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Metallic contaminant levels of borehole water sources within metal scrap dumpsites in Aboh Mbaise, Imo State, Nigeria

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ABSTRACT

The borehole water samples within the surroundings of metal scrap dumpsites in Aboh Mbaise, Imo state were collected and assessed for heavy metals (Pb, Zn, Cr, Cd, Cu, Fe, and Mn) concentrations. The results revealed that all the heavy metals analyzed were detected in all the samples. The pH of the borehole water samples from B to E were found to be acidic (5.12 – 6.21) and below the recommended pH value for drinking water by WHO. Only sample A was found with pH value within the WHO acceptable limit. The heavy metals detected were all within the WHO limit for safe drinking water. The water quality index (WQI) model for the analyzed properties of the water samples revealed that the borehole water samples from the area were of good quality. Average daily dose (ADD) values were all less than unity. The order of hazard quotient (HQ) for adults and children via ingestion was Cd > Pb > Mn > Zn > Cu > Fe > Cr. The highest HQ value was recorded in Cd followed by Pb which indicates that these heavy metals may pose significant risks to adults and children who may drink water from the groundwater. The hazard index (HI) via ingestion for both adults and children were greater than one suggesting that there could be great potential risks to the health of both adults and children in the study area who consume the borehole water. A low to moderate contamination factor was observed for all the metallic contaminants in the samples. The pollution load index for all the metals was generally low in the study area, indicating that the water is unpolluted and no multi-element health implication in consumption of the water, but prolonged consumption can cause serious health problems. Even with low concentrations of these toxic metals as observed, regular consumption of the borehole water from these areas without treatment may pose long term health effects due to metal bioaccumulation in the

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human system. It is therefore suggested that adequate measures should be geared toward regulating the activities of metal scrap dealers in the area.

Keywords**:** Metallic contaminants, metal scrap dumpsite, Aboh Mbaise, Borehole water, health risk

1. INTRODUCTION

Scrap metals are recyclable materials left over from products that is manufactured and consumed, such as damaged vehicles and worn out parts, building materials, refrigerators, stoves, etc. Most of these solid wastes have no economic value to the producer, which indicates that most of the solid wastes could become irrelevant depending on its recyclability [1]. Metal scraps are complex and the wastes are not easily degraded.

The ability of heavy metals to leach from scrap metal dumpsites into the soil could contaminate ground water [2]. Metal scraps are left over materials of metal parts that can be recycled such as auto parts, used wire and metals from manufacturing and assembling operations. Solid wastes such as scrap metals are posing serious threats to the quality of soil, vegetation, and groundwater [2]. One of the important sources of drinking water for humans is groundwater, which contains a larger percentage of the available fresh water resource. It is an important reserve of good quality water [3]. Pollution of water by heavy metals has become a question of considerable public and scientific concern in the light of the evidence of their toxicity to human and biological systems [4].

Heavy metals occur naturally in the earth crust and become concentrated as a result of human mediated activities. The common sources of these heavy metals are mainly from mining and industrial wastes, vehicular emissions, lead-acid batteries, fertilizer applications, paints, and treated woods. Metallic pollutants such as arsenic, cadmium, chromium, lead, etc. are particularly of great concern, especially due to their high level of toxicity even at very low concentrations. The contamination of groundwater arising from metallic pollutants is really a key environmental concern because of their toxicity even at minimal levels. Heavy metals tend to cause serious health problems due to their toxic, persistent, and bio- accumulating nature in living tissues [5]. The environmental impact of scrap metal dumpsites on vegetation, soil, and groundwater in Yenagoa metropolis, Nigeria has been reported [6]. Duru et al. assessed the physicochemical characteristics of borehole water samples from a reclaimed section of a mechanic village [7].

Elevated levels of heavy metal in borehole water could be injurious to human health when consumed [8, 9]. The damage caused by the presence of heavy metals in the human body depends on its toxicity, the exposure duration as well as the vulnerability of an individual to metal toxicity [10-12].

