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Assessments of Heavy Metal Contamination in Groundwater Source from Benin Formation Aquifer in and around Dumpsite Environment, and its Impact on Human Health

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ABSTRACT: The paper examines the level of exposure and the health risk associated with chromium (Cr), Nickel (Ni), Lead (Pb), and Iron (Fe) in boreholes in and around dumpsite environment of Asoro, Otofure and Ikhueniro in Benin City, Nigeria. Literature review, structured questionnaire, and ArcGIS were applied to achieve the aim of the study. The results show that the level of exposure of the inhabitants of the study communities to Fe in the three sites investigated was R > 1 for adult, teenagers, and children respectively. ArcGIS geospatial map model revealed that heavy metals assessed in the study dissipated in the direction of groundwater flow. Correlation at P < 0.5 confidence level confirmed the influence of the dumpsites on the quality of groundwater sourced in the area. Based on the result, the groundwater in the study area cannot be consumed unless treated.

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Finkelman *et al.* (2000) pointed out that the impact on human health by natural materials like water, rocks and minerals has been known for thousands of years but there have been few systematic, multidisciplinary studies on the relationship between geologic processes and human health. This field of study deals with the interrelationship between human and geologic processes as well as the systematic ways of assessing and managing the impacts caused as a result. Groundwater being the main source of drinking water globally, especially in the developing nations, needs to be protected and monitor at regular interval to ascertain its suitability for consumption purposes (Li *et al.* 2019a and b; Wang *et al.* 2019; Li and Wu, 2019a; Omorogieva and Andre-Obayanju, 2020. This natural resource has a direct link with man because water is regarded as the power house of the ecosystem sustainability, economic growth and societal development (Jaishankar *et al.* 2014; Holland *et al.* 2015; Adimalla *et al.* 2020; Zhou *et al.* 2020). However, increasing human population and technological advancement as well as lack of awareness of the detrimental effects of contaminated drinking water has led to its poor management (Bruggen *et al.* 2010; Nwankwoala, 2011; Liu and Yang, 2012; Dube and January, 2012; Holland *et al.* 2020). Furthermore, leaky aquifer within dumpsite environment may become vulnerable to groundwater contamination by metals due to the deep excavation left behind during urban development (Akujieze, 2004; Akujieze and Irabor, 2014; Omorogieva and Andre-Obayanju, 2020). More worrisome, in developing countries like Nigeria especially in the coastal communities and semi urban areas, groundwater are exposed to contaminants, and as a result become detrimental to consumers through oral ingestion (Selinus *et al.* 2013; Tonjoh and Omorogieva, 2020). Some aquifers within Benin Metropolitan City (BMC) Nigeria are susceptible to groundwater contamination due to open dumping of municipal and hospital wastes in excavated sites. For example, Omorogieva (2018) reported that wastes dumped in Ikhueniro open dumpsite in Benin City include lead acid battery, sewage and industrial effluents, ferrous and non-ferrous materials, abandoned vehicles, polythene wastes, chemical containers, food wastes, e-waste, garden wastes, paint and chemical solvent. These wastes contain hazardous environmental contaminants like Pb, Fe, Cr, Mercury (Hg), Arsenic (As) among others, and are beyond the

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average crustal values. Similarly, Akujieze (2004); Akujieze and Oteze, 2007; Imasuen and Omorogieva (2013a); Omorogieva *et al.* (2016); Omorogieva and Tonjoh (2020) have studied the impacts of these wastes, particularly the heavy metals in urban groundwater system within Benin Formation Aquifer (BFA), and reported anomaly in the concentration of toxic heavy metal like Pb, Cr, Cd, As amidst other parameters in the study. Onyeobi and Akujieze (2014); Omorogieva *et al.* (2016) demonstrated that soil characteristics play a pivotal role in groundwater contamination and area close to high anthropogenic activities like mining and dumpsite environment have a greater impact. Taylor (2009); Taylor *et al.* (2010); Omorogieva, 2018; Zhou *et al.* (2020); Adimalla *et al.* (2020) revealed high incidence of exposure and health risk in people living in the area of high anthropogenic activities arising in the release of deleterious metals and other contaminants in the environment through food chain. Omorogieva (2018) reported that people living in and around Ikhueniro, Otofure and Okhuahe open dumpsites depend largely on groundwater from the underlying aquifer in Benin Formation were susceptible to deleterious metals like Pb, Fe, Ni and Cr. Previous scholars who have worked in a similar environment locally and internationally have applied various methods like the geochemical, geophysical, and biophysical assays to evaluates the concentration and distribution of potentially toxic metals as well as synergistic elements such as Arsenic (As), Cadmium (Cd), Copper (Cu), Lead (Pb) and Aluminum (Cushman *et al.* 2001; Kuypers *et al.* 2008; *Taylor et al.* 2009; Mackay *et al.* 2010; Imasuen and Omorogieva, 2013a & b; Aiyesanmi and Imoisi, 2013; Akujieze and Idehai, 2014). However, this study combine literature review, structured questionnaire and ArcGIS to form a novel approach in assessing the level of exposure of people living in and around the perimeter of Ikhueniro, Asoro and Otofure urban and sub urban communities within BMC to Cr, Pb, Ni and Fe as well as their health risk (HR); this is aimed at strengthening policy formulation based on the robust scientific research and enforcement of existing laws gear towards sustainable water resources management for the benefits of mankind.

