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Pollution and Health Risks Assessment of Ground Water Sources around a Waste Disposal Site in Owerri West Local government Area of Imo State

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Abstract

The study examined the consequences of waste dump sites on the groundwater characteristic by examining the chemical and physical properties of underground water in boreholes around the Umuerim dumpsite in Nekede, Owerri West Local government Area of Imo State. Five composite groundwater samples were collected from boreholes at different radial distances from the dumpsite. The physicochemical properties of the water samples were determined and the data obtained analyzed for pollution, consumption suitability and non-carcinogenic and potential carcinogenic hazard risks using chemometric models. Results revealed temperature (26±2.40 ºC), turbidity (9.49±1.49 NTU), pH (6±1.47), dissolved oxygen (4.61±1.38 mg/L), total acidity (57±38.81 mg/L), total alkalinity (335±709.96 mg/L), chloride (29.4±51.62 mg/L), nitrate (4.04±1.51 mg/L), phosphate (1.55±0.52 mg/L) and sulphate (2.33±0.58 mg/L) of which only temperature and pH were not in agreement with World Health Organization (WHO) recommended limit. The results for heavy metals (Mg, Zn, Cu, Mn, Fe, Pb, Cr, Ca, Co, and Cd) concentrations showed lower concentrations to the permissible limit of WHO except for Fe in all samples, Pb (in BH1, BH3) and Cd, only in BH2, which showed moderate to very high contamination. Even though, the heavy metal pollution load index (< 1) was indicative of no pollution, the overall water quality index revealed that the ground water is unsuitable for consumption. The contamination of groundwater was from the dumpsite suggested by the positive correlations (r > 0.5) exhibited by many pollutants. Though the inhabitants are not at risk of chronic daily intake and non-carcinogenicity of heavy metals by the consumption of these groundwater sources, the potential carcinogenic risk (PCR) revealed unfavorable results with total PCR of 2.06E-2 for adult and 9.83E-2 for children. This represents a call for concern and need for effective waste management in order prevent the pollution of these groundwater sources.

1. Introduction

Groundwater is a treasured fresh water reserve and founds about two-third of the fresh water reserves of the world [1]. The rate of transformation of urban o cities in Nigeria is alarming and the major cities are growing at rates between 10 to 15% each year. In studies relating to the Nigerian understanding, consideration has been raised on the desertion of some works on rain, well and borehole water quality as a collective work, thereby resulting in lack of literatures, especially on borehole water quality assessment due to the belief that it is poured through the natural purification process [2]. Sadly this is often not the case as due environmental considerations were not followed before most boreholes were dug. Majority of the boreholes are constructed at close proximity to waste dumpsite, latrines, vicinity of metal scrap yards, etc., hence rendering the groundwater source vulnerable to contamination [3-4].

Groundwater is absentminded through hand-dug pits; hand-pump maneuvered shallow-wells and submersible pump operated bottomless well or boreholes [5]. When boreholes to obtain groundwater are constructed near waste dumpsites, they are often contaminated by leachates through percolation from top soils. Leachate is created in a landfill as a significance of the interaction of water with solid waste. Leachate might contain melted or suspended material related with wastes disposed off in the landfill, as well as many spinoffs of biological and chemical reactions. Potency of leachate from MSW landfills changes with the advancement of biological movement happening in landfill. Leachate coming from young landfill has both great dissolved solids, along with high concentration of organic matter [5-6].
Previous reports have shown that there is an increase in pollutants concentration in groundwater sources over the years due to increasing anthropogenic activities and have resulted in increased public concern about the quality of groundwater in the area [7]. So many Studies have been conducted to examine vulnerability of groundwater pollution due to anthropogenic activities [8-10]. In Orji area of Owerri, results from previous studies showed that groundwater of the area is of poor quality due to man-made activities related to automechanic activities [9-10]. More recent studies have also shown that groundwater in Nekede area of a reclaimed automechanic village may be unsuitable for consumption due to high contamination by heavy metals such Pb, Ni and Cd [11]. Water high in heavy metal concentration is detrimental to human health when ingested. The severity of damage to the body depends on the toxicity of the heavy metal type, extent of the exposure and individual susceptibility [1,12,13,14]. The need for portable water supply, for both domestic and industrial uses has created much concern for water quality analysis [1,7]. The key to sustainable water supply is to ensure that the quality of water sources is suitable for their intended uses. Therefore, the study was set to evaluate groundwater sources around a waste dumpsite in Umerim, Nekede area of Owerri, Imo State. The significance of this study lies in the fact that inhabitants of the study area lack access to pipe borne water supply and depend solely on groundwater sources for their domestic uses, hence the need to regularly analyze these sources. The report of this study would be a useful tool for creating awareness amongst the residents, planers and decision-makers for future water supply scheme in the area.

