Assessment of Heavy Metals Contamination in Groundwater from Afigya Kwabre District, Ghana

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Abstract-* Forty (40) boreholes in the study area were sampled to study the heavy metals contamination in groundwater. The purpose of this study was to understand the impact of heavy metals on groundwater quality in the study area. Sampling of groundwater, samples analysis in the laboratory, Heavy metal pollution index, pollution evaluation index and statistical techniques were methods applied in the study. The study revealed that Fe > Mn > Pb = Cu > Cd is the order in which the concentrations of the heavy metals in the groundwater decreases. Lead and and iron show high mean concentration values as compare to the WHO (2012) recommended values. Assessment of human health risk by hazard quotient (HQ) and Hazard index revealed no alarm for non-carcinogenic adverse risk except three communities namely Nkukua Buoho (HQ = 2.5194, HI = 2.2251), Denase (HQ = 1.3856, HI = 2.5583) and Nkwantakesse 2 (HQ = 3.1994, HI = 3.2203). Again, in some of the samples, the cancer risk values were greater than 1.0×10^{-6}, which shows the possibility of cancer risk occurrence after a longer period of using the groundwater for drinking without prior treatment. The study identified both geogenic and anthropogenic activities as the sources of heavy metal concentration in the groundwater. The correlation analysis showed that there are no strong correlations among the heavy metal pairs, suggesting different sources, independence and different behaviors during transport. The Cd, HPI, and HEI concentrations show that 10%, 17.5%, and 7.5% respectively as highly polluted due to the public sewage which is the main possible source in the study area.

***Indexed Terms-* Afigya Kwabre, Groundwater, Heavy metals, contamination**

I. INTRODUCTION

One of the essential natural resources needed for the socio-economic development of a country is water. Clean drinking water promotes good hygiene and improved health. The socio-economic activities include industrial and commercial activities, navigation, transportation, hydroelectric power generation, and agricultural activities. In areas where surface water is scarce, some of these activities depend heavily on groundwater resources. However, the quantity and quality of groundwater can easily be affected by factors such as mining, population growth and agricultural activities. Thus, the contamination of the available water causes its quality to be compromised, rendering it unusable for some purposes. In recent times, the change in climatic condition has also negatively affected surface water by causing a lot of small water bodies to dry up whilst most of the remaining ones are highly polluted (Urama and Ozor, 2010). These have resulted in increased demand for groundwater for different purposes globally. Hence, there is a need to prudently manage groundwater resources, requiring both quantitative and qualitative approaches (Mogheir and Singh, 2002). Water quality assessment has, therefore, become an essential tool for sustainable water resource development. For this purpose, a lot of researchers have given the study of the impact of water quality on human health a lot of attention especially in developing countries where about 80% of all death is related to consumption of contaminated water (WHO, 2002). The availability of water and its quality is essential for public health, agriculture, and industry (Vanloon and Duffy, 2005). However, Asamoah and Amorin (2011) observed that groundwater is prone to contamination from the introduction of toxic elements through both natural processes and anthropogenic activities. Also, Ghasemi et al., (2011) observed that heavy metal contamination in groundwater has become one of the serious environmental issues due to increase of rate of contamination associated with the anthropogenic activities. In fact, limited concentration of some of the heavy metals dissolved in water are good for human health when within a certain range of concentration while others are harmful (Raju, 2007; Wang, 2013). Naturally, heavy metals occur in the Earth's crust, therefore, they are found in soils and rocks in different concentrations. For example, Pelig-Ba (1998) in their study of mercury, lead, copper, zinc, cadmium, iron, manganese, chromium and arsenic in groundwaters from the Upper West and Upper East Region and the Accra Plains in Ghana found that the mean Cd, Mn and Cu concentrations for all the study areas fell within the WHO limits, whereas the values of Pb, Cr and Fe exceeded the WHO limits for drinking water. They concluded that the chemical composition of the rocks in the area could be the dominant source of the heavy metals. Again, heavy metals contamination of groundwater due to anthropogenic activities such as mining, improper waste disposal, application of agrochemicals, etc. is now a global issue.

The application of multivariate statistical techniques to characterize groundwater sources is reported by many researchers. However, the application of such technique together with the pollution evaluation index to assess the suitability of the groundwater in the Afigya Kwabre (in a small scale) is lacking. Afigya Kwabre District has a high population density of 263 per sq. km and a high population growth rate of 4% annually. The people in the District rely heavily on groundwater for all their water needs. However, the relationship between the use of groundwater and public health in the District is unknown. This work, therefore, understand the suitability of the groundwater for drinking purpose in the District with respect to selected heavy metals concentrations in the groundwater. The study involved the application of both statistical methods and pollution evaluation indices. The District is located between latitudes 6o 5' N and 7o 1' N, and longitudes 1o 4' W and 1o 25' W (Fig. 1).