MATERIALS AND METHODS

Location and Geology: The study area (Fig. 1) is located within Benin Metropolitan City (BMC), and falls within the Geographical Coordinates of 5°44′N and 7′37′′N, and 5°44 and 6′43′′E, having its highest peak of 672 m above sea level (Omorogieva, 2016; Omorogieva and Tonjoh, 2020). Three rivers, namely Ogba, Ikpoba and Owegie-Ogbovben drain the area as represented in Figure 2. Ogba river rose from the highland area at Ekehuan Ugbiyokho axis of the region and flows southwest for about 12km as sub tributary of the Ossiomo river. Conversely Owegie-Ogbovben river system drains the northwestern portion of the basin and flows westward with an estimated catchment area of about 10km^2 while Ikpoba river being the largest of the drainage system took its source from the western highland in the northeaster portion of the region with an estimated catchment area of 722km^2 (Akujieze, 2004; Ikhile, 2016). The areas could be described as a tropical climate, with a distinctive dry and wet seasons characterized by huge and tall trees that performs the function of a canopy, and as a result prevents the penetration of sunlight from reaching the forest floor (Ojo *et el.* 1999). The annual mean temperature is 27^{o}C with a range of 1^{o}C–2^{o}C, while the average relative humidity is 60% according to the Edo State Bureau of Statistics (2013) represented in Table 1 & 2 respectively. The area is underlain by the Benin Formation, the youngest of the Niger Delta Sedimentary Basin. The rock type found here is mainly Sedimentary, and is characterized by reddish brown lateritic with fairly indurated Clay and Sand (Fig. 3). The sedimentary sequences are poorly bedded with discontinuous clay horizons at various depths. It is estimated to be about 800m thick under Benin City and about 1830 near the shore. They are exposed at various erosion sites, sand quarry sites, and road cuttings; dipping at an angle of 2^o – 8^o south (Ikhile, 2016, Akujieze, 2004).

Samples collection and analysis: A total of 15 representative groundwater samples from borehole drilled within and around the study areas (Ikhueniro, Otofure and Asoro) were obtained from previous study of Omorogieva (2018, Omorogieva and Andre-Obayuwana,2020). The samples were collected randomly from existing boreholes with aid of a pumping machine in a prerinsed rubber bottle of 75 cL capacity to represent each study area based on the rate of consumption. Following the determination of pH in situ, 0.5mg/L of nitric acid (HNO_3) was added to each of the samples for the purpose of reducing the pH < 2; this is because below pH 2, adsorption to container wall, precipitation, and other biological degradation are minimized (Radulescu *et al*. 2014).

All samples were collected from the Oligocene-Pleistocene Benin Formation characterized by medium to shallow aquifer with fine to medium grain size, well sorted and sandy clay characteristic at Ikhueniro and Asoro whereas in Otofure, the aquifer are relatively deep and confined with medium to coarse sand and clay performing the function of a cap and seal to the groundwater.

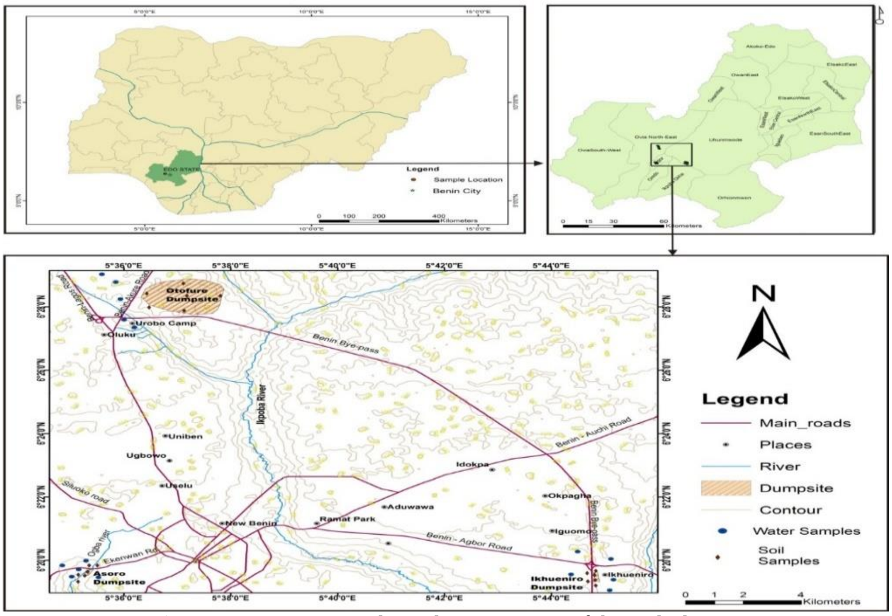

Fig. 1 Location, access and sampling points map of the studied areas.

