Assessing the Heavy Metal Content in Shallow Hand Dug Well Waters to Determine Water Quality in Okpuno-Awka, Southeastern Nigeria

Ifeoma Linda Onyekwelu[1*], Daniel Chukwuemeka Ozoko[2]

[1]Department of Geology, Faculty of Physical Sciences, Nnamdi Azikwe University, Awka P.M.B. 5025, Awka, Nigeria.

[2]Department of Geology and Mining, Faculty of Physical Sciences, Enugu State University of Science and Technology, P.M.B. 01660, Agbani, Nigeria.

***Corresponding Author**

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ABSTRACT

Shallow hand dug well water is the main source of water supply for the local population in Okpuno-Awka area. This study investigated the effects of heavy metal pollution on natural water sources in Okpuno-Awka of Southeastern Nigeria by conducting a geochemical assessment of contaminants from dumpsite leachates. Samples within the proposed influence zone at which the leachates can contaminate the natural water sources were targeted. These include samples collected from hand dug wells, surface waters at about 300m-1000m away from the dumpsite and some leachate samples collected at the dumpsite. Laboratory analysis was conducted on the water samples to determine the levels of heavy metals, following established standard methods. These heavy metals include iron (Fe^{3+}), manganese (Mn^{+}), Lead (pb^{+}), Arsenic (Ar), Cadmium (Cd), Chromium (Cr^{3+}), Cobalt, Zinc and Nickel (Ni). The presence of various heavy metals measured suggests a diverse range of waste materials that points to the source of Pb, Zn, Fe, Cd, Cr and Mn. The results from the analysis showed that the observed concentrations of Fe in borehole water samples ranged from 0.016 mg/l (BH 2) to 0.216 mg/l (BH 12) while Manganese varied between 0.009 and 2.142 mg/l. Arsenic for hand dug well samples ranged from 0 to 0.078mg/l. Some other parameters were within the permissible limits of regulatory standard for drinking water. The quality of water in the metropolis has therefore been grossly affected as the heavy metals present in them have rendered the water unsafe and unhealthy for consumption and therefore should not be consumed without proper treatment

Keywords: Leachates, Contaminations, Dumpsite, Heavy Metals, Groundwater, Surface water.

INTRODUCTION

In many parts of Southern Nigeria, shallow had dug well water is still the primary source of water supply for local communities. This can be attributed to the ease of access to these water sources coupled with the unreliable and inadequate supply of alternate water sources (Ifediegwu et al., 2019). Having a steady and drinkable water supply is crucial for the development of a stable society, fostering economic growth and maintaining public health. Despite the fact that portable water is crucial to human living, 1.1 billion people worldwide depend on contaminated drinking water from hand dug wells and surface waters. Furthermore, around 2.4 billion people worldwide struggle with inadequate access to basic hygiene facilities (WHO, 2008). According to WHO and UNICEF (2004), in sub-Saharan Africa, at least 44% of the entire population (approximately 320 million people) lack access to a reliable and safe water supply.

Although shallow hand dug well water appears sufficient for drinking and household purposes, it often exhibits notable seasonal variations in heavy metal levels, particularly during the rainy seasons due to significant contamination (Jain, 1998). In developing countries, it is common to see wastes dumped indiscriminately, with waste sites often located near residential areas, markets, farms and roadsides in many communities (Abd ElSalam and Abu-Zuid, 2015). Managing these wastes has become a significant challenge for governments and urban administrators due to the risks they pose to public health, the environment and the economy (*Nwigwe, 2008*). In most developed countries, controlling water pollution is a top priority and as such, policies often include measures like pollution prevention at the source and mandatory licensing for waste discharge (Mgbenu and Egbueri, 2019). While developed countries have implemented effective waste management systems, such as controlled incinerations and safe landfills, developing nations continue to struggle with this issue due to inadequate policies or lack of enforcement. In most developing nations, the biggest hurdles to effective waste management are the absence of reliable data on waste generation and the use of substandard landfills that do not meet safety requirements (Mor et al., 2006).

Like many urban centers globally, Awka's rapid and unplanned population growth has led to proportional surge in waste generation within the state. Successive governments have made efforts to establish a functional waste management system in the state. These efforts led to the establishment of a dumpsite in Okpuno, within the Awka metropolis. The dumpsite receives waste from most areas of the state resulting in a massive amount of toxic and carcinogenic liquid, known as leachate (Afolayan et al., 2012). The leachates contain heavy metals can contaminate water sources, posing serious health risks to humans. Therefore, assessing water quality and its influencing factors is crucial ensuring sustainable water resources. Studies reveal that a mere 4.9% of surface water is fresh and safe for human consumption (Annapooorna and Janardhana, 2015) and other purposes. Beaven and Walker (1997), Hoffman et al., (1997), and Esakku et al., (2003) conducted independent studies on how leachate-borne heavy metals affect natural waters sources. They concluded that leachates poses a significant threat to human health due to its detrimental impact on overall water quality. Moreover, the leachate's lateral spread and downward seepage into nearby surface and groundwater systems heightens the risks of heavy metal contamination making the water unsuitable for consumption. Water pollution is notoriously challenging and expensive to rectify once it occurs (Mgbenu and Egbueri, 2019), underscoring the importance of this research. Residents of Okpuno-Awka in Southeastern Nigeria rely on various water, including hand-dug wells and streams. Therefore, this research aims to assess the effect of heavy metals from the Okpuno-Awka dumpsite leachates on water quality, determining its suitability for drinking and other domestic purposes.

METHODOLOGY

Location of the study area

Figure 1 displays a map of Anambra State highlighting the specific study area while figure 2 depicts the location of the study area. Okpuno-Awka, lies between latitides 6°11′00″ and 6°17′00″ N and longitudes 7°02′00″ and 7°07′00″ E. It covers an estimated land area of approximately 72.82/km. Okpuno-Awka has a sizable population, being part of Awka town which serves as the Anambra State capital. The study area falls within the humid tropical rainforest zone, characterized by two distinct seasons, a rainy season which roughly spans from April to November), and a dry season that lasts from December to March). The two seasons are attributed to the southwest trade winds from the Atlantics and the northeastern wind blowing across the Sahara (Mgbenu and Egbueri, 2019). During the dry seasons, temperatures reach as high as 32^{o}C, while the average relative humidity sometimes drops to as low as 20% (Egboka, 1993). The area features a relatively flat terrain due to its underlying geology with few elevated points ranging from 120m to 213 m above sea level. The Araka River is the largest watercourse flowing through the study area. It originates in Abagana, flowing through Amawbia, and then northwards through the study area to the Ajali River. The study area falls within the Niger Delta Basin which features rocks dating back to the Upper Cretaceous period (Reyment, 1965). Okpuno-Awka is primarily underlain by Imo Formation, consisting of blue-grey clays, shallow-marine shales, sandstones, limestones and calcareous sandstone (Figure 1). It is estimated to be approximately 1,000m thick dates back to the Paleocene to lower Eocene period (Reyment, 1965; Ekwenye et al., 2020).

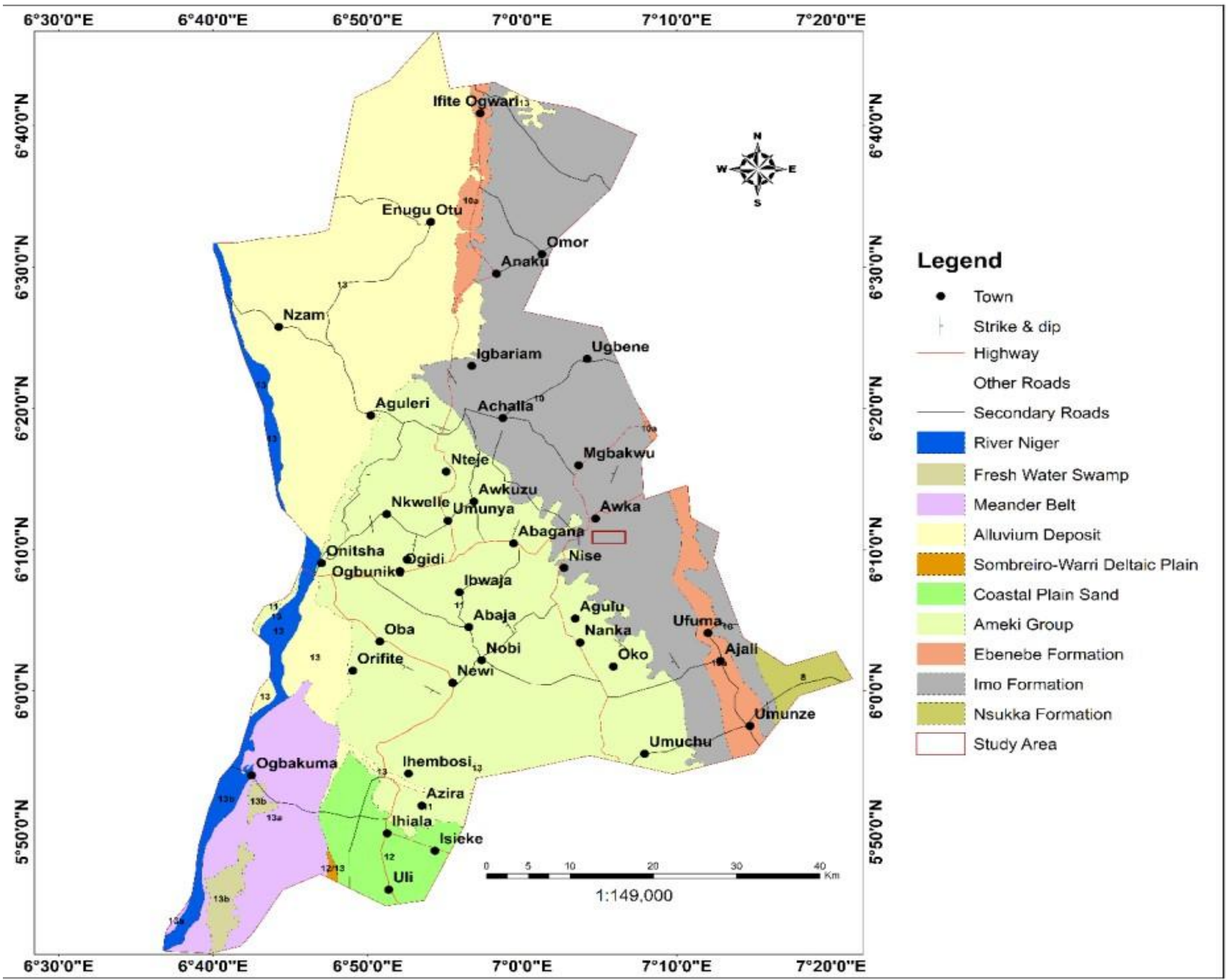

Figure 1: Geologic map of Anambra State showing the study area.