So much apprehension has been generated on the need for the supply of safe and portable water, which is needed for both domestic and industrial applications. This demands the need to regularly evaluate the quality of borehole water supplied for different purposes [13]. There is a need to ensure sustainable safe drinking water supply through the safeguarding of the groundwater sources like borehole. Pollution risk and danger due to the consumption of polluted water have been documented in so many reputable publications [14-16]. The consequences and health effects resulting from consumption of borehole water contaminated with heavy metals is well documented [17-20].

The need for evaluation of borehole water quality in the study area arises from the fact that inhabitants of the area under investigation lack access to pipe-borne water, hence the use of borehole water sources for drinking and other domestic requirements. Therefore, regular evaluation of quality of borehole water sources in the area is of great importance. This is in addition to the paucity of documented evidence of the quality of borehole water sources in the area.

This study is therefore aimed at determining some metallic contaminants in the borehole water within the vicinity of metal scrap dumpsites in Aboh Mbaise Local Government Area of Imo state. In order to achieve this, the study determined the concentration of Cd, Co, Cr, Cu, Fe, Mn, Pb and Zn. Contamination factor (C_f) and pollution load index (PLI) were used to ascertain the level of metallic pollution of the borehole water samples. Water quality index (WQI) was used to determine the suitability of the borehole water samples for drinking, while the health risk inherent in the consumption of the water was established with health risk assessment.

2. MATERIALS AND METHODS

2. 1. Study Area

Aboh Mbaise is a Local Government Area in Imo State, Nigeria (Fig. 1). It has an area of about 184 km² and a population of 195,652 as at the 2006 census; this must have significantly enlarged after more than a decade. Aboh-Mbaise is located between latitude: 5.4501° N and longitude: 7.2334° E with an elevation of 24 meters above sea level. The study area is classified within the tropical rain forest zone. Two climatic periods of the wet and dry season are usually witnessed in the area. The wet season is repressive and gloomy, the dry season is characterized by long hours of sunshine, and it is normally warm all year round. Over the course of the year, the temperature typically varies from 18 °C to 34 °C, and usually the daily mean temperature is rarely below 28 °C. Though, there are very few industries in the study area. The increasing presence of metal scrap dumpsites in the area calls for concern.

It is believed that the existence of metal scrap dumpsites within the surroundings has the tendency of releasing heavy metals into the surroundings. These heavy metals may infiltrate into the underground water aquifer or even find their way into the surface water through runoff. So there is a need to ascertain the quality of borehole water around the scrap metal dumpsite in the study area.

This is owing to the fact that there is no functional potable water supply in this area and most homes in the state. Therefore to solve the water supply problem, majority of the residence dug there boreholes in order to supply water for drinking and other uses. Therefore, there is need to analyze these borehole water samples.

2. 2. Sample collection and pre-treatment

The collection of borehole water samples from the study sites was undertaken in July, 2019 with 1 litre polyethylene container. Samples were collected from Uvuru, Afor Enyiogugu, Eziala Enyiogugu, Akwate, and Azara Egbeulu in Owerri North which was taken to serve as the control site, and were labelled A, B. C, D and E respectively. Prior to collection of each sample, the polyethylene container were rinsed two times with the sample to be collected to avoid any form of contamination. The samples after collection were labelled systematically and immediately, put in a bag to minimize photochemical effects. At each sample site, latitude, longitude, and altitude were recorded with a GPS map satellite phone as shown in Fig. 2 and Table 1. After the physical parameters were determined, samples meant for metallic content analyses were acidified with 2 drops of 2M HNO_3. This was to ensure sample stability as well as to maintain the oxidation state of the metals and prevent adherence to the walls of the sample bottles. The samples were appropriately labelled and immediately taken to the laboratory for heavy metal analysis.