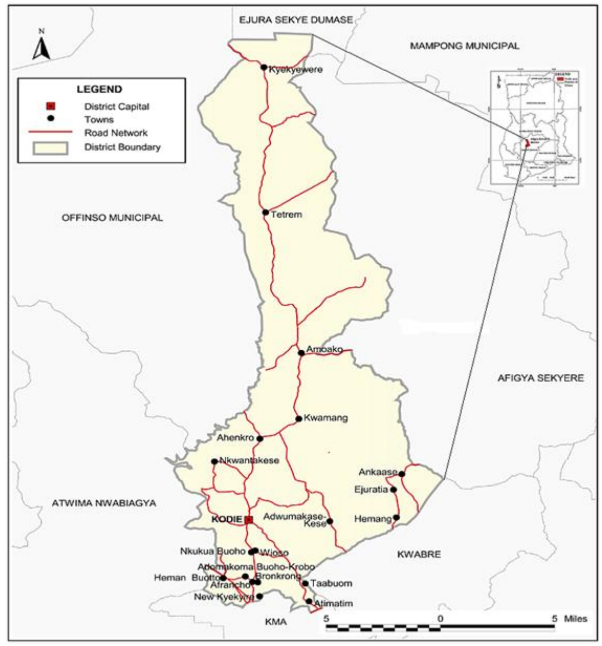

Fig.1 Map of Afigya Kwabre District (Ghana Statistical Report, 2010)

II. HYDROGEOLOGY OF THE STUDY AREA

The study area has an equatorial climate and two rainfall periods. The period for the minor rainfall is between September and November while the major rainfall period is between March and July. The landscape of the area is a dissected plateau with heights reaching 800 m to 1200 m above sea level. Isolated hills in the south around the Buoho community have altitude up to 1,200 m above mean sea level (Yidana et al., 2015). The undulating nature of the relief of the area makes the flow of water easy. Many rivers and streams drain the area and notable among these are the Offin, Oyon and Abankro Rivers. The study area is underlain by rocks of the Voltaian Supergroup and granitoids of the Birimian. The hydrogeology of the rocks of the area is controlled by secondary hydrogeological parameters such as weathering, fractures and fissures (Yidana et al., 2015). According to Kesse (1985), the Pan-African tectonic activities caused the sandstones of the Voltaian to partially metamorphose, hence their primary porosities are very much reduced. Yidana et al. (2015) noticed that the semi-confined Voltaian aquifers are amongst the most difficult aquifers to study in Ghana, and success rates for drilling prolific wells in the terrain rarely exceed 60%. In terms of groundwater occurrence, the Birimian aquifers have been noted to be generally better than the Voltaian (Yidana et al., 2015). The confined granitoids belong to the Crystalline Basement Aquifer Province (Obuobie et al., 2016; Banoeng-Yakubo et al., 2010) where groundwater occurs mainly in the saprolite, saprock and the fractured bedrock.

III. METHODOLOGY

Forty (40) boreholes were sampled for trace metals analysis in November 2015. The volumes of the bottles were 500 ml. The groundwater outlets were flushed for approximately 10-15 minutes to pump out water that had settled in the pipes before collecting samples. To preserve the samples, 10 ml of 69% nitric acid was added to the samples. The samples were placed in an ice chest containing ice blocks. They were then transported to Laboratory for analysis. In the laboratory, groundwater samples were analysed employing the standard methods (APHA, 1995). All the selected heavy metals were analysed using Atomic Absorption Spectrophotometer (AAS) with air acetylene flame. The accuracy of the laboratory analysis was checked by duplication of three samples with different codes and the differences were fall within the acceptable range of ± 5%.

IV. HEAVY METAL POLLUTION INDICES

The Heavy Metal Pollution Index (HPI) denotes the overall quality of water. According to Mohan et al. (1996), the following equations (equation 1 and 2) are used to calculate the index as:

$$Q_i = \sum_{i=1}^{n} \frac{\{M_i - I_i\}}{S_i - I_i} \times 100 \qquad (1)$$

Where Mi is the concentration of the heavy metal in the groundwater, Ii is the ideal concentration of the heavy metal in drinking water and Si is the standard values of the heavy metal.

$$HPI = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i} \qquad (2)$$

Where Qi is the sub-index, Wi is the unit weight of the heavy metal, and n represents the total number of parameters used in the calculation (Mohan et al., 1996). The (-) sign denotes the numerical difference between the two values ignoring the algebraic sign (Edet & Offiong, 2002; Alexandra et al., 2013; Giri & Singh 2014).

