Evaluation of Heavy Metal Concentrations in Well Water Collected from Different Locations within a Mining Site in Tsofo Birnin-Gwari, Kaduna State, Nigeria

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ABSTRACT

Heavy metal contamination of ground water in Tsofo Birnin Gwari village was assessed. The six Well water samples were analyzed using atomic absorption spectrophotometer for mercury, copper, nickel, manganese, chromium, zinc, lead and iron concentrations. The levels were compared with the World Health Organization (WHO) specified maximum contaminant levels for mercury, copper, nickel, manganese, chromium, zinc, lead and iron as 0.001, 1.0, 0.02, 0.2, 0.05, 3.0, 0.01, and 0.3 mg/L respectively. From the results obtained, none of the samples analyzed contained manganese and chromium in concentrations above the maximum contaminant level. The average concentration of each metal was 0.21 mg/L (Hg), 3.12 mg/L (Cu), 0.05 mg/L (Ni), 0.10.mg/L (Mn), 0.01 mg/L (Cr), 2.22 mg/L (Zn), 1.46 mg/L (Pb) and 1.15 mg/L (Fe), while the highest minimum concentration for all the metals was 0.82 mg/L and the lowest minimum concentration was 0.06 mg/L. The highest maximum concentration was 8.82 mg/L and the lowest maximum concentration was 0.02 mg/L. These concentrations are above the standard limit. All samples analyzed contained one or more of the eight heavy metals studied in varying concentrations. The results obtained from this study suggest a significant risk to the population given the toxicity of these metals and the fact that Wells are the only source of water supply in this environment.

Keywords: Mining site, AAS, heavy metals, WHO, water, toxicity

INTRODUCTION

The term ‘heavy metal’ refers to any metallic chemical element that has a relative high density and is toxic or poisonous at low concentration. To a small extent, they enter our bodies via food, drinking water and air. There are thirty-five metals that are of concern because of occupational or residential exposure and twenty-two of these metals are the heavy metals which include: mercury, lead, chromium, iron, nickel, manganese, copper and zinc [1].

As trace elements, some heavy metals such as copper, zinc and selenium are essential to maintain the metabolism of human body. However, at high concentration, they can lead to poisoning. Heavy metals poisoning could result for instance, from drinking water contaminated from lead pipes, high ambient air concentration near emission sources or intake via the food chain [2]. Heavy metals concentrations especially above permissible limit are dangerous because they tend to bio-accumulate, meaning, an increase in the concentration of a chemical in a biological organism over time, compared to chemicals in the environment.

Chemical compounds accumulate in living things anytime they are taken up and stored faster than they are broken down (metabolized) or excreted [3]. Heavy metals can enter a water supply by industrial and consumer waste, or even from acid rain breaking down soils and releasing heavy metals into stream, lakes, rivers and ground water. Examples of heavy metals that are harmful to humans include mercury, lead, and arsenic. Humans are exposed to heavy metals through inhalation of air pollutants. Food sources such as vegetables, grains, fruits, fish and shell fish can become contaminated when exposed to surrounding soils and water that are high in heavy metal concentrations [4].

There are many heavy metals in our environment both naturally and from anthropogenic pollution. Some of these, including copper, iron and zinc, play important roles in our bodies. Others have no known benefit for health. Examples of these are lead, which is found in paint in hot homes as well as many other sources; arsenic, which can be found in Well water and wood products; and mercury, which can build up in fish. At very high levels, most of heavy metals can cause health problems [5].

Atomic absorption spectroscopy (AAS) is one of the commonest instrumental methods for analyzing for metals and some metalloids. Metalloids like antimony, arsenic, selenium and tellurium. Atomic absorption spectroscopy is a spectro-analytical procedure for quantitative determination of chemical elements employing the absorption of optical radiation (light) by free atoms in the gaseous state. Solid samples are dissolved and liquid sample vapourized in a flame or graphite furnance. As the atoms are vapourized, they absorb UV light and the amount of light absorbed is used to determine their concentration [6].

Therefore, this research work is aimed at analyzing the concentration of heavy metals in water from different Wells around a mining site in Tsofo-Gwari within Kaduna metropolis, Nigeria.

MATERIALS AND METHODS

Description of Sampling Site

Tsofon Gwari, also known as Birnin Gwari, is one of the twenty-three local government areas of Kaduna state. It is geographically located between latitudes 10° 49' 34" North and longitudes 6°39 ' 18" East. It has a total land area of 6,185 square kilometres and a population of 252,363. Kaduna State is bordered by Zamfara, Katsina and Kano States to the North, Bauchi and Plateau States to the East, Nassarawa State to the South; and Niger State and Abuja (FCT) to the West.

