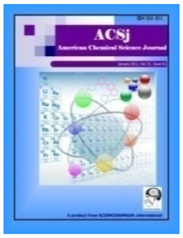

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Assessment of Heavy Metals in Ground Water from Nasarawa State, Middle Belt, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author BWT designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors MIGA and IGI managed the analyses of the study. Author EUO managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aim: To assess contamination of borehole water by heavy metals (Fe, Zn, Pb, Cr, Cu, Ni, Mn).
Study Design: Water samples collected from fifty two boreholes in twelve Local Government Areas (L.G.A) of Nasarawa State were analyzed for the heavy metal concentrations.
Place and Duration of Study: Samples were collected from Akwanga, Awe, Doma, Garaku, Karu, Keana, Keffi, Lafia, Nasarawa, Nasarawa Eggon, Toto, and Wamba, during the dry season.
Methodology: The water samples were prepared according to standard methods. Heavy metal levels in the samples were quantitatively determined using atomic absorption spectrometry (AAS).
Results: The highest concentrations of Zn (1.81±1.19 mg/l) and Fe (0.89±1.73 mg/l) were recorded at Keana, while their lowest levels were observed at Lafia. Pb ranged from

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0.01±0.00 to 0.04±0.05 mg/l in the areas. The highest Cu (0.32±0.51 mg/l) and Ni (0.07±0.06 mg/l) contents were obtained at Doma. Nasarawa recorded the highest concentration of Mn (0.08±0.04 mg/l) and the lowest at Lafia (0.01 ± 0.00 mg/l). Water Cr contents was highest at Keana (0.24±0.32 mg/l) and lowest at Lafia and Akwanga. Ni levels were low. Analysis of Variance (ANOVA) indicated that heavy metal concentrations were not significantly different (P < .05), except for Zn. Fe levels (0.70 mg/l) at Kagbu Error (N/Eggon), Offu and Ugya (0.75 mg/l) at Toto, where higher than the SON and WHO acceptable limits for drinking water, except at Idadu, where the value (0.35 mg/l) was within the WHO acceptable limit. Concentrations of Pb in borehole water from Tide, Nidan, and Towship (Akwanga), Arusu (0.014 mg/l) in Garaku and Keana were above the WHO threshold value for drinking water. Cr levels at Idadu (0.70 mg/l) in Doma, Angbragba (0.7 mg/l) and Owene (0.21 mg/l) at Keana, and Main market (0.07 mg/l), were also above the SON and WHO acceptable limits. Concentrations of Cu at Galle South (1.03 mg/l) in N/Eggon and Yashi Madaki (1.05 mg/l) in Wamba were higher than the SON standard but within the acceptable WHO (2.0 mg/l) standard.

Conclusion: Boreholes water was not contaminated by Mn, Zn, and Ni. Pb, Fe, Cu, and Cr levels in water were above SON and WHO. Metal levels above the standards might be attributed to surface contamination originating from anthropogenic and geological sources. Continuous monitoring of the heavy metal levels in water from the boreholes is recommended.

Keywords: Heavy metals; contamination; ground water; Nasarawa state; Middle Belt; Nigeria.

1. INTRODUCTION

The total replenishable water resource in Nigeria is estimated at 319 billion cubic meters, while the groundwater component is estimated at 52 billion cubic meters, an indication that Nigeria has adequate groundwater resources to meet its current water demands. However, with all the efforts put by various Governments and agencies to improve access to potable water supply to all Nigerians, it is estimated that only 58% of the inhabitants of the urban and semi-urban areas and 39% of rural areas have access to potable water supply [1].

Groundwater provides potable water to an estimated 1.5 billion people worldwide daily and has proved to be the most reliable resources for meeting rural water demand in sub-Saharan Africa [2]. The pollution of groundwater has become a major environmental issue, particularly where groundwater represents the main source of drinking water [3,4]. This situation is so common in many lesser developed countries like Nigeria, that the security of drinking water supply has been chosen as one of the ten Millennium Development Goals [5].

