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# Mercury, Cadmium and Nickel Contamination Levels in Water Samples of Bagega Artisanal Gold Mining Communities: The Environmental Health Importance.

**MS Sallau[1], MH Majiya[2]* and AA Nuhu[1].**

[1]Depatment of Chemistry, Ahmadu Bello University, Zaria.
[2]Department of Chemistry, School of Preliminary Studies, IBB University, Lapai.

**ABSTRACT**

The environmental health implication of some heavy metals cannot be overlooked due to their toxic, mutagenic or carcinogenic nature. Recently, toxicity due to heavy metals was reported in Zamfara State of Nigeria with some fatalities. This study was, therefore, carried out to assess the concentration of three important heavy metals (Ni, Cd and Hg) in water samples of the affected locations. Surface, borehole and domestic well water samples were obtained from Topeki, Bagega, Tunga-kudeku and Dereta. Heavy metals concentration levels in these samples were quantitatively determined using Atomic Absorption Spectrometry (AAS). It was observed that while all samples were found contaminated with Ni, samples from Topeki, Bagega and Tunga-kudeku also contained Hg. Therefore, it was concluded that, in general, water bodies within the study area may not be fit for drinking by humans and animals.

**Keywords:** artisanal gold mining, carcinogenic, environmental health, mutagenic, contamination, water.

**_*Corresponding author_**

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## INTRODUCTION

Concentration of heavy metals in different media may be harmless or beneficial at one concentration level, but might be toxic/mutagenic/carcinogenic at another concentration level. This is actually the reason why WHO and other international/local regulating bodies came up with minimum and maximum permissible limits of heavy metals in drinking water and food. Mercury and other toxic heavy metals are among the pollutants that cause severe threats to humans and the environment and have begun to cause concern in many countries due to the possibilities of their geoaccumulation, bioaccumulation and biomagnifications in ecosystem [1].

Prolonged exposure to heavy metals such as mercury, cadmium, nickel and zinc can cause deleterious health effects in humans [2]. Even though mercury poisoning is not acute, it can be chronic as a result of the cumulative effect of the metal. Mercury (both inorganic and organic forms) has been reported to be toxic to human and animals. For example, it can cause spontaneous abortion, congenital malfunction, erythrism (an abnormal irritation), acrodynia, gingivitis, stomatitis, neurological disorder, total brain damage and central nervous system disorder [3]. Human exposure to cadmium either through drinking water, inhalation and ingestion has been reported to cause obstructive lung disease, cadmium pneumonitis, bone defects, increased blood pressure and myocardial dysfunction, pulmonary oedema and even dead in some cases [3].

Not much is known about nickel poisoning, but report from International Agency for Research on Cancer (IARC) revealed that both metallic nickel and other forms of nickel compounds are carcinogenic to humans [4]. Exposure to nickel may present with serious health implications, such as chronic bronchitis, reduced long function, cancer of the lung and nasal sinus [4].

Trace heavy elements are present in natural water systems and their occurrence can be due to natural sources or due to human activities such as mining, fuels, smelting of ores and improper disposal of industrial wastes [5]. Investigation of heavy metals in water is very essential since slight changes in their concentration above the acceptable levels, whether due to natural or anthropogenic factors, can result in serious environmental and biological problems [6].

Bagega and neighbouring communities are part of the region where active artisanal gold mining is being carried out in Zamfara State, Nigeria. Due to the illegal mining operations by the people of these remote communities, there are recent reported cases of acute Pb poisoning which happened to be the worst heavy metal poisoning reported in Nigeria till date. Thus, the incidence has not only attracted the attention of local researchers but also the attention of international organisations such as Médecins Sans Frontières (MSF), US Center for Disease Control and Prevention (CDC), Blacksmith Institute (BI) and World Health Organisation (WHO). Series of researches and investigations conducted and reported so far by both local and international organisations were mainly on Pb (specifically on blood samples), with little or no investigation on multiple toxic heavy metals in environmental samples (e.g. water) within the region. To address this problem, this work was conducted to investigate the contamination level of multiple toxic heavy metals in water sources of this locality. This work will go a long way in making available data for quantitative investigation which will serve as additional background information about contamination characteristics of other toxic metals in the water samples of the study area. The aim of this work was to quantitatively determine the concentration level of Mercury (Hg), Cadmium (Cd) and Nickel (Ni) in water samples from different sources within the study area, and to statistically treat the data obtained using student t-test in order to assess whether or not the heavy metals contents of the samples were within the maximum permissible limits set by World Health Organisation [7].

