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Assessment of Concentration and Health Indices of Selected Heavy Metals in Borehole Water in Ogwashi-Uku and its Satellite Towns in Delta State, Nigeria

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ABSTRACT: With increasing dependence on borehole water due to surface water contamination from industrial activities and urbanization, understanding the quality of groundwater has become critical. Hence, the objective of this paper was to determine the concentration and health indices of selected heavy metals in borehole water in Ogwashi-Uku and its satellite towns in Delta State, Nigeria using appropriate standard methods. Data obtained show that the mean concentrations found were Cu (0.1233 ppm), Pb (0.078 ppm),Cd (0.016 ppm), and Zn (0.180 ppm). Notably, Pb levels were concerning in several samples,suggesting potential health risks associated with prolonged exposure. Using the Estimated Daily Intake (EDI), Target Hazard Quotient (THQ) and Target Cancer Risks (TCR), the results indicated that while some heavy metal concentrations exceeded World Health Organization (WHO) recommended limits, others remained within acceptable thresholds. The study underscores the necessity for ongoing monitoring and regulation of groundwater quality to safeguard public health in the region, calls for further research into the sources of contamination and the implementation of effective water management strategies.

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Water is an essential and abundant natural resource crucial for the survival of humans, animals, and all living organisms. It reflects the geological features of the surrounding environment and serves various purposes, including domestic, agricultural, and industrial uses (Aswal*et al.*, 2023; Ewool*et al.*, 2024; Abba *et al.*, 2024). The quality and portability of water for these purposes depend on three key properties: physical, chemical, and biological (Akter*et al.*, 2016; Appiah-Opong*et al.*, 2021; Dippong*et al.*, 2023).Water can be categorized as either surface water or groundwater. Groundwater is trapped and stored beneath the earth's surface in soil and rock formations. Most rocks are primarily composed of inorganic substances that interact with groundwater, potentially dissolving various inorganic elements such as copper (Cu), lead (Pb), cadmium (Cd), zinc (Zn), and other metals. However, anthropogenic factors, (Dippong*et al.*, 2023; Mihali and Dippong, 2023; Obiri, 2007; Asante *et al.*, 2006; Smedley and Kinniburgh, 2002; Birch *et al.*, 1996; Gbedzi*et al.*, 2022) such as urbanization, mining, and industrial activities, significantly impact water quality, leading to pollution and contamination. Consequently, there is a pressing need for thorough studies on water quality to assess its suitability for drinking purposes.Over the past seven

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years, the dependency on surface water for human consumption has drastically decreased, resulting in a surge in borehole drilling. This increase is primarily due to surface water pollution and contamination following the construction of the Ogwashi-Uku earth dam, the rice milling industry, and more recently, the Ubu River Bridge along the Asaba-Ogwashi-Ughelli expressway. These developments have raised concerns among the local populace regarding the safety and portability of surface water. As a result, more individuals are opting for borehole water over surface water (Baba *et al.,* 2008).

While trace elements of heavy metals are essential for human health (Baba *et al.,* 2008), the types and amounts of heavy metals to which individuals are exposed can vary based on several factors (Baba *et al*., 2008).

There have been reports of heavy metal pollution and contamination in water across Nigeria (Bawa-Allah, 2023; Wasiu *et al.,* 2016; Ehiemere *et al.,* 2022; Okareh *et al.,* 2023; Obasi and Akudinobi, 2020) and elsewhere (Abba *et al.,* 2024; Gümgüm *et al.,* 1994; Fernandez-Luqueno *et al.,* 2013; Kumar *et al.,* 2020; Hadzi*et al.,* 2018; Asare *et al.,* 2023). Heavy metals have been assessed in groundwater (Asante *et al.,* 2006; Hadzi *et al.,* 2018; Shaji *et al.,* 2021). When the concentration of heavy metals in groundwater exceeds recommended limits and humans are overexposed, they can become harmful and toxic to health (Kar *et al.,* 2008; Dippong *et al.,* 2022; Fernandez-Luqueno *et al.,* 2013; Shaji *et al.,* 2021; Agbasi and Egbueri, 2022).Regulatory standards have been established to define acceptable limits for heavy metal composition in water (Agbasi and Egbueri, 2022). The objectives of this study are to determine the concentration and health indices of selected heavy metals in borehole water in Ogwashi-Uku and its satellite towns in Delta State, Nigeria.