2. Material and Methods

Study area

The study area is in Nekede town of Imo State (Figure 1). Nekede is a town in South-eastern Nigeria. It is located near the city of Owerri. The area is an Igbo speaking town that is made up of three district villages, viz Umuoma, Umualum and Umudibia. This town also hosts the Imo State new Owerri capital. Federal University of Technology is 20 minute drive from Nekede. It lies on the junction of the Nworie River and the Otamiri River [7, 15]. The population of Nekede is fast developing into a city with increasing population due to the sighting of the Federal Polytechnic, Nekede, a Federal Government–owned higher institution. It is bounded by latitudes 5034’N and longitude 6052’ and 7005’E.

Sampling and sample collection

The groundwater samples were collected from five boreholes around the dumpsites to check the effect of groundwater contamination on the surrounding boreholes relative to the dumpsite. Five (5) composite samples were collected for water quality analysis. The water samples were collected by means of a screw-capped bottles and 2-liter hand plastic that have remained treated to avoid contamination by any physical, chemical or microbial means. The collected borehole samples were transferred into 2 sterile plastic containers. The groundwater samples were collected in the early morning, afternoon and night periods and homogenized to form a composite sample. Preceding to collection as part of quality control measures, all the bottles used for the sample collection were washed and rinsed with distilled water. The bottles were rinsed three times with the sample water at the point of collection before the final water sampling was done. The bottles were held at the bottom while filling, to avoid contamination of water from the hands or fingers. All the sample containers were kept in ice boxes and brought to the laboratory for analysis.