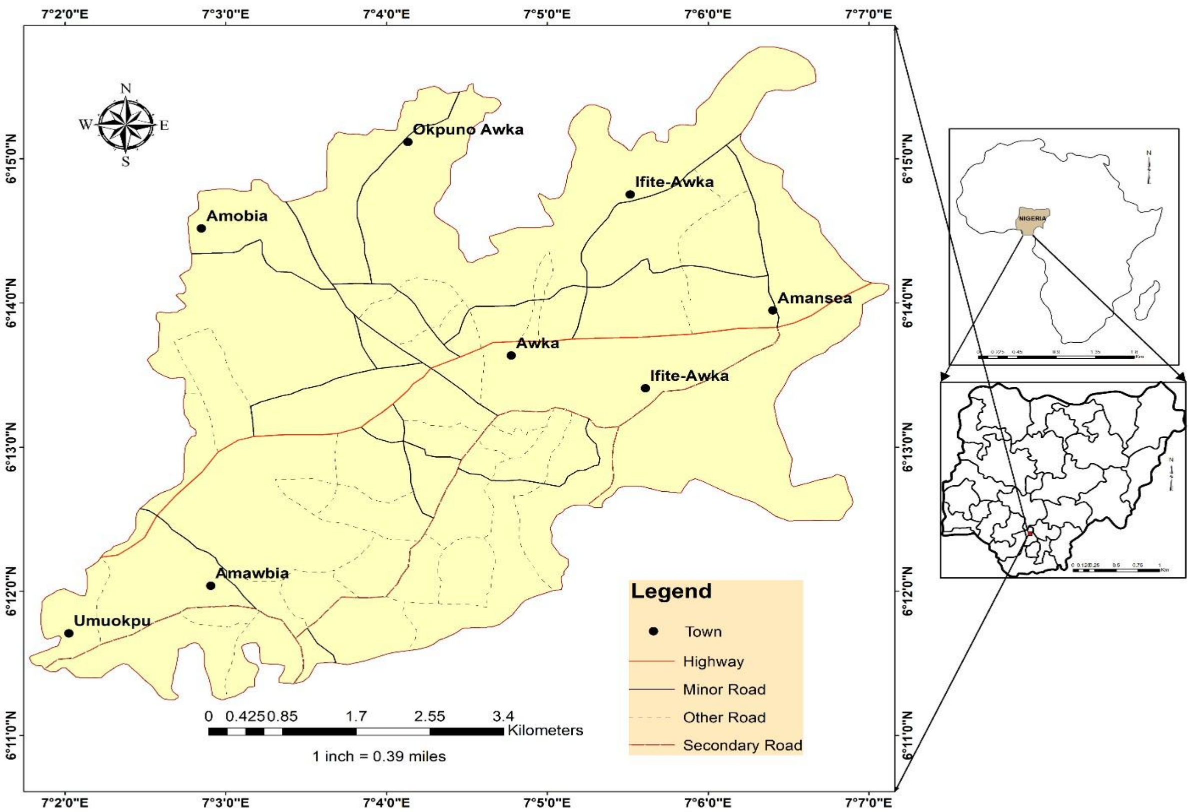

Figure 2: Location map of the study area

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Geology of the study area

The study area is located within the Niger Delta Basin whose rocks are Upper Cretaceous in age. Lithological units mapped in the area are (from the oldest to the youngest), Imo Formation (Paleocene) and Nanka Formation (Eocene). Figure 2 below shows the geologic map Awka and environs. The type locality of these formations has been described by Reyment 1965.

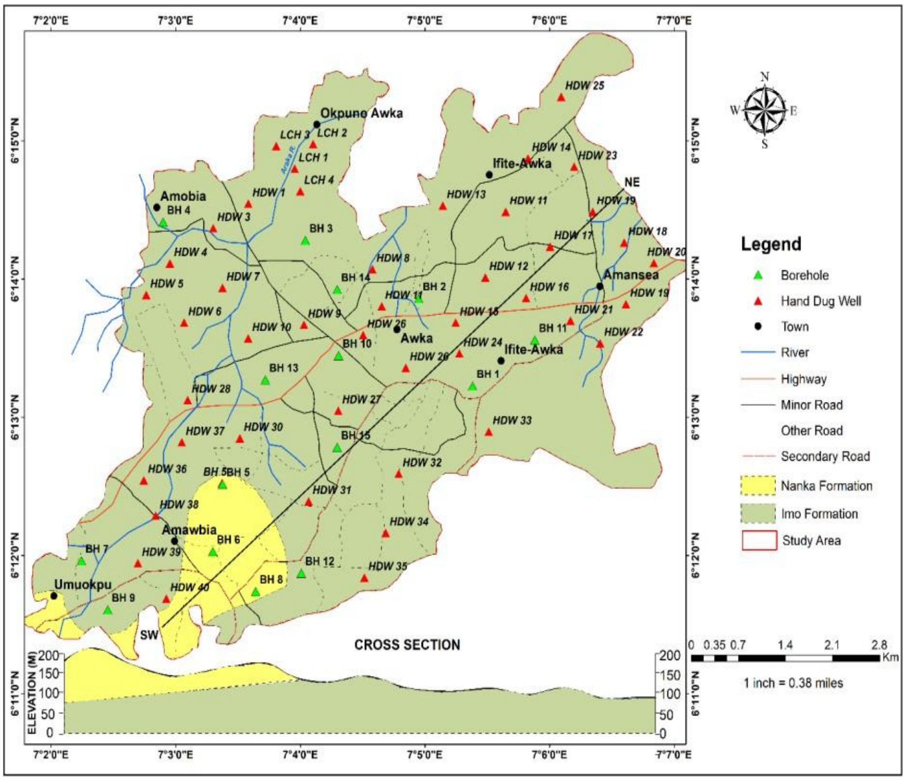

Figure 3: Geological map of the study area showing the sampled points

Water sample collection

Water samples were collected from shallow hand dug wells in 1litre polythene bottles. The samples collected were within the proposed influence zone within which the leachates can contaminate the natural water sources.

As a precaution, the polythene sample bottles used in collecting the water samples were flushed with phosphatefree detergent, rinsed with de-ionized water and rinsed again with the sample fluids prior to collection. A few drops of concentrated hydrochloric acid was added to prevent precipitation of unstable metals that easily change their form when exposed to different environmental conditions and also to prevent adsorption of some metals onto the surface of the container. To ensure validity of results, analysis was completed within a period of 48 hours of sample collection. The samples were stored in an ice box and transported to Simuch Scientific Analytical laboratories, Enugu state, Nigeria for chemical analyses within 24 hours of sampling. The Atomic

Absorption spectrophotometer (AAS) was employed to determine the heavy metal content which include Iron (Fe), zinc (Zn), copper (Cu), Nickel (Ni), Cadmium (Cd), Chromium (Cr), Manganese (Mn), Lead (Pb), and Arsenic (As). The procedure for conducting the AAS, for heavy metals was performed according to standard methods and procedures (APHA, 2005).

Analysis of Heavy metals

The assessment of heavy metals was performed on a Varian AA 240 Atomic Absorption Spectrophotometer as per the procedure outlined in APHA, 2005 (Bulk Scientific 210 VGP). Prior to the analysis, the sample was meticulously homogenized by shaking and 100 ml was poured into 250 ml beaker. Then, 5 ml of concentrated Nitric acid was added and the mixture heated to a boiling point until the volume decreased to approximately 15–20 ml, by gradually adding 5 ml increments of concentrated Nitric acid until complete dissolution of the residue is achieved. After cooling, the mixture was then transferred to a conical flask and diluted to 100 ml with metal

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free distilled water. The sample was then introduced into the oxidizing acetylene flame. Upon aspiration of the aqueous sample, the sensitivity for absorption was observed at 1%.

RESULTS AND DISCUSSION

The concentration and statistical summary of results of the analysis are presented in tables 1 and 2 which indicates that the primary contaminants in the dumpsites are Iron (Fe), Cadmium (Cd), Chromium (Cr), Manganese (Mn), Lead (Pb), Nickel (Ni) and Arsenic (As). The results obtained from the laboratory analyses were also compared with those of WHO (2017) and NIS (2017). Most of cadmium, Nickel, Lead and Arsenic emerged as major pollutants in the samples taken near the dumpsite.

The presence of various heavy metals measured suggests a diverse range of waste materials that points to the source of Pb, Zn, Fe, Cd, Cr and Mn (Table 1). The presence of high heavy metal levels likely result from human activities like disposal of primarily municipal wastes and large proportion of industrial wastes.