Weightage of parameters is assigned base on their importance and it's between zeros to one. It can also be considered as inversely proportional to the standard value for each element (Moghaddam et al., 2014). The quality of water sample is classified based on heavy metal pollution index is as: low heavy metal pollution (HPI <100), heavy metal pollution on the threshold risk (HPI = 100) and high heavy metal pollution (HPI > 100) (Edet & Offiong, 2002).

V. HEAVY METAL EVALUATION INDEX

Edet and Offiong (2002) defined HEI as the overall quality of water with respect to concentrations of heavy metals it contains and it is calculated by using Eqn. (3):

$$HEI = \sum_{i=1}^{n} \frac{H_c}{H_{mac}} \qquad (3)$$

Where Hc is the concentration of heavy metal in the groundwater and Hmac is the maximum admissible concentration (MAC) of the heavy metal.

VI. DEGREE OF CONTAMINATION (C_d)

According to Backman et al. (1997), the contamination index (Cd) summarizes the combined effects of various parameters considered to be harmful to human health in water and it's calculated as follows:

$$C_d = \sum_{i=1}^{n} C_{f_i} \qquad (4)$$

Where $C_{f_i} = \frac{C_{A_i}}{C_{N_i}} - 1$ (5)

Where Cfi is the contamination factor, CAi is the analytical value, CNi is the upper permissible concentration of the heavy metal, N is the normative value and CNi is taken as MAC.

VII. RISK ASSESSMENT

The evaluation of the heavy metals in the water samples for possible adverse health effects associated with exposure to such chemicals revealed that the level of exposure through ingestion (ADDi) was observed using (6).

$$ADD_i = \frac{(C_i \times IR \times EF \times ED)}{(BW \times AT)} \qquad (6)$$

Where EF, ED, BW, AT are Exposure frequency, Exposure duration, Body weight, and Average time respectively (Siriwong, 2006). Ci is given by table 1 the slope factor (SF) the reference dose (RfD) are presented in table 2 (Wongsasuluk et al., 2014).

Table 1 Input parameters to characterize the ADD value

Exposure parameters	Symbols	Units	Value
Cadmium	Cd	Mg/L	5.0 10-4
Cupper	Cu	Mg/L	4.0 10-2
Lead	Pb	Mg/L	3.5 10-3
Zinc	Zn	Mg/L	0.3
Iron	Fe	Mg/L	0.7
Manganese	Mn	Mg/L	0.014
Ingestion rate	IR	L/Day	2.2
Exposure frequency	EF	Days/Year	365
Exposure duration	ED	Years	70
Body weight	BW	Kg	70
Average time	AT	Years	25,550days

Table 2 The toxicity responses to heavy metals as the oral reference dose (RfD)

Heavy Metals	Oral RfD (mg/kg/day)
Cd	5.0 10-4
Cu	4.0 10-2
Pb	3.5 10-3
Zn	0.3
Fe	0.7
Mn	0.014

There is a need for hazard assessment as it helps to evaluate the possibility of an agent to cause carcinogenic hazard to the public and the circumstances under which such hazards may occur (WHO, 2003; Ogunfowokan et al., 2005). The assessment is done by using equation (7) below:

$$\text{Hazard quotient (HQ)} = \frac{ADD}{RfD} \qquad (7)$$

Where HQ and RfD are the hazard quotient and the oral/ dermal reference dose (mg/L/day) respectively (Bartholomew et al., 2008).

$$Hazard\ index\ (HI_i) = \sum HQ_i \qquad (8)$$

According to Lim et al. (2008), when the HI/HQ ratio is greater than one, it indicates an unacceptable risk of non-carcinogenic effects on public health, however, when the HI/HQ ratio is less than one then it indicates an acceptable level of risk. Equation (9) was used to calculate the (Boateng et al., 2015).

$$CDI = C_i \times \frac{DI}{BW} \qquad (9)$$

Where Ci is the concentration of the heavy metal in the groundwater samples (mg/l), DI is average daily intake rate (2.2 L/day), and BW is body weight (70 kg).