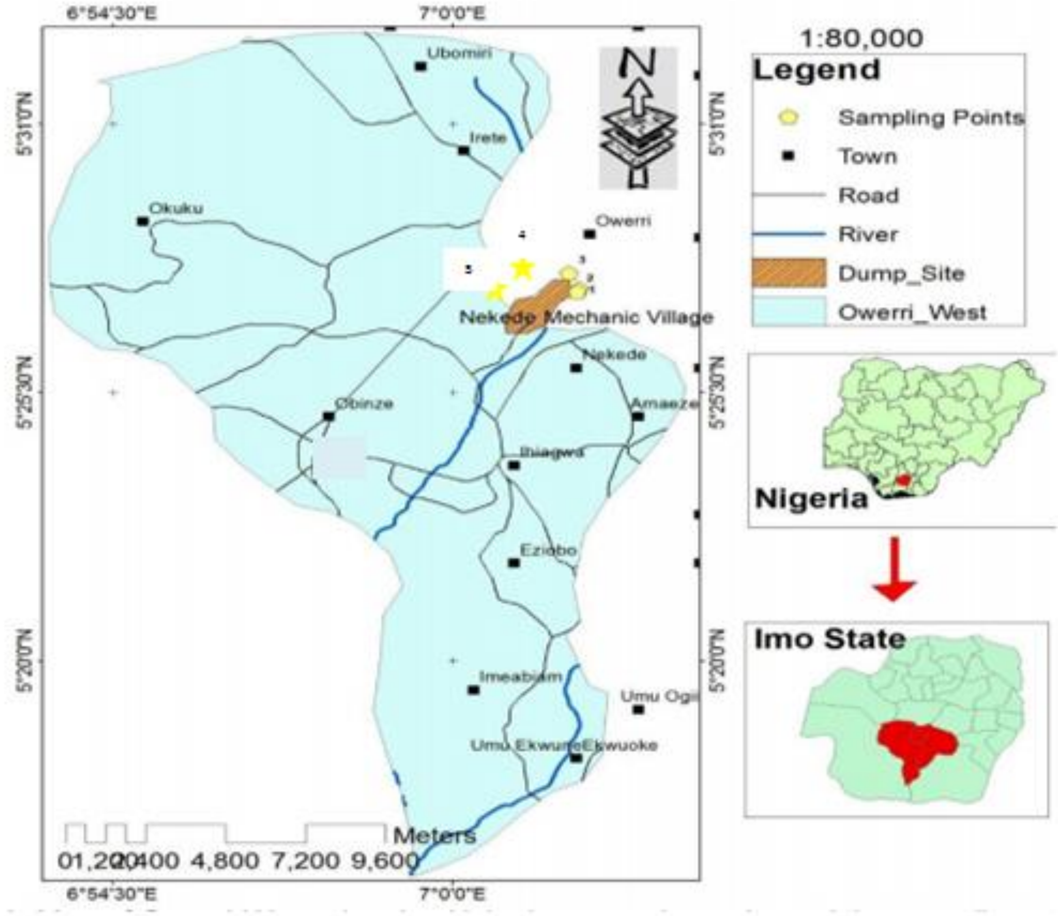

Figure 1. Map of Nekede dumpsite and sampling points

Analytical techniques and laboratory analysis

The adopted methods of analysis for the examination of all parameters in potable and waste water were in accordance with APHA, 2005 standard recommendation. All samples were analyzed for selected physical, chemical and heavy metal parameters.

On-site analysis

Temperature, hydrogen ion concentration (pH), conductivity, and dissolved oxygen were subjected to in-situ measurement. Dissolved oxygen was measured with the aid of a dissolved oxygen (DO) meter (0rion 3 star model). Hydrogen ion concentration (pH) was determined using the pH 211 microprocessor meter model. Both instruments have an in-built thermometer that was used to measure temperature [5].

Off-site analysis

Examined parameters including pH, temperature (0C), total suspended solid (TSS), total hardness (TH), nitrate (No-3), dissolved oxygen (Do), phosphate (Po4), sulphate (So3), Calcium (Ca), Magnesium (Mg), Zinc (Zn), Manganese (Mn), Chromium (Cr), Cobalt (Co), Cadmium (Cd) chloride (Cl-), iron (Fe), copper (Cu), and lead (Pb), were analyzed at the laboratory for portability. Following digestion method described previously [9]. Atomic absorption spectrophotometer was used to determine the concentration of each heavy metal at specific wavelengths. The atomic absorption spectrophotometer, Agilent 240 FS AA Model (USA), used for metallic content determination has high accuracy level of 99.776%, can achieve high sensitivity – typically > 0.9 absorbance and precision of < 0.5% relative standard deviation (RSD) from ten second integrations for 5 mg/L Cu standard.

Data analysis

The data obtained from triplicate analysis were reported as mean and standard deviation. Chemometric models such contamination factors, pollution load index, water quality index, daily dose via ingestion or dermal, hazard quotient, hazard index, chronic daily intake and potential carcinogenic risk were used to assess the level of contamination, suitability of the sachet water for consumption and the non-carcinogenic health risks associated with such consumption.

Contamination Factor and Pollution Load Index

To assess the level of contamination of heavy metals in the sachet water samples, the contamination factors (Cf) and pollution load index (PLI) were computed as proposed by Forstner and Calmano [16] and Thomilson et al. [17] presented in equation 1 and 2.

$$Cf = {}^{C_m}/_{R_L} \qquad (1)$$

$$PLI = (Cf_1 * Cf_2 * Cf_3 \dots \dots . . Cf_n)^{1/n} \qquad (2)$$

Where Cm is the measured heavy metalconcentration in the sample and RL is the recommended limit taken from WHO presented in Table 3 and n is the number of metals considered in the study

Water Quality Index

The water quality index was computed as described in previous studies presented in equations 3 and 4 [9,10, 11, 18]. The SI is the subindex of ith parameter; qi is the rating based on concentration of ith parameter [calculated as the ratio of determined concentration (Cdet) to the recommended limits (RL) i.e C_det⁄R_L *100] and Wi is the relative weight of each parameter (Table 7) was assigned based on the importance if each parameter while WQI is the water quality index.

$$\mathrm{SI} = W_i X q_i \qquad (3)$$

$$WQI = \sum SI \qquad (4)$$

The model gives a single value which provides information on the suitability of consuming the groundwater samples.

