



EVALUATION OF HEAVY METAL POLLUTION OF GROUNDWATER IN GASHUA TOWN IN YOBE STATE, NIGERIA. AGADA LIVINUS EMEKA

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ABSTRACT

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The main source of drinking water in Gashua and its environs is groundwater. Groundwater is available to the people in the study area through hand dug wells and boreholes. The main aim of this study was to determine the concentration of heavy metals (lead, arsenic, cadmium, copper, chromium and iron) in the groundwater and discuss their possible health implications. A total of fifteen (15) water samples from both hand dug wells and boreholes were obtained from the study area. The water samples were analyzed using Atomic Absorption Spectrophotometer (AAS). The results obtained were compared with both National and International (NAFDAC, NSDWQ and WHO) set standards. The results obtained revealed that the concentrations of lead, arsenic, iron and cadmium exceeded the regulatory limits set by NAFDAC, NSDWQ and WHO. Copper and chromium concentrations were within the permissible limits. Thus the groundwater is polluted with lead, arsenic, iron and cadmium. The health consequences of consuming water polluted by heavy metals were discussed. There is need for regular monitoring of groundwater quality in the study area. The regular investigation of the groundwater quality in Gashua and its environs will help to save lives and prevent the increase in diseases related to heavy metal ingestion through drinking water.

1.0 INTRODUCTION

Advancement in urbanization and industrial development in recent times has raised much concern in environmental study. The ecosystem is presently threatened by both domestic and industrial waste materials. Drinking water is an essential material in every community and its source needs to be carefully monitored periodically to avoid health hazards due to heavy metal pollution and other chemical agents. Heavy metals are individual metals and metal compounds that can cause serious health hazards to humans when consumed beyond permissible level. They are common environmental pollutants in the groundwater due to natural or anthropogenic sources. Anthropogenic

sources of heavy metals to groundwater include mining and industrial waste, vehicle emissions, lead acid batteries, fertilizers, paints, treated wood, ageing water supply infrastructure, domestic effluents, and urban storm water-runoff. Heavy metals are also added to the groundwater through natural chemical weathering process and leaching of soil. Acid rains most times exacerbate this process by releasing heavy metals trapped in the soils into the groundwater. Heavy metals occur as natural constituents of the earth crust, and are persistent environmental contaminants since they cannot be degraded or destroyed (Nasrabadi et al., 2015; Asadpour, 2015; Akbarzadeh et al. 2015).

In rocks they exist as their ores in different chemical forms, from which they are recovered as minerals. Heavy metal ores include sulphide, such as iron, arsenic, lead, zinc, cobalt, gold, silver, nickel and oxides such as aluminum, manganese, gold, selenium and antimony. In most cities, towns and rural areas, groundwater is often used without treatment. Groundwater comprises of water from springs, wells and boreholes (Wilson et al., 1990). Humans are exposed to heavy metals through drinking of contaminated water, inhalation of air pollutants, and consumption of food, such as vegetables, grains, fruits and fish. All metals when consumed in sufficient quantities could cause health hazards, but there are some which in their small quantities in diets contribute to effective body metabolism and healthy growth, examples are iron, copper, zinc, chromium, selenium and manganese. Metals such as lead, mercury, arsenic and cadmium are of no biological significance to human body, rather they constitute health hazards. Heavy metals can cause serious health effects with varied symptoms depending on the nature and quantity ingested (Akan et al., 2011).

Many studies have been carried out on heavy metal pollution of water resources all round the world (Wang et al., 2007; Waziri et al., 2009; Zhang et al., 2009; Nasrabadi et al., 2009, Edet and Offiong, 2009; Prasad and Bose, 2001). Waziri et al., (2009), observed that both surface and ground water in Gashua and Nguru area of Yobe State were polluted with heavy metals. Nevertheless, sufficient study has not been conducted on heavy metal contamination of groundwater in Gashua town of Yobe State in Nigeria. Base on this observation, due emphasis was given to to the analysis of the following heavy metals, cadmium, lead, chromium, arsenic, copper and iron. More-over, as a result of the growth in the population of people in the town and the increasing demand for save drinking water, it is important to regularly monitor the status of the groundwater quality in the area. The main objective of this study is to evaluate the risk

potential associated with the presence of heavy metals in groundwater in Gashua town of Yobe State.