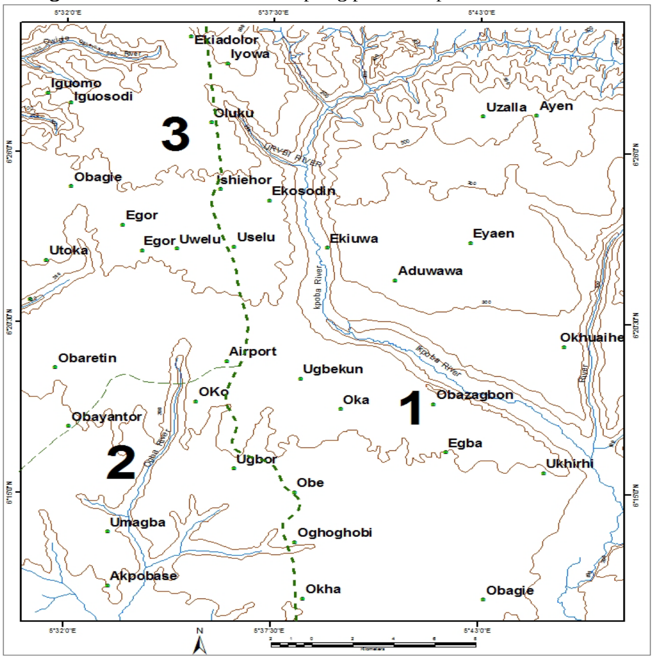

Fig. 2 Benin region sub-basin extracted from Ikhile, (2016) in Akujieze, (2004)

Table 1 Average monthly minimum temperature (OºC) modified after Edo State Bureau of Statistics (2003); Omorogieva (2018)

	Months												
Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Ann. Avg.
2003	-	-	-	-	-	-	-	-	-	-	-	-	-
2004	-	-	-	-	-	-	-	-	-	-	-	-	-
2005	21.80	25.10	24.50	24.90	23.90	23.40	22.90	22.50	23.20	23.20	24.20	24.00	23.63
2006	25.10	25.20	24.30	24.90	23.20	23.30	22.90	22.70	22.70	23.20	23.70	23.30	23.71
2007	21.50	24.90	25.10	24.30	23.60	23.60	23.20	22.90	22.80	23.20	23.50	23.00	23.43
2008	22.00	23.70	24.20	23.70	23.20	23.20	22.80	23.00	23.10	23.20	24.50	23.90	23.39
2009	23.40	24.60	25.00	23.90	23.80	23.80	23.50	22.90	23.20	22.60	23.30	24.50	23.66
2010	24.30	25.40	25.50	24.40	24.90	24.90	23.00	22.90	22.90	23.00	23.50	22.90	23.89
2011	21.90	23.90	24.40	23.90	23.80	23.80	22.80	22.50	23.00	23.00	23.90	22.80	23.29
2012	22.30	24.10	24.90	24.20	23.60	23.60	22.90	22.30	23.10	22.90	23.90	23.10	23.35
Mean	22.61	24.29	24.75	24.06	23.81	23.81	22.96	22.64	23.05	22.95	23.84	23.32	23.47

Table 2 Average monthly relative humidity (%) at 0900 GMT

	Month												
Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Ann. Avg.
2003	-	-	-	-	-	-	-	-	-	-	-	-	-
2004	-	-	-	-	-	-	-	-	-	-	-	-	-
2005	62.00	81.00	82.00	84.00	84.00	90.00	82.00	89.00	87.00	86.00	86.00	84.00	83.08
2006	88.00	84.00	82.00	82.00	86.00	85.00	91.00	91.00	91.00	88.00	78.00	73.00	84.92
2007	46.00	82.00	83.00	83.00	85.00	88.00	90.00	92.00	91.00	87.00	85.00	78.00	82.50
2008	58.00	67.00	80.00	84.00	83.00	85.00	88.00	90.00	88.00	83.00	84.00	78.00	80.67
2009	78.00	84.00	80.00	84.00	83.00	83.00	88.00	91.00	87.00	86.00	76.00	84.00	83.67
2010	81.00	82.00	80.00	82.00	82.00	86.00	87.00	90.00	89.00	85.00	85.00	78.00	83.92
2011	64.00	79.00	82.00	83.00	83.00	87.00	91.00	91.00	89.00	86.00	82.00	71.00	82.33
2012	72.00	86.00	81.00	81.00	85.00	89.00	91.00	90.00	90.00	87.00	87.00	78.00	84.75
Mean	68.63	80.63	81.25	82.88	83.88	86.63	88.50	90.50	89.00	86.00	82.88	78.00	83.23

Source: Edo State Bureau of Statistics (2013); Omorogieva (2018)

Fig. 3 Geological map of Benin City and environs (Akujieze, 2004)

The positions of the wells sampled were recorded by field Global Positioning System (GPS), Garmin GPSMAP 78S series, and are shown in Figure 1. The pH was further determined in the laboratory using a buffer 4 and 7 solution to calibrate the pH metre. The electrode was carefully suspended in the sample and allowed to stand until the reading becomes steady, and the values were recorded. The average of the value obtained in the field and in the laboratory was taken as final reading for the study.

