Novateur Publications
International Journal of Innovations in Engineering Research and Technology [IJIERT]
ISSN: 2394-3696 Website: ijiert.org
Volume 12, Issue 2, February – 2025

DETERMINATION OF THE HEAVY-METALS POLLUTION INDEX (HPI) OF GROUNDWATER SYSTEM NEAR SELECTED WASTE DUMPSITES IN PORT HARCOURT

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Article History: Received on: 09/01/2025
Accepted on: 22 /02/2025

DOI: https://doi.org/10.26662/ijiert.v12i2.pp1-14

Abstract
This study was carried out to determine the heavy-metal pollution index (HPI) of groundwater sample near selected waste dumpsite in Port Harcourt. Two waste dumpsites in Choba and Aluu communities in River state were randomly sampled. Two different boreholes were sampled at different distances of 50m, 100m and 150m away from the dumpsites. Groundwater samples were collected from the boreholes and were taken to laboratory for identification of presence and concentration of the heavy metals. The results of the analysis revealed that; eight different heavy metals were discovered in the water samples around the dumpsites, and they include Copper, Mercury, Lead, Barium, Cadmium, Chromium, Iron and Zinc, the concentrations of these heavy metals were within the accepted standards for all the water sampled in Choba while that of Aluu were also within accepted standards except for Lead which is slightly higher than accepted standard at 50m and 100m away from the waste dumpsite, Heavy-metal Pollution Index (HPI) for water samples obtained at distances of 50, 100, and 150 meters away from the waste dumpsite in Aluu indicated that they were good for drinking while the HPI for water sampled from Choba showed that the water samples from 50m and 100m were good for drinking while the water sample from 150m was very good for drinking. It was concluded, among others, that, the concentration of heavy metal and heavy-metal pollution index of the groundwater around waste dumpsites depends on distance of the groundwater sample from the waste dumpsite. Therefore, it was recommended, among others, that regular and robust test should be carried out on boreholes of people living close to waste dumpsites in order to check for level of contamination and take necessary actions if the water is contaminated

Keywords, Heavy-Metal Pollution Index (HPI) Ground-water, waste dumpsites.

1.0 Introduction
Groundwater is the water present beneath Earth's surface in rock and soil pore spaces and in the fractures of rock formations. About 30 percent of all readily available freshwater in the world is groundwater. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of

water. Groundwater is a major part of the natural water cycle. Some part of the precipitation that lands on the ground surface infiltrates into the subsurface (Famiglietti.2014). The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Groundwater is recharged from the surface; it may discharge from the surface naturally as springs and seeps, and can form oases or wetlands. Groundwater is also often withdrawn for agricultural, municipal, and industrial use by constructing and operating extraction wells. The study of the distribution and movement of groundwater is known as hydrogeology, also called groundwater hydrology (Famiglietti.2014).

The World Health Organization (WHO, 2017) reported that 786 million people in the world do not have access to safe drinking water. This is roughly one in ten of the 7.4 billion world's population. Nigeria is not exempted from the world water crisis which is affecting other countries in many parts of the world. According to report in Water-facts and Figures (2016) reports, there are over sixty-three (63) million Nigerians having no choice but to get water wherever they can, leading to fifty-seven (57) million people not having access to safe water and twenty-five thousand children die every year from diarrhea caused by unsafe water and poor sanitation.

It is impossible to conceive or even think of a functional and normal human life without safe drinking water. Water makes up about seventy percent (70%) of the globe's surface and sixty percent (60%) of the human body with its functions, not only limited to digestion, absorption, circulation, transportation of nutrients and maintenance of body temperature, but also required to replace fluids lost during respiration, urination and perspiration (Adamu & Adekiya. 2016). Unsafe drinking water is one of the greatest human health issues especially in developing countries (Adegoroye, 2018). Evidences of contaminated water consumption have manifested severally in annual deaths of 4.0% and total disease burden of about 5.7%. The most vulnerable of this water-borne-related deaths and diseases with diarrhea on the lead, are the children (0-5yrs) as over hundred (100,000) die yearly (Akpoveta et al., 2016)

Generally, water used in the homes, industries, agricultural irrigations, commercial centers and other purposes are majorly sourced from underground. The present-day activities of humans which arise as a result of advancement and urbanization led to the increase in agricultural, biomedical, nuclear, industrial and even domestic wastes which has brought about untold contamination to the groundwater and the general ecology (Momodu & Anyakora, 2015; Nwoke and Edori, 2020)

The underground water contamination by chemical species such as heavy metals, nitrates, fluorides, microorganisms etc. can affect the health status of humans who is the ultimate user of the water. These chemical species find their way into the water aquifer through leaching. Such human activities that introduce these unwanted species to the groundwater are processing of metals, exploration, production and eventual exploitation of oil, agricultural activities, mining and through indiscriminate disposal of the byproducts of these human activities have added to the already overburdened situation (Adeyemi and Awokunmi, 2016; Edori et al., 2019). The manner in which the inhabitants of a particular area dispose wastes can also contribute to the level of contamination of the groundwater. The groundwater can be easily polluted through wastes, sewage and effluents that originates from homes, industries and commercial centers through percolation into the water underground.

