidisciplinary and Advanced Studies*: Engineering and Technology, 3(2):67-76