2.0 MATERIALS AND METHODS

2.1 Study Area

Gashua is a town in Yobe state, north-eastern Nigeria, situated close to the convergence of Hadeija and Jama 'are rivers in the Chad Basin. It is located on latitude 12° 52' North and longitude 11° 2' East. The Chad formation consists of three water-bearing horizons i.e. the Upper, Middle and the Lower Zones (Matheis, 1989). The study area is directly underlain by the rocks of the upper Member of the formation. Lithologically, the upper Member is composed of layers of clayey grits and sands or sandstones of varying thickness (Makinde et al., 2010). It has a population of about 125,000 according to 2006 national population census result. The climate is characterized by short wet season (June-September) and long dry season (October to May), with high temperature of 39°C to 45°C. In the raining season, temperatures fall to 23 to 28°C, with rainfall of 500 to 1000mm.

2.2 Sample Collection

Water samples were collected from fifteen (10) boreholes and five (5) hand dug wells sited at different locations within Gashua town and its environs. The samples were collected in pre-cleaned sample bottles of 0.25 liter capacity. The bottles were rinsed first with distilled water before filling, rinsed a further two or three times with the water being sampled, and then the water samples were taken. The sample locations are; Abacha, Tashar- Kuka, Low- cost, Takari, Unguwar Lawan, Katuzu, Zango, Sabon-gari, G.R.A, Unguwar kuka, Kabala and Tanda area of Gashua town.

2.3 Sample Preservation and Storage

The water samples were filtered through pre-washed 0.45µm Millipore nitrocellulose filters to remove any suspended material and preserved immediately after collection with nitric acid (HNO₃) in order to avoid precipitation of the metals. The samples were stored at 4°C in a refrigerator prior to the analysis.

2.4 Sample Digestion

The water samples were digested with concentrated nitric acid (HNO₃). 10 ml of concentrated HNO₃ was added to 50ml of the water samples and the mixture was heated at a temperature of 60°C for one hour. The mixture was allowed to cool and then filtered to remove any material that could clog the atomizer.

2.5 Sample Analysis

The digested water samples were analyzed for heavy metals using Atomic Absorption Spectrometer (AAS). 1000mg/l standard solution of the metals were prepared in 10ml HNO₃ (0.1M) for calibration curve from the standard salt of each metal in 100ml volumetric flask. From this stock solution,

100mg/l of each metal was freshly prepared by diluting in 100ml volumetric flask with distilled water and then the working solution (10mg/l) of each metal was prepared. The determination of lead, chromium, arsenic, iron, cadmium and copper were carried out by direct aspiration of the water into air acetylene flame.

2.6 Data Analysis

The data obtained was analyzed using STATISTICA software. Basic statistics such as minimum, maximum, mean, standard deviation and correlation coefficient were used to evaluate the data obtained. Correlation coefficients among various heavy metals were calculated and possible sources of heavy metal were identified.

3.0 Result and Discussion

Heavy Metals Concentration (mg/L)						
Sample	Lead (Pb)	Chromium (Cr)	Cadmium (Cd)	Arsenic (As)	Copper (Cu)	Iron (Fe)
1	0.015	0.061	0.045	0.030	0.085	1.400
2	0.020	0.030	0.057	0.013	0.190	0.300
3	0.012	0.070	0.031	0.021	0.203	0.600
4	0.022	0.050	0.040	0.030	0.196	0.900
5	0.020	0.030	0.023	0.021	0.185	1.500
6	0.019	0.040	0.036	0.024	0.650	1.100
7	0.012	0.060	0.048	0.040	0.724	1.200
8	0.021	0.040	0.024	0.028	0.140	1.300
9	0.015	0.042	0.054	0.030	0.610	1.000
10	0.010	0.070	0.031	0.032	0.840	1.600
11	0.020	0.030	0.020	0.020	0.720	0.900
12	0.018	0.050	0.018	0.024	0.526	0.800
13	0.015	0.030	0.022	0.028	0.850	1.200
14	0.020	0.046	0.024	0.015	0.920	0.200
15	0.012	0.040	0.035	0.020	0.154	1.000
Average	0.017	0.046	0.034	0.025	0.466	1.000
S.D	0.004	0.014	0.013	0.007	0.308	0.405
Max.	0.022	0.070	0.057	0.040	0.920	1.600
Min.	0.010	0.030	0.018	0.013	0.085	0.200

S.D = Standard deviation, Max = Maximum, Min = Minimum.