Digestion and Analysis: Digestion of samples with aqua regia (HNO_3 67%: HCl 37% = 3:1) was achieved. The liquid digestion was read off with Atomic Absorption Spectrophotometer (AAS) model 969 Unicam series with air acetylene flame (America Public Health Association, 2005; Adeleke and Abegunde, 2011; Radulescu *et al.* 2014).

Health risk assessment: Health Risk Assessment (HRA) provides an individual with health questionnaire to evaluate the level of their health risks, and the quality of life based on the level of exposure to certain toxicants (Baker *et al.* 2007). It incorporates three key elements – an extended questionnaire, a risk calculation or score, and some form of feedback i.e. face-to-face with a health advisor (Gazmararian *et al.* 1991, Baker *et al.* 2007). Furthermore, Centers for Disease Control and Prevention view HRA as a systematic approach to collecting information from individuals that are identified as risk factors, provides individualized feedback, and links the person with at least one intervention to promote health, sustain function and or prevent disease (Alexander, 2000, CDC, 2017). In the current study, a research questionnaire was designed in collaboration with public health Medical Doctor to obtain basic information on the demography, medical history, sources of contamination, symptoms associated with heavy metal; the assessment was based on oral ingestion (Jia *et al.* 2020; Edogbo *et al.* 2020).

Exposure level assessment: Equation 1 provided by Institute National De Veille Sanitaire and World Health Organization was applied to determine the levels of exposure (INVS 2002, WHO, 2011). In this study, body weights of 70kg and 10kg respectively were allocated to adults and teenagers from 5 to 14 years while 5kg was assigned to infants less than 5 years of age. The dataset was subjected to correlation analysis. (INVS, 2002, WHO, 2011)

$$\text{MDI} = \frac{\text{BW x ADI x Measured Value}}{\text{X}} \qquad 1$$

Where MDI = Maximum Daily Intake (mg/L); X = Quantity of water consumed per day (mg/L)

Determination of Health Risk (HR)/Level of Exposure (INVS, 2002)

$$Risk\ (R) = \frac{MDI}{ADI} \text{.........} 2$$

Where ADI = Acceptable Daily Intake; R < 1 is defined as low; R = 1 is defined as medium; R > 1 is defined as high

Contamination plume: Groundwater contamination plume was model by using ArcGIS. The inverse distance weighting (IDW) interpolation approach was considered by the using the equation 3

$$\check{v}_1 = \frac{\sum_{i=1}^{n} \frac{1}{d_i^p} v_i}{\sum_{i=1}^{n} \frac{1}{d_i^p}} \qquad 3$$

v ˆ = value to be estimated; v i = known value; $d^p{}_i$..., $d^p{}_n$ = distances from the n data points to the power of p of the point estimate

RESULTS AND DISCUSSION

The results obtained in the study areas (Asoro, Ikhueniro and Otofure) showed that the risk quotient (RQ) for adults were > 1 implying high level of exposure of the adults in the communities to Cr, Pb, Ni & Fe (Tables 3, 4, 5 & 6). The adult category range from16years of age and above; this constitute 33.99% (59) of the total population assessed (Table 7). On the other hand, the children under the ages of 0 – 4 years contributed 28.67% (43), whereas the teenagers ranging from 5-15 years of age consist of 32% (48) of the total population. In Otofure, RQ for teenagers and infants for Chromium were 0.38 and 0.26 (< 1) respectively; this is defined as low risk (Table 3 & 8). Similarly, Pb RQ in Otofure and Ikhueniro for teenagers and infants respectively range from 1 to > 1, indicating medium to high level of exposure. The result of Ni for adult, teenager and infants were < 1 (Table 5) indicating low risk. More worrisome is the RQ of Fe recorded in the groundwater for the three locations under study; RQ for adult ranged from 168 in Ikhueniro and Otofure to 229.17 in Asoro, and 48 to 65.48 while in 32 to 291 were recorded in infants within the age brackets of 0 – 4 years (Table 6).

Table 3 Health risk assessment of Chromium based on sample analysis

Location	MDI			ADI	Risks = MDI/ADI		
	Adult 16yrs above	Teenager 5-15yrs	Infants 0-4yrs		Adult 16yrs Above	Teenager 5-15yrs	Infants 0-4yrs
Ikhueniro	0.175	0.05	0.167	0.05	3.5	1.00	3.34
Asoro	0.981	1.394	0.921	0.05	19.62	27.88	18.42
Otofure	0.066	0.019	0.013	0.05	1.32	0.38	0.26

Table 4 Health risk assessment of Lead based on sample analysis (mg/L)