2. 3. Sample analysis

The borehole water samples were analyzed according to the methods reported by previous publications [20, 21]. The physical properties (EC, pH, TDS,) were determined at the sample site. pH of the borehole water samples were determined with Checker plus pH meter by HANNA Instruments, total dissolved solids (TDS) and electrical conductivity (EC) were established with portable handheld TDS/EC meter (ketotek). The concentrations of metallic elements which include cadmium (Cd), copper (Cu), chromium (Cr), iron (Fe), manganese (Mn), lead (Pb) and Zn was established by Atomic Absorption Spectrophotometer (AAS) using PerkinElmer AAnalyst 400.

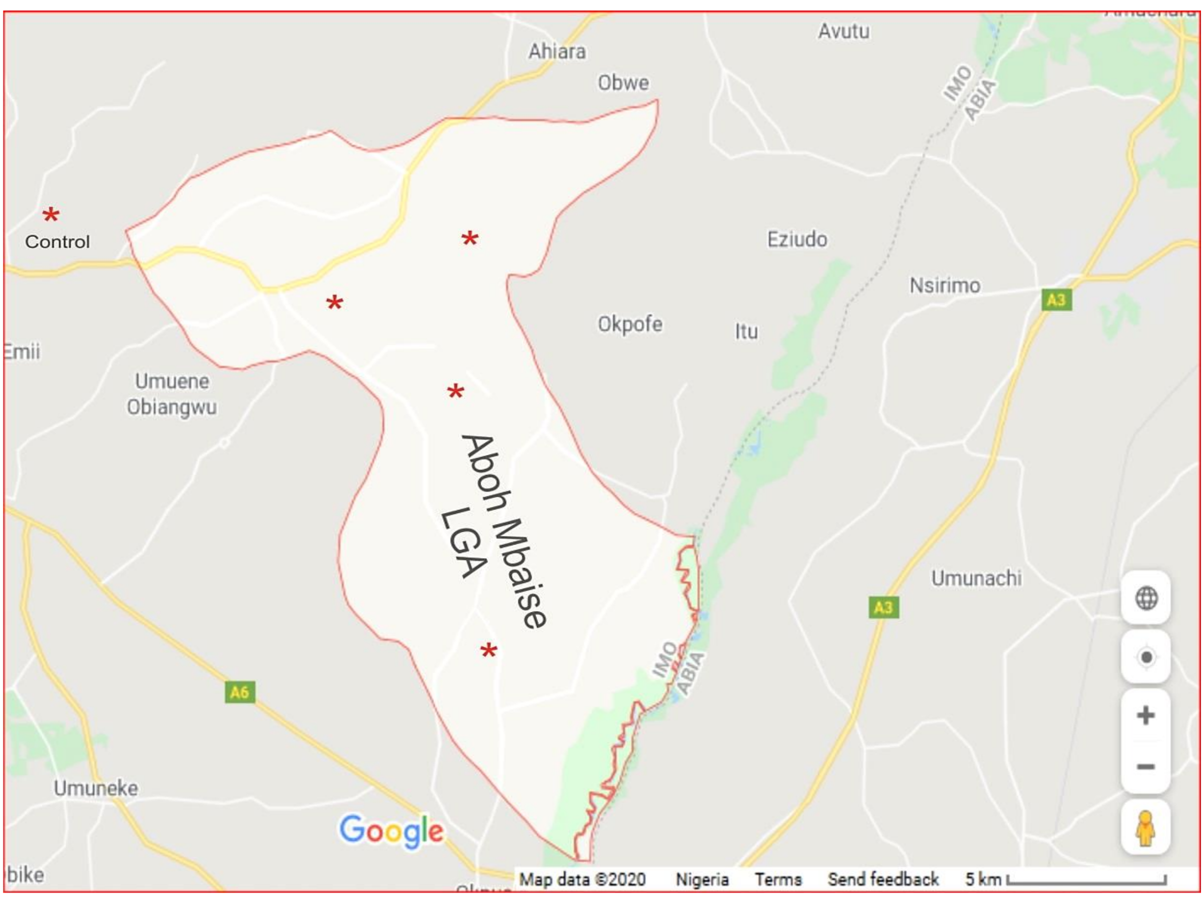

Fig. 1. Map of study location showing sample points

Fig. 2. Some metal scrap dumpsites in the study location.