Some empirical work carried out to investigate the heavy metal prevalence in ground water particularly close to waste dumpsite are presented as thus, Festus et al (2016) carried out study on water samples collected from boreholes close to a dumpsite in Rumuolumeni, Port Harcourt in the months of January, April, August and November. The waster sampled were analyzed for physicochemical properties and heavy metals using APHA standard methods. The data obtained did not reveal any significant changes between the months and the seasons. Temperature values were within the WHO standard but higher than the FMENV requirements in all the sample points. pH values were lower than the standard requirements by the relevant agencies and are unacceptable. The values for conductivity, hardness and alkalinity were below the acceptable limits by WHO, NAFDAC and FMENV. Total dissolved solids (TDS) values in the sample points were above the standard requirements by the agencies (WHO, NAFDAC AND FMENV). The cations Manganese (Mn), Lead and Cadmium (Cd) were higher than the recommended values by the agencies (WHO, NAFDAC and FMENV.) Iron (Fe) values fell within the WHO requirements in the sample points but were above the NAFDAC and FMENV values in those points. Cobalt (Co) values were lower than the standard requirements from the relevant agencies. The observed result is an indication of water contamination. The dumpsite may have impacted on the water quality. Therefore, the water is not suitable for drinking since it can constitute a source of health risk and hazard.

Yerima Kwaya et al., (2019) carried out investigation on the groundwater quality of Maru town and environs in terms of Heavy metals concentration using the pollution indices and multivariate statistical approaches. 29 groundwater samples were taken from dug wells and one Borehole in the area and analyzed for the presence of Heavy metals, Temperature and PH. The concentration of the analyzed metals in the groundwater arranged in decreasing order is Cr >Fe >Mn >Zn >Cu >Ni with three elements Cr, Fe and Mn had concentrations above the WHO recommended limits. Calculated Pollution indices revealed low Cd and HEI values for the area while HPI gives an overall high value, consequently translating the area into high groundwater pollution zones.

Nwoke and Edori (2021) conducted empirical study on presence of six chemical species Pb, Cd, As, nitrates, fluorides and sulphates in the groundwater (borehole) samples from four boreholes sited close to a dumpsite in Rumuolumeni, Port Harcourt, Rivers State, Nigeria. Nitrates, fluorides and sulphates were analyzed using standard conventional methods while the heavy metals were determined and analyzed with Atomic Absorption Spectrophotometer. The mean values obtained for the different chemical species within the months of investigation for the stations were in the range: lead; 0.012±0.001- 0.015±0.000mg/L, with an average of 0.013±0.001mg/L within the months, Cd; 0.004±0.002-0.005±0.001mg/L, with an average of 0.005±0.001mg/L within the months, As; 0.002±0.001-0.003±0.002mg/L, with an average of 0.003±0.001mg/L within the months, nitrates; 0.413±0.172-0.730±0.691mg/L, with an average of 0.511±0.139mg/L within the months, fluorides; 0.004±0.001-0.006±0.001mg/L, with an average of 0.005±0.001mg/L within the months and sulphates; 0.197±0.046-0.338±0.072mg/L, with an average of 0.290±0.055mg/L within the months. These values obtained for the different chemical species showed that the boreholes sited near the dumpsite were still at the level that will not pose any health risk to the user, for their concentrations were still within limits allowed by WHO and USEPA. Even though the government and its agencies should regulate the mode of dumping of refuse and also the siting of boreholes so that the groundwater will not be polluted.

Harahap and Simatupang (2020) carried out research aims at determining the distribution of lead (Pb), mercury (Hg) and copper (Cu) metal content in community wells around the Batu Bola landfill. This research method is to apply exploratory descriptive method. The results of the measurement of metal content were then analyzed by comparing the measurement result data with quality stones issued by Permenkes No. 492 of 2010 concerning Requirements for Drinking Water Quality and Government Regulation Number 82 of 2001 concerning Management of Water Quality and Control of Water Pollution in Class I. The concentration of Hg in well 1 and well 2 is <0.0004 mg/L. While the threshold set by the government is 0.001 mg/L and 0.002 mg/L. The concentration of lead metal (Pb) in well 1 and well 2 is <0.003 mg/L, while the quality standards set by the government are 0.01 mg/L and 0.03 mg/L. The measurement of the concentration of copper metal (Cu) in well 1 and well 2 is <0.006 mg/L, while the quality standards set are 2 mg/L and 0.02 mg/L. The metal content test results showed that all the wells were still below the established quality standards.

These empirical studies are part of the widespread reports confirming that contamination of groundwater, due to presence of waste dumpsites, have increased in recent years and have resulted in increased public concern about the quality of groundwater (Bunce, 2004). They revealed that the compounds contained in groundwater, sometimes used as drinking water, are dangerous to human health, particularly the heavy metals, because of their possible mutagenic and carcinogenic reaction (Okuo et al., 2007). Groundwater bodies are prone to contamination from both man-made and natural activities (Owabor et al 2010). The seepage of wastes dumped inside the underground dumps such as pit dump sites, pit toilets or leachate from fertilizer applications and debris from erosion can produce harmful effects on ground water quality especially in areas near the waste dumpsites. Hence, this study is carried out to determine the heavy metal pollution index of selected groundwater near waste dumpsite in Port Harcourt. The objectives are to: Collect and analyse groundwater samples near waste dumpsites in Choba and Aluu Communities in River state for some selected heavy metals. Compare the concentrations of the selected heavy metals with drinking water standards. And determine the heavy metals pollution index of the collected groundwater samples.