Location	MDI				Risks = MDI/ADI		
	Adult 16yrs Above	Teenager 5-15yrs	Infants 0-4yrs	ADI	Adult 16yrs Above	Teenager 5-15yrs	Infants 0-4yrs
Ikhueniro	0.003	0.001	0.001	0.010	0.300	0.100	0.100
Asoro	0.081	0.023	0.015	0.010	8.100	2.300	1.500
Otofure	0.003	0.001	0.001	0.010	0.300	0.100	0.100

High or low levels of exposure to heavy metal can cause myriad health problems. For example, Fe, Cr, Pb & Ni concentration at high level can lead to cancer and reproductive dysfunction (Jaishankar *et al.* 2014; Engwa *et al.* 2019; Edogbo *et al.* 2020). High concentrations of Pb have been reported from groundwater around the globe resulting in low intelligent quotient (Tailor *et al.* 2010; Omorogieva, 2018; Edogbo *et al.* 2020).

Table 5 Health risk assessment of Ni based on sample analysis (mg/L)

Location	MDI				Risks = MDI/ADI		
	Adult 16yrs above	Teenager 5-15yrs	Infants 0-4yrs	ADI	Adult 16yrs Above	Teenager 5-15yrs	Infants 0-4yrs
Ikhueniro	0.01	0.003	0.002	0.02	0.53	0.15	0.10
Asoro	1.862	0.021	0.355	0.02	93.1	1.05	17.75
Otofure	0.224	0.003	0.021	0.02	11.2	0.15	1.05

Table 6 Health risk assessment of iron based on sample analysis (mg/L)

Location	MDI			ADI	Risks = MDI/ADI		
	Adult 16yrs above	Teenager 5-15yrs	Infants 0-4yrs		Adult 16yrs Above	Teenager 5-15yrs	Infants 0-4yrs
Ikhueniro	50.40	14.40	49.60	0.30	168.00	48.00	32.00
Asoro	458.33	130.95	87.30	0.30	229.17	65.48	291.00
Otofure	50.40	14.40	9.60	0.30	168.00	48.00	32.00

Table 7 Demographic information

Variable	Attributes	Frequency	Percentage (%)
Age	0 – 10	43	28.67
	11 – 20	48	32.00
	21 – 30	18	12.00
	31 – 40	16	10.67
	41 – 50	17	11.33
	51 – 60	3	2.00
	61 – 70	5	3.33
Sex	Male	70	46.67
	Female	80	53.33
Martial	Single	99	66.00
	Married	51	34.00
Educational Attainment	None	8	5.33
	Kg 1- 3	16	10.67
	Primary	44	29.33
	Secondary	69	46.00
	University	13	8.67

Table 8 Water consumption dataset

Variable	Attributes	Frequency		Percentage (%)	
		Yes	No	Yes	No
Do you drink water from your well?	Children	5	48	3.33	32.00
	Teenager	5	26	3.33	17.33
	Adult	13	53	8.67	35.33
Do you drink water from your borehole?	Children	51	2	34.00	1.33
	Teenager	28	3	18.67	2.00
	Adult	59	7	39.33	4.67
Do you treat the water before drinking it?	Children	16	37	10.67	24.67
	Teenager	8	23	5.33	15.33
	Adult	5	61	3.33	40.67
How do you treat your water?	Boiling	21	129	14.00	86.00
	Application of alum	8	142	5.33	94.67
Do you have alternative source of drinking water	Sachet water	138	12	92.00	8.00
	Rain water	1	149	0.67	99.33
	Well	11	139	7.33	92.67
How long have you been drinking this water?	0 – 2 years	34	116	22.67	77.33
	3 – 5 years	50	100	33.33	66.67
	6 – 8 years	45	105	30.00	70.00
	9 – 11 years	8	142	5.33	94.67
	12 years up	2	148	1.33	98.67
	Other sources	11	139	7.33	92.67

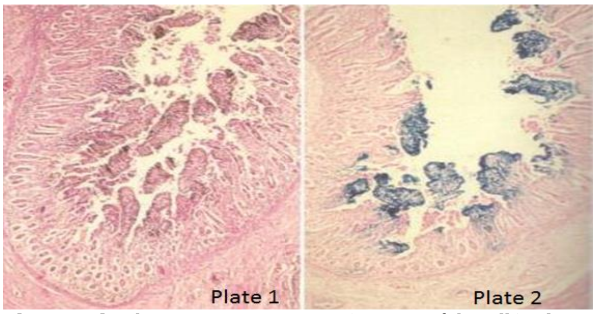

Plate 1 and 2 shows acute iron toxicity (necrosis of the villi). Plate 2 Iron encrustation of the necrotic intestinal villi, adapted from Selinus *et al.* (2013)

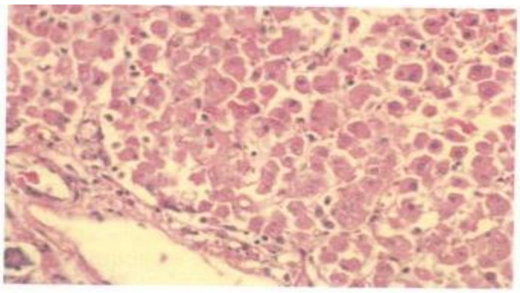

Plate 3. Degeneration of the liver cells as a result of iron toxicity (section of the liver of same patience in plate 1 and 2).