Table 2. Comparison of the heavy metal concentration values obtained with the national and International set standards.

	Heavy Metals concentrations in mg/L					
	Lead	Chromium	Cadmium	Arsenic	Copper	Iron
Gashua	0.017±0.004	0.046±0.014	0.034±0.013	0.025±0.070	0.466±0.308	1.000±0.405
NAFDAC	0.010	0.050	0.100	0.010	2.000	0.200
WHO	0.010	0.050	0.010	0.010	2.000	0.300
NSDWQ	0.010	0.050	0.030	0.010	1.000	0.300

Table 3. Pearson’s Correlation of the Heavy Metals.

	Lead	Chromium	Cadmium	Arsenic	Copper	Iron
Lead	1					
Chromium	-0.618	1				
Cadmium	-0.195	0.151	1			
Arsenic	-0.422	0.484	0.215	1		
Copper	-0.182	0.002	-0.244	0.168	1	
Iron	-0.313	0.156	-0.115	0.670	-0.054	1

Iron is an essential element in human nutrition. Estimates of the minimum daily requirement of iron depend on age, sex, physiological status and iron bioavailability and range from about 10 to 50mg/day. In the study area the concentration of iron in the groundwater ranges from 0.20 to 1.60mg as shown in figure 1 above. The regulatory limits for iron in drinking water by WHO ,NSDWQ and NAFDAC are 0.3mg/L,0.3mg/l and 0.2mg/L respectively. The average iron content in the groundwater in the study area is 1.0 ± 0.405mg/L as shown in table 2. High concentration of iron is associated with undesirable taste, laundry staining, scaling in pipes, vomiting, teeth staining and cardiac problems. The groundwater is therefore polluted with iron.

At appropriate concentration, copper is important to human body but at high concentration it becomes toxic to the body system. High levels of copper can cause a bitter metallic taste in water and result in blue

green stains on plumbing fixtures. The concentration of copper in the study area ranges from 0.085 to 0.920mg/L. The regulatory limits for copper in drinking water by both WHO and NAFDAC is 2mg/L, and by NSDWQ it is 1mg/l. The average copper content in the groundwater in the study area is 0.466 ± 0.308mg/L as shown in table 2. Therefore, the groundwater is not polluted in terms of its copper content. The primary sources of copper in drinking water are corroding pipes and brass components of household piping systems. The amount of copper in drinking water also depends on the hardness and PH of the water. High concentration of copper in human body can cause anemia, liver and kidney damage, stomach and intestinal irritation (Agada et al., 2011). Generally, heavy metals are naturally occurring substances which are often present in the environment in small amount, but in large amount they constitute health hazards.

Lead can be present in drinking water as a result of dissolution from natural sources, or from household systems containing lead. It is a toxic metal which got spread through the burning of fossil fuel, mining, and manufacturing processes. The concentration of lead in the ground water in the study area ranges from 0.01 to 0.022mg/L. The average concentration of lead in the groundwater in the study area is 0.017 ± 0.004 mg/L. The regulatory limits for lead in drinking water by WHO, NSDWQ and NAFDAC are 0.010mg/l respectively as shown in table 2 above. The groundwater in the area is polluted by lead. Lead can affect every organ in the body. Long term exposure to lead can severely damage kidneys and the organs responsible for male reproduction. Lead has been classified as carcinogen by the Environment Protection Agency (EPA, 1999). In some cases, long term exposure to lead can cause weakness in fingers, wrists, waist, ankles, small increase in blood pressure and anemia. Children who are exposed to high levels of lead may experience slow cognitive development, reduced growth, and other health effects (Akan et al., 2011).