VIII. STATISTICAL ANALYSIS

Table 3 Statistical summary of the groundwater data

Parameter	Unit	Minimum	Maximum	Mean	Std. Deviation	WHO (2012)
Fe	mg/l	0.00	13.26	0.35	2.10	0.30
Zn	mg/l	0.00	0.13	0.01	0.02	5.00
Pb	mg/l	0.00	0.36	0.03	0.07	0.01
Cu	mg/l	0.00	0.43	0.03	0.07	2.00
Mn	mg/l	0.00	0.21	0.07	0.06	0.10
Cd	mg/l	0.00	0.02	0.00	0.00	0.00

The result of the analysis of the samples taken from the study area is presented in table 3. The study revealed that Fe > Mn > Pb = Cu > Cd is the order in which the concentrations of the heavy metals in the groundwater decreases. Fe and Mn are metals that occur naturally in rocks and they are dissolved into the groundwater through rock-water interaction. The range of Fe concentration in the groundwater range was 0-13.26 mg/l with a mean of 0.35mg/l. Most of the samples showed no concentration of Fe. However, the sample taken from Kyekyewere showed an extremally high Fe concentration of 13mg/l. This high concentration of iron seen in the sample taken from Kyekyewere may be attributed to the dissolution of minerals such as amphibole in the rocks. The continuous drinking of water which contains excess iron concentration may result in public health issues (US-CDC, 2011). The concentration of Mn ranges from 0 to 0.21mg/l and a mean of 0.07mg/l which is above the permissible limit of 0.10mg/l (WHO, 2012). The concentration of Pb ranges from 0 to 0.36mg/l. Most of the communities with high concentrations of Pb above the WHO (2012) recommended value of 0.01 mg/l are located in the southern part of the study area which is heavily populated. This indicates that the concentration of Pb may be influenced by anthropogenic activities such as pit latrine and improper waste disposal. This may also account for the observed concentration of Cd above the permissible limit of 0.01 mg/l in Denase which is located in the southern part of the study area.

From the results of the correlation analysis of heavy metals in Table 4, it can be seen that the concentrations for different heavy metals are not correlated in the study area. This indicates that the concentrations of the various heavy metals in the groundwater samples are influenced by different factors. The lack of associations of the heavy metals indicates that their concentrations in the groundwater have not been influenced by contaminants from the same sources. Their concentrations are likely controlled by rock weathering. Application of the principal component analysis was employed to uncover the possible sources of heavy metals in the groundwater samples. The study implored R-mode Cluster Analysis to show relationships between variables. The technique helped in the determination the relationship existing amongst the heavy metals in the groundwater as well as the possible influencing factors. Before the clustering process, the data were normalized. The dendrogram (Fig. 2) shows three clusters which reflect possible strong mutual correlations that exist among the parameters. Factor analysis was used by varimax rotation to identify the similarity and dissimilarity of the variables and possible pollution sources. The Eigen values and Eigen vectors were evaluated for the covariance matrix and the data was transformed into factors. The principal component analysis was also applied to uncover the degree of heavy metal pollution as well as the possible sources of contaminations (Table 5). In this study three components with eigenvalues greater than one explained 61.36 % of the total variance were extracted in R-mode analysis (Table

6). PC1 with a moderate positive loading for Pb, Cu and Cd and moderate negative loadings for Mn and Fe contributed 24.91% of the total variance. This indicates that Pb, Cu, Cd, Mn and Fe are derived from different sources (Bhuiyan et al., 2010). PC2 accounts for 19.70% of the total variance with a moderate positive contribution of Fe and a weak positive contribution of Pb, Mn and Cd and weak negative contribution of Zn. PC3 with a moderate positive contribution of Zn, a weak positive contribution of Pb and a weak negative contribution of Cu and Fe accounts for 16.75 % of the total variance. This observation suggests that anthropogenic activities such as waste disposal and agriculture have negative impacts on the groundwater quality in the study area.

Table 4 Correlation coefficient matrix for heavy metals in the groundwater samples.

	Fe	Zn	Pb	Cu	Mn	Cd
Fe	1					
Zn	-.042	1				
Pb	-.061	-.091	1			
Cu	-.059	-.057	.013	1		
Mn	.225	-.014	-.104	-.214	1	
Cd	-.030	-.044	.286	.136	-.067	1

Table 5 rotated component matrix of three component

	Component		
	1	2	3
Fe	-.428	.517	-.300
Zn	-.161	-.447	.616
Pb	.562	.487	.369
Cu	.508	-.208	-.596
Mn	-.607	.473	.079
Cd	.586	.459	.195

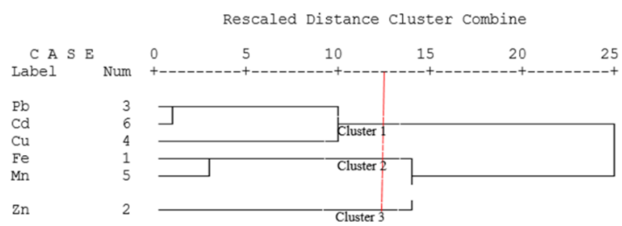

Figure 2 Dendrogram of selected metals in water samples using ward's method

Table 6 Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.495	24.910	24.910	1.495	24.910	24.910	1.328	22.141	22.141
2	1.182	19.700	44.610	1.182	19.700	44.610	1.287	21.447	43.588
3	1.005	16.753	61.363	1.005	16.753	61.363	1.066	17.775	61.363
4	.922	15.367	76.730						
5	.748	12.472	89.203						
6	.648	10.797	100.000						