Sample Collection

Ground water samples were collected from different Wells around Tsofo-Gwari in Kaduna State, Nigeria. Each sample was collected into plastic containers from different Wells and each plastic container was labeled (six wells water samples). All samples were collected same day and kept in 2 L plastic containers which have been previously washed with 10% HNO_3 and 1:1 HCl for 48 h. A few drops of HNO_3 were added in order to prevent loss of metals, bacteria and fungi growth.

Sample Digestion

The samples were transferred into the instrument/preparatory laboratory under Kaduna Environmental Protection Agency (KEPA). The samples were digested with concentrated nitric acid. Exactly10 ml of nitric acid was added to 50ml of water in a 250 mL conical flask. The mixture was evaporated to half its volume on a hot plate after which it was allowed to cool and then filtered.

Preparation of Standard

The 1000 mg/L stock solution of mercury, lead, chromium, iron, nickel, manganese, copper, and zinc were prepared by dissolving 24.62, 1.63, 1.60 g of their salt with 5% nitric acid in a 1 L volumetric flask. The mixture was shaken and the flask made up to the 1litre mark with the nitric acid for each metal. Calibration solutions of the target metal ions were prepared from the standard stock by serial dilution.

Sample Analysis

The digested water samples were analyzed for the concentrations of mercury, lead, chromium, iron, nickel, manganese, copper, and zinc using the model 210VGP scientific atomic absorption spectrophotometer (AAS). The calibration plot method was used for the analysis.

Air-acetylene was the flame used and hallow cathode lamp of the corresponding elements was the resonance line source. The wave length for the determination of the elements were 253.7 nm, 283.31 nm, 510 nm, 434 nm, 1.54056 nm, 279.8 nm, 217.9 nm and 213.856 nm for mercury, lead, chromium, iron, nickel, manganese, copper, and zinc respectively. The digested samples were analyzed in duplicate with the average concentration of the metal present being displayed in mg/L by the instrument after extrapolation from the standard curve.

Statistical Analysis

Data entry was done on MS Excel spreadsheet. Mean concentration and Descriptive statistics analysis for the sampled points were calculated using data from individual study site.

RESULTAND DISCUSSION

Table 1: Heavy metal concentrations in the analysed Well water

		Concentration (mg/L)							
S/NO	Sampling Points	Hg	Cu	Ni	Mn	Cr	Zn	Pb	Fe
1	WW1	0.40	1.11	0.08	0.14	0.24	2.10	0.00	2.31
2	WW2	0.10	1.45	0.00	0.12	0.01	0.00	0.02	1.00
3	WW3	0.31	8.82	0.09	0.09	0.02	4.30	6.60	1.05
4	WW4	0.06	0.00	0.12	0.14	0.02	2.79	0.00	0.82
5	WW5	0.29	1.87	0.07	0.09	0.00	2.81	0.16	0.83
6	WW6	0.30	3.47	0.00	0.06	0.00	1.23	0.55	2.03

The results in Tables 1 and 2 show the concentration of heavy metals in mg/L and the mean statistical analysis for the heavy metals analyzed. It is very important to analyze the level of heavy metal concentration in drinking water. Generally, water may contain high or low levels of heavy metals such as copper, lead, mercury, nickel, chromium, iron and manganese [7, 8].

Table 2: Mean concentration and descriptive statistics analysis for the sampled points

Elements	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	Std. Dev.	Limits (mg/L)
Hg	0.06	0.31	0.21	0.05	0.001
Cu	0.34	8.82	3.12	1.52	1.0
Ni	0.00	0.12	0.05	0.02	0.02
Mn	0.06	0.14	0.10	0.01	0.2
Cr	0.00	0.02	0.01	0.00	0.05
Zn	0.00	4.30	2.22	0.73	3.0
Pb	0.00	6.60	1.46	1.29	0.01
Fe	0.82	2.31	1.15	0.23	0.3

Metals in our water supply may occur naturally or maybe as a result of contamination. Naturally occurring metals are dissolved in water when it comes into contact with rock or soil material. Other sources of metal contamination are corrosion of pipes and leakage from waste disposal sites [9].

For the protection of human health, guidelines for the level concentration of heavy metals in water have been set by different organizations such as USEPA. WHO, NSDW, EPA and European Union Commission. Thus, heavy metals have Maximum Permissible Levels in water as specified by these organizations. Therefore, this research will be using World Health Organization (WHO) specified Maximum Contaminant Level for mercury, copper, nickel, manganese, chromium, zinc, lead and iron as 0.001, 1.0, 0.02, 0.2, 0.05, 3.0, 0.01, and 0.3 mg/L respectively for comparison. The results from this research work show that the eight heavy metals studied namely mercury, copper, nickel, manganese, chromium, zinc, lead and iron have maximum contaminant levels of 0.31 mg/L, 8.82 mg/L, 0.12 mg/L, 0.14 mg/L, 0.02 mg/L, 4.30 mg/L, 6.60 mg/L and 2.31 mg/L respectively.