## MATERIALS AND METHODS

All experiments were performed with analytical grade chemicals (Sigma-Aldrich) and deionised distilled water was used throughout the entire analysis. Measurements were made using Varian model-AA240FS Atomic Absorption Spectrophotometer (AAS) equipped with a hollow cathode lamp.

### Study area

The study area comprised of Bagega and selected neighbouring communities (Dareta, Tunga-kudeku and Topeki) as shown in Fig. 1. These villages were selected because of their proximity to each other along the same route and to Bagega where major Artisanal gold mining activities are taking place. Bagega being the district headquarters of the entire study area lies on the geographical coordinates of latitude $11^{o}$ 51' 47" N and longitude $6^{o}$ 0' 15" E.

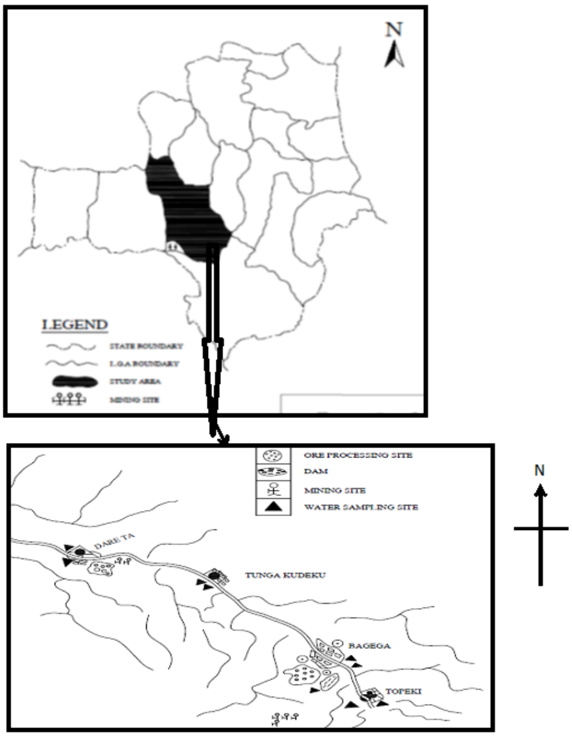


**Figure 1: Map of Zamfara State, Nigeria showing Bagega gold Mining region**

**Collection and Preservation of Water samples**

All Water samples for this research work were obtained on $21^{st}$ of April 2013 between 8.00am-4.00pm. A total of forty five (45) water samples were collected at Bagega and three (3) other neighbouring communities (Dareta, Topeki and Tunga-kudeku). In each community, ten (10) ground water samples were collected randomly from both borehole and domestic wells. In addition, Five (5) surface water samples were also collected at different points of Bagega Dam (pond). Sampling was carried out in accordance with APHA [8] standard method of water sampling. Pre-cleaned 2 litre polyethylene sampling bottles were used for sampling. At each sampling point, the bottles were rinsed 3 times with the water before collection of the samples. The samples were preserved by acidifying with $2cm^3$ of concentrated $HNO_3$ in order to achieve a pH of 2. All the samples were returned to the laboratory and the analysis was carried out immediately.

**Pre-Treatment of Water Samples**

Water samples were digested according to APHA [8]. Briefly, $1000cm^3$ of well mixed, acid preserved sample was transferred into a beaker. $50cm^3$ of conc. $HNO_3$ was added and heated to a boiling and evaporated on a hot plate to about $20cm^3$. Heating and addition of conc. $HNO_3$ continued until digestion was completed as indicated by a light colour, clear solution. The content was then transferred to $100cm^3$ plastic bottles, cooled and diluted to mark. Portions of the solution were used for Hg, Cd and Ni determinations using flame atomic absorption spectrophotometer (model-AA240FS) after calibrating the equipment with different standard concentrations.

**Quantitative Determination of Hg, Cd and Ni in the Water Samples**

In this work, flame Atomic absorption spectrophotometer (A240FS, Varian) equipped with a hollow cathode lamp (each for Hg, Cd and Ni), was used for quantitative determination of Hg, Cd and Ni in water samples respectively. Standard calibration curves for the concentration ranges of 0.0001ppm-4.0000ppm, 0.0001ppm-1.0000ppm and 0.0001ppm-2.0000ppm were used for Hg, Cd and Ni respectively. These curves were linear with coefficient of determinations of $R^2$ = 0.98, 0.99 and 0.98 for Hg, Cd and Ni respectively.