2. Materials and Methods

2.1 Research Design

This study adopted Experimental design. The design is suitable for this study because it involves carrying out empirical study in which the researcher has room to control and manipulate the independent variable based on the limitations and scope of this study. In this study, the independent variables which are at the disposal of the researcher are distant of boreholes from dumpsite and time interval for the collection of water samples from boreholes while the dependent variable is the concentration of heavy metals in the water sample

2.2 Study Area

The study areas are Choba Community in Obioakpor LGA and Aluu Community in Ikwerre LGA all in River state. Two waste dumpsites located within these two communities were the focal point of the study along with some boreholes sited at various distances away from the waste dumpsites see Figure 1. These study areas as well as the entire Rivers State, lies within the Niger Delta Sedimentary Basin. Lithostratigraphically, the rocks are divided into the oldest Akata Formation (Paleocene), the Agbada Formation (Eocene) and the Youngest Benin Formation (Miocene to Recent) which hold the ground water aquifer in the area and the main subject of interest in this current study.

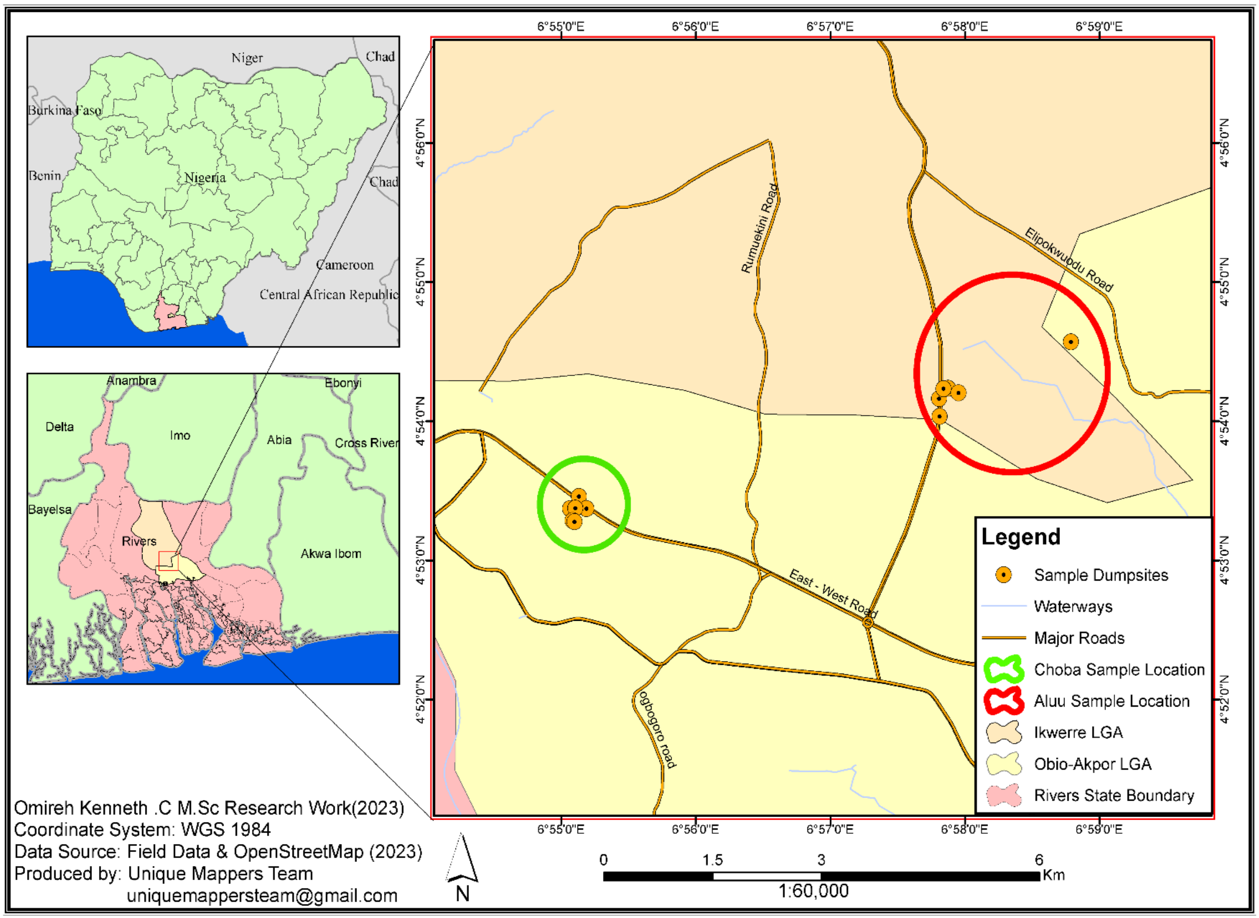

Figure 1: Map of the Study Area showing locations where main water samples were collected

2.3 Type of Data:

The data used in this study include both primary and secondary data. The primary data were sourced from the study area which included data on the concentration of the heavy metal in the water sample, data on the distance of the sampled boreholes from the dumpsites and the time interval for collection of the water samples. The secondary data was mainly data on the permissible limit for different concentration of heavy metal in water from (WHO, 2015).