MATERIALS AND METHODS

Study Area: The study was carried out in Ogwashi-Uku which is the administrative headquarters of Aniocha South Local Government Area.The coordinates of Ogwashi-Uku town lies between $6^{0}10'$ 59.06" N and $6^{0}31'$ 27.72" E. (Fig. 1) (Ijabor *et al.,*2023).

The research will cover all of Ogwashi-Uku and its satellite towns allowing for the comparison of different regions and their respective levels of heavy metal concentration. The research will focus on selecting representative sampling points in Ogwashi-Uku and its satellite towns, taking into account various factors such as proximity to potential sources of contamination (industrial areas, agricultural lands, urban centers), different reaches of the river (upstream, downstream), and areas with different land uses (residential, commercial, agricultural, industrial). Ogwashi-Uku is found in the Niger Delta Structural Basin region in which three sedimentary cycles have occurred. The Benin, the Agbada and the Akata formations are the three subsurface stratigraphic associated with this sedimentary cycles (Ijabor *et al.,* 2023).

Sample Collecting and Preparation: The samples were collected from 26 different points within the study area. Sampling point was chosen as to cover the entire study area. The samples were collected between July and August 2024 following recommended procedures. The water samples were collected directly from the boreholes. The water samples were collected from hostels, schools, hotels, business centres, shopping malls, and residential buildings.

Several 500 mL container were used to collect sample. These containers have been washed with detergent and rinsed with the borehole water then soaked in nitric solution for 24 hours. Before collecting samples into containers, the borehole water which flows through pipes was allowed to run for at least 2 minutes (Akter *et al.,* 2016; Ijabor *et al.,*2024; Rahman *et al.,* 2019; Reza and Singh, 2010; Adhikary *et al.,* 2012). All collected water samples were acidified concentrated nitric acid. This was done to prevent precipitation and allow metals remain in solution and also to prevent metals from sticking to the container wall (Aswal *et al.,* 2023; Mihali and Dippong, 2023; Sharma and Tyagi 2013; Ullah *et al.,* 2023).The results of the analysis for heavy metals concentration in borehole water samples for Ogwashi-Uku and its satellite towns are presented in Table 1 and discussed. The heavy metals detected are Copper (Cu), Lead (Pb), Cadmium (Cd) and Zinc (Zn). Table 1 also provides names of sampling points.Table 2 presents the pH, conductivity, turbidity and total dissolved solid of the borehole water with obtained values measured immediately after each sample collection.

Water Analysis: The assessment of heavy metals (Cu, Pb, Cd and Zn) was conducted using a Varian AA240 Atomic Absorption Spectrophometer. The physiochemical parameters of the borehole water sample, including pH electrical conductivity, turbidity and total dissolved solids (TDS), were measured using a portable Orion Star A215 pH/Conductivity Meter from Thermo Scientific, USA.