IX. POLLUTION EVALUATION INDICES OF WATER

The calculated Heavy metal pollution index had a mean of 128.66 with a range of 0.01-1725.20 (Table 7). The HPI results showed that seven samples (17.5%) were above the critical limit of 100 proposed for drinking water by Prasad and Bose (2001). The affected communities include Aduamoa (158.43), Ahenkro New York (203.63), Buoho Glotto (288.88), Maase Edwenase (416.63), Denase (823.91), Nkukua Buoho (1200.20), and Nkwantakese 2 (1725.20). The degree of contamination has a mean value of -2.03 and a range of -5.99 to 38.58. Which is far below the value of 1, this value of Cd average in this research revealed the area to have low contamination in terms of the heavy metals. In this study the grouping by (Edet and Offiong, 2002) and (Backman et al., 1997) was adopted, which are: low (Cd < 1) medium (Cd 1-3) and high (Cd >3). As per the above classification, 87.5 % of the samples were classified as low zone, 2.5 % as medium zone and 10 % as high zone. The Cd and HPI indices show that four of the samples are highly polluted while three are moderately polluted. Computed heavy metal evaluation index (HEI) for this study gives a mean of 4.5297 with minimum and maximum values of 0.3 and 20.4 respectively. Adopting the procedure used by Boateng et al. (2015), the computed values of HEI were divided into 3 classes using a multiple of the mean value. The three classes demarcated are HEI < 10 low, HEI 10-20 medium and HEI > 20 high. Based on these, 36 locations which represent 90% of all the locations had low HEI values, while 1 location covering 2.5% of the sample falls within the medium class while three locations (7.5%) have high HEI value in this study.

X. HUMAN HEALTH RISK ASSESSMENT

In recent times, Heavy metal pollution has become a serious environmental issue. This is because of the negative impact associated use of heavy metal contaminated water for drinking purpose. Hazard Quotients (HQ), Hazard Index (HI) and CDI index were used in this study. The study revealed that the groundwater of the study area is within the acceptable level of non-carcinogenic adverse health risk (Table 8). The HI values of all the metals range from 0.0115 to 0.3.2203 with a mean of 0.4570. The analysis shows that 7.5% of the samples are above the acceptable risk for non-carcinogenic adverse public health of HI<1 in the samples taken from Nkuakua Buoho (2.5194), Denase (2.5583) and Nkwantakese 2 (3.2203). Also, the ADD values range from 0 to 0.4167, 0 to 0.0042, 0.000 to 0.0112, 0.000 to 0.0136, 0.0003 to 0.0065 and 0.0000 to 0.00005 mg/kg/day for Fe, Zn, Pb, Cu, Mn and Cd respectively (Table 9). Some of the samples have ADD values greater than 1.0×10^{-6}, therefore, longtime usage of the groundwater for drinking can cause public health issues. CDI was employed to assess the total exposure of the groundwater users and the values are given in Table 10. The order of CDI indices in groundwater samples was identified as Fe > Mn > Cu > Pb > Zn > Cd. When CDI value is greater than 1.0×10^{-6} then it is not acceptable for drinking purpose due to health risk associated with it use (USEPA, 2011). The study revealed that there is a risk of cancer occurrence as a result of the use of the groundwater in the study area for drinking purpose since some of CDI of some of the groundwater samples show CDI values greater than the acceptable value (Iqbal and Shah, 2013).

Table 7 Water pollution indices

Sample No.	Name of community	C_d	HPI	HEI
1	Kyekyewere Nsankyerem	-5.76	0.28	0.24
2	Kyekyewere Zongo	-5.99	0.01	0.01
3	Kyekyewere Abofrem	38.58	71.72	44.58
4	Tetrem Besease	-5.97	0.02	0.03
5	Tetrem Kondeso	-5.90	4.42	0.10
6	Tetrem Zongo	-5.59	0.51	0.41
7	Soko1	-4.20	80.33	1.80
8	Soko2 (near the school)	-5.72	0.34	0.28

