

Evaluation of Levels of Heavy Metals (Pb, Cd, Fe, Mn, Zn, Cu) and Anions (NO_3^- , PO_4^{3-}) in Surface and Ground Water Sample collected from Kafin Hausa

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Abstract

The poor sanitary and sewage disposal system in Kafin Hausa has made it a matter of necessity to evaluate the level of contamination of the various sources of water in the town. The aim of this study was to evaluate the levels of heavy metals and anions in surface and ground water collected from sixteen (16) sites in Gambawa, Tamburawa and a River in Kafin Hausa. Atomic Absorption spectrophotometer was used to determine the levels of the heavy metals whereas the levels of nitrate (NO_3^-) and phosphate (PO_4^{3-}) were analysed using spectrophotometric methods. Copper (II) sulphate was used as a catalyst. The samples were analysed for their levels of lead (Pb), cadmium (Cd), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), nitrate (NO_3^-) and phosphate (PO_4^{3-}). The following ranges were obtained for Pb (0.017 to 0.0095 mg/L), Cd (0 to 0.0055 mg/L), Fe (0.029 to 0.051 mg/L), Mn (0.032 to 0.092 mg/L), Zn (0.016 to 0.032 mg/L), Cu (0.016 to 0.032 mg/L), NO_3^- (0.7003 to 0.771 mg/L), PO_4^{3-} (0.596 to 1.26 mg/L). The results obtained showed that the concentrations of all the heavy metals were within the recommended standard limit set by WHO. Cadmium showed strong positive correlations with Pb, Cu and Fe at a significance level of 0.01 (2-tailed) while Positive correlations were also recorded for Cu with Fe at a significance level of 0.01 (2-tailed). The possible sources of these heavy metals displaying positive correlations were considered to be similar. The mean concentrations recorded for nitrate in all the samples were below the maximum permissible limit set by WHO. However, the levels PO_4^{3-} were above the maximum permissible limit. However, phosphorus is needed for bumper agricultural harvest; it has been implicated for eutrophication.

Keywords: Heavy-Metals, Surface Water, Ground Water, Gambawa.

1. Introduction

Ground water and surface water are the major sources of drinking water in Kafin Hausa; hence it became necessary to evaluate the ground and surface water quality with respect to heavy metals contamination and anions. Some of these heavy metals are vital for human health when they are available in minute amounts (Co, Cu, Cr, Ni, Zn, Fe, Mn) while others are carcinogenic or toxic, thus affecting the central nervous system (Cd, As), IARC (2012), the kidneys or liver (Pb, Cd, Cu) or skin, bones, or teeth (Cd, Cu, Cr) Kim *et al.*, (2019). Furthermore, contamination of the ground and surface water by domestic waste, industrial effluents and agricultural chemicals are problems overwhelming developing countries. Also, anthropogenic wastes were often not treated in most developing countries before discharging them into the environment.

In recent years, increasing attention has been given to studies on ground and surface water contamination, though less concern has been given to this in Kafin Hausa town. Hence, there is the need to continuously assess the quality of ground and surface water using Atomic Absorption Spectrophotometer (AAS) technique in this community. However, since ground water is directly in contact with soil, rock and plateaus, it solubilizes heavy metals. These metals are not biodegradable; as such they persist and accumulate in the environment. Also, they cannot be metabolized by the body and bio-accumulative in the human system (Es'haghi, *et al.*, 2011).

There is no in-depth study yet concerning the levels of heavy metals and anions in ground and surface water in Kafin Hausa town, Jigawa State, Nigeria. It was therefore the aim of this study to evaluate the levels of Manganese (Mn), Cadmium (Cd), Lead (Pb) and Copper (Cu), Zinc (Zn), Iron (Fe), and some anion NO_3^- and PO_4^{3-} in the ground and surface water in Kafin Hausa town.