Table 1: Results of heavy metals of the water samples analyzed in the study area

ID	Fe3+ (mg/l)	Mn (mg/l)	As (mg/l)	Zn (mg/l)	Cd (mg/l)	Ni (mg/l)	Cu (mg/l)	Location
LCH 1	1.305	1.614	0.623	0.139	0.070	0.086	0.61	Okpuno-Awka
LCH 2	2.199	2.154	0.899	0.098	0.067	0.069	0.03	Okpuno-Awka
LCH 3	1.128	3.564	1.026	0.076	0.055	0.104	0.02	Okpuno-Awka
LCH 4	2.085	3.675	0.699	0.059	0.065	0.096	0.01	Okpuno-Awka
BH 1	0.094	2.122	0.532	0.048	0.021	0.064	0.20	Ifite-Awka
BH 2	0.016	0	0	0.043	0.034	0.065	0.19	Awka
BH 3	0.047	0	0.112	0.035	0.020	0.048	0.12	Okpuno-Awka
BH 4	0.031	1.346	0.098	0.034	0.027	0.062	0.20	Amawbia
BH 5	0.019	0.564	0.034	0.034	0.021	0.012	0.11	Amawbia
BH 6	0.02	0.876	0.076	0.125	0.011	0.041	0.29	Amawbia
BH 7	0.305	1.043	0.054	0.123	0.035	0.045	0.04	Umuokpu
BH 8	0.192	0.985	0.063	0.098	0.024	0.044	0.04	Amawbia
BH 9	0.128	0.976	0.043	0.056	0.044	0.051	0.04	Umuokpu
BH 10	0.075	1.097	0.054	0.054	0.015	0.038	0.01	Awka
BH 11	0.054	1.124	0.532	0.038	0.045	0.080	0.21	Ifite-Awka
BH 12	0.216	0.464	0	0.033	0.011	0.570	0.18	Amawbia
BH 13	0.047	0.265	0.112	0.035	0.022	0.042	0.15	Awka
BH 14	0.131	1.922	0.098	0.044	0.016	0.051	0.07	Awka
BH 15	0.119	0	0.031	0.055	0.022	0.053	0.11	Awka
HDW 1	0.021	0.009	0.056	0.044	0.021	0.043	0.14	Okpuno-Awka
HDW 2	0.191	1.346	0.054	0.034	0.021	0.040	0.09	Amobia
HDW 3	0.127	0.464	0.043	0.155	0.018	0.038	0.11	Amobia
HDW 4	0.085	0.866	0.043	0.093	0.015	0.037	0.12	Amobia
HDW 5	0.014	1.123	0.056	0.098	0.022	0.047	0.16	Amobia
HDW 6	0.016	0.154	0.052	0.076	0.018	0.080	1.18	Amobia
HDW 7	0.057	0.564	0.063	0.057	0.052	0.61	0.40	Amobia
HDW 8	0.031	0.875	0.013	0.033	0.010	0.045	0.04	Awka
HDW 9	0.019	1	0.054	0.038	0.029	0.039	0.14	Awka
HDW 10	0.31	0	0.052	0.044	0.013	0.056	0.06	Awka
HDW 11	0.305	0.092	0	0.065	0.011	0.044	0.04	Awka
HDW 12	0.054	1.146	0.112	0.044	0.015	0.040	0.10	Awka

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HDW 13	0.016	0.565	0.098	0.074	0.030	0.047	1.04	Ifite-Awka
HDW14	0.087	0.446	0.034	0.125	0.018	0.420	0.13	Ifite-Awka
HDW 15	0.041	1.043	0.046	0.094	0.010	0.060	0.19	Awka
HDW 16	0.019	0.124	0.034	0.098	0.019	0.012	0.49	Amansea
HDW 17	0.425	0.534	0.063	0.086	0.021	0.212	0.15	Amansea
HDW 18	0.919	0.275	0.063	0.073	0.041	0.000	0.06	Amansea
HDW 19	0.538	2.142	0.054	0.088	0.014	0.028	0.00	Amansea
HDW 20	0.425	0.072	0.054	0.126	0.043	0.015	0.13	Amansea
HDW 21	0.414	0.074	0.033	0.057	0.012	0.044	0.80	Amansea
HDW 22	0.596	1.246	0.023	0.083	0.016	0.038	0.79	Amansea
HDW 23	0.317	0.354	0.054	0.078	0.000	0.030	0.09	Ifite-Awka
HDW 24	0.531	0.456	0.032	0.044	0.033	0.045	0.05	Ifite-Awka
HDW 25	0.419	1.143	0.054	0.045	0.012	0.011	0.00	Ifite-Awka
HDW 26	0.33	1.656	0.112	0.064	0.030	0.020	0.04	Awka
HDW 27	0.355	0.569	0.067	0.074	0.010	0.019	0.00	Awka
HDW 28	0.592	0.776	0.043	0.135	0.021	0.030	0.08	Amawbia
HDW 29	0.648	0.043	0.052	0.094	0.010	0.017	0.01	Awka
HDW 30	0.075	1.946	0.044	0.088	0.019	0.022	0.10	Amawbia
HDW 31	0.454	0.464	0.053	0.126	0.028	0.025	0.03	Amawbia
HDW 32	0.716	0.215	0.027	0.151	0.030	0.019	0.07	Ifite-Awka
HDW 33	0.597	0.056	0.013	0.112	0.033	0.018	0.03	Ifite-Awka
HDW 34	0.961	0.049	0.321	0.126	0.029	0.030	0.00	Ifite-Awka
HDW 35	0.912	0.124	0.022	0.214	0.017	0.029	0.09	Ifite-Awka
HDW 36	1.129	0.216	0.078	0.127	0.020	0.024	0.11	Amawbia
HDW 37	0.413	0.519	0.217	0.051	0.024	0.030	0.02	Amawbia
HDW 38	0.833	0.641	0.031	0.028	0.028	0.030	0.05	Amawbia
HDW 39	0.616	0.051	0.333	0.232	0.040	0.027	0.01	Amawbia
HDW 40	0.623	0	0.215	0.631	0.037	0.051	0.06	Amawbia

Table 2

ID	Cr (mg/l)	Co (mg/l)	Pb (mg/l)	Location
LCH 1	0.107	0.074	0.612	Okpuno-Awka
LCH 2	0.114	0.084	0.731	Okpuno-Awka
LCH 3	0.107	0.064	0.903	Okpuno-Awka
LCH 4	0.121	0.082	0.725	Okpuno-Awka
BH 1	0.097	0.027	0.322	Ifite-Awka
BH 2	0.093	0.016	0.306	Awka
BH 3	0.086	0.010	0.277	Okpuno-Awka
BH 4	0.087	0.021	0.279	Amawbia
BH 5	0.081	0.017	0.232	Amawbia
BH 6	0.065	0.012	0.432	Amawbia
BH 7	0.076	0.014	0.435	Umuokpu
BH 8	0.080	0.012	0.364	Amawbia
BH 9	0.067	0.010	0.234	Umuokpu
BH 10	0.074	0.017	0.264	Awka
BH 11	0.070	0.011	0.211	Ifite-Awka

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue XII December 2025

BH 12	0.089	0.013	0.213	Amawbia
BH 13	0.059	0.016	0.315	Awka
BH 14	0.051	0.012	0.413	Awka
BH 15	0.029	0.017	0.232	Awka
HDW 1	0.056	0.049	0.432	Okpuno-Awka
HDW 2	0.073	0.038	0.335	Amobia
HDW 3	0.095	0.061	0.464	Amobia
HDW 4	0.077	0.070	0.234	Amobia
HDW 5	0.076	0.056	0.384	Amobia
HDW 6	0.088	0.061	0.512	Amobia
HDW 7	0.070	0.059	0.212	Amobia
HDW 8	0.087	0.042	0.311	Awka
HDW 9	0.084	0.053	0.412	Awka
HDW 10	0.092	0.037	0.325	Awka
HDW 11	0.072	0.064	0.422	Awka
HDW 12	0.064	0.059	0.506	Awka
HDW 13	0.089	0.045	0.364	Ifite-Awka
HDW14	0.060	0.027	0.234	Ifite-Awka
HDW 15	0.058	0.052	0.364	Awka
HDW 16	0.080	0.058	0.411	Amansea
HDW 17	0.079	0.062	0.313	Amansea
HDW 18	0.058	0.037	0.315	Amansea
HDW 19	0.051	0.076	0.313	Amansea
HDW 20	0.063	0.043	0.212	Amansea
HDW 21	0.075	0.047	0.332	Amansea
HDW 22	0.056	0.028	0.335	Amansea
HDW 23	0.063	0.055	0.364	Ifite-Awka
HDW 24	0.086	0.031	0.535	Ifite-Awka
HDW 25	0.048	0.092	0.604	Ifite-Awka
HDW 26	0.064	0.027	0.610	Awka
HDW 27	0.068	0.058	0.584	Awka
HDW 28	0.063	0.049	0.412	Amawbia
HDW 29	0.088	0.068	0.512	Awka
HDW 30	0.064	0.041	0.510	Amawbia
HDW 31	0.082	0.071	0.511	Amawbia
HDW 32	0.087	0.031	0.305	Ifite-Awka
HDW 33	0.093	0.042	0.254	Ifite-Awka
HDW 34	0.094	0.083	0.316	Ifite-Awka
HDW 35	0.098	0.051	0.387	Ifite-Awka
HDW 36	0.055	0.063	0.241	Amawbia
HDW 37	0.074	0.031	0.319	Amawbia
HDW 38	0.063	0.044	0.425	Amawbia
HDW 39	0.099	0.057	0.319	Amawbia
HDW 40	0.076	0.038	0.538	Amawbia

Iron (Fe^{3+})

Iron exists in all-natural waters with varying concentrations. Excessive Fe in potable water is detrimental and the standard set for this metal is mainly focused on palatability and its potentially high corrosivity. High Iron levels in water (> 0.3 mg/L) can cause orange discoloration to water and individuals unaccustomed to high iron intake may be subjected to laxative effects. The iron content in the dumpsite leachate samples ranged between 1.128 mg/l (LCH 3) and 2.119 mg/L (LCH 2) (Figure 4) while the observed concentrations in borehole water samples ranged from 0.016 mg/l (BH 2) to 0.216 mg/l (BH 12). The variation in concentrations of iron in shallow hand dug well samples fall within the range of 0.014 mg/l (HDW 5) and 1.129 mg/l (HDW 36). The results indicate highest Fe concentration of 2.119 mg/L in the leachate samples collected from Okpuno-Awka dumpsite which is far above the acceptable limit of 0.03 mg/L set by WHO and NIS. High content of iron in the leachates indicates that the dumpsite likely contains iron and steel scrap and other metallic objects such as motor spare parts at the dumpsite.