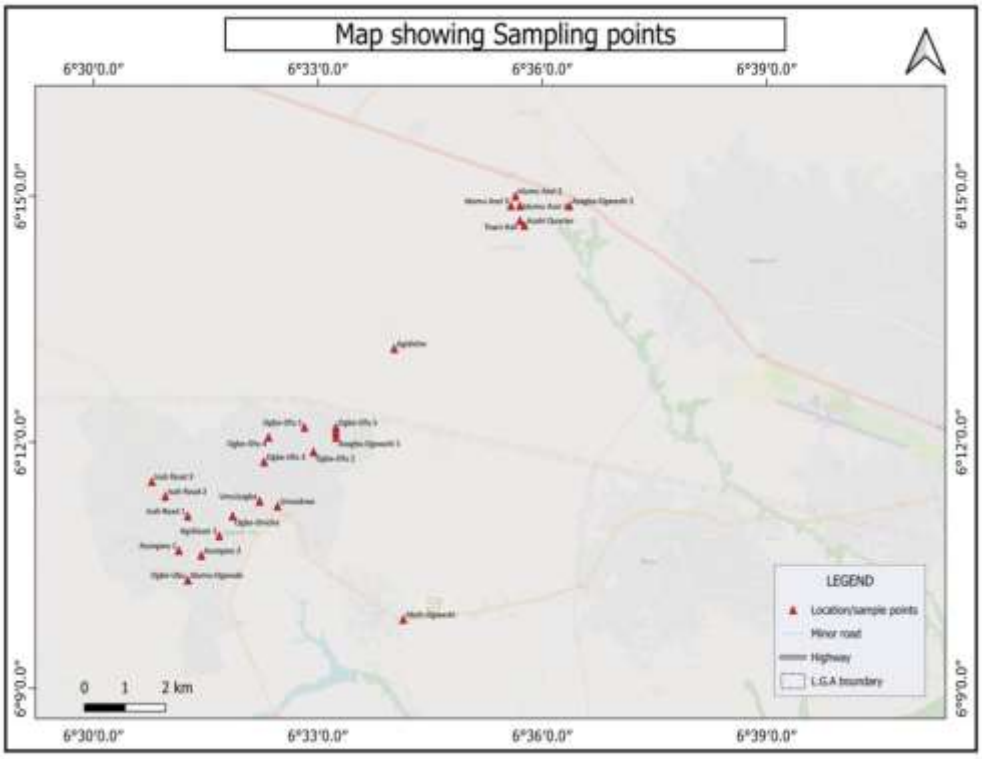

Fig. 1: Map of the Study Area

Heavy metals levels in drinking water types: The heavy metal levels in the borehole water sample collected are presented in Table 1. In Ogwashi-Uku and its satellite towns, the concentration of metals in the borehole water sample was in the order Cu>Zn >Pb> Cd.

RESULTS AND DISCUSSION

The mean concentration of Cu, Pb, Cd and Zn in borehole water for Ogwashi-Uku and its satellite towns was 0.1233, 0.078, 0.016 and 0.180 ppm respectively. Cu was not detected in borehole water of Ogbe-Ubu and Umuokwe. The level of Cu was highest in Ogbe-Ofu 3 with value 0.969 ppm followed by 0.488 ppm in Agidiasei 1.

The lowest level of Cu with value 0.0055 ppm was obtained in Azungwu 2 followed by 0.0072 ppm in Idumu-Ogwude. For level of Cu detected in the water samples from the boreholes was below the maximum allowed limit of 2.000 for Cu set by the World Health Organization (WHO). The highest level of Pb obtained in all sample of borehole water is 0.198 ppm at Isah Road 1 followed by Idumu Ogwude with value of 0.192 ppm. The least value of Cu was obtained at Isah Road 2 with a value of 0.002 ppm Idumu Asei 3 with a value of 0.010 ppm. These values for Cu obtained in all borehole water samples appear to be to be higher than WHO recommended limit of 0.010 ppm except for value obtained at Isah Road 2.Cadmium has its highest value as 0.043 ppm recorded at Ogbe-Ofu 4 and lowest value of 0.001 ppm obtained at Idumu Asei 2. All obtained Cd values in all sampled borehole water are higher than 0.003 ppm which is the recommended limit set by WHO. The highest value of Zinc (Zn) obtained is 0.389 ppm at Agidiehe followed by 0.278 ppm at Ogbe-Ubu. Azagba-Ogwashi 1 had least recorded value of 0.078 ppm followed Ogbe-Ofu 4 with value of 0.087 ppm.

However, all values recorded for Zn in Ogwashi-Uku and its satellite towns are below WHO permissible limit of 3.000 ppm.Table 1 is also a comparison of the values of analyzed metal with WHO recommended limits (WHO, 2017). As shown in table 1, the concentrations of metals analyzed for the borehole water sample in Ogwahsi-Uku and its satellite towns were all below the WHO recommended limit, except for average Pb and Zn levels that are above the WHO recommended limit.The Electrical Conductivity (EC) which is directly proportional to the salinity of the water has values ranging from 2.82 to 102.5 µSm/cm. The highest value was obtained at the borehole in Idumu Asei 3 and the lowest value was obtained at Idumu Asei 1.