Chromium is found in rocks, chemicals, plants and soil and it can be a liquid, solid or gas. The concentration of chromium in the groundwater in the study area ranges from 0.030 to 0.070mg/L. The average concentration of chromium in the study area is 0.046 ± 0.014 mg/L. The WHO, NSDWQ and NAFDAC regulatory limits for chromium in drinking water are 0.050mg/L respectively. The drinking water is not polluted by chromium. Chromium and its compounds are known to cause cancer of the lung, nasal cavity, paranasal sinus and suspected to cause cancer of the stomach and larynx (ATSDR, 2000). Chromium (iii) has been classified as an essential nutrient that helps the body to use sugar, protein, and fat (Hati et al., 2005). However, under certain environmental conditions and certain metallic transformations, chromium (iii) may readily be oxidized to chromium (VI) compounds that are toxic to human health (ATSDR, 2000).

All soils and rocks including coal and mineral fertilizers contain some cadmium; it is a very toxic metal. The concentration of cadmium in

the study area ranges from 0.018 to 0.057mg/L as shown in table 1 above. The average concentration of cadmium the study area is 0.034 ± 0.013 mg/L as shown in table 2. The WHO, NAFDAC and NSDWQ regulatory limits for cadmium in drinking water are 0.010mg/L, 0.010mg/l and 0.030mg/l respectively. The groundwater is polluted cadmium. Cadmium metal is used mainly as anticorrosive and electroplated on steel. Cadmium sulphide and selenite are commonly used as pigments in plastics. Ingesting very high levels of cadmium irritates the stomach, leading to vomiting and diarrhea. Long term exposure to lower levels leads to a buildup in the kidneys and possible kidney disease, lung damage and fragile bones.

Arsenic could be introduced into groundwater through both natural and anthropogenic sources. Arsenic occurrence in water is caused by the weathering and dissolution of arsenic bearing rocks; minerals and ores. Fossil fuel combustion is a source of arsenic to the environment through atmospheric deposition. The concentration of arsenic in the groundwater in the study area ranges from 0.013 to 0.040mg/L. The WHO and NAFDAC regulatory limits for drinking water are 0.01 and 0.05mg/L respectively as shown in table 2. The average concentration of arsenic in the groundwater in the study area is 0.025 ± 0.007 mg/L. By NAFDAC regulation, the groundwater is safe for drinking. Arsenic is odorless and tasteless. It can be found in paints, dyes, metals, drugs, soaps and semiconductors. Inorganic arsenic is a known carcinogen and can cause cancer of the skin, lungs, liver and bladder. Lower level exposure can cause nausea and vomiting.

Pearson's correlation coefficient is used to measure the strength of the association between two continuous variables. The relationship between two variables could be positive or negative. If the relationship between two variables is positive, this implies that when one of the variable is increasing the other variable will also increase. And if the correlation is negative, it simply implies that increasing one of the variables will lead to decreasing the other variable.

Pearson's correlation can take values from -1.0 to +1.0. When the correlation value is -1.0, then there is a perfect negative correlation, when the value is 0.0, then there is no correlation. A correlation value of 1.0 is a perfect positive correlation. The variables having the values $R > 0.5$ and $R < -0.5$ are considered significant. Iron and arsenic correlated positively well in the study area as shown in table 3. The iron concentration in the groundwater samples in the study area was more than the regulatory limits of both WHO and NAFDAC as shown in table 2. This implies that there is a source of pollution that is increasing the iron concentration in the groundwater. If this process is allowed to continue, the concentration of arsenic in the groundwater will increase with time. Lead correlated negatively with cadmium, chromium, arsenic, copper and iron as shown in table 3. This shows that lead and the metals it correlated negatively with do not have a common source or origin.

4.0 Conclusion

It was observed that the concentrations of the following heavy metals iron, lead, arsenic,

and cadmium, exceeded the regulatory limits established by NAFDAC and the World Health Organization (WHO, 2006). The high concentrations of these metals in the drinking water might have caused the people in the study area some health problems. Many of the people in the study area might have suffered from some physiological effects on kidney, digestive system, circulatory system, nervous system, etc. This study is associated with some limitations. Therefore, there is need for more comprehensive investigation, where the concentrations of all the heavy metals present in the groundwater will be determined. This is necessary for proper correlation between the presence of heavy metals in the drinking water and the prevailing diseases in the study area. The statistical analysis of the heavy metals showed a positive correlation with each other as shown in table 3. The increase of one metal may increase the concentration of the other metal under the same condition. It is advisable that water quality evaluation with emphasis to heavy metal concentration should be carried out every six months in the study area.

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