Apart from causing kidney dysfunction, it also affects reproductive system, liver, and brain as well as central nervous system (CNS); this may eventually result in death of the victim. Exposure to environmental Pb can also result in mental retardation in children (Bhatia, 2002; Taylor *et al.* 2010; Jaishankar *et al.* 2014). Excess of iron (Fe) overload in the human system can cause gene mutation, a health situation known as hemochromatosis (Plate 1 and 2). Plate 1 show an acute iron toxicity while plate 2 represents the portion of the villi of the same Liver that has been affected by excess iron ingestion leading to necrosis of the villi (Selinus *et al.* 2013); furthermore, Plate 3 represents the degeneration of the liver cells in plate 1 & 2 as a result of iron toxicity. In addition to health problems constituted by excess iron in drinking water; it also has environmental problem of staining container and affects plants growth (https://www.livestrong.com/acticle). Nickel, Lead and Chromium are well known for their health and environmental impacts. For example, they are known to be carcinogenic, respiratory and birth defects (Bakare–Odunola, 2005; Taylor, 2010); Brain damage and cardiovascular disease (WHO, 2001; ATSDR, 2012), short breath, sperm damage as well as impact on pregnant women (Elis *et al.* 2001, Adimalla *et al.* 2020). Grahame *et al.* (2014), Li and Gibson (2014) demonstrated that short term exposure to residual burning of biomass can have adverse pulmonary effects and reduces the human immune defense. Furthermore, Hime *et al.* 2015) in a review of toxicology, epidemiology and clinical trial studies affirm that domestic wood burning, forest fires and crustal dust can negatively affect the respiratory system especially in children under the ages of 5 years. The health history dataset obtained in the study showed that hyper salivation, one of the symptoms associated with acute heavy metal concentration in humans has an exposure frequency of 13 in infants, 10 in teenagers and 21 in adults (Table 9).

Table 9 Dataset of health history obtained from field survey

Variable	Attributes	Frequency		Percentage (%)	
		Yes	No	Yes	No
Blood in urine	Children	Nil	53	0.00	35.33
	Teenager	Nil	31	0.00	20.67
	Adult	Nil	66	0.00	44.00
Hyper salivation	Children	13	40	8.67	26.67
	Teenager	10	21	6.67	14.00
	Adult	21	45	14.00	30.00
Seizure disorder	Children	1	52	0.70	34.67
	Teenager	2	29	1.30	19.33
	Adult	1	66	0.70	44.00
Skin rashes	Children	15	38	10.00	25.33
	Teenager	9	22	6.00	14.67
	Adult	23	43	15.33	28.67
Heart pain	Children	5	48	3.33	32.00
	Teenager	5	26	3.33	17.33
	Adult	15	51	10.00	34.00

In the same vein, Seizure disorder, skin rashes, heart and joints pain as a symptoms of heavy metal load in human system were also reported at various frequencies in this study. For example, 1 infant, 2 teenagers & 1 adult were recorded during health survey to have experience regular seizure disorder; 15 infants, 9 teenagers and 23 adults for skin rashes while 5 infants and teenagers respectively as well as 15 adults confirm the symptoms in then. Heavy metals have been linked to various sources in the geoenvironment including waste dumpsite, industrial and vehicular emissions (Searle *et al.* 2001; Mandishona *et al.* 1998; Omorogieva and Tonjoh, 2020 Edogbo *et al.* 2020; Adimalla *et al.* 2020). Figure 4 – 6 represents the spatial distribution and the spreading model of Cr, Pb, Ni and Fe in the aquifers as the source of groundwater sampled in the study area. The figures indicated that these heavy metals have a higher concentration values from sampling points and gradually reduces in the direction of groundwater flow. The high concentration at the point of sampling was influenced by the deeply excavated pits laden with environmental toxicants from dumped municipal wastes including heavy metals (Giri and Singh 2015; Engwa *et al.* 2019; Omorogieva and Andre-Obayanju, 2020; Zhou *et al.* 2020). It is evidence that high consumption rate of groundwater from borehole located within and around these sites through oral ingestion has contributed to the health challenge recorded in the study (Fig. 8 and Table 9). This was further juxtaposed by the correlation matrix in Table 10. Chromium correlated strongly with Fe, Ni and Pb with a correlation coefficient of 0.8823, 0.8241 and 0.7458 respectively.