Table 1: Concentrations (mg/L) of Heavy Metals in the Borehole Water of Ogwashi-Uku and its Satellite Towns

Samples points	Copper ppm	Lead ppm	Cadmium ppm	Zinc ppm
Asahi Quarter	0.0438	0.042	0.017	0.178
Town Hall	0.1588	0.063	0.008	0.147
IdumuAsei 1	0.1277	0.093	0.029	0.178
IdumuAsei 2	0.0986	0.083	0.001	0.178
IdumuAsei 3	0.0801	0.010	0.005	0.162
Ogbe-Ofu 1	0.0880	0.036	0.027	0.160
Ogbe-Ofu 2	0.1039	0.169	0.016	0.139
Ogbe-Ofu 3	0.969	0.134	0.018	0.128
Umuisagba	0.0777	0.100	0.007	0.194
Ogbe-Onicha	0.0596	0.017	0.010	0.138
Agidiasei 1	0.488	0.082	0.036	0.562
Isah Road 1	0.0355	0.198	0.028	0.189
Isah Road 2	0.0250	0.002	0.002	0.146
Isah Road 3	0.0193	0.034	0.004	0.120
Azungwu 1	0.0094	0.022	0.018	0.149
Azungwu 2	0.0055	0.012	0.010	0.130
Idumu-Ogwude	0.0072	0.192	0.035	0.108
Ogbe-Ubu	0.00	0.079	0.026	0.278
Umuokwe	0.00	0.025	0.020	0.227
Aboh-Ogwashi	0.0308	0.145	0.027	0.139
Ogbe-Ofu 4	0.0451	0.084	0.043	0.087
Ogbe-Ofu 5	0.0953	0.143	0.027	0.187
Agidiehe 1	0.0888	0.056	0.018	0.389
Azagba-Ogwashi 1	0.1879	0.048	0.026	0.078
Agidiehe 2	0.2075	0.077	0.018	0.149
Azagba-Ogwashi 2	0.1537	0.093	0.007	0.128
Mean	0.1233	0.078	0.016	0.180
WHO Limit	2.0000	0.010	0.003	3.000

Table 2: Physiochemical Properties of Water Sample for the Boreholes in Ogwashi-Uku

S/N	Samples	pH	Conductivity (µSm/cm)	Turbidity	Weight of noncable	Drivable + residue	TDS (Mg/L)	
1	Asahi Quarter	5.40	42.2	-05.4	45.385	45.389	0.8	8
2	Town Hall	5.47	22.6	-02.6	48.993	48.999	1.2	12
3	IdumuAsei 1	5.88	2.82	-03.4	47.213	47.223	2.0	20
4	IdumuAsei 2	5.57	14.6	-04.6	52.147	52.154	1.4	14
5	IdumuAsei 3	7.83	102.5	-04.5	62.957	62. 999	2.0	20
6	Ogbe-Ofu 1	5.92	44.5	-04.0	46.904	46.912	1.6	16
7	Ogbe-Ofu 2	5.51	29.1	-04.1	51.837	51.843	1.2	12
8	Ogbe-Ofu 3	5.29	16.8	-04.6	56.467	59.473	1.2	12
9	Umuisagba	6.45	31.6	-05.2	52.147	52.153	1.2	12
10	Ogbe-Onicha	6.02	38..8	-04.4	45.277	45.282	11.0	110
11	Agidiasei 1	5.27	36.0	-03.4	45.787	45.792	1.0	10
12	Isah Road 1	6.46	21.3	-02.2	45.063	45.068	1.0	10
13	Isah Road 2	6.31	19.1	-04.5	52.486	52.493	1.4	14
14	Isah Road 3	6.25	20.0	-02.0	52.487	52.493	1.2	12
15	Azungwu 1	5.50	57.5	-02.7	47.667	47.679	2.4	24
16	Azungwu 2	5.51	29.2	-02.1	52.932	52.942	2.0	20
17	Idumu-Ogwude	5.53	19.7	-02.3	42.743	42.751	1.6	16
18	Ogbe-Ubu	5.82	76.0	-03.8	60.319	60.326	1.4	14
19	Umuokwe	5.30	15.8	-01.8	50.197	50.204	1.4	14
20	Aboh-Ogwashi	5.75	18.0	-02.1	59.461	59.466	1.0	10
21	Ogbe-Ofu 4	5.50	14.6	-02.5	46.245	46.254	1.8	18
22	Ogbe-Ofu 5	5.38	13.4	-0.48	48.556	48.564	1.6	16
23	Agidiehe	5.88	15.6	-04.0	45.612	45.622	2.0	20
24	Azagba-Ogwashi 1	6.85	16.8	-04.6	60.703	60.709	1.2	12
25	Agidiehe	5.58	12.7	-02.3	46.595	46.599	0.8	8
26	Azagba-Ogwashi 2	5.53	18.8	-02.0	48.217	48.228	2.2	22