2.4 Procedure for Data Collections.

1. Two dumpsites (Dumpsites in Choba Community in Obioakpor LGA and Aluu Community in Ikwerre LGA) were sampled within River state and they were labeled Site 1 (S1) and Site 2 (S2) respectively.
2. Two different boreholes were sampled at different distances of 50m, 100m and 150m away from the dumpsite site 1 and site 2 these boreholes was labelled B1a, B1b and B1c, for Site 1 and B2a, B2b, B2c for Site 2
3. Geo-mapping procedures was used to ascertain the coordinate of the dumpsites and the boreholes sampled.
4. Groundwater samples were collected from the boreholes in October, Hence, considering that there are two sampled boreholes in each sampled area, which makes twelve water samples was collected from the sites, six water samples for each area sampled for the study during the months.

5. The groundwater samples were taken to laboratory for identification of presence and concentration of the heavy metals

2.4.1 Procedure for identification of Presence and Concentration of the Heavy Metals in the water sample

The determination of presence and concentration of the heavy metal content in the sample was carried out according to the SNI 6989.8-2009 procedure; SNI 6989.6-2009 and SNI 062462-1991. this procedure involves

1. 50ml of sample was put into 100 ml Erlenmeyer, added 5ml of concentrated HNO3 then covered with a funnel.
2. It is heated slowly until the remaining volume is 15ml-20ml, if the digestion is not complete (not clear) then add another 5 ml of concentrated HNO3 then cover and heat again (not boiling) until all the metal dissolves.
3. The levels of the heavy metal were tested by testing the test samples one by one into the Atomic Absorption Spectrophotometer (AAS, Shimadzu AA-6300). AAS device with a wavelength of 283.3 nm. Furthermore, the metal absorption of each metal was carried out.
4. The AAS was calibrated with relevant Shimadzu AAS spectroscopic grade standards. Flame atomic absorption spectrophotometer (Shimadzu double beam Atomic Absorption Spectrophotometer) (Direct determination - Flame: Pb, 0.1ppm; Furnace: Pb, 0.3 ppb).
5. Some heavy metal that would be suspected based on results of other similar study in Rivers State are Manganese, Lead, Cadmium, Iron, Cobalt, Mercury, Zinc, Arsenic Chromium
6. The calculation of Heavy metal Pollution Index (HPI) involves the following steps;

1. Calculation of weightage of the parameter Wi. The weightage parameter Wi = 1/Si, Where Wi is the unit weightage and Si the recommended standard for the parameter,
2. Calculate the quality rating for each of the heavy metal Qi. Individual quality rating is given by the expression Qi = Vi/Si, Where Qi is the sub index of the parameter, Vi is the monitored value of the parameter and Si the standard or permissible limit for the parameter.
3. Then HPI model is computed using the following equation

$$\frac{\sum_{i=1}^{n} WiQi}{\sum_{i=1}^{n} Wi} \qquad (1)$$

2.5 Statistical Analysis

Descriptive statistic (means, percentages, graphs) was used for data analysis. Simple linear regression was used to develop the model. The data analysis was carried out using the X-L Stat package.

3.0 Results and Discussions

Eight different heavy metals were discovered in the water samples from the two sites as different distances from the dumpsites, and the metals includes, Copper (Cu), Mercury (Hg), Lead (Pb), Barium (Ba), Cadmium (Cd) Chromium (Cr), Iron (Fe) and Zinc (Zn). The discussion is based on WHO (2020) standard for drinking water.

3.1 Comparison of the concentrations of the selected heavy metals with drinking water standards

Table 1 and Table 2 shows the comparison of the heavy metal concentration in the water samples collected at differences distance away from the dumpsites and the recommended WHO standard. From Table 1 it is observed that in Aluu area, the concentrations of cupper, mercury, barium, cadmium, Chromium, and iron were lower than the recommended standard limit within the distances of 50, 100 and 150m away from the waste dumpsite. However, the results revealed that the concentration of these aforementioned heavy metals increase as distance toward the waste dumpsite decreases which is an indication that the source of the metal is mostly likely to be the waste material in the dumpsite.

It is also observed that the concentration of Lead was higher than the recommended standard within the distances of 50 and 100 away from the waste dumpsite, and that the concentration of the lead also increases as distance toward the waste dumpsite decreases which is also an indication that the source of the metal is mostly likely to be the waste materials in the dumpsite.

Table 1 Concentration of heavy metal in water sampled from borehole at different distances from a waste dumpsite in Aluu area compare to WHO standard.

Distance	50m	100m	150m	WHO Standard
Copper	0.0038	0.0031	0.0024	0.020
Mercury	0.00027	0.00022	0.00013	0.001
Barium	0.027	0.022	0.0130	0.030
Cadmium	0.018	0.013	0.0080	0.050
Chromium	0.0028	0.0022	0.0020	0.003
Zinc	0.039	0.017	0.0120	3.000
Lead	0.0126	0.0105	0.0095	0.010
Iron	0.0155	0.0125	0.0065	0.300

From Table 2, it is observed that in Choba area, the concentrations of cupper were lower than the recommended standard within the distances of 50, 100 and 150m away from the waste dumpsite. The results also revealed that the concentration of the cupper increase as distance toward the waste dumpsite decreases which is an indication that the source of the metal is mostly likely to be the waste material in the dumpsite similar to what was observed in Aluu area.