2. Related Works

Boarh and Amisra (2010) reported that the levels of Cr, Mn, Zn, Cu, Ni, Cd and As, in ground and surface water of Ggolaghat District, Assam in India were 0.04386, 0.09746, 0.7028, 0.025, 0.01536, 0.01482 and 27.61 respectively. This study found that the quality of ground and surface water in the district were unsafe for human consumption as the level of Arsenic (As) was beyond the recommended limit set by WHO. Similarly, the concentration of heavy metals determined by Radulescu *et al.*, (2014), in surface water samples collected Romania were below the recommended limit set by WHO. Furthermore, Yusuf *et al.*, (2021), assessed that the levels of Cu, Cd, Pb and Cr in River Kafin Hausa but found out that the levels of Pb, Cd and Cr exceeded the recommended limit set by WHO. Hence, the researchers concluded that the River water is not suitable for human consumption. Nevertheless, the surface and ground water in Kafin Hausa town have been given little or no attention and this called for a great concern, knowing the hazard associated with heavy metals.

3. Materials and Methods

3.1 Study Area

Kafin Hausa (Figure 1) is 362 m above sea level and located between latitude $12^{\circ}14'26''\text{N}$ and longitudes $9^{\circ}54'47''\text{E}$. Kafin Hausa has a population of 12,609 people. It observes two seasons which are the dry and the wet seasons. The average humidity level is 29 percent while the average temperature of the area is 34°C . The major occupations are trading in the Kafin Hausa Central market where a variety of goods are bought and sold. Also, Farming is major occupation of the people of Kafin Hausa where various crops like rice, beans, sesame, millet, onions etc., are grown.

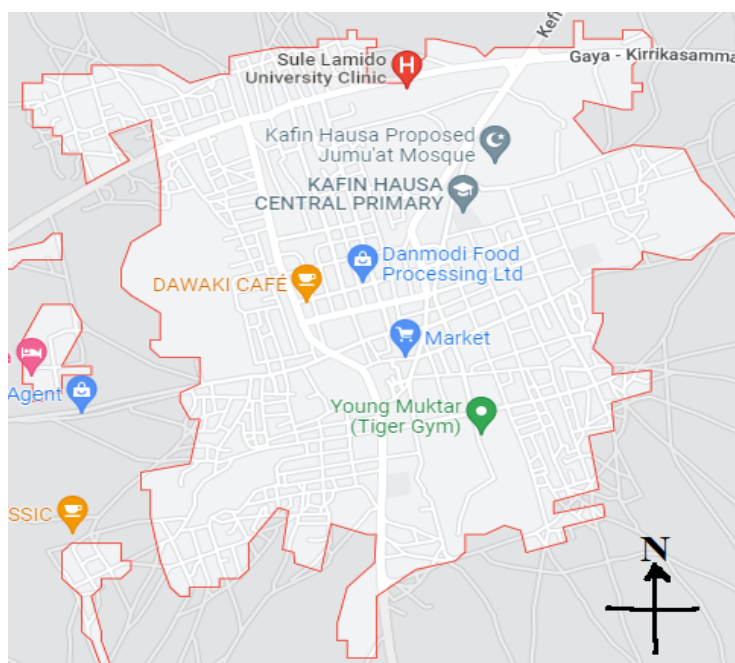


Figure 1: Map of Kafin Hausa Town

3.1.1 Sample Collection

Water samples were collected from sixteen (16) sites in Gambawa, Tamburawa and a River at the outskirts of Kafin Hausa in 1000 cm³ white polyethylene bottles from four (4) sites. The water samples used for heavy metals analysis were acidified using 3.0 cm³ of 1:1 trioxonitrate (V) acid (Mitsios and Golia 2005). All the samples were appropriately labeled as river water, open well water, tap water and borehole water respectively, stored in a large plastic bucket with ice blocks and transported to the Chemistry laboratory, Sule Lamido University Kafin Hausa. The water samples were filtered and then stored in a fridge at 4 °C.