Table 1. Coordinates of sampling points.

S/N	Sample site	Longitude	Latitude	Altitude	Duration of Borehole
1	Sample A Uvuru	5º28′9.73″N	7º12′8.09″E	79m	6 months
2	Sample B Afor Enyiogugu	5º28′8.65″N	7º12′7.72″E	105m	2 years
3	Sample C Eziala Enyiogugu	5º28′19.74″N	7º12′23.63″E	115m	6 years
4	Sample D Akwate	5º27′54.43″N	7º11′55.37″E	106	3 year
5	Sample E Azaraegbulu, Emekuku	5º28′33.31″N	7º7′24.02″E	151m	7 months

2. 4. Data analysis

The data were subjected to mean, standard deviation, variance and coefficient of variance. The coefficient of variation was determined according to Eq. (1). Co-efficient of variation was used to establish the variation in concentration of the analyzed parameters in the study area. The level of variation was categorized as little variation (CV% < 20), moderate variation (CV% 20-50) and high variation (CV% > 50).

$$COVAR = \frac{SD}{Mean}\, x\, 100 \qquad (1)$$

2. 5. Contamination factor assessment

This was used to determine the level of metallic contamination of the borehole water samples. The C_f was determined using Eq. (2).

$$C_f = \frac{C_m}{C_s} \qquad (2)$$

where C_m is the concentration of a measured parameter in the borehole water sample and C_s is the standard concentration of that parameter. WHO (World Health Organization) standards for safe drinking water were taken as the standard concentrations in this study [22].

2. 6. Pollution Load Index (PLI)

PLI is a potent tool that provides a simple and comparative means for assessing the level of metal pollution. It gives a summative indication of the overall level of toxicity at a particular sampling point. The PLI value greater than 1 is polluted, less than 1 is not pollution whereas values equal to 1 indicates contaminant loads close to the standard concentration [23]. The pollution load index was determined mathematically using Eq. (3).

$$PLI = n\sqrt{C_{f1} \times C_{f2} \times C_{f3} \times \ldots\ldots C_{fn}} \quad (3)$$

where PLI is pollution load index, n is the total number of investigated metals and C_{f1} -C_{fn} is the individual contamination factor [23]

2. 7. Water Quality Index (WQI)

The water quality index was calculated to ascertain the overall suitability of the borehole water in the study area for human consumption. The water quality index was calculated using the weighted arithmetic WQI determination method. The water quality index was estimated using ten parameters according to Eq. (4) – (7) [20, 24].

$$W_r = \frac{w_p}{\sum_{i=1}^{n} w_p} \quad (4)$$

$$Q_r = \frac{C_m}{C_s}\, x\, 100 \quad (5)$$

$$S_{index} = W_r\, x\, Q_r \quad (6)$$

$$WQI = \sum S_{index} \quad (7)$$

where W_r represents the relative weight of the parameters, Q_r stands for the quality rating, n is number of parameters under investigation, w_p stands for weight of each of the parameters, C_m is the mean concentration of each of the parameter analyzed, C_s is the standard value (WHO standard for safe drinking water) of the parameter analyzed and S_{index} is the sub index of *i*th parameter. The water quality was classified as reported by Ramakrishnaiah et al. and Duru et al., where WQI < 50 represents excellent water quality, 50 < WQI ≤ 100 means good water quality, 100 < WQI ≤ 200 stands for poor water quality, 200 < WQI ≤ 300 means very poor water quality and WQI > 300 refers to water that is unsuitable for drinking [20, 25]