9	Boaman Abase	-5.99	0.01	0.01
10	Boaman (police station)	-5.97	0.03	0.03
11	Boaman Kokoado	-5.78	0.27	0.22
12	Kwaman Bonglo	-5.98	0.02	0.02
13	Kwaman Zongo	-5.89	0.11	0.11
14	Ahenkro (New York)	-1.74	203.63	4.26
15	Ahenkro 2	-5.77	0.44	0.23
16	Denase	11.18	823.91	17.18
17	Kodie Zongo (near Mowire)	-5.57	2.58	0.43
18	Kodie Masalachie	-5.79	0.24	0.21
19	Bouho DA school	-5.39	14.00	0.61
20	Buoho Glotto	0.29	288.88	6.29
21	Atimatim Taabuom	-5.94	0.06	0.06
22	Maase Essen	-5.81	0.19	0.19
23	Maase Edwenase	2.65	416.63	8.65
24	Agyarko Buoho	-5.40	16.17	0.60
25	Nkukua Buoho	19.10	1200.20	25.10
26	Nkwantakese 1	-5.57	0.50	0.43
27	Adwumakasekese Subrintem	-5.53	0.55	0.47
28	Nkwantakese 2 (near health centre)	29.65	1725.20	35.65
29	Aduamoa	-2.48	158.43	3.52
30	Aduman	-5.90	0.09	0.10
31	Aboabugya Eboom	-5.80	0.22	0.20
32	Aboabugya Beposo	-5.61	0.47	0.39
33	Adwumakasekese (Meth. Pri.)	-4.91	49.45	1.09
34	Ankaase Ohenedaho	-5.94	0.08	0.06
35	Wawase 1 (on Denase road)	-5.97	0.03	0.03
36	Wawase 2	-5.48	0.63	0.52
37	Mpobi Sunroase	-5.91	0.11	0.09
38	Ankaase (DA school)	-3.47	3.97	2.53
39	Ejuratia (near Meth. Church.)	-4.14	81.46	1.86
40	Heman	-5.86	0.16	0.14
Maximum		38.58	1725.20	44.58
Minimum		-5.99	0.01	0.01
Mean		-2.03	128.66	3.97

Table 8 Non-carcinogenic risk (hazard quotient, HQ) and overall toxic risk (hazard index, HI) of the groundwater.

	HQ						HI
No	Fe	Zn	Pb	Cu	Mn	Cd	HI
1	0.0000	0.0000	0.0000	0.0158	0.2093	0.0000	0.2251
2	0.0000	0.0000	0.0000	0.0014	0.0100	0.0000	0.0115
3	0.5953	0.0000	0.0000	0.0080	0.3383	0.0000	0.9416
4	0.0000	0.0000	0.0000	0.0335	0.0092	0.0000	0.0427
5	0.0000	0.0000	0.0000	0.0000	0.0103	0.0571	0.0675
6	0.0004	0.0000	0.0000	0.0000	0.3437	0.0000	0.3441
7	0.0000	0.0000	0.1474	0.0386	0.1079	0.0087	0.3027
8	0.0000	0.0000	0.0000	0.0067	0.2510	0.0000	0.2577
9	0.0000	0.0000	0.0000	0.0075	0.0044	0.0000	0.0119

10	0.0000	0.0000	0.0000	0.0160	0.0198	0.0000	0.0358
11	0.0000	0.0000	0.0000	0.0043	0.1985	0.0000	0.2028
12	0.0000	0.0000	0.0000	0.0117	0.0133	0.0000	0.0251
13	0.0000	0.0082	0.0000	0.0036	0.0815	0.0000	0.0932
14	0.0000	0.0000	0.3776	0.0724	0.0110	0.0000	0.4610
15	0.0000	0.0000	0.0000	0.3408	0.0026	0.0050	0.3483
16	0.0000	0.0000	1.3856	0.0727	0.1051	0.9950	2.5583
17	0.0000	0.0000	0.0000	0.0025	0.3437	0.0275	0.3738
18	0.0000	0.0000	0.0000	0.0225	0.1739	0.0000	0.1964
19	0.0000	0.0000	0.0253	0.0173	0.2831	0.0000	0.3256
20	0.0000	0.0000	0.5351	0.0658	0.2552	0.0000	0.8561
21	0.0000	0.0000	0.0000	0.0158	0.0441	0.0000	0.0599
22	0.0000	0.0139	0.0000	0.0164	0.1365	0.0000	0.1668
23	0.0000	0.0000	0.7726	0.0378	0.0197	0.0000	0.8301
24	0.0000	0.0000	0.0294	0.0012	0.2487	0.0000	0.2793
25	0.0000	0.0000	2.2251	0.0190	0.2752	0.0000	2.5194
26	0.0000	0.0000	0.0000	0.0370	0.3677	0.0000	0.4047
27	0.0000	0.0028	0.0000	0.0338	0.4021	0.0000	0.4387
28	0.0000	0.0000	3.1994	0.0028	0.0180	0.0000	3.2203
29	0.0000	0.0000	0.2933	0.0343	0.2122	0.0000	0.5398
30	0.0000	0.0000	0.0000	0.0418	0.0620	0.0000	0.1039
31	0.0000	0.0003	0.0000	0.0242	0.1609	0.0000	0.1854
32	0.0000	0.0000	0.0000	0.0010	0.3477	0.0000	0.3487
33	0.0000	0.0000	0.0916	0.0296	0.0433	0.0000	0.1644
34	0.0000	0.0000	0.0000	0.0000	0.0568	0.0000	0.0568
35	0.0000	0.0000	0.0000	0.0064	0.0217	0.0000	0.0281
36	0.0000	0.0000	0.0000	0.0012	0.4651	0.0000	0.4663
37	0.0000	0.0000	0.0000	0.0000	0.0828	0.0000	0.0828
38	0.0306	0.0000	0.0000	0.0015	0.2270	0.0000	0.2590
39	0.0000	0.0000	0.1507	0.0000	0.1609	0.0000	0.3115
40	0.0000	0.0000	0.0000	0.0159	0.1187	0.0000	0.1346