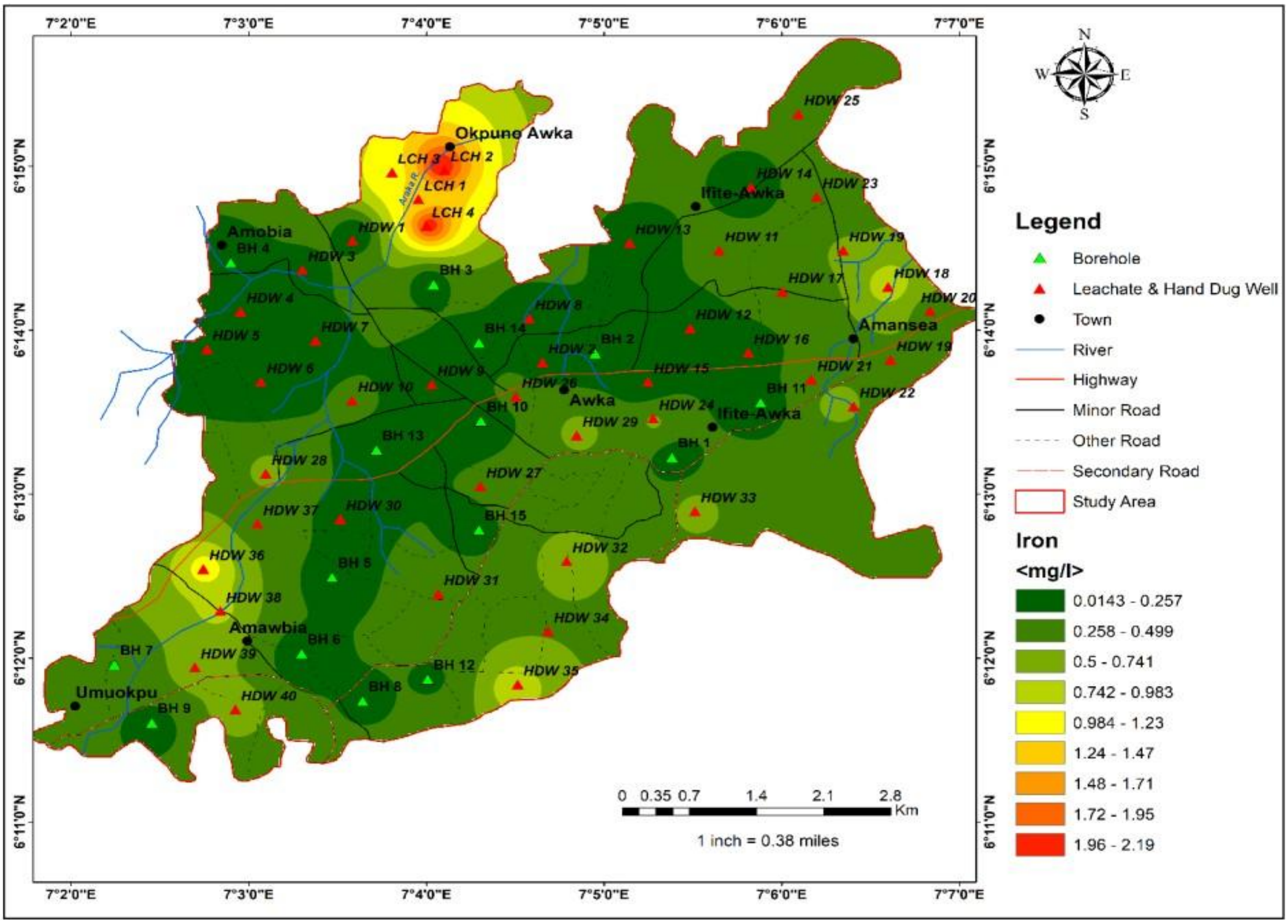

Figure 4: Spatial distribution of iron in water

Manganese (Mn)

Manganese concentration is highest in the Okpuno-Awka leachate water sample (LCH 3) (3.675 mg/l) followed by shallow hand dug well sample acquired from Amansea (HDW 22) (2.142 mg/l). The guideline value is 0.4mg/l (WHO, 2003). Generally, Manganese concentrations in leachate samples is higher than Mn concentration recorded in borehole and shallow hand dug well samples (Figure 5). Its limit of detection is 0.01µg/l by AAS, 0.05 µg/l by ICP/MS, and 0.50 µg/l by ICP/OES. According to the guideline value, Manganese levels have exceeded the acceptable limit, indicating pollution. Inadequate and excessive amounts can have adverse outcomes, leading to neurological effects including tremor, gait disorders (seen in primates), psychological symptoms such as irritability and emotional liability due to high level in drinking water etc. A notable example is amyotrophic lateral sclerosis according to Olesen and Steiner (2004), a degenerative neurological disorder that may be associated with inadequate Mg or Mn levels. Reduced consumption of Mg or Mn reduces the body's

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ability to retain and use thiamin (vitamin B1). Olesen and Steiner also noted that there is a possible connection between excessive Mn exposure and the development of Parkinson's disease.

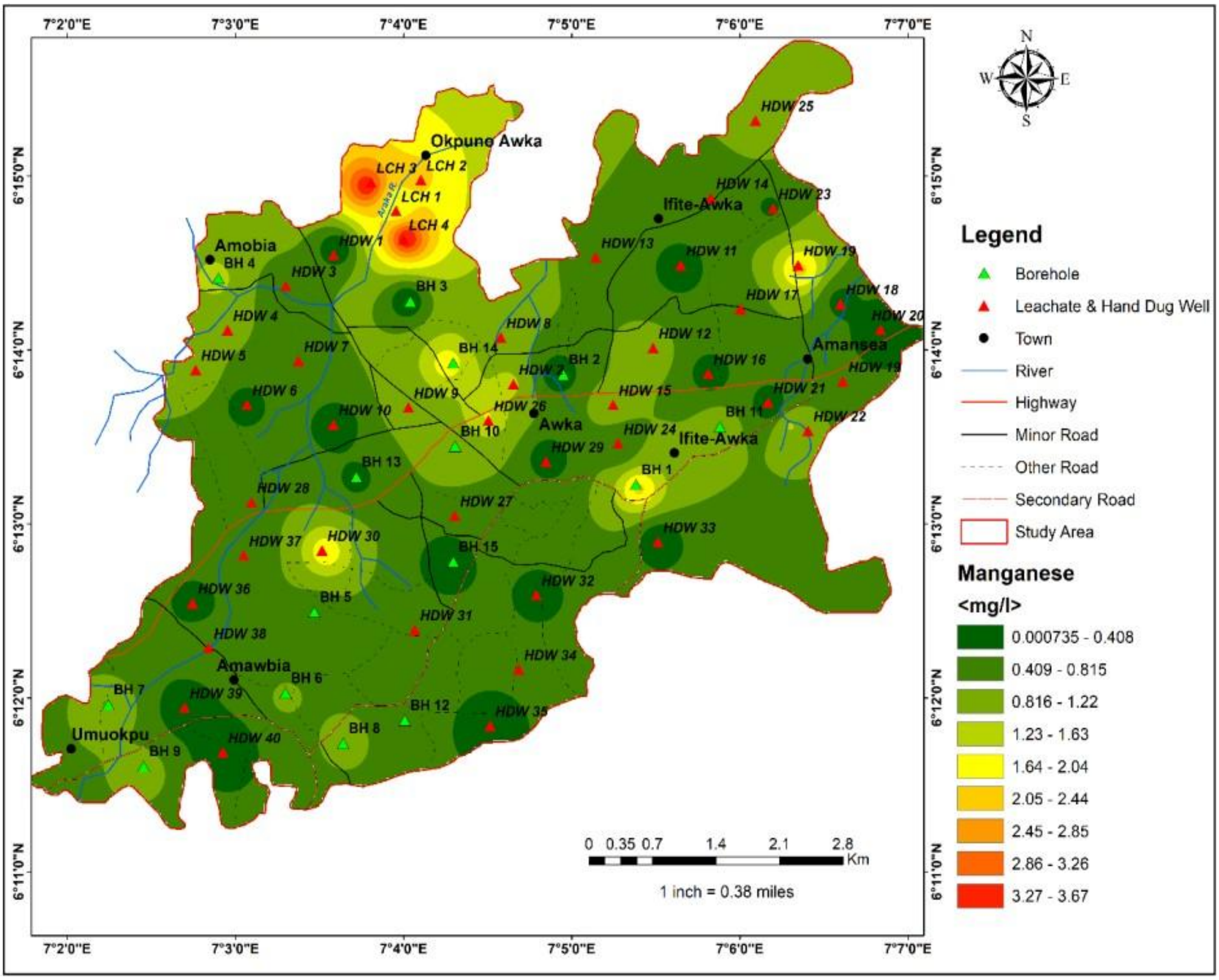

Figure 5: Spatial distribution of manganese in water

Arsenic (As)

Arsenic concentration is observed to be highest at Okpuno-Awka dumpsite leachate sample (LCH 3) (1.026 mg/l), followed by Ifite-Awka borehole water sample (BH 11) (0.532 mg/l). However, no arsenic was detected in Awka (BH 2), Amawbia (BH 12) and Awka (HDW 11) (Figure 6). The result indicates that arsenic is distributed more in the dumpsite leachate samples than the borehole water and shallow hand dug well samples. Elevated As concentrations in the leachate samples may be associated with industrial waste inputs, such as motor spare parts, used engine oil containers and used detergent containers; high As levels may also be produced by the disposal of associated latrine (Carla, 2000). Runoff from farms and wastewater from households frequently can release As into rivers, in both soluble and particulate forms. The interaction of clay, shale minerals, Al, Fe and Mn oxides and organic matter with As species impacts their sorption, solubility and oxidation kinetics (Plant *et a*l., 2000). The mobility of As is reduced under reducing conditions.