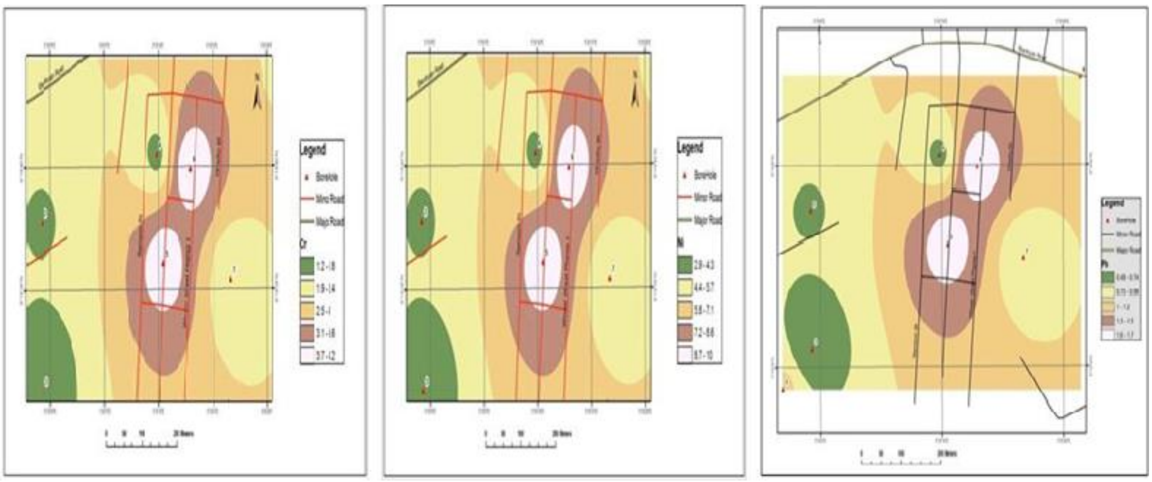

Fig 4 Spatial distribution and spreading model of Cr, Ni & Pb in Asoro aquifer

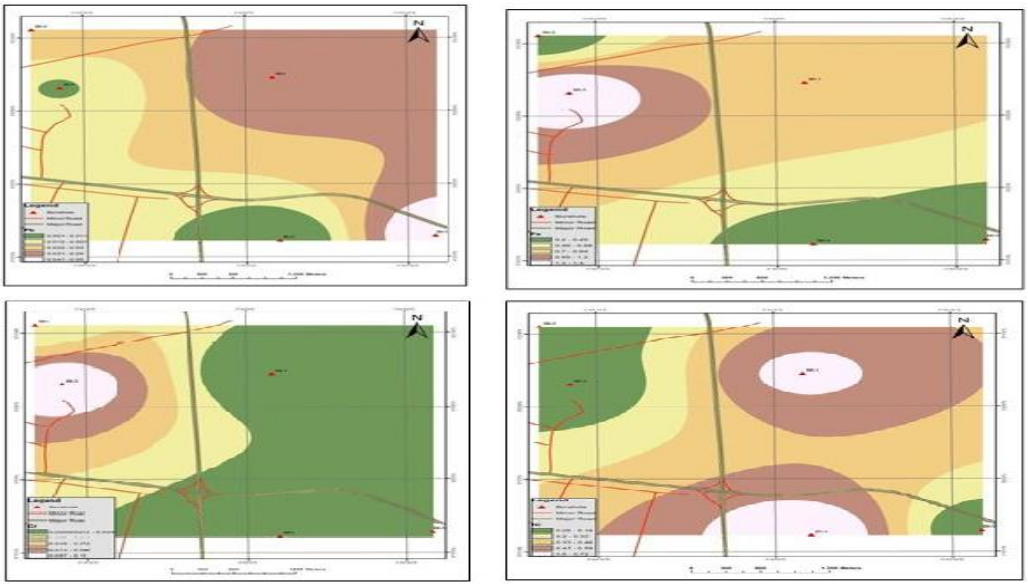

Fig 5 Spatial distribution and spreading model of Cr, Ni & Pb in Ikhueniro aquifer