Mercury is a toxic substance which has no known function in human biochemistry or physiology and does not occur naturally in living organisms. From the result obtained in this analysis, the minimum concentration of mercury detected in the water sample was 0.06 mg/L with the maximum being 0.40 mg/L. The average for mercury was 0.24mg/L. The maximum permissible limit was 0.001 mg/L. The amount of mercury has been exceeded which will lead to serious health effects such as brain damage, kidney, central nervous system and even death [10].

Copper is an essential substance to human life, but chronic exposure to copper in drinking water is subject to considerable public concern. In this research, copper is the heavy metal having the highest concentration among all the heavy metals analyzed. From the results of the Well water samples, the average concentration for copper was 3.12 mg/L. The minimum level of copper concentration was 0.34 mg/L and the maximum concentration was 8.82 mg/L in the five samples analyzed with the exception of the fourth sample which is below detection limit. The five samples analyzed were all above the Maximum Permissible Limit (1.0 mg/L) of WHO (1996) which can lead to adverse health effects of anaemia, liver, kidney damage, abdominal pain, vomiting, headache, nausea and diarrhea. [11].

In the analysis of the water samples collected for nickel, two of the collected water samples did not contain detectable levels of nickel which is below detection limit (BDL) but four contained nickel and the average concentration of nickel was 0.02 mg/L. The maximum contaminant level is 0.12 mg/L and the minimum concentration is 0.01 mg/l. These may lead to the health effects of decreased body weight, liver damage, skin irritation and carcinogenic to human [12, 13].

Manganese is one of those trace elements so often over looked, yet essential to health. From the results obtained from this analysis, the minimum concentration of manganese detected in the water samples was 0.06 mg/L, while the maximum concentration was 0.14 mg/L. None of the water samples contained manganese above the specified maximum contaminant level of 0.2 mg/L. However, manganese was detected in average level of 0.10 mg/L in the water samples. If it is above the range, it may lead to health effects like weakness of the body and skin problems [14, 15].

Chromium is essential to animals and humans. From the result obtained, the minimum concentration of chromium detected in the water sample was 0.01 mg/L, while the maximum concentration was 0.02 mg/L. None of the water samples contained chromium above the specified maximum contaminant level of 0.05 mg/L. However, chromium was detected in average amount of 0.01 mg/L in the water samples. If it is above the range, it may lead to health effects of irritating the skin, cancer and liver damage [16, 17]

The possible long term effect of chronic exposure to lead in drinking water is subject to considerable public concern. Only four samples of water were analyzed for lead and of these four samples the levels ranged from 0.01 to 6.6025 mg/L. The average was 1.46 mg/L which is above the acceptable limit of 0.01 mg/L. Studies have linked lead exposure even at low levels with an increase in blood pressure, blood anaemia, muscle weakness, and brain damage [18, 19]

Zinc is a lustrous bluish-white metal. Zinc is a very common substance that occurs naturally in air, water and soil, but zinc concentrations are rising unnaturally, due to addition of zinc through human activities. Six samples of water were analyzed for zinc. The minimum concentration of zinc detected in the water samples was 0.01 mg/L while the maximum concentration was 4.5 mg/L. The average level for zinc was 2.22 mg/L. The maximum permissible limit was 3.00 mg/L. The level of zinc exceeded the normal standard and may lead to health effects such as stomach cramps, skin irritations, vomiting, nausea and anaemia [20, 21].

Iron is an essential element for most life on earth, including human beings. All the samples contain iron in levels above the maximum allowable contaminant level of 0.3 mg/L. The maximum concentration detected was 2.31 mg/L while the minimum concentration detected was 0.82 mg/L. The values exceeded the normal standard which may lead to health effects such as anaemia, causing tiredness, headache and loss of concentration [22, 23]

CONCLUSION

This study evaluated the quality of Well water by determining heavy metals in Tsofo Birnin–Gwari mining site. The six well water samples collected were analyzed using atomic absorption spectrophotometer for mercury, copper, nickel, manganese, chromium, zinc, lead and iron. The results showed high concentration of these heavy metals and in some cases the levels were above the World Health Organization (1996) specified maximum contaminant level. These results infer that the population is at risk of accumulating these heavy metals onto their bodies that are above the Maximum Contaminant Level (MCL) set by WHO, given the toxicity of these metals and the fact that many use Wells as the only sources of water supply in their environment.

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