Quantitative Health Risk Assessment

An individual risk pathway as a result of human exposure to trace metals contamination could be through inhalation via nose and mouth, direct ingestion and dermal absorption through skin. Dermal absorption and ingestion routes are common exposure pathway for water pollutants. Mathematical methods used to determine human health risk through these two pathways was calculated using Equations below adapted from the US EPA risk assessment guidance for superfund (RAGS) methodology [19].

$$EXP_{in} = \frac{C_{water} x\ IR\ x\ EFx\ ED}{BW\ x\ AT} \qquad (5)$$

where, Expin: exposure dose through ingestion of water (mg/kg/day); Expderm: exposure dose through dermal absorption (mg/kg/day); Cwater: average concentration of the estimated metals in water (µg/L); IR: ingestion rate is (2.2 L/day for adults; 1.8 L/day for children) obtained from [19]; EF: exposure frequency (365 days/year); ED: exposure duration (70 years for adults; and 6 years for children); BW: average body weight (70 kg for adults; 15 kg for children); AT: averaging time (365 days/year × 70 years for an adult; 365 days/year × 6 years for a child); SA: exposed skin area (18,000 cm2 for adults; 6600 cm2 for children); Kp: dermal permeability coefficient in water, (cm/h), 0.001 for Cu, Mn, Fe and Cd, while 0.0006 for Zn; 0.002 for Cr and 0.004 for Pb [18]; ET: exposure time (0.58 h/ day for adults; 1 h/day for children) and CF: unit conversion factor (0.001 L/cm3) [18, 19].

Potential non-carcinogenic risks due to exposure to heavy metals were determined by comparing the exposure route with the reference dose (RfD) for the two pathways [19] (Table 8). Hazard quotient (HQ) toxicity potential was evaluated using the expression equation 6.

$$HQ_{in/derm} = \frac{EXP_{in/derm}}{RfD_{in/derm}} \quad (6)$$

where RfDin/ derm is ingestion/dermal toxicity reference dose (mg/kg/day). The RfDin and RfDderm values were obtained from the literature [20]. HQ < 1 is assumed to be safe and taken as not significant non-carcinogenic [18], but HQ value > 1 may be a major potential health concern in association with overexposure of humans to the contaminants. The overall potential non-carcinogenic effects posed by more than one metal and pathway, is obtained by summing the computed HQs across metals and its expressed as hazard index (HI) [19]. HI > 1 poses health risk [18-19].

$$HI = \sum_{i=1}^{n} HQ_{in/derm} \quad (7)$$

where HIin/derm is hazard index via ingestion or dermal contact. Chronic daily intake (CDI) of heavy metals through ingestion was calculated using Equation. 8;

$$CDI = C_{water}\ x\ \frac{DI}{BW} \quad (8)$$

where Cwater, DI and BW represent the concentration of trace metal in water in (mg/kg), average daily intake of water were taken as IR and BW was same in equation (5).

Potential carcinogenicity was calculated as an incremental lifetime probability cancer health risk [16] as presented in equation (9)

$$\mathrm{PCR} = \mathrm{EXP}_{in} \times \mathrm{CSF_I} \quad (9)$$

where EXP_in refers to estimated daily intake through ingestion and CSF_I refers to cancer slop factor for injestion with units mg/kg/day and (mg/kg/day)-1 respectively. CSF_I for carcinogenic metals were 4.1 mg/kg/day and 15 mg/kg/day for Cr and Cd respectively while value for Pb was no found [21-23].

3. Results and discussion

The results for the physical and chemical properties of the groundwater are presented in Table 1 and 2. The physical properties of sampled groundwater showed that the odour and turbidity of all samples in all were found to be within the WHO standard limit. However, temperature (25.4 ^{0}C – 26.6 ^{0}C) was below the standard limit of 35 ^{0}C - 40 ^{0}C. Temperature of water is often controlled by environmental factors and may be indicative of dissolved materials in the water [15,24].

Table 1. Physical Variable in the Waste Dumpsite

Physical	Temperature (^{0}C)	Odour	Turbidity (NTU)
W.H.O standard	35-40	Odourless	5.00
BH1	26.3	Odourless	2.03
BH2	26.1	Odourless	2.01
BH3	26.5	Odourless	1.85
BH4	26.6	Odourless	2.01
BH5	26.8	Odourless	1.59

The mean concentrations of chemical parameters of groundwater samples are shown in Table 2, the results were compared with WHO and NSDWQ standards. The mean pH (6±1.47) of groundwater indicated acidic conditions, which could be attributed to metal contaminants. pH is one of the factors which influence the fate and the transport of contaminants in the environment. Increasing acidity (low PH) can cause some metals and nutrients to dissolve in water thereby releasing toxic elements that may pollute ground water [8, 14]. Individual pH showed only alkaline at BH4 (8.1) while the other of acidity was BH2 (4.1) > BH1 (5.3) > BH5 (6.1) > BH3 (6.4). Similar studies on groundwater in other parts of Owerri reported acidic to alkaline pH [9-10]. Overall, 80 % of the samples didn't meet with the WHO and NSDWQ standards and care should be careful when consuming water from these water sources as they may cause electrolyte imbalance in the body [9].