3. HEALTH RISK ASSESSMENT

The average daily dosage for water could be determined in terms of human exposure to heavy metal contaminants through ingestion via mouth, inhalation via the nose and dermal absorption through the skin. The health risk assessment was determined according to Eq. (8) and (9) which was adapted from the USEPA risk assessment method [19, 26-28].

$$EXP_{ing}\ (\mu g/kgBWd) = \frac{Cw \times IR \times EF \times ED\ \times 100}{BW \times AT} \quad (8)$$

$$EXP_{derm} = \frac{Cw \times Dpc \times SA \times EF \times ET \times ED \times CF(6)}{BW \times AT} \quad (9)$$

where C_m = mean concentration of metal contaminant in water (mg/L), IR = water ingestion rate (2.2 L/day for adults, 1.8 L/day for children), EF = exposure frequency (365 days/year), ED = exposure duration (70 years for adults and 6 years for children), BW = body weight (average of 70kg for adults and 15kg for children), AT = average time (365 days/year x 70 years for an adult; 365 days/year × 6 years for a child), SA = skin area that is exposed (for adult is 18,000 cm^2 and children is 6,600 cm^2), Dpc = dermal permeability coefficient in water (cm/h), Cu, Mn, Fe and Cd values is 0.001, Cr value is 0.002, Zn value is 0.0006, while 0.004 is for Pb and Ni, ET = exposure time (for adult is 0.58 h/day and children is 1 h/day), CF = 0.001 L/cm^3 is taken as the conversion factor, EXPing is exposure dose through ingestion of water (mg/kg) and EXPderm is exposure dose through dermal absorption (mg/kg) [19, 27-29].

3. 1. Hazard quotient hazard and index

The risks associated with exposure to the heavy metals were determined using hazard quotient. The hazard quotient was estimated mathematically by comparing the exposure path with the reference dose (RfD) for ingestion and dermal absorption of the borehole water samples as shown in Eq. (10) [27].

$$HQ = \frac{EXP}{RfD} \tag{10}$$

where RfD is the dermal toxicity reference dose value (mg/kg/day) [26, 27]. HQ < 1 shows that it poses no effect to human health and is safe for drinking but HQ >1 can be a potential health concern to humans on exposure to these contaminants [30]. The risk due to human association with more than one metallic contaminant was obtained by summing up the estimated HQ of the various heavy metals and is taken as hazard index as shown in Eq. (11);

$$HI = \sum_i^n HQ = HQ_{[Pb]} + HQ_{[Zn]} + HQ_{[Cr]} + HQ_{[Cd]} + HQ_{[Cu]} + HQ_{[Fe]} + HQ_{[Mn]} \tag{11}$$

where HI is the hazard index due to contact with the borehole water samples. HI > 1 suggests that consumption of the borehole water could cause health risks [27].

4. RESULTS AND DISCUSSION

Table 2 is the result of physicochemical parameters and levels of metallic contaminants in the borehole water samples. The physicochemical characteristics are important in determining the quality of borehole water. pH of safe drinking water according to WHO standard is between 6.50-8.50. The observed pH level ranged from 5.12-7.53. Only sample A is in line with the WHO standard for safe drinking water as shown in Table 2. The observed pH of borehole water samples B – E indicated that these borehole water samples were acidic (5.12-6.21) and not within the WHO permissible limit for drinking water. The EC values which were within the WHO permissible limit for safe drinking water ranges from 2-42 µs/cm. Electrical conductivity is influenced by the presence of dissolved salts such as sodium chloride and potassium chloride which produce ion that migrates in solution and then generates electric current. According to Table 2, EC of the borehole water samples ranges from 1-32 mg/L, which was within the WHO limit. The higher the EC, the greater is the TDS.

Table 2. Physiochemical parameters and levels metallic contaminants in the borehole water.