The limit of detection of arsenic is 0.1µg/l by ICP/MS and 2µg/l by hydride generation, AAS or FAAS (WHO, 2004). WHO (2008), set a temporary guideline value of 0.01mg/l informed by a population exposed to arsenic in drinking water; with concentrations correlated to heightened life time skin cancer risk of 10-5 was calculated to be 0.00017mg/l; whereas maximum contamination level (MCL) by the EPA (2001) is 0.05mg/l. New standard value currently proposed is 0.005mg/l (WHO, 2004). Based on the findings; As in the study area is a potential pollutant that poses environmental risks.

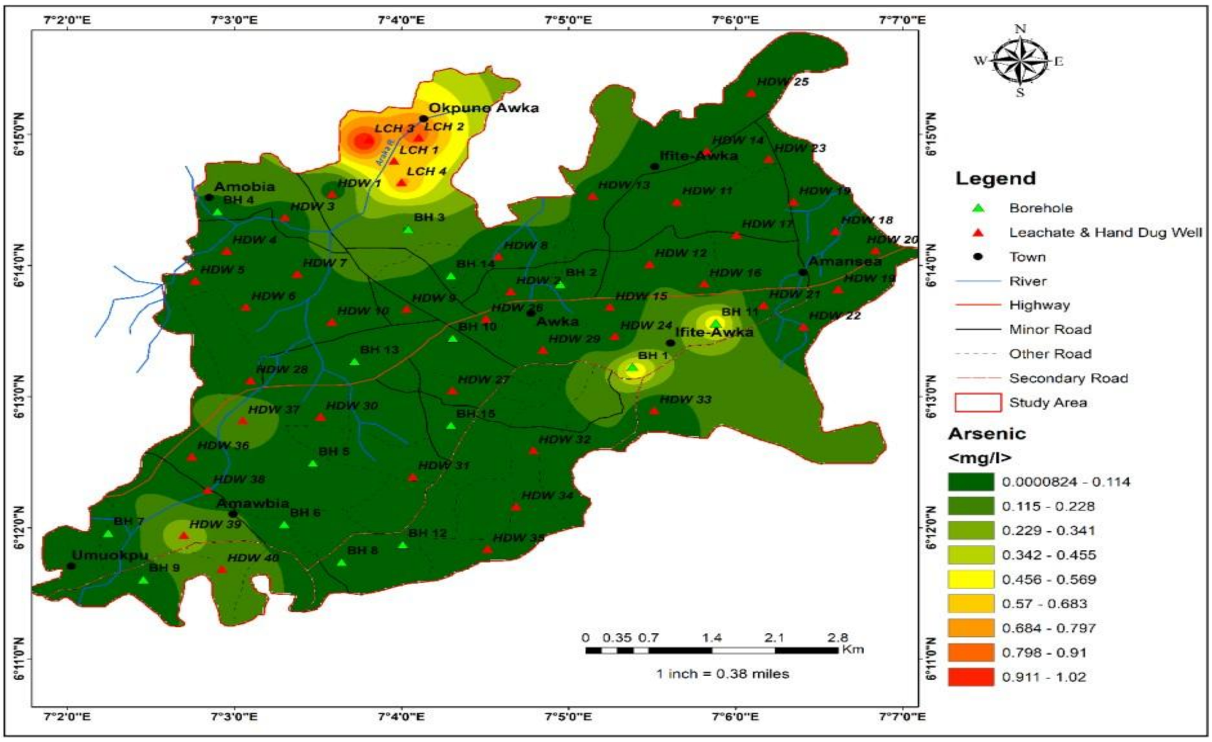

Figure 6: Spatial distribution of Arsenic in water

Zinc (Zn)

Zinc distribution from the study can be said to be even throughout the districts. Water sample collected from Amawbia shallow hand dug well sample (HDW 40) has the highest value (0.631 mg/l) followed by sample obtained from Amawbia (HDW 3) (0.155 mg/l) (Figure 7). The concentration of Zinc is relatively higher with respect to Pb concentration in the study area. In general, high-zinc sandy soils and soil rich in CaCO3 produce more zinc-efficient plants. Zinc is a vital trace element, whose levels in surface and groundwater usually remain below 0.01 and 0.05 mg/l, respectively. However, tap water often contain more zinc levels resulting from dissolution of zinc into water from pipes. Furthermore, zinc concentrations above 3 mg/l in drinking water could be objectionable to consumers (NSDWQ, 2007). According to WHO, (2008), the threshold value for Zn is 5 mg/l.

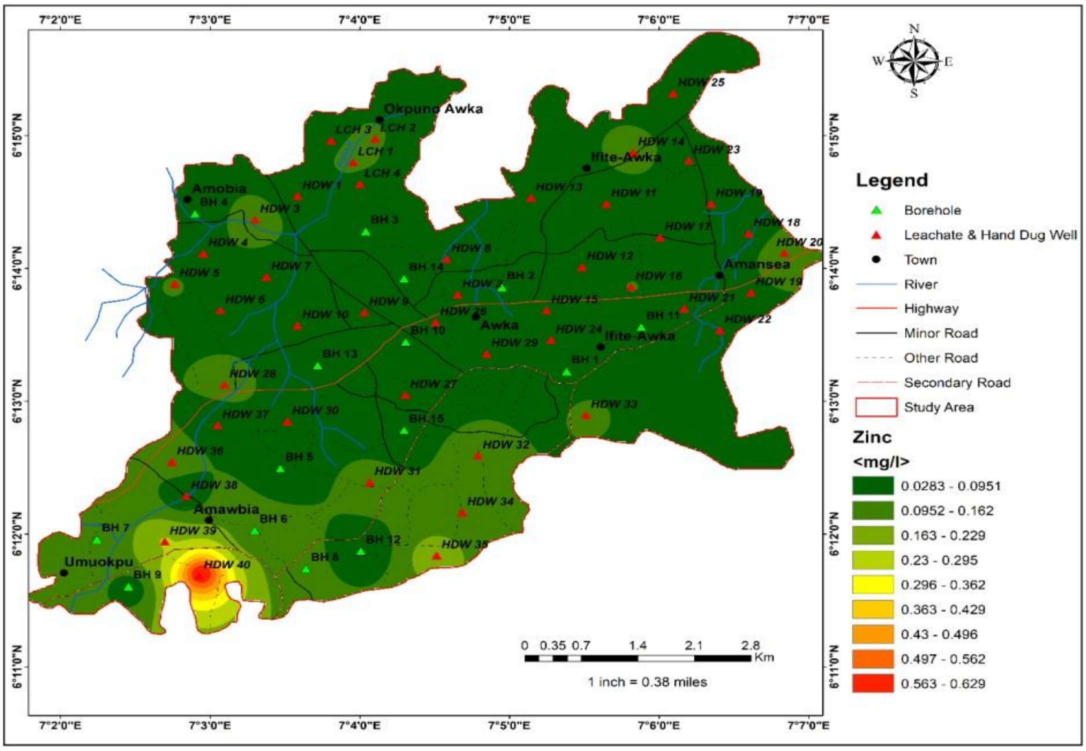

Figure 7: Spatial distribution of zinc in water

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue XII December 2025

Cadmium (Cd)

All the four leachate samples obtained from Okpuno-Awka dumpsite recorded high concentration of cadmium ranging from 0.070 mg/l (LCH 1) to 0.055 mg/l (LCH 3). Next is a high concentration of Cd in the borehole water sample collected from Ifite-Awka mechanic village (0.045 mg/l) (BH 11) (Figure 8). The dumpsite leachate samples generally demonstrated higher values of cadmium than the borehole and shallow hand dug well samples.

Cadmium is common in organic-rich wastes and mineral deposits composed mostly of cadmium sulfide and cadmium carbonate (Plant et al., 2000). Cadmium solubility is limited by $CdCO_3$. Hence, it occurs at higher concentration in low-pH conditions. It may also sorb onto organic substances, such as humic and fulvic acids, potentially leading to higher Cd concentrations in organic-rich waters with local Cd inputs (Plant et al., 2000, Carla 2000).

Long term exposure to the metal can lead to kidney amage, anemia, emphysema, anosmia (loss of sense and smell), cardiovascular diseases, renal problems and increased risk of hypertension (Plant and Raiswell, 1983). Research suggests itai-itai disease is connected to Cd, which is very painful and results in bone deterioration and fragility (WHO 2006).