3.2 Experimental Procedures

3.2.1 Sample Digestion for the Determination of Total Phosphorus and Total Nitrogen

To 50 cm³ of the water sample in a 125 cm³ Erlenmeyer flask was added 1 cm³ of 2.5 M H₂SO₄ solution and 25 cm³ of alkaline persulphate solution. The resulting solution was boiled gently on a preheated hot plate until a final volume of 10 cm³ was reached. The solution was cooled and diluted to 30 cm³ capacity with distilled water, (Liang et al., 2007)

3.2.2 Procedure for phosphate determination

Exactly 30 cm³ of the sample was pipetted into a 50 cm³ calibrated flask with the addition of 8 cm³ of the mixed reagent and mixed thoroughly. The solution was allowed to stand for 20 minutes for optimum color formation, thereafter, the absorbance of the sample was measured at 880 nm, using reagent blank as the reference solution (Charles, et al. 2003).

3.2.3 Procedure for nitrate determination

Exactly 5 cm³ of the digested sample was pipetted into a 50 cm³ volumetric flask and 10 cm³ of 0.5 M NaOH solution and 10 cm³ of the reducing reagent were added and then heated for 15 minutes at 52 °C. 10 cm³ of 0.0581 M acidic sulphanilamide solution was added, shaken thoroughly for 5 minutes for the diazotization reaction to go to completion. Thereafter, 10 cm³ N-(1-Naphthyl) ethylenediamine dihydrochloride solution was added to form an azo dye. The absorbance of the pink-colored dye solution was measured at 540 nm against the corresponding reagent blank (Johnes, et al., 1992).

3.2.4 Sample digestion for Heavy Metals

Exactly 500 cm³ of the filtered water sample in a 1000 cm³ was placed on a hot plate and evaporated to about 50 cm³. It was allowed to cool and transferred into a 250 cm³ beaker. 5 cm³ of concentrated HNO₃ was added and the resulting solution was heated at 85 °C until a clear solution was obtained (APHA, 1999). The digested sample was allowed to cool, then transferred into a 100 cm³ volumetric flask and made up to mark with deionized water. This solution was then used for the heavy metals analysis using Atomic Absorption Spectrophotometer (AAS).

4. Results and Discussion

4.1 Heavy Metals

4.1.1 Lead (Pb)

The results of the heavy metals and anions analyzed were presented in Table 1. The concentration of Pb ranged from 0.0017 to 0.0095 mg/L (Table 1). The highest value was recorded in samples collected from river while the lowest level was observed in sample from Tap water. The high value recorded for Pb in the river may be due to runoff from the surrounding farmland. The Pb content of all the samples were lower than the maximum permissible limit of 0.01mg/L set by WHO (2011). This indicates that the water is safe for human consumption in respect to Pb. However, lead (Pb), has no known biological function. The concentration of Pb reported by Radulescu et al., (2014) and Yusuf et al., (2021) were greater than the values obtained in this study.

4.1.2 Cadmium (Cd)

Similarly, the levels of Cd ranged from (ND to 0.0055 mg/L) (Table 1). The highest value of Cd was observed in river water while the lowest level was recorded in Tap water. Meanwhile, the high level of Cd in River water may be attributed to runoff from farmland. Cd concentration was below detectable limit in borehole water. Likewise, the Cd content of all the samples was lower than the maximum permissible limit of 0.03 mg/L set by WHO (2011). Also, the concentration of Cd reported by Boarh and. Misra (2010), was similar to the values obtained in this study. Whereas, the level of Cd recorded by Yusuf *et al.*, (2021), was higher than the value obtained in this study.

4.3 Copper (Cu)

Furthermore, the concentration of Cu ranged from (0.016 to 0.032 mg/L) (Table 1). The highest level of Cu was found in the samples collected from River, whereas the lowest value was obtained in Borehole water. Copper is both an essential nutrient and a drinking water contaminant. More so, the Cu content of all the samples analyzed was below the maximum permissible limit of 2 mg/L set by WHO, (2011). The concentration of Cu reported by Boarh and. Misra (2010), was similar to the values recorded in this study.