Table 2. Chemical variables in groundwater sample

Chemical	pH	DO (mg/L)	Total acidity (mg/L)	Total alkalinity (mg/L)	Total hardness (mg/L)	Cl^- (mg/L)	NO_3^- (mg/L)	PO_4^{2-} (mg/L)	SO_4^{2-} (mg/L)
WHO	6.5-8.5	2	NS	200	100	250	10	5	250
NSDWQ	6.5-8.5	Ns	NS	Ns	Ns	250	50	Ns	100
BH 1	5.3	5.54	42	20	30	13	5.0	1.85	2.0
BH 2	4.1	5.0	115	15	16	121	5	1.91	3.0
BH 3	6.4	5.28	37	15	28	13	4.4	1.16	2
BH 4	8.1	1.88	ND	1605	62	ND	1.4	0.85	<0.01
BH 5	6.1	5.34	34	20	8	-	4.4	2	<0.01
Mean	6	4.61	57	335	28.8	29.4	4.04	1.55	2.33
SDV	1.47	1.54	38.81	709.96	20.62	51.62	1.51	0.52	0.58

ND - Not detected
Ns – Not supplied

Dissolved oxygen is an important factor used in assessing water quality as it gives information on the dissolved organic matter in the water [24, 25]. The permissible limit for dissolved oxygen is 2 mg/L of which only BH4 (1.88 mg/L) showed lower value to the limit. Other samples had values higher than the permissible limit and they are in the order BH2 < BH3 < BH5 < BH1. Total acidity ranged from not detected at BH4 to 115 mg/L at BH2 with mean of 57±38.81 mg/L. Total alkalinity of the water samples ranged from 15 mg/L to 1605 mg/L with mean of 335±709.96 mg/L. Only BH4 showed very high total alkalinity above permissible limit of 100 mg/L set by WHO, which also corresponded to the high pH recorded for the point. Alkalinity of water is a measure of its acid-neutralising capacity and also acting as a buffer; protecting the water and its life forms from sudden shifts in pH [10]. The recommended limit for total hardness is 100 mg/L, of which all water samples showed lower value when compared to the limit (Table 2). Chloride, nitrate, phosphate and sulphate concentrations of the groundwater samples were below the permissible limits of 250 mg/L, 10 mg/L, 5 mg/L and 250 mg/L respectively set by WHO (Table 2). Results obtained in this study are comparable with other reports on groundwater within the states [8, 9, 10, 11, 18].

The results for heavy metals (Mg, Zn, Cu, Mn, Fe, Pb, Cr, Ca, Co, and Cd) concentrations in the water are presented in Table 3. All studied metals showed lower concentrations to the permissible limit of WHO except for Fe in all samples, Pb (in BH1, BH3) and Cd, only in BH2 (Table 3). The elevated levels of these metals (especially) may have been increased in the groundwater due to the dumpsite. Studies have shown that dumpsites increase levels of heavy metals in soil [12], which can leach from topsoil into groundwater, thus contaminating it [6,8].Lead was observed to be above standard and limits in BH1 and BH3. Heavy metals when consumed in excess have many toxic effects on human health with children being the most vulnerable population [1, 13, 14]. Excessive exposure to these metals (Fe, Pb and Cd) is associated with various neuro-developmental and can cause gastro-intestinal discomfort and kidney and kidney damage [26].

Table 3. Heavy metal concentration in groundwater sample

Parameter	Mg	Zn	Cu	Mn	Fe	Pb	Cr	Ca	Co	Cd
WHO	150	1.5	0.5	0.5	0.03	0.015	0.1	75	Ns	0.003
NSDWQ	0.2	3	1	0.2	0.3	0.01	0.05	75	Ns	0.003
BH 1	0.03	<0.01	0.00	0.0107	0.46	0.016	<0.01	5.669	0.057	ND
BH 2	0.16	<0.01	0.03	<0.01	0.44	0.004	<0.01	7.045	0.077	0.005
BH 3	0.04	0.16	0.03	<0.01	0.40	0.380	<0.01	12.774	0.051	ND
BH 4	0.47	<0.01	0.08	<0.01	0.44	0.009	<0.01	11.295	0.063	ND
BH 5	0.10	<0.01	0.09	<0.01	0.91	<0.01	<0.01	14.072	0.072	ND
Mean	0.25	0.08	0.05	0.01	0.65	0.19	<0.01	10.197	0.064	0.003
SDV	0.311	0.113	0.064	0.008	0.361	0.269	<0.01	6.403	0.018	0.004