The results of the EDI of individual heavy metals were determined by using equation suggested by Dhar *et al* (2021). THQ (non-carcinogenic health risks) and TCR (carcinogenic health risks) for water obtained at the different sampling points were calculated using equations suggested by Dhar *et al* (2021) and results are presented in Table 3, 4 and 5. The EDI values of Cu, Pb, Cd and Zn for adults ranged from 0−0.0047725, 0.00023−0.004416, 0.000023−0.000989, and 0.001794−0.012926, µg/kg−BW−day respectively. The EDI values of each heavy metal are very low when compared with

recommended limit of 1 as suggested by the New York State Department of Health. The ratio of EDI to rfd for this study is less than 1.0 which is also evident in figure 2, implying that these metals do not pose any potential health risks (Dhar *et al.*, 2021).

Table 3: Estimated Daily Intake (EDI) of Water Sample in Ogwashi-Uku

S/N	Sample points	Copper ppm	Lead ppm	Cadmium ppm	Zinc ppm
1	Asahi Quarter	0.0010074	0.000966	0.000391	0.004094
2	Town Hall	0.0036524	0.001449	0.000184	0.003381
3	IdumuAsei 1	0.0029371	0.002139	0.000667	0.004094
4	IdumuAsei 2	0.0022678	0.001909	0.000023	0.004094
5	IdumuAsei 3	0.0018423	0.00023	0.000115	0.003726
6	Ogbe-Ofu 1	0.002024	0.000828	0.000621	0.00368
7	Ogbe-Ofu 2	0.0023897	0.003887	0.000368	0.003197
8	Ogbe-Ofu 3	0.022287	0.003082	0.000414	0.002944
9	Umuisagba	0.0017871	0.0023	0.000161	0.004462
10	Ogbe-Onicha	0.0013708	0.000391	0.00023	0.003174
11	Agidiasei 1	0.011224	0.001886	0.000828	0.012926
12	Isah Road 1	0.0008165	0.004554	0.000644	0.004347
13	Isah Road 2	0.000575	0.000046	0.000046	0.003358
14	Isah Road 3	0.0004439	0.000782	0.000092	0.00276
15	Azungwu 1	0.0002162	0.000506	0.000414	0.003427
16	Azungwu 2	0.0001265	0.000276	0.00023	0.00299
17	Idumu-Ogwude	0.0001656	0.004416	0.000805	0.002484
18	Ogbe-Ubu	0	0.001817	0.000598	0.006394
19	Umuokwe	0	0.000575	0.00046	0.005221
20	Aboh-Ogwashi	0.0007084	0.003335	0.000621	0.003197
21	Ogbe-Ofu 4	0.0010373	0.001932	0.000989	0.002001
22	Ogbe-Ofu 5	0.0021919	0.003289	0.000621	0.004301
23	Agidiehe	0.0020424	0.001288	0.000414	0.008947
24	Azagba-Ogwashi 1	0.0043217	0.001104	0.000598	0.001794
25	Agidiehe	0.0047725	0.001771	0.000414	0.003427
26	Azagba-Ogwashi 2	0.0035351	0.002139	0.000161	0.002944