4.1.4 Manganese (Mn)

Manganese is an essential element for both humans and animals. The level of Mn ranged from (0.032 to 0.097 mg/L) (Table 1). The highest level of Mn was found in Tap water while the lowest was observed in Borehole water. The Mn content of all the samples were lower than the permissible limit of 0.4 mg/L set by WHO (2011). Meanwhile, epidemiological studies had shown that there is an adverse neurological effect when human being is exposed for extended period to a very high level of Mn in drinking water. Nevertheless, the level of Mn in the areas studied did not pose any health risk. The concentration of Mn reported by Boarh and. Misra (2010), was greater than the values recorded in this study.

4.1.5 Zinc (Zn)

In addition, the levels of Zn ranged from (0.016 to 0.032 mg/L) (Table 1). The highest level of Zn was found in Borehole water while the lowest was found in well water. This may be attributed to the soil bed rock constituents. Similarly, the Zn content of all the samples were below the maximum permissible limit of 3 mg/L set by WHO (2011). Zinc is an essential trace element and its concentration in this study is within the safe limit. The concentration of Zn reported by Radulescu *et al.*, (2014), was greater than the values obtained in this study

4.1.6 Fe (Fe)

Similarly, the level of Fe ranged from (0.029 to 0.051 mg/L) (Table 1). The Fe content of all the samples were within the recommended limit of 3 mg/L set by WHO (2011). Conversely, the level of Fe reported by Boarh and. Misra (2010); and Radulescu *et al.*, (2014) were significantly greater than the values obtained in this study. Iron is an essential element in human diet, particularly in the iron (II) oxidation state.

Table 1: Levels of Heavy Metals and Anions in Surface and Ground Water Samples from Kafin Hausa

Heavy Metals/Anions	River	Open well	Tap water	Borehole
Pb	0.0095±0.00	0.0044±0.00	0.0017±0.00	0.0025±0.00
Cd	0.0055±0.00	0.0036±0.00	0.0018±0.00	ND
Cu	0.032±0.00	0.0250±0.00	0.0288±0.00	0.0160±0.001
Mn	0.048±0.00	0.0810±0.00	0.0970±0.00	0.0320±0.001
Zn	0.021±0.00	0.0160±0.00	0.0270±0.00	0.0320±0.001
Fe	0.051±0.00	0.0440±0.00	0.0360±0.00	0.0290±0.001
NO ₃	0.7708±0.02	0.7003±0.00	0.7095±0.01	0.7468±0.02
PO ₄ ³⁻	0.8873±0.01	0.5963±0.02	1.2615±0.03	0.7053±0.02

Statistical analysis showed that there was a significant difference among the heavy metals' concentration from the various sampling sites. The Least Significant Difference (LSD) value for heavy metals was 5.22×10^{-4} . This value was above the difference between the mean concentrations of Pb in Tap water and Borehole, Open well and Tap water, indicating that the level of Pb in Tap water was significantly lower than the its level in Borehole and Open well water. Similarly, the mean concentration of Cu, Mn, Zn, Fe in River and Tap water, Open well and Tap water, Borehole and Tap water were all above the LSD value too. This revealed that the level of Cu, Mn, Zn, Fe in River was significantly greater than the level of Cu, Mn, Zn, Fe in Borehole, Open well and Tap water. Similarly, it also signifies that the level of Cu and Mn in Borehole is lower than the levels of Cu and Mn in Tap water, Open well and River; (Figure 2). In addition, a significant variation was observed in the level of Cd among the various samples. On the other hand, there was no significant difference at $p < 0.05$ between the level of Pb in Open well and Tap water.