Parameters	A	B	C	D	E	Mean	SD	VAR	COVAR	WHO 2003/2004
pH	7.53	6.21	5.34	5.12	5.48	5.936	0.877	4.297	14.77	6.50-8.50
EC µs/cm	40.00	28.00	26.00	42.00	2.00	27.60	14.28	195.2	51.74	1000.00
TDS Mg/L	32.00	14.00	12.00	21.00	1.00	16.00	10.26	92.38	64.13	250.00
Pb (mg/L)	0.002	0.001	0.002	ND	ND	0.002	5E-04	5E-07	25.00	0.05
Zn (mg/L)	0.030	0.020	0.060	0.040	0.020	0.034	0.015	2E-04	44.12	5.00
Cr (mg/L)	0.004	0.001	0.001	0.002	0.001	0.002	0.001	1E-06	50.00	0.05
Cd (mg/L)	ND	0.001	0.002	ND	ND	0.002	5E-04	4E-07	25.00	0.005
Cu (mg/L)	0.005	0.010	0.003	0.001	0.001	0.004	0.003	9E-06	75.00	1.00
Fe (mg/L)	0.120	0.020	0.004	0.030	0.020	0.039	0.041	0.001	105.10	0.30
Mn (mg/L)	0.001	0.001	0.002	0.002	0.002	0.002	5E-04	4E-07	25.00	0.50

SD is Standard deviation, VAR is Variance, ND is not detected and COVAR is coefficient of variance

The concentration of Pb from the borehole samples ranged from 0.001 to 0.002 mg/L in samples A, B, and C, while in sample D and E Pb was not detected. The values were within WHO permissible limit of 0.05 mg/L. Elinge et al. reported elevated levels of Pb and indicated that Pb could damage the nervous system most especially in children and may also cause blood and brain disorders [31]. High level of Pb in groundwater systems could traced be to dumping of material containing Pb in landfill [9]

All the borehole water samples showed Zn concentration within the WHO permissible limit of 5.0 mg/L. Zn concentration in the samples ranges from 0.020 to 0.060 mg/L with a mean value of 0.034 mg/L. Tadiboyina and Rao reported higher zinc concentrations in groundwater samples [32]. Zinc concentrations ranging from 0 to 0.190 mg/L were reported in Newmont Ghana gold mining concession areas [33]. The zinc level obtained in the present study is comparable to the values reported by Samuel et al. [34]. At high concentration, Zn could be very toxic. It plays a vital role in physiological and metabolic process of many organisms [35].

The chromium content of the five samples ranged between 0.001-0.004 mg/L with a mean value of 0.002 mg/L. Cr concentrations recorded in the present study were less than the WHO permissible limit for safe drinking water as shown in Table 2. Exposure to chromium for a long period could cause serious damage to the kidney, liver, circulatory and nervous tissue [36]. High Cr values have been reported in Nassarawa state, Nigeria, which was attributed to surface contamination originating from anthropogenic and geological sources [30].

The concentration of cadmium was recorded only in samples B and C, which ranged from 0.001 to 0.002 mg/L while it was not detected in samples A, D and E. Cadmium levels obtained in this study were within WHO permissible limits of 0.005 mg/L. Cadmium is found mostly in association with Zinc-coated pipes and fittings. Target organs for cadmium are liver, placenta, kidneys, lungs, brains, and bones [27]. At low concentration, cadmium could causes serious health effects such as kidney damage, bronchitis, and osteomalacia. Cadmium may also affect the nervous system and increase the development of cancer [37].

The observed Cu level in the present study which ranges from 0.001 to 0.010 mg/L is within the WHO Cu permissible limit for safe drinking water. At high concentration Cu could cause chronic anaemia, vomiting, diarrhea, nausea, abdominal pain, liver, kidney damage and stomach, and intestinal irritation. The presence of Cu in borehole water could either come from copper pipes or additives used in controlling algal growth, but Cu is essential in life [38].