Note: NSDWQ values are the maximum permitted levels in the Nigerian Standards for Drinking Water Quality, ND – not detected NS – Not specified.
*W.H.O values are the maximum permitted levels in the W.H.O Drinking Water Quality Guideline.

Relationship between parameters

Correlation is the mutual relationship between two variables. Direct relationships exist when increase or decrease in one parameter results in an increase or decrease in the value of another parameter [8, 17, 24]. The result of the correlation matrix is presented in Tables 4 and 5, which showed that there are some parameters showed significant correlations. Total acidity showed significant relationship with all anions (Table 4). Also, the anions showed positive association between them. For heavy metals (Table 5), most positive relationship was exhibited by Zn and Fe, Cu and Ca, Zn and Cu respectively. Positive association is indicative if similar contamination source, which are likely the dumpsites. Similar relationships for these parameters have been observed in other studies in water [10, 20, 25, 26].

Table 4. Relationship between Chemical Parameters

Variable	Total Acidity	Total Alkalinity	Total Hardness	Cl^-	NO_3^-	$P0_4^{3-}$	$S0_4^{2-}$	DO
Total Acidity	1							
Total Alkalinity	-0.61*	1						
Total Hardness	-0.62*	0.90**	1					
Cl^-	0.95**	-0.32	-0.36	1				
NO_3^-	0.69*	-0.98**	-0.98**	0.43	1			
PO_4^{3-}	0.62*	-0.76*	-0.76*	0.39	0.81*	1		
SO_4^{2-}	0.81**	-0.59*	-0.34	0.76*	0.68*	0.32	1	
DO	0.52	-0.99**	-0.87**	0.22	0.97**	0.76*	0.53*	1

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2 – tailed)

Table 5. Relationship between Heavy Metals

Variable	Mg	Zn	Cu	Mn	Fe	Pb	Cr	Ca	Co	Cd
Mg	1									
Zn	-0.19	1								
Cu	0.58*	0.65**	1							
Mn	-0.40	-0.25	-0.68*	1						
Fe	0.17	0.99**	0.63**	-0.18	1					
Pb	-0.37	-0.27	-0.26	-0.22	-0.36	1				
Cr	0	0	0	0	0	0	1			
Ca	0.13	0.64*	0.78**	-0.68*	0.58*	0.34	0	1		
Co	0.22	0.42	0.40	-0.37	0.46	-0.71*	0	0.68*	1	
Cd	-0.19	1	-0.24	-0.25	-0.24	-0.27	0	-0.25	0.42	1

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2 – tailed)

Contamination and pollution load assessment

The contamination factors and pollution load index for heavy metals of groundwater samples is shown in Table 6. Following classifications for contamination factors described previously [9, 10], the contamination factors for the individual heavy metals showed low contamination (Cf < 1) for Mg, Zn, Cu, Mn, and Cr in all samples, also Pb were generally low (except for BH1 which was moderate with Cf =1.06 and BH3 which was very high with Cf = 23.33) while Cd also was low generally except in BH2 (Cf= 1.66) with moderate contamination (Table 6).

Table 6: Contamination factor and pollution load index for metals

Sampling points	NO_3^-	PO_4^{2-}	SO_3^{2-}	Mg	Zn	Cu	Mn	Fe	Pb	Cr	Cd	PLI
BH1	0.50	0.37	0.01	0.00	0.00	0.00	0.02	15.33	1.06	0.01	0.00	0.34
BH2	0.50	0.38	0.01	0.00	0.06	0.06	0.02	14.66	0.26	0.01	1.66	0.23
BH3	0.44	0.23	0.01	0.00	0.11	0.06	0.00	13.33	23.33	0.01	0.00	0.37
BH4	0.14	0.17	0.01	0.00	0.00	0.16	0.00	14.66	0.60	0.01	0.00	0.48
BH5	0.11	0.40	001	0.00	0.00	0.18	0.00	30.33	0.06	0.01	0.00	0.45

The dumpsites may have impaired the groundwater quality. Similarly, Duru [10] reported moderate to very high contamination for Pb and Cd in groundwater in an area in Nekede, Owerri North Local Government Area which was associated with waste from automechanic activities. However, the pollution load index which measure the overall load were generally less than one indicative of no pollution by this contaminant. This has also been reported for groundwater sources in the area [9, 10, 11]. The order for PLI was BH4 > BH5 > BH3 > BH1 > BH2.