It is also observed that the concentrations of mercury were lower than the recommended standard limit within the same distances of 50, 100 and 150m away from the waste dumpsite, and that the concentration of the cupper increase as distance toward the waste dumpsite decreases which is an indication that the source of the metal is mostly likely to be the waste material in the dumpsite. These same results were observed for the other six heavy metals discovered in the water sampled within the area. However, it was observed that the concentration of all the heavy metals were higher in the water sample within the Aluu area than those sampled within Choba at same distance away from the dumpsites.

Table 2 Concentration of heavy metal in water sampled from borehole at different distance from a waste dumpsite in Choba area compare to WHO standard

Distance	50m	100m	150m	WHO Standard
Copper	0.0036	0.0030	0.00225	0.020
Mercury	0.00019	0.00017	0.00015	0.001
Barium	0.026	0.021	0.012	0.030
Cadmium	0.0016	0.0010	0.0006	0.050
Chromium	0.00185	0.0013	0.0009	0.003
Zinc	0.0095	0.0075	0.006	3.000
Lead	0.0086	0.0055	0.0025	0.010
Iron	0.005	0.0035	0.002	0.300

3.2 The Heavy-metal Pollution Index (HPI) of the collected Groundwater Samples

Table 3 showed that heavy metal pollution index (HPI) evaluated for distances of the 50, 100 and 150 meters away from the waste dumpsite based on the concentration and standard limits of the eight heavy metals discovered in the water sampled from boreholes within the Aluu area. (see the procedure and formula in chapter three). Using the WHO (2020) drinking water quality standard based on HPI, HPI range of 0-0.25 is very good water quality for drinking, 0.26-0.50 is good for drinking, 0.51-0.75 is poor while 0.76 and above is not suitable for drinking. Based on this standard, it could be observed that the water sampled from the boreholes within the distances of 50, 100 and 150 meters were good for drinking. However, it could be noticed the HPI increased as the distance toward the waste dumpsite reduces. This is an indication that as we site the borehole closer to the dumpsite, the quality of water reduces with respect to the heavy metal sampled,

Thus, it is possible to develop a model showing the relationship between the HPI and distance from the dumpsite, which will help to predict the HPI of water in borehole that could be drilled at any distance within the dumpsites, particularly, in the dumpsite. This model could also help to predict the distance at which the HPI is 0 which represent point of highest water quality without any trace of heavy metal. Figure 3 showed the graphical representation of the relationship between HPI and distance away from the dumpsite. The model is expressed as

$$\mathbf{y = -0.0014x + 0.53} \quad (1)$$

where y is HPI and x is distance, thus we have that

$$\mathbf{HPI = -0.0014D + 0.53} \quad (2)$$

To determine the HPI of water sample in an assumed borehole that could be drilled at the center of the dumpsite were distance is assumed to be zero, we have that

$HPI = -0.0014(0) + 0.53$, **HPI= 0.53**

Thus, HPI of water sample in any boreholes that could be drilled at the center of the dumpsite were distance is zero is 0.53 which, according to the recommended standard, would have poor quality.

Also, the distance away from the dumpsite at which the HPI is zero is obtained by equating HPI equal to zero in equation 4.2 and calculating the value of D. this is expressed as

$0 = -0.0014(D) + 0.53$, thus, **D = 378.6m**

This is the distance away from the dumpsite at which the quality of water from the borehole will be perfect without any trace of the heavy metals in the water sample from the dumpsite in this study area

Table 3 Heavy Meatal Pollution Index For water sampled From Boreholes in ALLU area at different distances from a waste dumpsite

Distance	Heavy metals	Wi	Qi	WiQi	HPI	Remark
50m	Copper Mercury Barium Cadmium Chromium Zinc Lead Iron	50 1000 100 20 333.3 0.333 100 3.33	0.19 0.27 0.90 0.38 0.933 0.013 1.26 0.051	9.5 270 90 7.6 310.09 0.0043 126 0.169	0.45	Good for Drinking
100m	Copper Mercury Barium Cadmium Chromium Zinc Lead Iron	50 1000 100 20 333.3 0.333 100 3.33	0.16 0.22 0.73 0.26 0.73 0.006 1.06 0.041	8.0 220 75.0 5.2 244.09 0.002 106 0.135	0.41	Good for Drinking
150m	Copper Mercury Barium Cadmium Chromium Zinc Lead Iron	50 1000 100 20 333.3 0.333 100 3.33	0.12 0.13 0.43 0.16 0.67 0.004 0.95 0.022	6.00 130 43 3.20 223.31 0.00133 95 0.07	0.31	Good for Drinking