The observed concentration of Fe and Mn were all within the WHO permissible limit for safe drinking water. The values of Mn ranges from 0.001 to 0.002 mg/L with a mean value of 0.002 mg/L. Fe values were observed to range from 0.004 to 0.120 mg/L with a mean value of 0.039 mg/L. The concentration of Fe obtained in the present study is comparable to values reported in related research [7, 39]. Iron is an essential element required for the development and existence of living things. Fe is an important element required for proper metabolism processes in living organisms [20, 40]. The concentration of iron higher than 0.3 mg/L in water could stain clothes during laundry [22]. In small quantities, certain heavy metals like iron, copper, and zinc are considered essential nutrients for healthy living [41-43].

Table 3. Shows the individual contamination factors and PLI of metals in the sample.

Metal	Contamination factor					
	A	B	C	D	E	Mean
Pb	0.04	0.02	0.04	0.00	0.00	0.04
Zn	0.00 6	0.004	0.012	0.008	0.004	0.0068
Cr	0.08	0.02	0.02	0.04	0.02	0.04
Cd	0.00	0.2	0.4	0.00	0.00	0.4
Cu	0.005	0.01	0.003	0.001	0.001	0.004
Fe	0.4	0.067	0.013	0.1	0.067	0.13
Mn	0.002	0.002	0.004	0.004	0.004	0.004
PLI	0.00	0.00	0.00	0.00	0.00	0.00

Table 3 is the individual contamination factors and pollution load index of the metals in the borehole water samples. A low to moderate contamination was observed for all the metals in the samples. The Obtained values of contamination factor were categorized as reported in previous publication [37]. The pollution load index of the metals was generally low in the study area, indicating that the water is unpolluted but prolong consumption can cause serious health problems.

Table 4. Estimation of WQI of the sampled boreholes water sources.

Parameters	C_s	w_p	W_r	C_m	Q_i	S_{index}
pH	7.50	4	0.100	5.94	79.20	7.92
EC	1000.00	4	0.100	27.60	2.76	0.276
TDS	250.00	4	0.100	16.00	6.40	0.640
Pb	0.05	5	0.125	0.002	4.00	0.500
Zn	5.00	3	0.075	0.034	0.68	0.051
Cr	0.05	5	0.125	0.002	4.00	0.500
Cd	0.005	5	0.125	0.020	400.00	50.00
Cu	2.00	3	0.075	0.004	0.20	0.015
Fe	0.30	3	0.075	0.039	13.00	0.975
Mn	0.40	4	0.100	0.002	0.50	0.05
		$\sum w_r = 40$				$WQI = \sum S_{index} = 60.93$

where: Cs, w_p, Wr, Cm, Qi and Sindex are as explained in the data analysis section

Table 5 is the result of WQI analysis of the sampled borehole water sources in the study area. The result revealed a water quality index value of 60.95, which suggests that the analyzed borehole water sources were within the good water quality category of WQI. This implies that the water could be consumed with little or no further treatment or purification.

4. 1. Health Risk Assessment

Table 5. Average daily dose for individual metals (mg/kg/day).

Metals	EXPin		EXPderm	
	Adult	Children	Adult	Children
Pb	6.29E-03	0.024	1.19E-06	3.52E-06
Zn	0.107	0.408	3.04E-06	8.98E-06
Cr	6.29E-03	0.024	5.97E-07	1.76E-06

Cd	6.29E-03	0.024	2.98E-07	8.80E-07
Cu	1.00E-02	0.048	5.97E-07	1.76E-06
Fe	1.20E-01	0.468	5.82E-06	1.72E-05
Mn	6.29E-03	0.024	2.98E-07	8.80E-07

The average daily dose of the individual metals is presented in Table 5. The average daily dose of the heavy metals for adult showed that Zn has the highest value via ingestion, while Fe has the highest ADD value via ingestion for children. The ADD via dermal absorption of groundwater for adult indicates that Fe has the highest value. Both Mn and Cd have the same value which is the lowest value recorded as shown in Table 5.