Water quality index (WQI)

WQI measures the suitability of consuming the borehole or groundwater based on single value generated from the model computed. The classification for WQI is associated with a qualitative scale of parameter intensity and can be classified thus; excellent (WQI < 50); good (50 < WQI < 100); poor (100 < WQI < 200); very poor (200 < WQI ≤ 300); unsuitable for drinking (WQI > 300). Based on the result obtained for WQI (356.42) in Table 7, the water samples are "unsuitable for consumption" and prolong consumption will bring about a health related issues. Poor to unsuitable water quality index was obtained in some studies conducted in Owerri [9, 10, 11].

Table 7. Water quality index

Parameters	Si	wi	Ci(mean)	qi	Si
NO_3^-	10	3	4.04	40.4	2.78
PO_4^{2-}	5	4	1.64	32.8	3.05
SO_3^{2-}	250	1	2.51	1.00	0.02
Mg	150	2	0.16	0.11	0.00
Zn	1.5	4	0.03	2.13	0.20
Cu	0.5	5	0.04	9.20	1.07
Mn	0.5	5	0.00	0.40	0.05
Fe	0.03	5	0.53	1766.66	282.06
Pb	0.015	5	0.08	540.00	62.64
Cr	0.1	4	0.00	1.00	0.09
Cd	0.003	5	0.00	33.33	3.86
		43			
				WQI	356.42

Human Risk Assessment

The mean values of metals Zn, Cu, Mn, Fe, Pb, Cr and Cd from the five different boreholes were subjected to health risk assessment model, which inform on the health risks associated with consumption (via direct ingestion and dermal absorption) of heavy metals on human (adult and children). The results for dermal and ingestion exposure for both adult and children were generally < 1 (Table 8), indicating no risk from these route of exposure.

Table 8. Dermal and ingestion exposure (mg/Kg/day) for adults and children

Metals	RFDderm	RFDing	Statistical parameters	Exp_{derm} (Adults)	Exp_{derm} (Children)	EXPin (Adult)	EXPin (Children)
Zn	120	300	Min	0.00	0.00	0.00	0.00
			Max	1.5E-5	1.3E-4	5.02E-3	1.9E-4
Cu	8	40	Min	0.00	0.00	0.00	0.00
			Max	1.44E-4	9.27E-4	2.8E-3	1.08E-3
Mn	0.96	24	Min	0.00	0.00	0.00	0.00
			Max	1.6E-6	1.08E-5	3.14E-4	1.2E-3
Fe	140	700	Min	6.42E-5	4.32E-4	1.25E-4	4.8E-3
			Max	1.46E-4	9.82E-4	2.86E-4	1.09E-2
Pb	0.42	1.4	Min	0.00	0.00	0.00	0.00
			Max	2.44E-4	3.01E-5	1.19E-3	4.56E-4
Cr	0.003	0.003	Min	0.00	0.00	0.00	0.00
			Max	0.00	0.00	0.00	0.00
Cd	0.025	0.5	Min	0.00	0.00	0.00	0.00
			Max	8.03E-7	5.4E-6	1.57E-4	6.0E-4

The hazard quotient through injection (HQ_{in}) and dermal (HQ_{derm}) of water from the groundwater for the metals were < 1 (Table 9) for both adults and children which indicates that these metals would pose no hazard to local residents. Similar observation was also made for some groundwater sources in Umuna, Orlu [18].