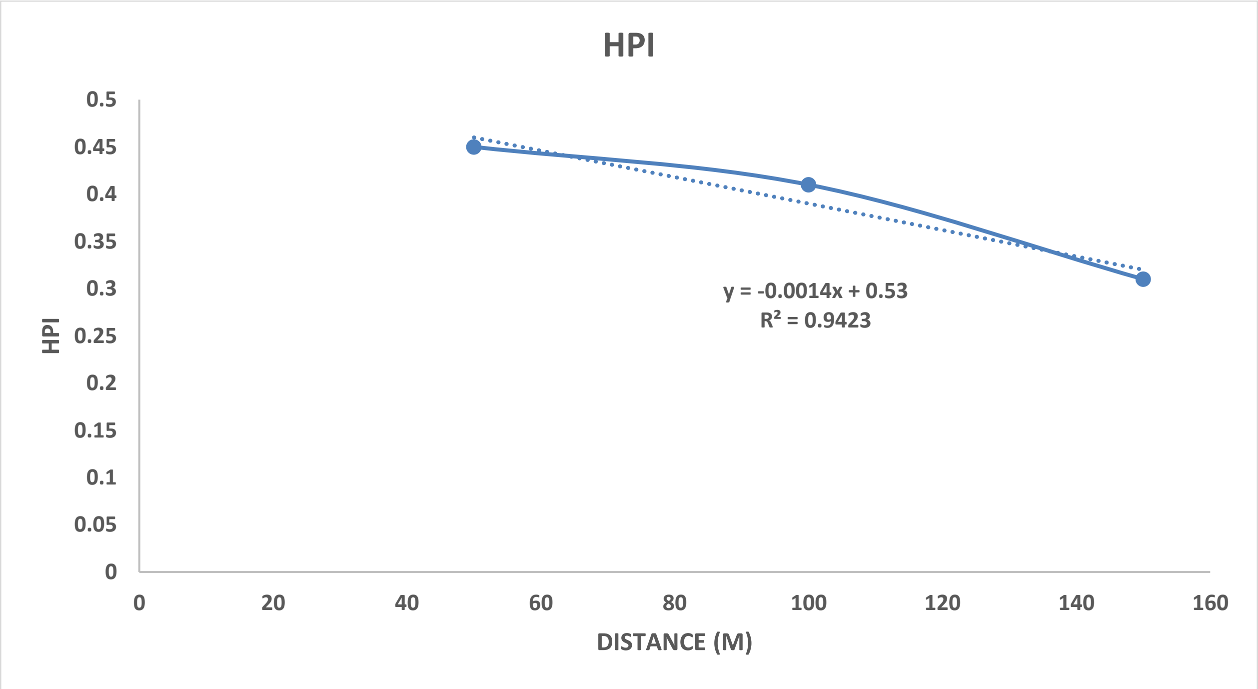

Figure 3 The relationship between HPI and distance from waste dumpsite for Aluu area.

Also, Table 4 showed that heavy metal pollution index (HPI) evaluated for distances of the 50, 100 and 150 meters away from the waste dumpsite based on the concentration and standard limits of the eight heavy metals discovered in the water sampled from boreholes within the Choba area. Using the same WHO (2020) drinking water quality standard based on HPI, HPI range of 0-0.25 is very good water quality for drinking, 0.26-0.50

is good for drinking, 0.51-0.75 is poor while 0.76 and above is not suitable for drinking. Based on this standard, it could be observed that the water sampled from the boreholes within the distances of 50 and 00 meters were good for drinking while that from 150meters were very good for drinking. It could also be noticed that the HPI increased as the distance toward the waste dumpsite reduces. This an indication of the fact that as position of the borehole is sited closer to the dumpsite, the quality of water from the borehole reduces with respect to the heavy metal sampled,

It is also possible to develop a model showing the relationship between the HPI and distance from the dumpsite, which will help to predict the HPI of water in borehole that could be drilled at any distance within the dumpsite especially at the distance where HPI is assumed to be zero which represent point of highest water quality without any trace of heavy metal. Figure 4 showed the graphical representation of the relationship between HPI and distance away from the dumpsite. The model is expressed as

y = -0.0016x + 0.4333 **3**

where y is HPI and x is distance, thus we have that

HPI = -0.0016D + 0.433 **4**

To determine the HPI of water sample in an assumed borehole that could be drilled at the center of the dumpsite were distance is assumed to be zero, we have that

HPI = -0.0016(0) + 0.433, **HPI= 0.43**

Thus, HPI of water sample in any boreholes that could be drilled at the center of the dumpsite where distance is zero is 0.43 which according to the recommended standard has good quality.

Also, the distance away from the dumpsite at which the HPI is zero is obtained by equating HPI equal to zero in equation 4.4 and calculating the value of D. this is expressed as

0 = -0.0016(D) + 0.433, thus, **D = 268.75m**

This is the distance away from the dumpsite at which the quality of water from the borehole will be perfect without any trace of the heavy metals sampled in Choba area

Table 4. Heavy Meatal Pollution Index For water sampled From Boreholes in Choba area at different distances from a waste dumpsite