4. 2. Hazard Quotient and Hazard Index

The hazard quotient for both adult and children via ingestion and dermal absorption are presented in Table 6. The order of HQ for adult via ingestion is Cd > Pb > Mn > Zn > Cu > Fe > Cr. The highest HQ value was recorded in Cd followed by Pb which indicates that these heavy metals may pose significant risks for adults and children who may drink water from the boreholes. The order of HQ for children via ingestion is Cd > Pb > Mn > Zn > Cu > Fe > Cr while that of adult is Cd > Pb > Mn > Zn > Cu > Fe > Cr. Cd showed highest HQ value followed by Pb, which indicates that these heavy metals may be of great potential risks to the health of adults and children who may drink water from the borehole water sources. Cd and Pb for adult were above 1, which implies that there is a tendency of adverse health effects while for children Cd, Pb, Mn Zn, and Cu were all above 1, which implies that there is also a tendency of adverse health effects. The HQ via dermal absorption for both adults and children is in the order of Cd> Pb> Mn> Cu> Zn> Fe> Cr which are all less than one indicating that there is little or no tendency of health risk from the metals via dermal absorption.

Table 6. Hazard quotient and Hazard index for individual metals.

Metals	HQin		HQderm	
	Adult	Children	Adult	Children
Pb	1.7959	6.857	3.4E-04	1.0E-03
Zn	0.36	1.36	1.01E-05	2.99E-05
Cr	4.19E-03	0.016	3.98E-07	1.17E-06
Cd	12.58	48.0	5.96E-04	1.76E-03
Cu	0.25	1.20	1.49E-05	4.4E-05
Fe	0.17	0.67	8.31E-06	2.45E-05

Mn	0.45	1.71	2.1E-05	6.29E-05
HI	15.61	59.813	9.91E-4	2.92E-03

The hazard index via ingestion and dermal absorption for both adult and children are presented in Table 6. Hazard index (HI) was obtained to assess the additive risks of more than one heavy metal to human health. The HI via ingestion for both adult and children were greater than one indicating that there could be great potential risks to the health of both adults and children living in the environment. HI via dermal absorption for both adult and children were below one indicating that there is no cumulative potential adverse health risk in the water samples within the environment.

5. CONCLUSIONS

The borehole water samples from the surroundings of metal scrap dumpsite in Aboh Mbaise L.G.A in Imo state were collected and assessed for physicochemical parameters and heavy metal (Cd, Cr, Cu, Fe and Mn, Pb and Zn) concentrations. The results revealed that all the heavy metals analyzed were detected in all the samples. The pH of the borehole water samples B to E was found to be acidic and below the recommended pH value for drinking water by WHO. Only sample A was found to be within the WHO permissible limit. The observed concentrations of the metallic contaminants were all within the WHO limit for safe drinking water. ADD values were all less than unity. The order of HQ for adult and children via ingestion is Cd> Pb> Mn > Zn > Cu> Fe> Cr. The highest HQ value was recorded in Cd followed by Pb which indicates that these heavy metals may pose significant risks for adults who may drink water from the groundwater. The HI via ingestion for both adults and children were greater than one indicating that there could be great potential risks to the health of both adult and children living in the area. HI through dermal absorption for both adult and children were below one, indicating no cumulative potential adverse health risk in taking water from the area under consideration. A low to moderate contamination factor was observed for all the metals in the samples. The pollution load index for all the metals were generally low in the study area for the analyzed metals, indicating that the water is unpolluted, but prolonged consumption of water could lead to serious health problems. The WQI value (60.93) falls within $50 < WQI \leq 100$ of the classification of water quality based on the weighted arithmetic WQI method. It indicates that the borehole waters from the sample sites were of good water quality. But even with low concentrations of this toxic metal as observed, regular consumption of the borehole water from these areas may result in long term health effect due to metal bioaccumulation in the human system.

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