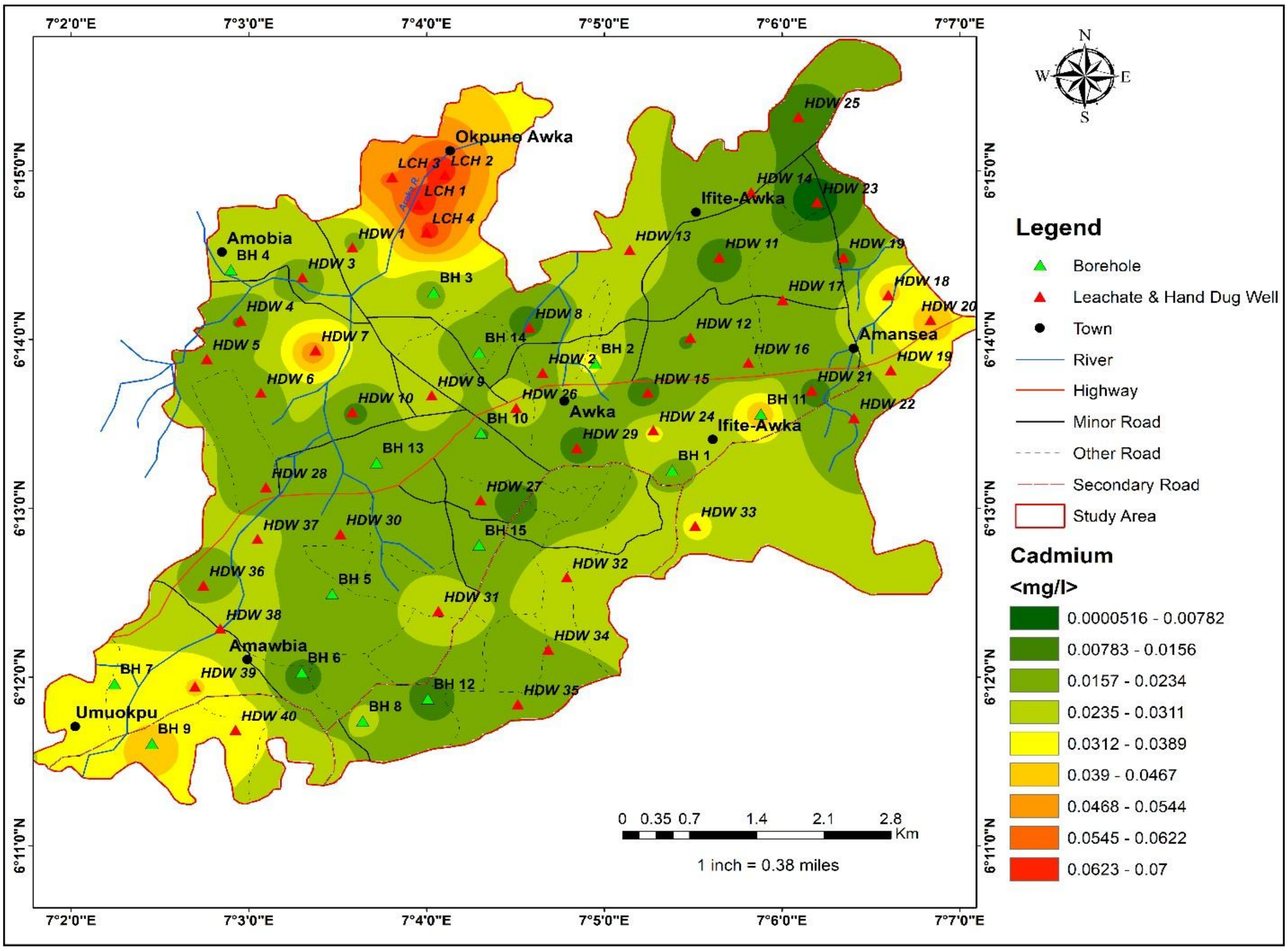

Figure 8: Spatial distribution of cadmium in water

Nickel (Ni)

The highest value for Ni was observed in Amawbia shallow hand dug well (HDW 7) (0.610 mg/l), followed by Amawbia borehole (BH 12) (0.57 mg/l); however, shallow hand dug well sample from the Amansea (HDW 18) showed absence of Ni. Similarly, no Ni was present in shallow hand dug well 16 (HDW 37) (Figure 9). In general, Ni is evenly distributed in the borehole water samples. Ni concentration in leachate water sample measures from 0.069 mg/l – 0.104 mg/l. The guideline value is 0.02mg/l, while the concentration in drinking water is normally less than 0.02mg/l. The limit of detection is 0.1 µg/l by ICP/MS, 0.5 µg/l by FAAS, 10 µg/l by ICP/AES.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue XII December 2025

This indicates that Ni is a potential contaminant in the area under investigation. The most common toxic effect of nickel exposure in the general population is skin allergy (WHO, 2005). However, it is believed to play a crucial role for certain plants and animals (APHA, 1999). According to Plant and Raiswell (1983), Carla, (2000), Ni deficiency can lead to various health issues including disrupted cholesterol balance, liver damage, ultrastructural changes in the liver cells, rough hair, reproductive issues and poor growth of offspring.

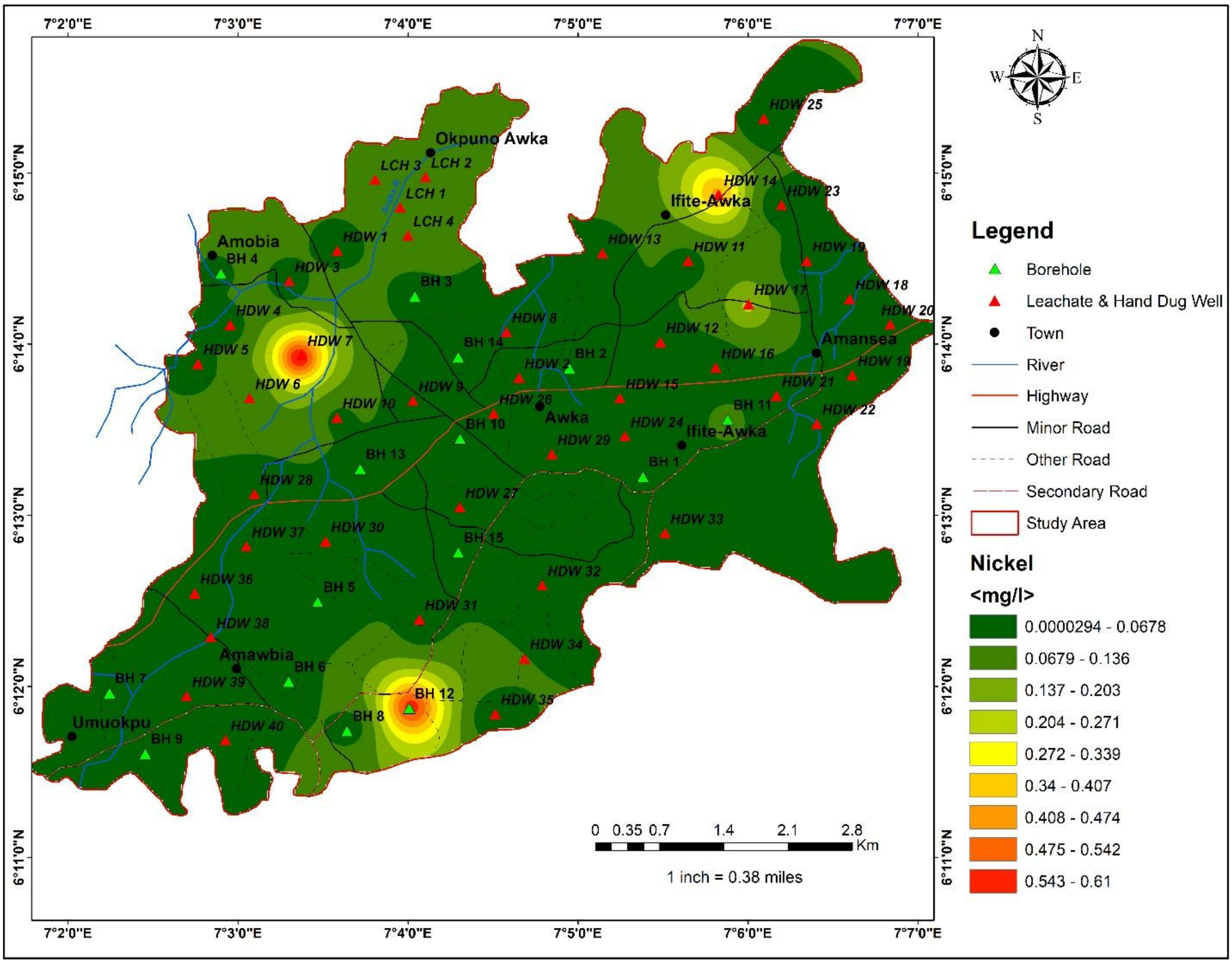

Figure 9: Spatial distribution of nickel in water

Copper (Cu)

This study recorded highest Cu value of 1.18 mg/l (HDW 6), followed by 1.04 mg/l (HDW 13) (Figure 10). However, Amansea shallow hand dug well 19, Ifite-Awka shallow hand dug wells 25 and 34 as well as Awka shallow hand dug well 27 shows absence of Cu. Generally, Cu can be said to be evenly distributed in the study area.

The guideline value of Cu is 0.05mg/l (at pumping station) and 0.2mg/l (after contact with pipes) (WHO, 2004), and concentration in drinking water range from ≤0.005 to > 0.30mg/l. The long term effects of copper in drinking water on susceptible individuals, such as Wilson's disease patients and others with disrupted copper metabolism remain somewhat uncertain (WHO, 2004). Copper imbalance has distinct consequences: deficiency leads to conditions like kidney and Menkes disease (steely hair syndrome in humans) as well as wool abnormalities in sheep, whereas excessive consumption causes inherited copper metabolism disorder characterized by progressive damage of tissues with excessive Cu levels ultimately resulting in mortality (WHO 2004).Cu likewise plays a role in converting dophamine, noradrenaline, adrenaline, in pigment production and other key neurotransmitters. The interaction between Zinc and Cu may contribute to the development of ischemic heart disease, which proposes that the interplay between reduced Cu intake alongside excessive Zn could be linked to increased cardiac mortality in both animals and man (Plant et al., 2000, Davis et al., 2005). Environmental contamination near smelters can result in elevated Cu levels, posing health risks including toxicity in infants consuming contaminated drinking water (pink disease) (Plant and Raiswell, 1983).