Distance	Heavy metals	Wi	Qi	WiQi	HPI	Remark
50m	Copper Mercury Barium Cadmium Chromium Zinc Lead Iron	50 1000 100 20 333.3 0.333 100 3.33	0.18 0.19 0.87 0.032 0.600 0.0032 0.86 0.017	9.0 190 87 0.64 199.99 0.0011 86 0.057	0.35	Good for Drinking
100m	Copper Mercury Barium Cadmium Chromium Zinc Lead Iron	50 1000 100 20 333.3 0.333 100 3.33	0.15 0.17 0.70 0.20 0.43 0.0025 0.55 0.012	7.5 170 70.0 4.0 143.32 0.0008 55 0.040	0.28	Good for Drinking
150m	Copper Mercury Barium Cadmium Chromium Zinc Lead Iron	50 1000 100 20 333.3 0.333 100 3.33	0.11 0.15 0.49 0.012 0.30 0.002 0.25 0.007	5.50 150 49 0.24 99.99 0.0007 25 0.023	0.19	Very Good for Drinking

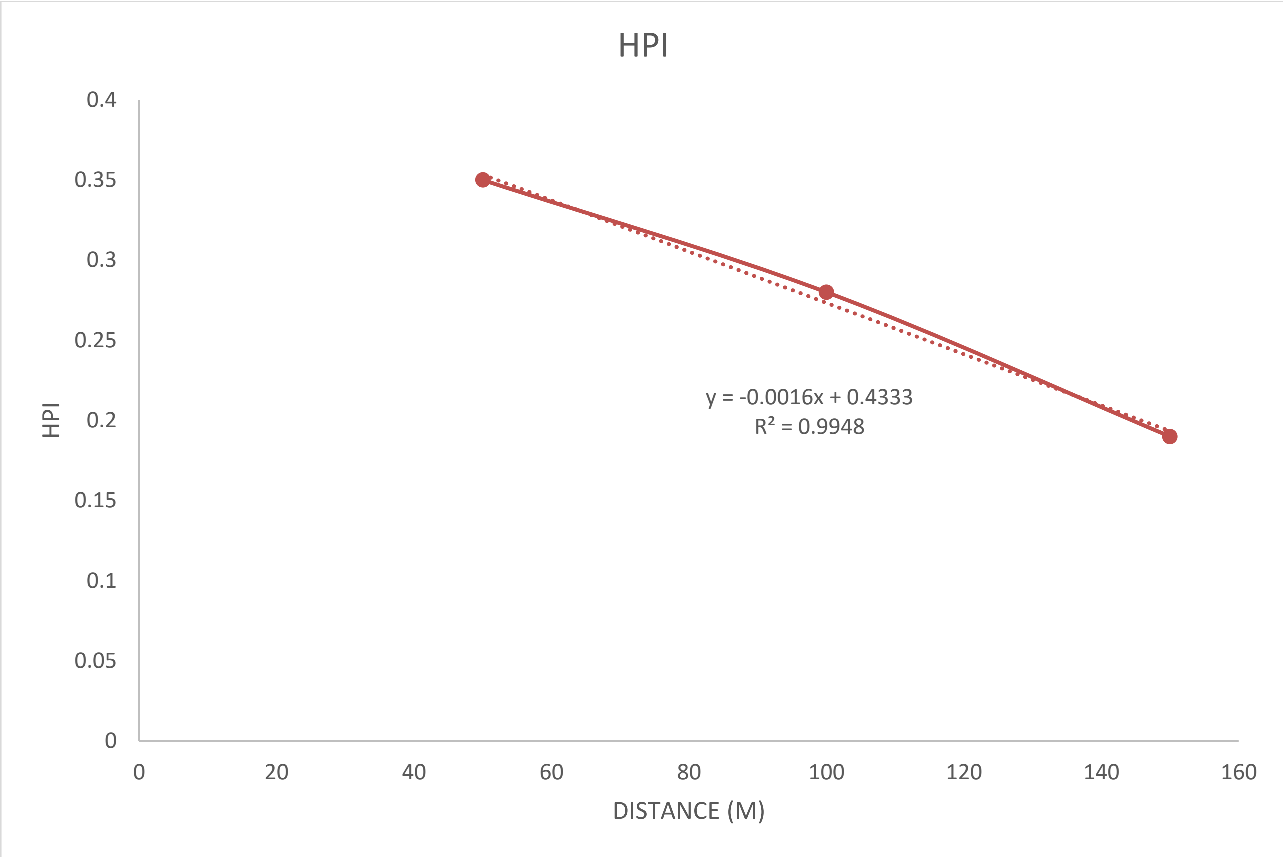

Figure 4 The relationship between HPI and distance from waste dumpsite for Choba area.

4 Discussions

4.2 Discussion of Findings

The first objective of this study was to collect and analyze the water samples obtained from boreholes close to waste dumpsites in two locations in Port Harcourt namely Aluu community in Ikwerre LGA and Choba community in Obio-akpor LGA, the analysis of the water sample collected revealed that eight different heavy metals were discovered in the water samples from these two sites as different differences from the dumpsites, and the metals includes, Copper (Cu), Mercury (Hg), Lead (Pb), Barium (Ba), Cadmium (Cd) Chromium (Cr), Iron (Fe) and Zinc (Zn). The presence of these heavy metals in the water samples could be attributed to gradual seepage of the soluble heavy metallic ion from the waste materials in the dumpsites through permeable and porous underground formations into the underground water aquifers leading to gradual contamination of the groundwater.