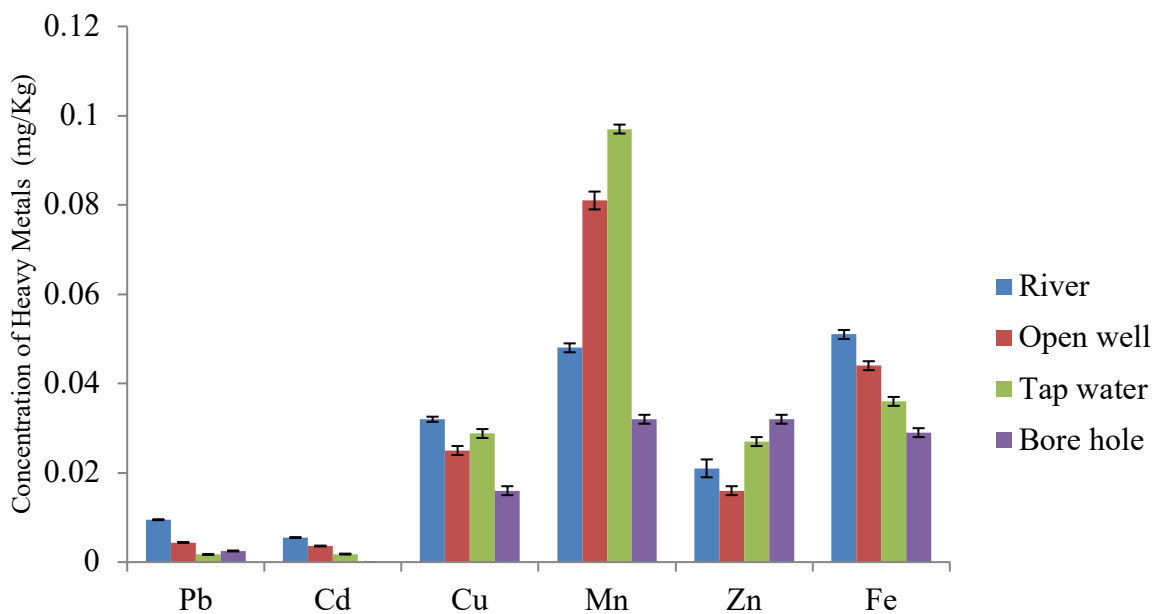


Figure 2: Concentrations of Heavy metals in water Samples Collected from Kafin Hausa

Pearson correlation analysis was conducted between heavy metal levels in water samples. Cd showed strong positive correlations with Pb, Cu and Fe at a significance level of 0.01 (2-tailed) while Positive correlations were also recorded for Cu with Fe at a significance level of 0.01 (2-tailed). The possible sources of these heavy metals displaying positive correlations were considered to be similar.

4.7 Nitrate (NO_3^-) and Phosphate (PO_4^{3-})

The mean concentration of NO_3^- in water samples range from 0.7003 to 0.771 mg/L (Table 1). However, the values obtained for NO_3^- were below the maximum permissible limit of 10 mg/L set by WHO. While the concentration of PO_4^{3-} ranged from 0.596 to 1.26 mg/L. These values were above the maximum permissible limit of 0.03 mg/L set by WHO. The levels of PO_4^{3-} (0.577 - 2.67 mg/L) reported by Ganesh *et al.*, 2012), was similar to the values obtained in this study. T-test statistical analysis at $p < 0.05$, showed that there was no significant difference between the concentration of NO_3^- and PO_4^{3-} in the water samples analyzed.

The result of this study indicated that all the analyzed heavy metals and anion were below the WHO standard permissible level for safe drinking water except that of PO_4^{3-} and it is therefore a good and safe drinking.

5. Conclusion

This study has determined the concentrations of lead (Pb), cadmium (Cd), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), nitrate (NO_3^-) and phosphate (PO_4^{3-}). In Kafin Hausa town It revealed that of all the heavy metals and anions analyzed only the concentration of PO_4^{3-} exceeded the permissible limit for good portable water set by WHO (2011). Therefore, it can be inferred that these water sources in Kafin Hausa are safe for consumption, use for other domestic activities and irrigation.

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