Heavy metal contamination of groundwater is a worldwide environmental problem affecting water resources [6,7], because of their strong toxicity even at low concentrations [8,9]. Heavy metals are natural components of the earth's crust, and they can enter the water and food cycles through a variety of chemical and geological processes [10,11]. Exposure to unsafe levels of heavy metals can cause serious health effects with varying symptoms depending on the nature and quantity of the metal ingested [12-14]. Heavy metal toxicity can result in damaged or reduced mental and central nervous function, lower energy levels, and damage to blood composition, lungs, kidneys, liver, and other vital organs [15]. Long-term exposure may result in slow and progressive physical, muscular, and neurological degenerative processes such as muscular dystrophy and multiple sclerosis [16,17].

Mechanism of metal toxicity include complexation of heavy metals with proteins to form complexes, in which carboxylic acid (–COOH), amine ($–NH_2$), and thiol (–SH) groups are involved. These modified biological molecules and lose their ability to function properly which result in the malfunction or death of the cells [16]. When metals bind to these groups, they inactivate important enzyme systems or affect protein structure, which is linked to the catalytic properties of enzymes. This type of toxin may also cause the formation of radicals which are dangerous chemicals that cause the oxidation of biological molecules [17].

The growing deficit of good quality water in developing countries, including Nigeria, has spurred the need to utilize other sources of water other than conventional treated waters at maximal risk of microbiological and chemical pollution [18]. In an effort to provide cheap, safe and potable water for rural communities, the government of Nigeria in collaboration with Nasarawa state government constructed boreholes within the premises of each Millennium Development Goals (MDG) Public Health Clinics (PHC) in the state. Agricultural activities take place around most of the boreholes. These non-treated water sources are being increasingly used as drinking water yet, testing to see whether the water is of good quality is almost non-existent. Preliminary research on some physicochemical properties of water from these boreholes has been reported [19]. This study was carried out to determine the spatial distribution and possible sources of contamination of the borehole water by heavy metals.

2. MATERIALS AND METHODS

2.1 Study Area

Nasarawa state is one of the thirty two (32) states including Abuja Federal Capital Territory (FCT) in Nigeria (Fig. 1); located centrally in the middle belt region of the country and lies between latitude 7º45´ and 9º25N´ of the equator and between longitude 7º and 9º37´E of the Greenwich meridian [14].

Fig. 1. Nigeria map showing Nasarawa state and sampling areas

2.2 Sampling and Sample Preparation

Water samples were collected into prewashed two liters polythene containers with screw caps in the month of April (dry season) from fifty two boreholes constructed in twelve L.G.A (Fig. 1), and 5 cm^3 concentrated HNO_3 added for preservation [20]. Digestion of water samples was carried out [21]: 3 cm^3 of concentrated HNO_3 was added and covered with a watch glass and heat gradually on hot plate, and continuously added until digestion was completed. The solution was evaporated to near dryness and cooled. Small quantity of 1:1 concentrated hydrochloric acid was then added, warm and filtered, and volume adjusted to 25cm^3 for heavy metal determination. Heavy metal contents were quantified using AAS. Internally added standards were used for the calibration of the AAS.

2.3 Statistical Analysis

Mean±SD (standard deviation) for heavy metal levels in ground water from each L.G.A was obtained. Analysis of variance (ANOVA) was used to establish any significant differences in metal levels in ground water from the studied areas.

3. RESULTS AND DISCUSSION

Variation in heavy metal levels in borehole water from Akwanga Local Government Area is shown in Fig. 2. Metal levels were low, except for Zn that variation was high. The highest and lowest Zn levels were recorded at Tide and Nunku respectively. Concentration of Pb was lowest in all the areas. In Awe (Fig. 3), heavy metal concentrations were relatively higher at Jangara, except for Zn whose concentration was highest at Gidan Ihume and lowest at Ankiri. Variations in metal levels at Doma (Fig. 4) indicated that Fe and Cr levels were higher at Idadu. The highest Cu concentration was observed at Agyema. Metal levels were generally low at Alwaza, except for Zn and Fe. At Graraku (Fig. 5), concentrations of heavy metals were low at Kana Apawu, except for Zn. The highest concentration of Fe was observed at Arusu. Cr level remained low in the area. Concentration of Zn at Kare and New Karu (Fig. 6) were relatively high, attaining the highest concentration at New Karu. Pb, Ni and Cr levels were low.