Table 4: Target Hazard Quotient (THQ) of Water Sample in Ogwashi-Uku

S/N	Samples points	Copper ppm	Lead ppm	Cadmium ppm	Zinc ppm
1	Asahi Quarter	2.50098E-05	0.002394	0.000391	1.3546E-05
2	Town Hall	9.06748E-05	0.003591	0.000184	1.1187E-05
3	IdumuAsei 1	7.29167E-05	0.005301	0.000667	1.3546E-05
4	IdumuAsei 2	5.63006E-05	0.004731	0.000023	1.3546E-05
5	IdumuAsei 3	4.57371E-05	0.00057	0.000115	1.2328E-05
6	Ogbe-Ofu 1	0.000050248	0.002052	0.000621	1.2176E-05
7	Ogbe-Ofu 2	5.93269E-05	0.009633	0.000368	1.0578E-05
8	Ogbe-Ofu 3	0.000553299	0.007638	0.000414	9.7408E-06
9	Umuisagba	4.43667E-05	0.0057	0.000161	1.4763E-05
10	Ogbe-Onicha	3.40316E-05	0.000969	0.00023	1.0502E-05
11	Agidiasei 1	0.000278648	0.004674	0.000828	4.2768E-05
12	Isah Road 1	2.02705E-05	0.011286	0.000644	1.4383E-05
13	Isah Road 2	0.000014275	0.000114	0.000046	1.1111E-05
14	Isah Road 3	1.10203E-05	0.001938	0.000092	9.132E-06
15	Azungwu 1	5.3674E-06	0.001254	0.000414	1.1339E-05
16	Azungwu 2	3.1405E-06	0.000684	0.00023	9.893E-06
17	Idumu-Ogwude	4.1112E-06	0.010944	0.000805	8.2188E-06
18	Ogbe-Ubu	0	0.004503	0.000598	2.1156E-05
19	Umuokwe	0	0.001425	0.00046	1.7275E-05
20	Aboh-Ogwashi	1.75868E-05	0.008265	0.000621	1.0578E-05
21	Ogbe-Ofu 4	2.57521E-05	0.004788	0.000989	6.6207E-06
22	Ogbe-Ofu 5	5.44163E-05	0.008151	0.000621	1.4231E-05
23	Agidiehe	5.07048E-05	0.003192	0.000414	2.9603E-05
24	Azagba-Ogwashi 1	0.000107291	0.002736	0.000598	5.9358E-06
25	Agidiehe	0.000118483	0.004389	0.000414	1.1339E-05
26	Azagba-Ogwashi 2	8.77627E-05	0.005301	0.000161	9.7408E-06

THQ values for the metals considered as shown in Table 4 and shown in figure 3. They are also less than 1. This implies non-carcinogenic risk for adults consuming the borehole water.

TCR is used to estimates the possibility of developing cancer due to overexposure to a specific carcinogen (Dhar *et al.*, 2021). Due to the absence of CSF for Cu and Zn, the TCR was calculated only for Pb and Cd.

The values calculated for TCR is presented in Table 5 and its comparison with the sampled locations is shown in figure 4. USEPA permissible limit for TCR is 10^{-4} (USEPA, 2019). The values of TCR obtained in this study are all lower than USEPA recommended limit.

Table 5: Target Cancer Risks (TCR) of Water Sample in Ogwashi-Uku

S/N	Samples points	Lead ppm	Cadmium ppm
1	Asahi Quarter	9.996E-09	1.21295E-08
2	Town Hall	1.4994E-08	5.708E-09
3	IdumuAsei 1	2.2134E-08	2.06915E-08
4	IdumuAsei 2	1.9754E-08	7.135E-10
5	IdumuAsei 3	2.38E-09	3.5675E-09
6	Ogbe-Ofu 1	8.568E-09	1.92645E-08
7	Ogbe-Ofu 2	4.0222E-08	1.1416E-08
8	Ogbe-Ofu 3	3.1892E-08	1.2843E-08
9	Umuisagba	2.38E-08	4.9945E-09
10	Ogbe-Onicha	4.046E-09	7.135E-09
11	Agidiasei 1	1.9516E-08	2.5686E-08
12	Isah Road 1	4.7124E-08	1.9978E-08
13	Isah Road 2	4.76E-10	1.427E-09
14	Isah Road 3	8.092E-09	2.854E-09
15	Azungwu 1	5.236E-09	1.2843E-08
16	Azungwu 2	2.856E-09	7.135E-09
17	Idumu-Ogwude	4.5696E-08	2.49725E-08
18	Ogbe-Ubu	1.8802E-08	1.8551E-08
19	Umuokwe	5.95E-09	1.427E-08
20	Aboh-Ogwashi	3.451E-08	1.92645E-08
21	Ogbe-Ofu 4	1.9992E-08	3.06805E-08
22	Ogbe-Ofu 5	3.4034E-08	1.92645E-08
23	Agidiehe	1.3328E-08	1.2843E-08
24	Azagba-Ogwashi 1	1.1424E-08	1.8551E-08
25	Agidiehe	1.8326E-08	1.2843E-08
26	Azagba-Ogwashi 2	2.2134E-08	4.9945E-09