This result aligned with the results of the study carried out by Nwoke & Edori (2021) on presence of six chemical species Pb, Cd, As, nitrates, fluorides and sulphates in the groundwater (borehole) samples from four boreholes sited close to a dumpsite in Rumuolumeni, Port Harcourt, Rivers State, Nigeria, in which they uncovered that Lead (Pb) and Cadmium (Cd) are present in groundwater sampled near waste dumpsites. This study also concurred with study by Harahap & Simatupang (2020) who carried out research aims at determining the distribution of lead (Pb), mercury (Hg) and copper (Cu) metal content in community wells around the Batu Bola landfill and later confirmed the presence of these metal in ground water around this dumpsite.

The second objective was focused on comparing the concentrations of the selected heavy metals with drinking water standards. In this study, the WHO (2020) drinking water quality standard was used as the quality standard to compare the water samples. The results revealed the concentrations of the metals were within the accepted standard for all the water sampled in Choba within the different distances from the dumpsite while that of Aluu area were also within accepted standard except for Lead which is slightly higher than accepted standard at 50m and 100m away from the waste dumpsite. This result is an indication that distances of 50m, 100m and 150m away from the waste dumpsite in Choba is still within the safe zone for drinking while the same cannot be said for Aluu since the concentration of Lead is already above the accepted recommended standard thus, the water sample within distances less than 100m from the Aluu dumpsite could be considered as being contaminated with Lead.

These results also aligned with study by Nwoke and Edori (2021) who conducted empirical study on presence of six chemical species Pb, Cd, As, nitrates, fluorides and sulphates in the groundwater (borehole) samples from four boreholes sited close to a dumpsite in Rumuolumeni, Port Harcourt, Rivers State, Nigeria and revealed that the values obtained for the different chemical and metals showed that the boreholes sited near the dumpsite were still at the level that will not pose any health risk to the user, for their concentrations were still within limits allowed by WHO and USEPA. The study also agreed with study by Harahap and Simatupang (2020) who carried out research aims at determining the distribution of lead (Pb), mercury (Hg) and copper (Cu) metal content in community wells around the Batu Bola landfill and the results of the measurement of metal content were then analyzed by comparing the measurement result data with quality stones issued by concerning Requirements for Drinking Water and they affirmed that the metal content test results showed that all the wells were still below the established quality standards. However, the results contradict results of Ravisankar and Prasada (2016) who carried out study about contamination of ground water due to trace metals in and around the Vijayawadaand found metals such as Al, As, Cd, Cr, Cu, Fe, Pb, Mn, Hg, Ni, Se, and Zn and their results revealed that some ground water samples are found to be more concentration of metals which exceed maximum limits values of WHO, standards.

The results also partly agree and partly disagree with study by Festus et al (2016) carried out study on water samples collected from boreholes close to a dumpsite in Rumuolumeni, Port Harcourt. The waster sampled were analyzed for physicochemical properties and heavy metals using APHA standard methods. Their results revealed that heavy meal Manganese, Lead and Cadmium were higher than the recommended values by the WHO while Iron (Fe) values fell within the WHO requirements in the sample points, they stated that their result indicates presence of water contamination which could be due to the dumpsite affecting the groundwater water quality thereby making the water unsuitable for drinking since it could constitute a source of health risk and hazard.

The third objective was based on calculating the heavy metal pollution index of the collected groundwater samples. Based on the results, heavy-metal pollution Index for water sample obtained boreholes at distances of 50, 100, and 150 away from the waste dumpsite in Aluu indicates that the water samples are good for drinking while the heavy metal pollution index for water sampled from boreholes within the same distances from Choba dumpsite showed that the water samples from 50m and 100m are good for drinking while the water sample from 150m was very good for drinking. These results revealed that the waste dumpsite in Aluu is more active than the one in Choba in terms of the nature and amount of waste dumped on the sites.

These results did not agree with study by Yerima Kwaya et al., (2019) carried out investigation on the groundwater quality of Maru town and environs in terms of Heavy metals concentration using the pollution indices and multivariate statistical approaches, as their calculated Pollution indices revealed that HPI gave an overall high value, consequently translating the area as high groundwater pollution zones.

5.0 Conclusions

Based on these findings, it was concluded that; first, substantial number of heavy metals are usually available in groundwater within and around waste dumpsites and the most likely ones are Copper (Cu), Mercury (Hg), Lead (Pb), Barium (Ba), Cadmium (Cd) Chromium (Cr), Iron (Fe) and Zinc (Zn)., two, the concentration of these heavy metal in the groundwater around waste dumpsites may or may not be within the acceptable limit for drinking water quality, thirdly, the heavy metal pollution index of the water within the sampled waste dumpsites areas is low and therefore can be considered as safe for drinking.

6.0 Recommendations

Based on these aforementioned conclusions, it was recommended that;

1. Regular and robust test should be carried out on groundwater from wells and boreholes of people living close to waste dumpsites in order to check for level of contamination and take necessary actions if the water is contaminated
2. Government and authorized agencies should ensure that waste dumpsites are well-designed and fitted with necessary gadgets that would prevent seepage of contaminant into the groundwater in order to prevent contamination of groundwater around and within dumpsites
3. The government and authorized agencies should use the model concept developed in this study to design a more robust platform that can be used to predict the level of ground water contamination in areas within and around waste dumpsite in order to accurately inform the public on area that are safe for residential building

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