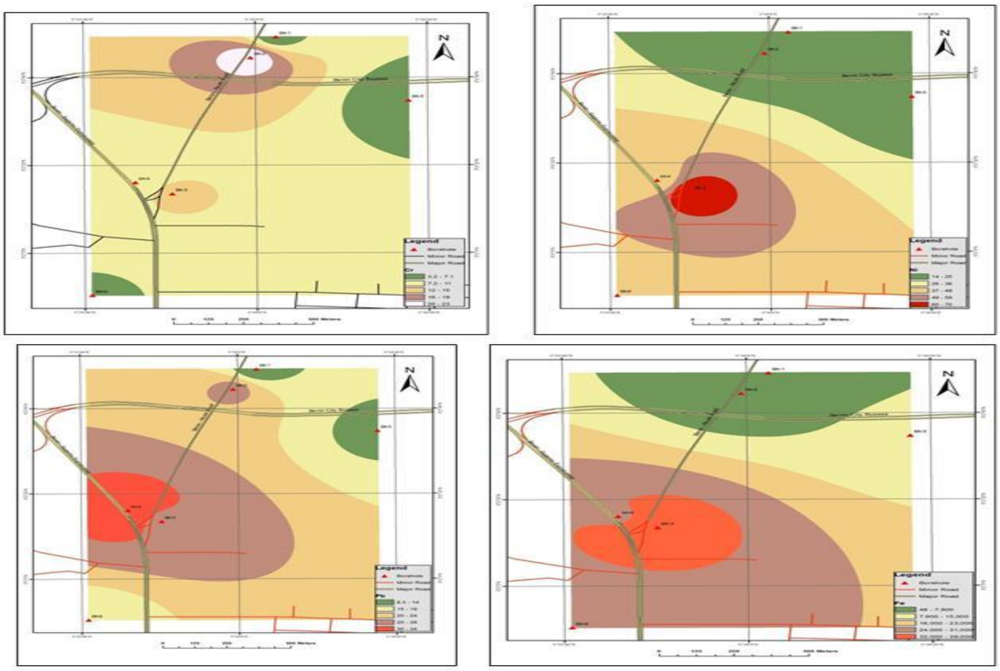

Fig 6 Spatial distribution and spreading model of Cr, Ni & Pb in Otofure aquifer

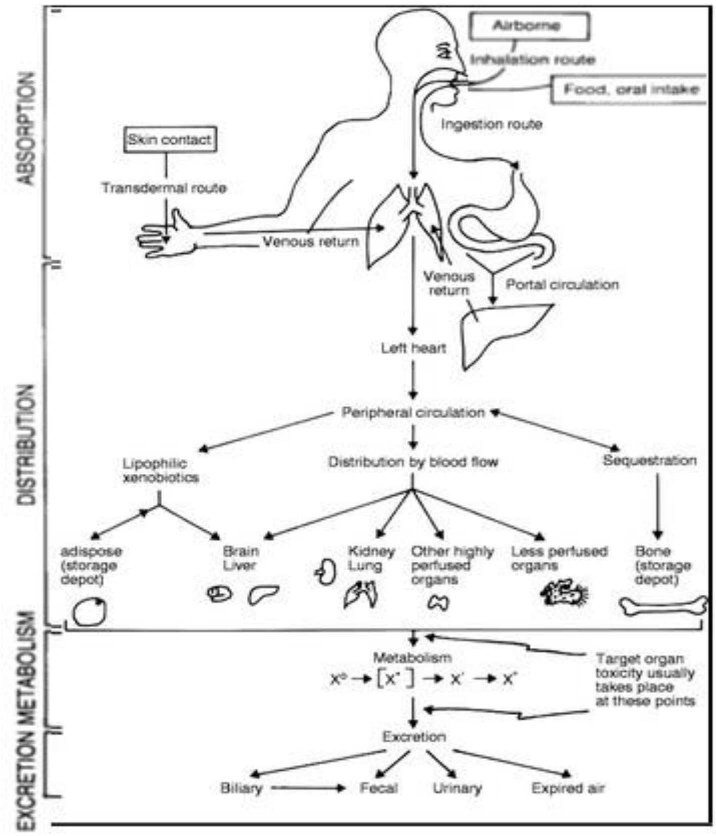

Fig. 8: pathway of groundwater ingestion (toxikenetics, absorption, distribution, metabolism and excretion) after Selinus et al. (2013)

Iron has a coefficient value of 0.6878 while Pb and Ni have a coefficient of 0.7233. Positive correlation is an indication that the heavy metals are from a similar source (Omorogieva and Tonjoh, 2020). Generally, iron can be removed from groundwater by the process of aeration or chemical oxidation followed by rapid sand filtration. However, banana ash pseudostem has been found to be most suitable for removal of iron in groundwater; it is cheap, coast effective and be source locally (Sharma *et al.* 2005, Das *et al.* 2006). Heavy metal like Pb, Cr and Ni can be removed from groundwater by chemical precipitation, ex situ remediation (solidification/stabilization, soil washing, vitrification and pyrometallurgic separation); these methods are coast effective and commercially available (Eyanko and Dzombak, 1997) According to Adikesavan *et al.* (2019), integrated approaches were found to serve as a better and an effective alternative for removal of toxic heavy metals as well as recovery of valuable metals from highly contaminated industrial sites; Electrokinetic (EK) processes and phyto-remediation had shown astonishing results in this regard with little or no disturbance to the natural environment. No doubt that anthropogenic activities arising from increase in population and technological advancement have contributed significantly to background values of heavy metal presence in the environment. A strict monitoring and compliance to environmental laws is advocated the best method of groundwater contamination of heavy metal.

Conclusion: This study has demonstrated the effectiveness of a scientific survey by using a structured questionnaire in assessing the level of exposure and health risk arising from consumption groundwater contaminated with heavy metal, as well as the application of ArcGIS in modeling groundwater contamination plume. The study revealed that groundwater quality of the studied areas has been compromised; consequently exposing the consumers of the groundwater derived from the contaminated boreholes in the communities to high health risk due to ecosystem interaction. Furthermore, the study revealed that the entire population in the study area is at risk of the health challenges that are associated with the heavy metal assessed. As a result, urgent attention by stakeholders, especially government is required to remedy the situation in view of the environmental and health impacts associated with in indiscriminate dumping of refuse in open sites without the necessary precautionary measures put in place.

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