Table 9. Hazard quotient and hazard index for each heavy metal for both children and adults

Metals	Statistical parameters	HQ_{derm} (Adults)	HQ_{derm} (Children)	HQing (Adult)	HQing (Children)
Zn	Min	0.00	0.00	0.00	0.00
	max	1.25E-7	8.58E-7	1.67E-5	6.4E-7
Cu	Min	0.00	0.00	0.00	0.00
	max	1.8E-5	1.21E-4	7.0E-5	2.7E-5
Mn	Min	0.00	0.00	0.00	0.00
	max	1.66E-6	1.12E-5	1.34E-5	5.0E-5
Fe	Min	4.58E-7	3.08E-6	1.78E-7	9.7E-9
	max	1.04E-6	7.04E-6	4.08E-7	1.55E-5
Pb	Min	0.00	0.00	0.00	0.00
	max	5.8E-4	7.16E-5	8.5E-4	325E-4
Cr	Min	0.00	0.00	0.00	0.00
	max	0.00	0.00	0.00	0.00
Cd	Min	0.00	0.00	0.00	0.00
	max	3.21E-5	2.16E-4	3.14E-4	1.2E-3
HI	Min	4.58E-7	3.08E-6	1.78E-7	9.7E-9
	max	6.32E-4	3.06E-4	1.26E-3	1.61E-3

The chronic risk assessment (CDI) for the metals in the groundwater samples through the ingestion pathway is given in Table 10 and were also less than 1, suggesting no chronic consumption of heavy metals from the water consumption. Similar findings were observed by [18, 27]. PCR was calculated because an individual could develop a cancer as a result of daily exposure to carcinogen for a lifetime. Thus that individual's lifetime cancer risk (ILCR) can be obtained from the Cancer Slope Factor (CSF). The computed PCR is presented in Table 11. Total PCR was 2.06E-2 for adult while 9.83E-2 for children; these values are low but didn't agree with the acceptable range of 1.0E-6 to 1.0E-4 [30]. Therefore there was significant potential carcinogenic risk arising from groundwater consumption in this study area. This represents a call for concern. Similar results were obtained for groundwater sources in a mining area in Ghana [31] and also in Iran [29]. Cd has been lined to lung cancer, prostate cancer and cancer of testes by such mechanisms as oxidative stress induction, DNA repair inhibition, apoptotic tendencies and aberrant gene expression [16]. Heavy metals exhibit their toxic effects via metabolic interference and mutagenesis on human kind, fish and animals [32-35].

Table 10. Chronic daily intake for each heavy metal for both children and adults

Metals	Statistical parameters	CDI (Adults)	CDI (Children)
Zn	Min	0.00	0.00
	max	5.03E-3	1.92E-4
Cu	Min	0.00	0.00
	max	2.82E-3	1.08E-4
Mn	Min	0.00	0.00
	max	3.36E-4	1.28E-3
Fe	Min	1.25E-4	4.8E-3
	max	2.86E-4	1.09E-3
Pb	Min	0.00	0.00
	max	1.19E-4	4.56E-5
Cr	Min	0.00	0.00
	max	0.00	0.00
Cd	Min	0.00	0.00
	max	1.57E-4	6.0E-4

Table 11. Potential carcinogenic risk assessment (PCR) for both children and adults

Metals	Statistical parameters	(Adults)	(Children)
Pb	Min	-	-
	Max	-	-
Cr	Min	0.00	0.00
	Max	0.00	0.00
Cd	Min	0.00	0.00
	Max	2.06E-2	9.83E-2
Total		2.06E-2	9.83E-2

Conclusion and recommendation

Results of laboratory analysis of the water samples indicated that metals and other contaminants from the dumpsite leachate have impaired the groundwater quality. The concentrations of metals (Zn, Fe, Pb, Cd) and other water quality parameters in some of the sampling locations slightly exceeded the WHO water quality guideline and the NSDWQ maximum acceptable limits. The contamination for some metals such as Fe and Pb were moderate to very high. The observed values of Fe and Pb is a public health concern and calls for immediate response by the relevant government agencies in terms of supply of treated pipe borne water to the area. Though the studied metallic pollutants indicated no pollution index, the WQI suggests that groundwater samples from the study area were unsuitable for consumption and should be treated before consumption. Many pollutants showed positive relationships which suggested that their source is from the dumpsite. Higher values from the human risk assessment (daily dose, CDI, HQ, HI, and PCR) were recorded for children than adults. The individual HQ and HI of the metallic pollutants for adult and children were all less than 1, which implies little or no health risk due to intake of the water samples. However, potential carcinogenic risks was observed for both adult and children and therefore representing a call for concern. The Umuerim dumpsite currently does not have an environmental management plan (EMP) and an environmental management system (EMS) in place to assess and address the potential environmental and human health risks associated with the dumpsite. Lack of government control including appropriate regulations and risk based guidelines, knowledge gap, lack of data, are reasons why developing nation including Nigeria cannot imbibe sustainable dumpsite management.

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