## RESULTS AND DISCUSSION

### Nickel

The levels of Nickel (Ni) concentration in well water samples analysed in the study area varied from a minimum of 0.128±0.027 mg/l to a maximum of 0.273±0.016 mg/l in Topeki and Dareta village samples respectively (Fig. 2). Similarly, the variation of Ni concentration in borehole water samples ranged from a minimum of 0.0724±0.0091 mg/l to a maximum of 0.323±0.006 mg/l in Topeki and Dareta village samples respectively. However, the Nickel (Ni) level of the surface water sample (Bagega dam) was found to be 0.218±0.074 mg/l (Fig. 2). With the exception of Bagega and Tunga-kudeku, there were significant differences ($P < 0.05$) between well water and borehole water values in each village of the study area. The values obtained for Ni level in all the water samples were above the WHO [7] maximum permissible limits of 0.02 mg/l. This indicates that all the different water samples were contaminated with Ni and, therefore, could pose a serious health challenge to the inhabitants of study area.

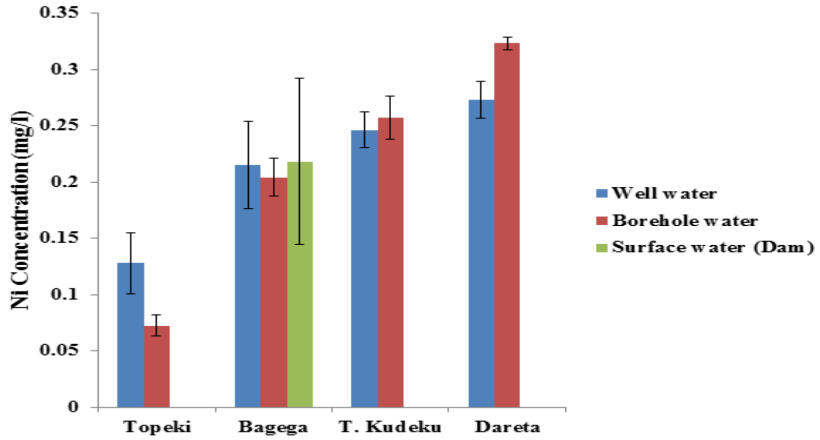


**Figure 2: Concentration of Nickel (Ni) in water samples of Bagega, Topeki, T. kudeku and Dareta in Zamfara State, Nigeria. Each bar represents mean ± standard deviation.**

### Cadmium

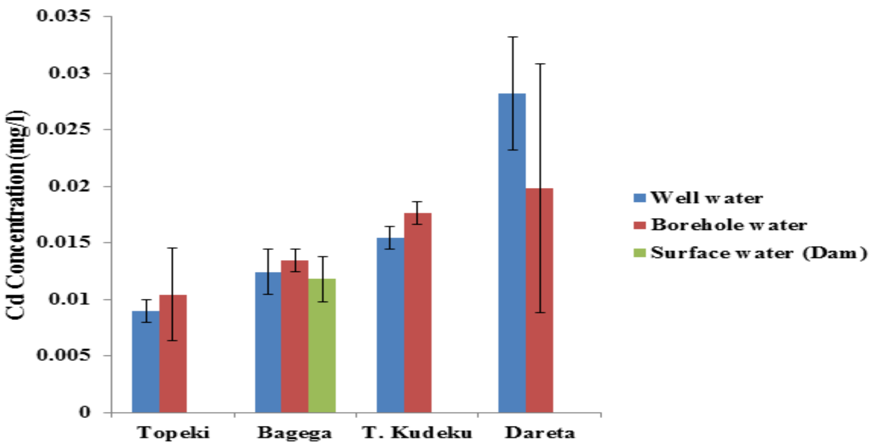


**Figure 3: Concentration of Cadmium (Cd) in water samples of Bagega, Topeki, T. kudeku and Dareta in Zamfara State, Nigeria. Each bar represents mean ± standard deviation.**

The levels of cadmium (Cd) concentration in well water samples analysed in the study area varied from a minimum of 0.009±0.001 mg/l to a maximum of 0.028±0.005 mg/l in Topeki and Dareta village samples respectively (Fig. 3). Similarly, the variation of cadmium (Cd) concentration in borehole water samples ranged from a minimum of 0.0104±0.0041 mg/l to a maximum of 0.019±0.001 mg/l in Topeki and Dareta village samples respectively (Fig. 3). However, the cadmium (Cd) level of the surface water sample (Bagega dam) was found to be 0.012±0.002 mg/l (Fig. 3). With the exception of Dareta and Tunga-kudeku, there were no significant differences ($P > 0.05$) between Well water and Borehole water values in each village of the study area. The levels of Cadmium (Cd) in all the water samples analysed were below WHO [7] maximum limits of 0.03 mg/l (Fig. 3). Therefore, all the ground waters and the surface water were not contaminated with cadmium and thus did not pose any serious health challenge to the populace.