Table 9 Exposure duration, ADD (mg/kg-day) for the groundwater

No	Fe	Zn	Pb	Cu	Mn	Cd
1	0.0000	0.0000	0.0000	0.0006	0.0029	0.0000
2	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000
3	0.4167	0.0000	0.0000	0.0003	0.0047	0.0000
4	0.0000	0.0000	0.0000	0.0013	0.0001	0.0000
5	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
6	0.0003	0.0000	0.0000	0.0000	0.0048	0.0000
7	0.0000	0.0000	0.0005	0.0015	0.0015	0.0000
8	0.0000	0.0000	0.0000	0.0003	0.0035	0.0000
9	0.0000	0.0000	0.0000	0.0003	0.0001	0.0000
10	0.0000	0.0000	0.0000	0.0006	0.0003	0.0000
11	0.0000	0.0000	0.0000	0.0002	0.0028	0.0000
12	0.0000	0.0000	0.0000	0.0005	0.0002	0.0000
13	0.0000	0.0025	0.0000	0.0001	0.0011	0.0000
14	0.0000	0.0000	0.0013	0.0029	0.0002	0.0000

15	0.0000	0.0000	0.0000	0.0136	0.0000	0.0000
16	0.0000	0.0000	0.0048	0.0029	0.0015	0.0005
17	0.0000	0.0000	0.0000	0.0001	0.0048	0.0000
18	0.0000	0.0000	0.0000	0.0009	0.0024	0.0000
19	0.0000	0.0000	0.0001	0.0007	0.0040	0.0000
20	0.0000	0.0000	0.0019	0.0026	0.0036	0.0000
21	0.0000	0.0000	0.0000	0.0006	0.0006	0.0000
22	0.0000	0.0042	0.0000	0.0007	0.0019	0.0000
23	0.0000	0.0000	0.0027	0.0015	0.0003	0.0000
24	0.0000	0.0000	0.0001	0.0000	0.0035	0.0000
25	0.0000	0.0000	0.0078	0.0008	0.0039	0.0000
26	0.0000	0.0000	0.0000	0.0015	0.0051	0.0000
27	0.0000	0.0008	0.0000	0.0014	0.0056	0.0000
28	0.0000	0.0000	0.0112	0.0001	0.0003	0.0000
29	0.0000	0.0000	0.0010	0.0014	0.0030	0.0000
30	0.0000	0.0000	0.0000	0.0017	0.0009	0.0000
31	0.0000	0.0001	0.0000	0.0010	0.0023	0.0000
32	0.0000	0.0000	0.0000	0.0000	0.0049	0.0000
33	0.0000	0.0000	0.0003	0.0012	0.0006	0.0000
34	0.0000	0.0000	0.0000	0.0000	0.0008	0.0000
35	0.0000	0.0000	0.0000	0.0003	0.0003	0.0000
36	0.0000	0.0000	0.0000	0.0000	0.0065	0.0000
37	0.0000	0.0000	0.0000	0.0000	0.0012	0.0000
38	0.0214	0.0000	0.0000	0.0001	0.0032	0.0000
39	0.0000	0.0000	0.0005	0.0000	0.0023	0.0000
40	0.0000	0.0000	0.0000	0.0006	0.0017	0.0000