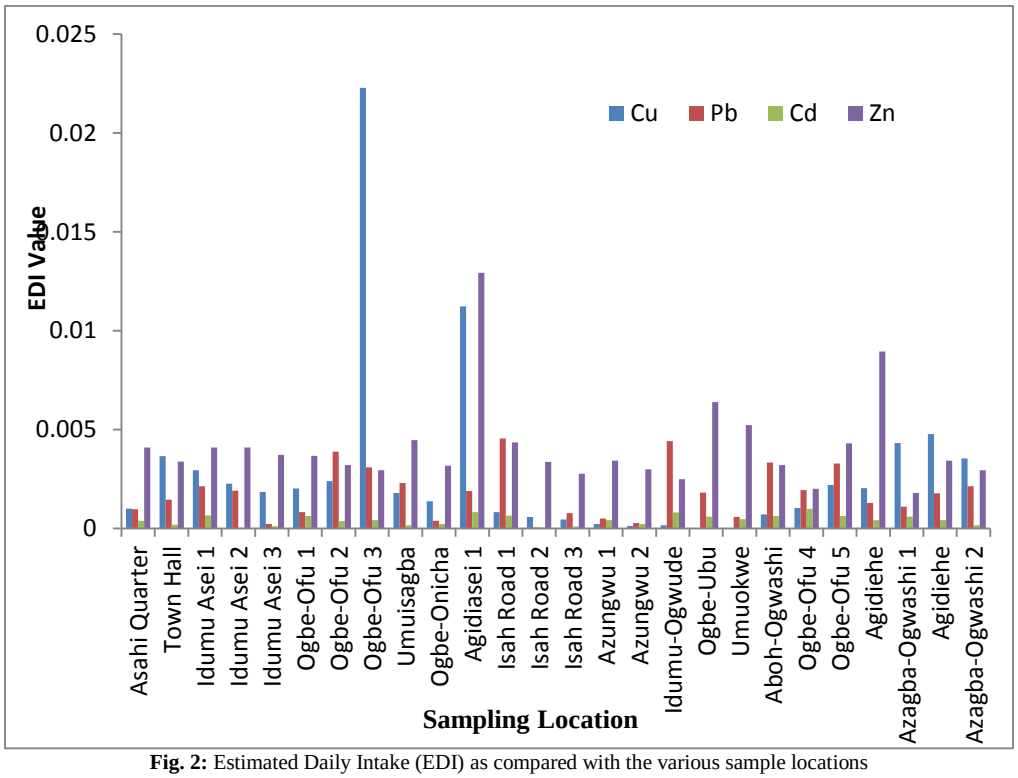

Fig. 2: Estimated Daily Intake (EDI) as compared with the various sample locations