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue XII December 2025

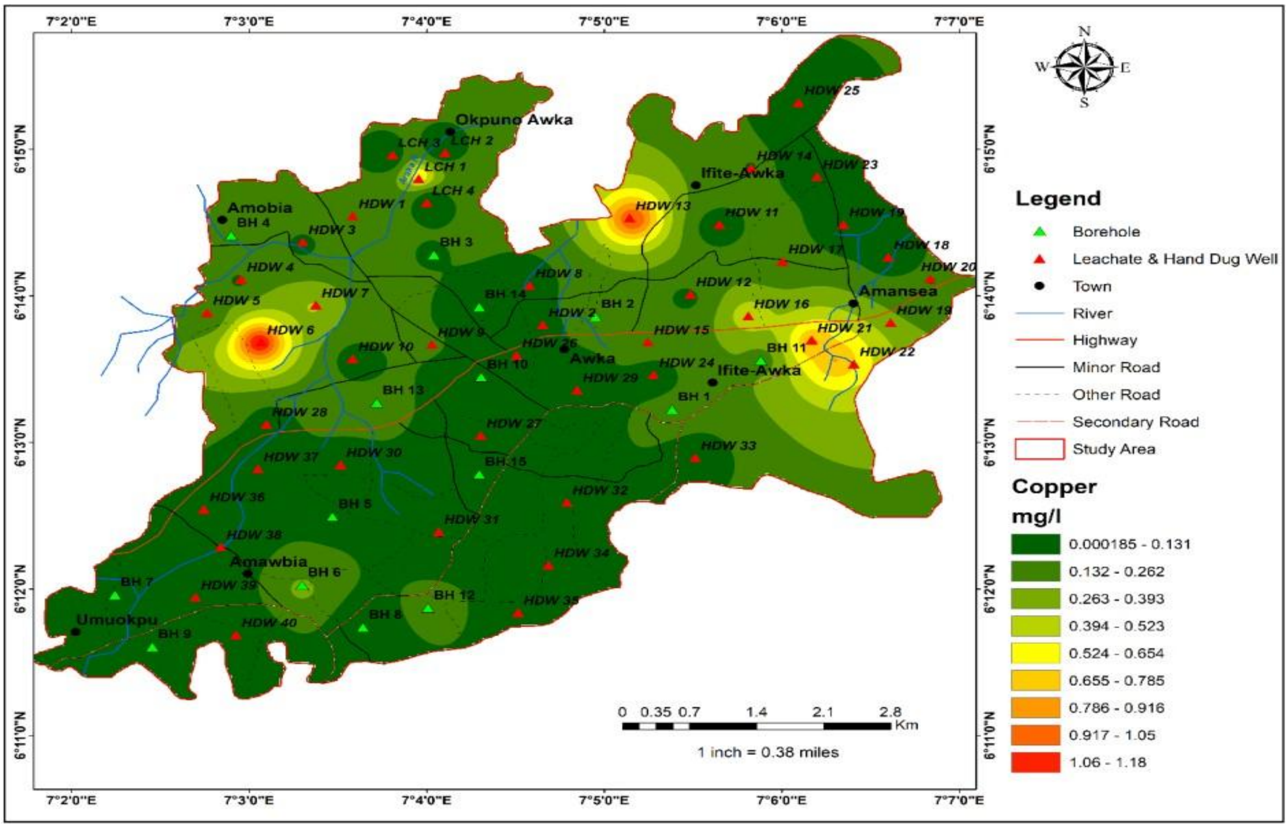

Figure 10: Spatial distribution of copper in water

Chromium (Cr)

This study recorded highest chromium values of 0.121 mg/l in the Okpuno-Awka dumpsite leachate sample (LCH 4), followed by 0.114 mg/l recorded at Okpuno-Awka dumpsite leachate (LCH 2). Similarly, among the borehole water samples collected, chromium concentrations vary from 0.029 mg/l – 0.097 mg/l with the lowest concentration observed at borehole 15 (Figure 11). The guideline value of Cr is 0.05mg/l (WHO, 2008). The significant levels of Cr in the leachate samples could be attributed to automobile exhaust, diesel tanks as well as vehicle parts which are dumped at mechanic village in the vicinity of the dumpsite.

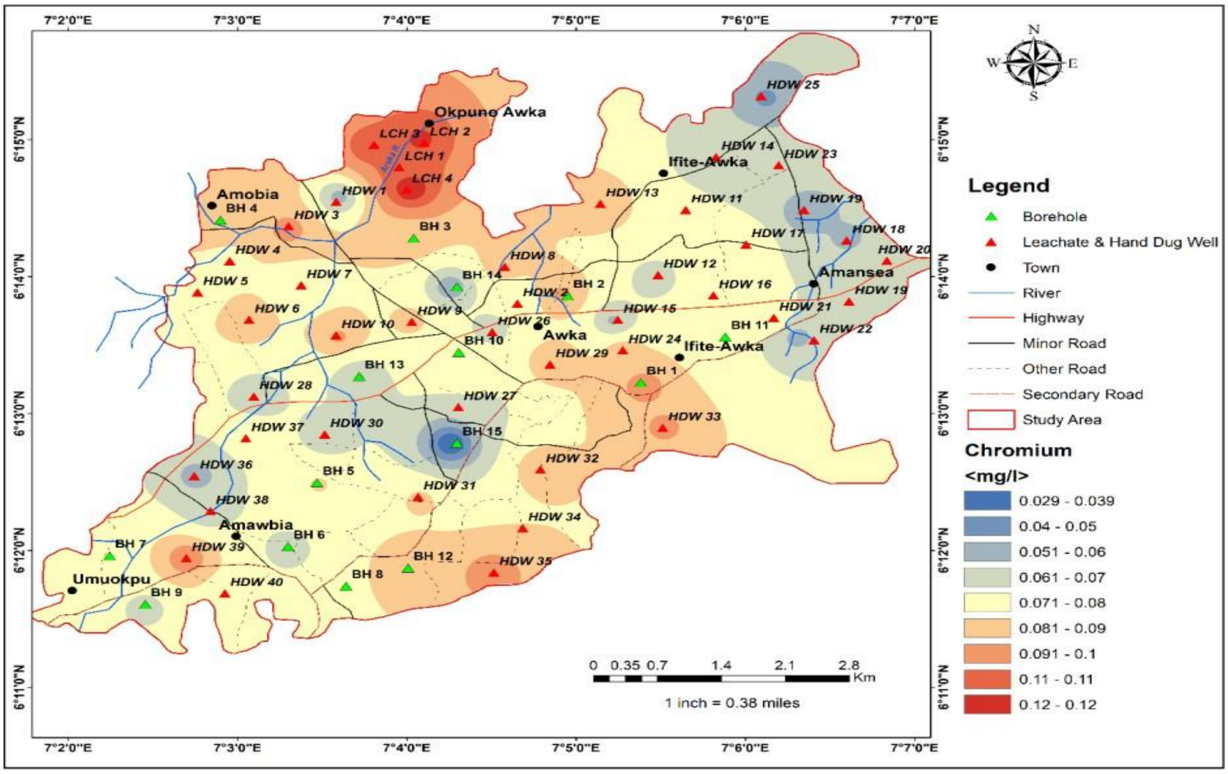

Figure 11: Spatial distribution of Chromium in water

Cobalt (Co)

The results of cobalt concentrations obtained from the four samples collected from Okpuno-Awka dumpsite leachate shows highest value of Cobalt (0.084 mg/l) at LCH 2, followed by LCH 4 (0.082 mg/l). However, in borehole water samples Co measures between 0.010 mg/l (BH 3 and BH 9) to 0.027 mg/l (BH 1) whereas, Co concentrations in shallow hand dug well samples varied from 0.027 mg/l (HDW 14 and HDW 26) to 0.092 mg/l (HDW 25) (Figure 12). The result indicates that cobalt is distributed more in the dumpsite leachate samples, borehole water and shallow hand dug well samples. Generally, Co attenuates minimal concentrations in the borehole samples of the study area and this suggests that Co may have been co-precipitated or adsorbed by oxides or iron by carbonate precipitation. This is in agreement with Plant et al., (2000), who reported that, Cobalt solubility is regulated through co-precipitation or adsorption by oxides or iron by carbonate precipitation, and by the formation of complex ions. Cobalt is vital for algae and some bacteria, while not necessary for higher plants but plays a vital role as an essential trace element for animal. The maximum Co level recommended by the United Nations Food and Agriculture Organization for irrigation waters is 100μg/l (APHA, 1999).

Humans require Cobalt as a crucial microelement in the form of vitamin B12 with a multifaceted pathway in the human diet (Plant et al., 2000). Co deficiency can lead to pernicious anemia syndrome characterized by impaired vitamin B12 absorption, leading to enlarged (macrocytic) red blood cell accompanied by neurological abnormalities. Excessive Co added to beer for foam enhancement has been linked to severe cardiomyopathy, hematologic, neurologic and thyroid abnormalities in human (plant et al., 2000, Davis et al., 2005). An inverse relationship was observed between Co/I ratios in geochemical environment and thyroid health with elevated Co levels in water and soil linked to thyroid enlargement.