Table 10 Chronic daily intake in the groundwater

No	Fe	Zn	Pb	Cu	Mn	Cd
1	0.000000	0.000000	0.000000	0.000633	0.002930	0.000000
2	0.000000	0.000000	0.000000	0.000057	0.000140	0.000000
3	0.416743	0.000000	0.000000	0.000318	0.004736	0.000000
4	0.000000	0.000000	0.000000	0.001342	0.000128	0.000000
5	0.000000	0.000000	0.000000	0.000000	0.000145	0.000029
6	0.000283	0.000000	0.000000	0.000000	0.004812	0.000000
7	0.000000	0.000000	0.000516	0.001545	0.001510	0.000004
8	0.000000	0.000000	0.000000	0.000270	0.003514	0.000000
9	0.000000	0.000000	0.000000	0.000301	0.000061	0.000000
10	0.000000	0.000000	0.000000	0.000641	0.000277	0.000000
11	0.000000	0.000000	0.000000	0.000171	0.002779	0.000000
12	0.000000	0.000000	0.000000	0.000470	0.000186	0.000000
13	0.000000	0.002451	0.000000	0.000143	0.001141	0.000000
14	0.000000	0.000000	0.001322	0.002895	0.000154	0.000000
15	0.000000	0.000000	0.000000	0.013631	0.000036	0.000002
16	0.000000	0.000000	0.004849	0.002908	0.001471	0.000498
17	0.000000	0.000000	0.000000	0.000102	0.004812	0.000014
18	0.000000	0.000000	0.000000	0.000901	0.002434	0.000000
19	0.000000	0.000000	0.000088	0.000692	0.003963	0.000000

20	0.000000	0.000000	0.001873	0.002631	0.003573	0.000000
21	0.000000	0.000000	0.000000	0.000633	0.000617	0.000000
22	0.000000	0.004180	0.000000	0.000657	0.001911	0.000000
23	0.000000	0.000000	0.002704	0.001512	0.000276	0.000000
24	0.000000	0.000000	0.000103	0.000047	0.003482	0.000000
25	0.000000	0.000000	0.007788	0.000759	0.003853	0.000000
26	0.000000	0.000000	0.000000	0.001479	0.005148	0.000000
27	0.000000	0.000849	0.000000	0.001351	0.005629	0.000000
28	0.000000	0.000000	0.011198	0.000111	0.000253	0.000000
29	0.000000	0.000000	0.001026	0.001373	0.002971	0.000000
30	0.000000	0.000000	0.000000	0.001673	0.000869	0.000000
31	0.000000	0.000094	0.000000	0.000967	0.002252	0.000000
32	0.000000	0.000000	0.000000	0.000040	0.004868	0.000000
33	0.000000	0.000000	0.000321	0.001183	0.000606	0.000000
34	0.000000	0.000000	0.000000	0.000000	0.000795	0.000000
35	0.000000	0.000000	0.000000	0.000258	0.000303	0.000000
36	0.000000	0.000000	0.000000	0.000048	0.006512	0.000000
37	0.000000	0.000000	0.000000	0.000000	0.001159	0.000000
38	0.021434	0.000000	0.000000	0.000059	0.003177	0.000000
39	0.000000	0.000000	0.000527	0.000000	0.002252	0.000000
40	0.000000	0.000000	0.000000	0.000636	0.001662	0.000000

CONCLUSION

This study reports on Fe, Zn, Pb, Cu, Mn and Cd contamination in Groundwater from the Afigya Kwabre District, Ghana. The study revealed that Fe > Mn > Pb = Cu > Cd is the order in which the concentrations of the heavy metals in the groundwater decreases. The average concentration values of Pb and Fe in the groundwater were higher than the WHO (2012) recommended values of 0.01mg/l and 0.30mg/l respectively. The human health risk assessment based on hazard quotient (HQ) and Hazard index (HI) analysis revealed that the groundwater samples are within acceptable level of non-carcinogenic adverse risk except three samples taken from Nkukua Buoho (HQ = 2.5194, HI = 2.2251), Denase (HQ = 1.3856, HI = 2.5583) and Nkwantakesse 2 (HQ = 3.1994, HI=3.2203). Again, the cancer risk assessment revealed that the groundwater samples exceeds the acceptable limit of 1.0×10^{-6}, indicating the possibility of cancer risk occurrence after a longer period of using the groundwater for drinking without prior treatment. Statistical analysis identified both geogenic processes and anthropogenic activities as contributing factors of heavy metal concentration in the groundwater. There is no strong correlation among the parameters which indicates different sources, independence and different behaviors during transport of the heavy metals. The Cd, HPI, and HEI values show that 10%, 17.5%, and 7.5% respectively, as highly polluted due to the pit latrine which is common in the study area. Identification of heavy metal contamination in the groundwater samples taken from some communities in the study area poses a threat to public health. The continuous exposure of heavy metals will lead to severe complications in the future due to the negative impact on public health. Monitoring of groundwater quality and employing appropriate treatment technology to treat the water before consumption will reduce additional exposure to heavy metals. The co-operation of the District assembly, national policymakers, as well as all stakeholders in the Water, Sanitation and Hygiene (WASH) sector is vital for coming up with appropriate strategies to prevent heavy metal toxicity in Ghana.

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