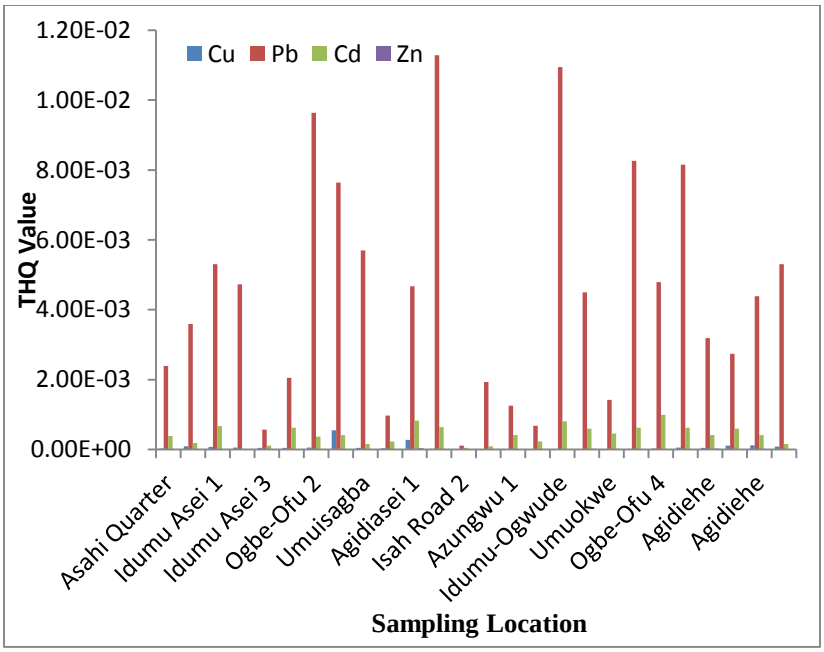

Fig. 3: Target Hazard Quotient (THQ) as compared with the various sample locations

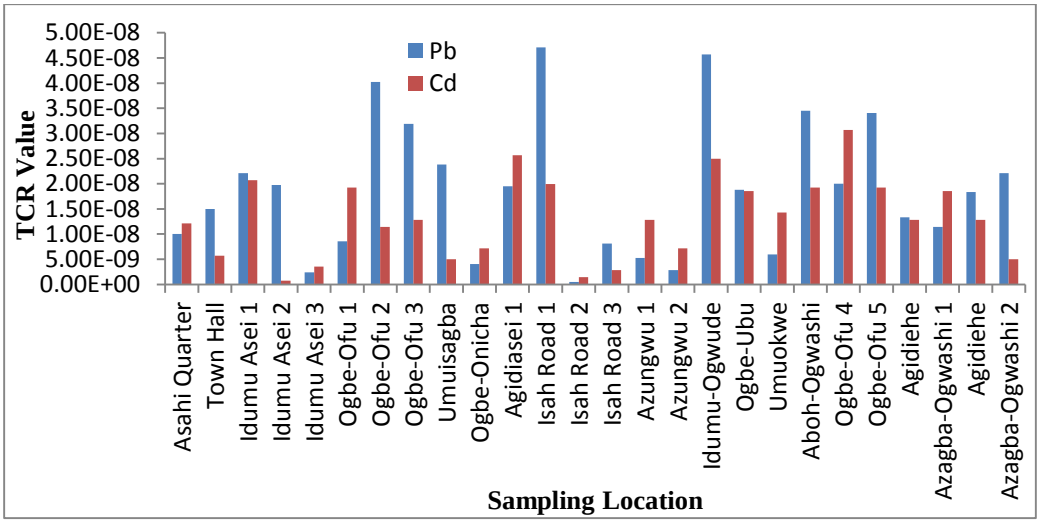

Fig. 4: Target Cancer Risks (TCR) as compared with the various sample locations

*Conclusion:*The determination of heavy metals in water samples from boreholes in Ogwashi-Uku and its satellite towns in Delta State was conducted using a Flame Atomic Absorption Spectrophotometer. The results indicate the presence of Copper (Cu), Lead (Pb), Cadmium (Cd), and Zinc (Zn) in the water samples. Notably, the concentrations of Cu and Cd are below the limits set by the World Health Organization (WHO). However, the levels of Pb and Zn exceed the natural range suggested by WHO guidelines. These metals can be toxic at elevated concentrations and may pose severe health risks with prolonged exposure.The analyses of various indices, including the Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), and Total Cancer Risk (TCR), suggest that the concentrations of Cu, Pb, Cd, and Zn in all borehole water samples do not pose a health threat to adults in the study area. Nonetheless, it is crucial to monitor the accumulation of these metals in water samples. Additionally, the practice of consuming untreated water must be discouraged to prevent the introduction of these toxic metals into the human system.

*Declaration of Conflict of Interest:*The authors declare no conflicting interest.

*Data Availability Statement:*Data are available upon request from the first corresponding author or any ofthe other authors

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