**Mercury**

Mercury (Hg) was observed in the water samples of Bagega, Topeki and Tunga-kudeku villages. The levels of mercury (Hg) concentration in well water samples analysed in the study area varied from a minimum of 0.188±0.421 mg/l to a maximum of 2.470±0.595 mg/l in Tunga-kudeku and Topeki village samples respectively (Fig. 4). Similarly, the variation of mercury (Hg) concentration in Borehole water samples ranged from a minimum of 0.048±0.110 mg/l to a maximum of 2.24±0.75 mg/l in Tunga-kudeku and Topeki village samples respectively (Fig. 4). But mercury (Hg) was not detected in the ground water samples of Dareta village. The concentration of Hg in the water samples of Dareta village might be below the detection limits of the method used.

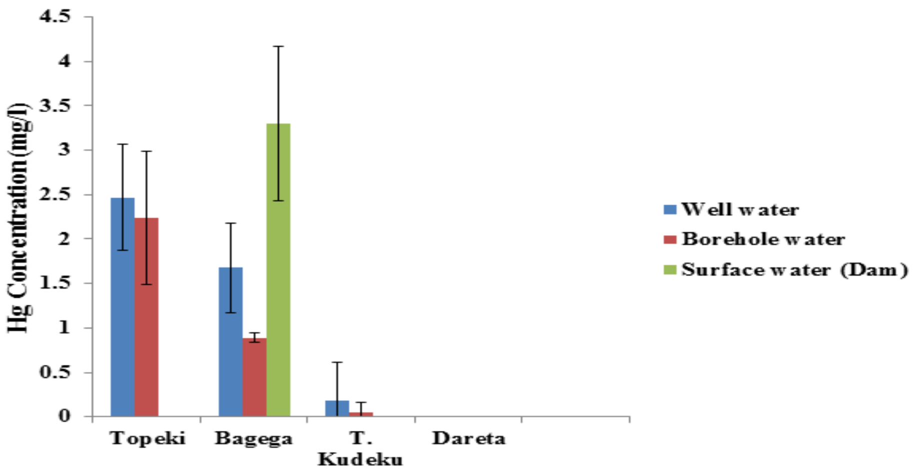


**Figure 4: Concentration of Mercury (Hg) in water samples of Bagega, Topeki, T. kudeku and Dareta in Zamfara State, Nigeria. Each bar represents mean ± standard deviation.**

In this investigation, the values of mercury (Hg) concentration obtained for well water samples were generally higher than those of the borehole water samples in the study areas. However, with the exception of Bagega village, there were no significant differences ($P > 0.05$) between Well water and Borehole water values in each of Topeki and Tunga-kudeku villages. The highest mercury (Hg) level was recorded for surface water sample (Bagega dam) which was found to be 3.301±0.871 mg/l (Fig. 4). This might be due to the fact that the surface water (Bagega Dam) was previously used by Artisanal miners for sluicing of ore for recovering of gold with the aid of liquid Hg metal. The values obtained for all these water samples were far higher than WHO [7] maximum permissible limits of 0.001 mg/l for drinking water (Fig. 4). This is of great concern to environmental health of the affected locations, and therefore all ground waters in these three villages (Bagega, Topeki and Tunga-kudeku) and surface water (Bagega Dam) were not fit for drinking and domestic purposes. The abnormal higher level of Hg in the ground water samples of Bagega and neighbourhood (Topeki and Tunga-kudeku) might be due to erosion and run-off water of Hg-contaminated waste from Bagega ore processing site which caused the leaching of Hg metal into the soil and subsequently contaminated the ground water source of the vicinity.

## CONCLUSIONS

From the present study, it was evident that the ground waters of all the studied villages as well as surface water of Bagega dam were contaminated with Ni. But Hg contamination was only observed in the ground waters of Topeki, Bagega and Tunga-kudeku villages as well as surface water of Bagega Dam. This was attributed to the excessive use of Hg for recovering of pure gold from its ore during processing at Bagega ore-processing site. Due to the toxic nature and health implication of these heavy metals, it has become clear that the water bodies within the study area were not suitable for drinking by human and animals alike.

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