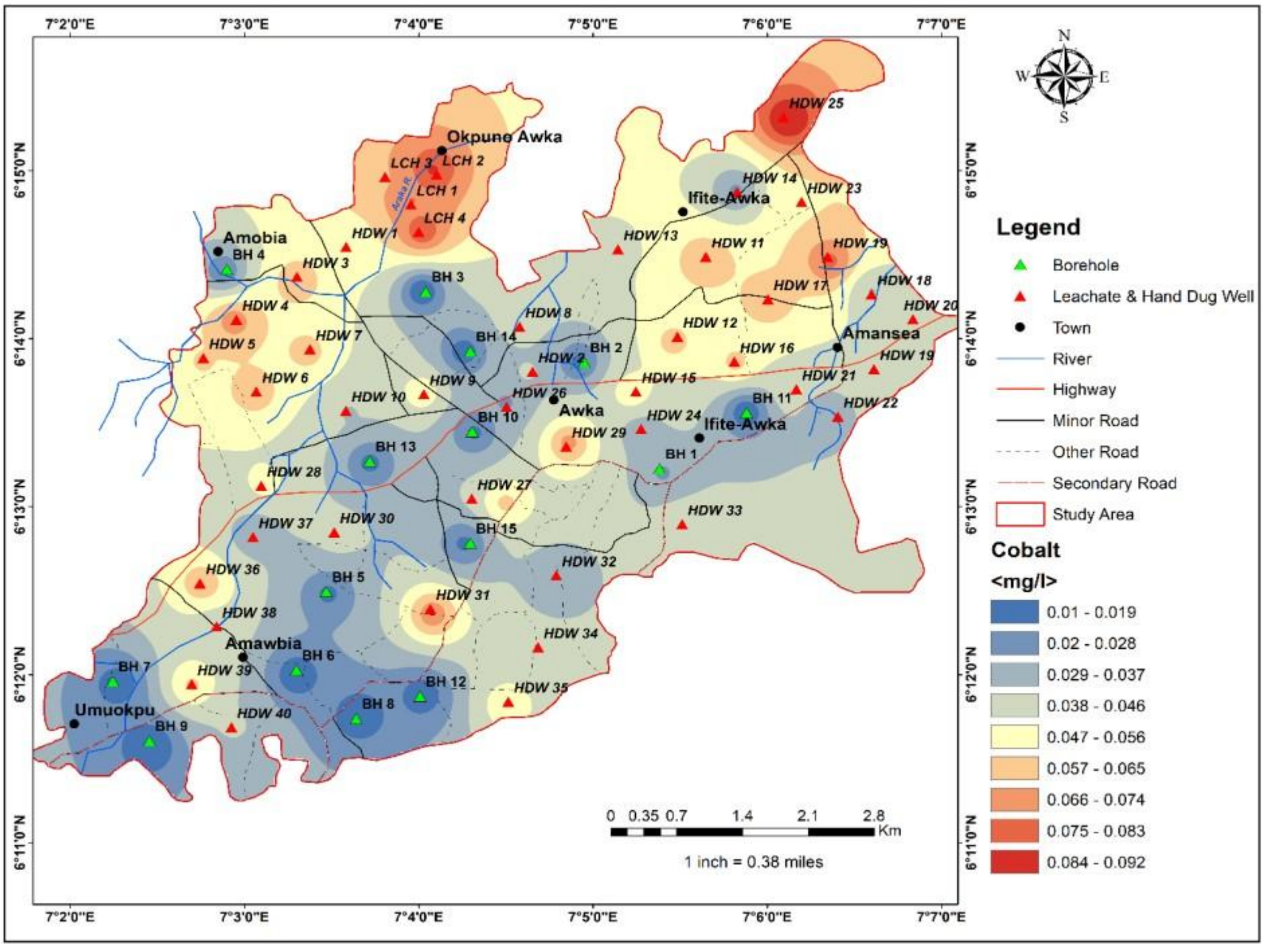

Figure 12: Spatial distribution of cobalt in water

Lead (Pb)

Lead levels are relatively uniform across the study area with a peak concentration (0.903 mg/l) at LCH 3, followed by 0.731 mg/l recorded at LCH 2. However, concentrations of lead in borehole water samples ranged from 0.211 mg/l (BH 11) to 0.435 mg/l (BH 7) and shallow hand dug well samples from 0.212 mg/l (HDW 7

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue XII December 2025

and HDW 20) to 0.610 mg/l (HDW 26) (Figure 13). Dumpsite leachate samples consistently exhibited higher lead levels than water samples from boreholes and shallow hand dug wells.

Lead levels in water are influenced by multiple factors including pH, temperature, water hardness and standing time of the water, where soft, acidic water exhibits highest corrosivity (Plant et al., 2000). The Pb content of dumpsite is influenced markedly by the industrial and domestic wastes from where they were derived. In general, Pb is more soluble and mobile in acidic soils than in alkaline soils, making it more susceptible to leaching while alkaline soils tend to retain lead forming residual concentrations (Plant et al., 2000, Carla, 2000). Surface water may be polluted due to intense agricultural activities going on along the banks. The concentration of dissolved Pb in natural water system, normally have pH near 8 and is very low. The low solubility is due to mainly its ability to combine readily with the carbonates, sulfates and hydroxide normally present in such waters to form compounds of low solubility (Plant et al., 2000). The solubility of Pb is primarily governed by $PbCO_3$ formation under low pH and low alkaline water holding higher levels of Pb.

The WHO (2008) guideline value for lead shows 0.01 mg/l, with concentrations in drinking water generally at amounts below 5µg/l. Lead's limit of detection is 1µg/l by AAS. A comprehensive review of lead's effect (WHO, 2006), has revealed suppression of the function of d-aminolaevulinic dehydratase (porphobilinogen synthase; one crucial enzyme involved in the biosynthesis of haem) at blood lead concentrations as low as 5 mg/l. Lead interferes with calcium metabolism, through direct effects and by impacting vitamin D regulation. Lead exposure leads to its accumulation in bones of animals and humans where it hinders normal maturation of erythroid elements in the bone marrow (Plant et al., 2000). These effects have been observed in children with blood lead levels between 12 and 120µg/l. Lead exposure can result in damage to the entire nervous systems, central and peripheral areas, inducing subencephalopathic neurological and behavioral effects. Additional effects include epidemiological effects (blood lead level of 30µg/l), intelligence quotient deficits of about four points in children; due to prenatal/postnatal exposure to lead (blood lead level ranging from 11 to 33µg/l), headache, irritability, constipation, weight loss, fatigue, hypertension, miscarriages, stillbirths and renal tumors. Studies in humans indicate that even low concentrations of lead may cause neuro-toxic effects other than cancer and that a guideline threshold based on this approach would also safeguard against carcinogenic risks (WHO, 2004). A study revealed that children exposed to high levels of lead in soils had a higher occurrence of dental cavities in the Tamar Valley, England, and in Ceredigion, Wales. (Plant et al., 2000).

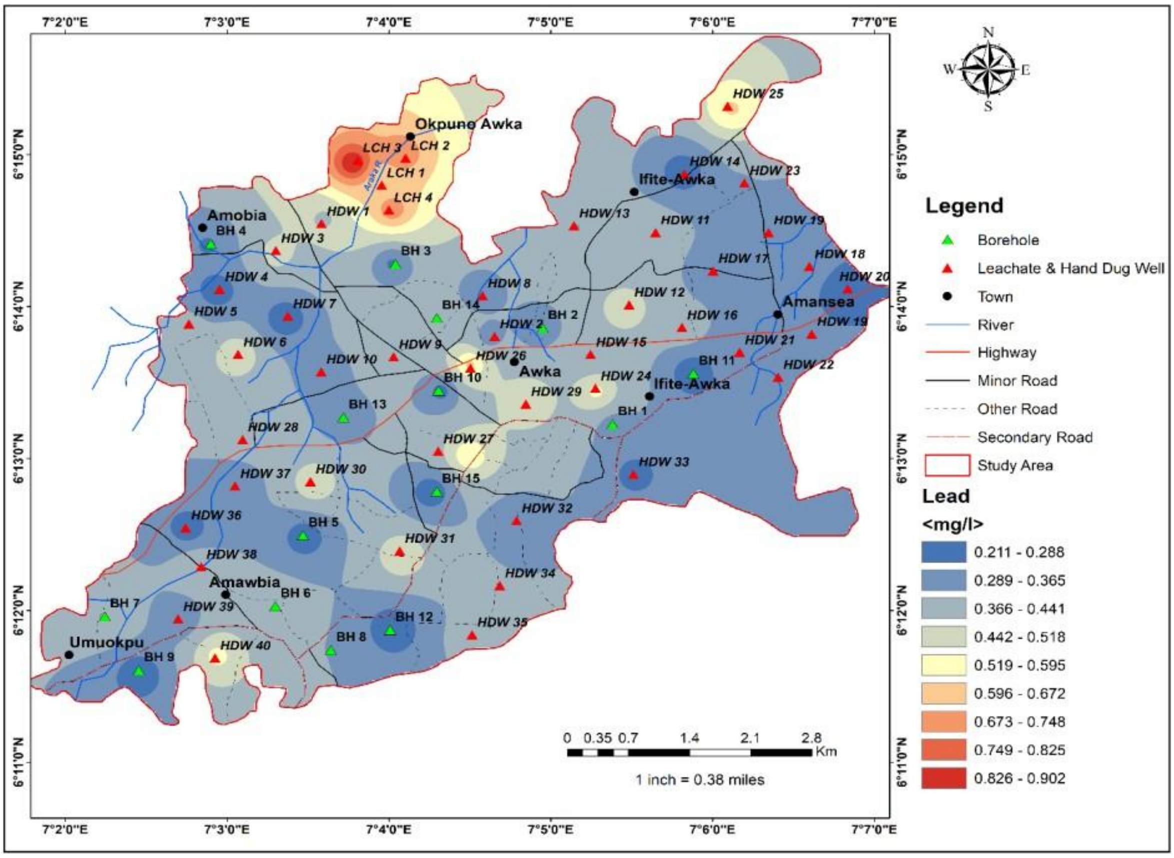

Figure 13: Spatial distribution of lead in water

CONCLUSION

From the study, it is evident that leachates yielding heavy metals from the Okpuno Awka dumpsite have considerably impacted the natural water sources in the Awka metropolis. The distribution of individual water quality classes revealed that all surface waters and groundwaters analyzed are variedly deteriorated in quality. The results showed that some of the analyzed heavy metals including Mn, Cd, Ni, Cr are present in both surface and groundwater at concentrations higher than the WHO permissible limits for consumption. Iron and Zn however is present at a concentration lower than the WHO limits in groundwater analyzed. The results also indicates that Arsenic is distributed more in the dumpsite leachate samples than the borehole water and shallow hand dug well samples. Cu can be said to be evenly distributed in the study area.

The quality of water in the metropolis has therefore been grossly affected as the heavy metals present in them have rendered the water unsafe and unhealthy for consumption and therefore should not be consumed without proper treatment. According to WHO (2011, 2017) 80% of diseases are waterborne (Khan et al. 2013) and 3.1% deaths occur due to the unhygienic and poor quality of water (Pawari and Gawande, 2015). Diseases such as cancers, diarrhea, typhoid, cholera, respiratory diseases, Wilson's disease, dermatitis and other forms of metabolic disorders are attendant risks associated with the intake of such untreated water. However, although most of the samples are contaminated, they can be used for some domestic purposes such as laundry and cleaning (Mgbenu and Egbueri, 2019).

Inasmuch as the study provides useful data on the outlook of heavy metal contamination within Okpuno Awka metropolis, the following recommendations have been put forward as measures that could be adopted in dealing with the problem:

1. The current structure of Okpuno Awka dumpsite should be revisited to accommodate bottom liners to serve as barriers for subsequent infiltration of the leachates into the underlying groundwater system.
2. A water treatment plant should be sited within the metropolis to treat surface and groundwater from the area before been channeled to homes for consumption.
3. Public enlightenment campaigns should be organized for the purpose of raising awareness on the need for safe waste disposal and treatment of water before use for any domestic activity including consumption.
4. The government and other policy makers should put additional efforts in ensuring that the different natural water sources in Okpuno Awka area are protected from further pollution and contamination to ensure environmental sustainability.

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