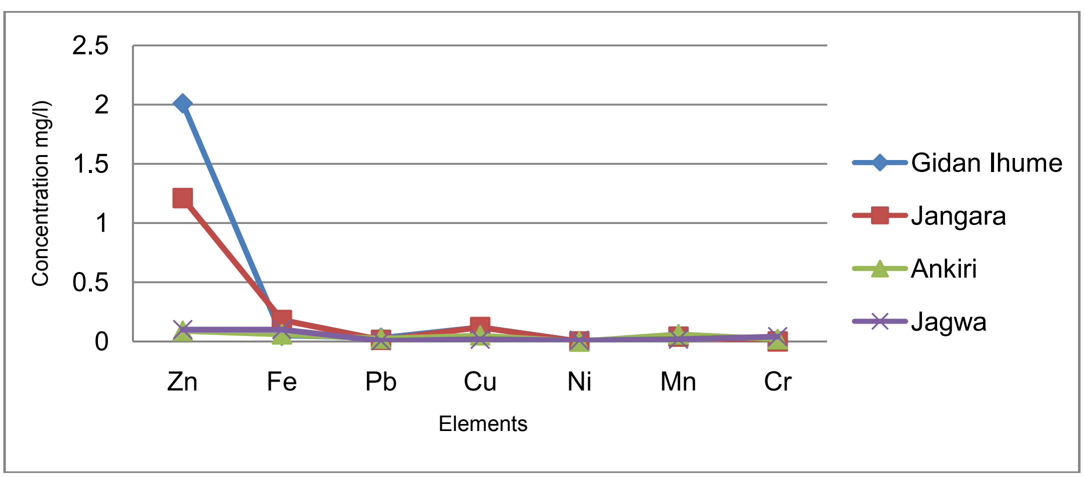


Fig. 2. Variations in metal levels in Akwanga L.G.A

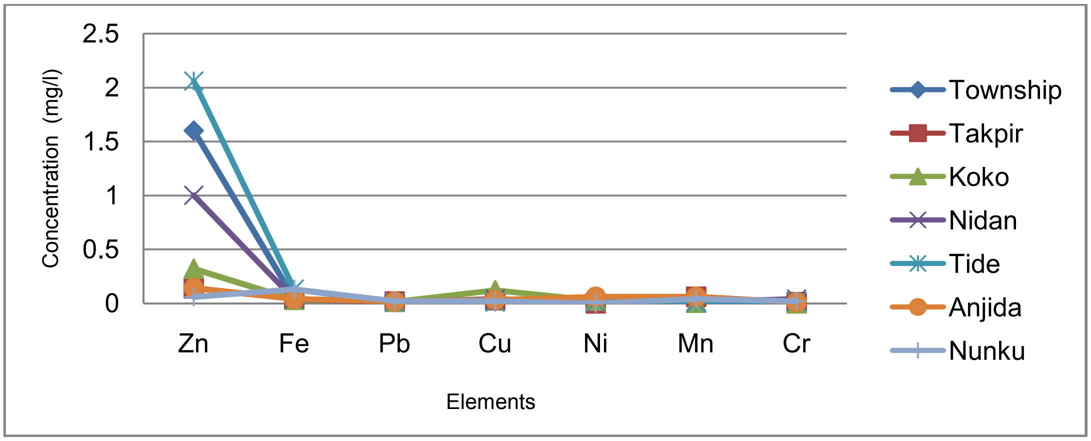


Fig. 3. Variations in heavy metal levels in Awe L.G.A

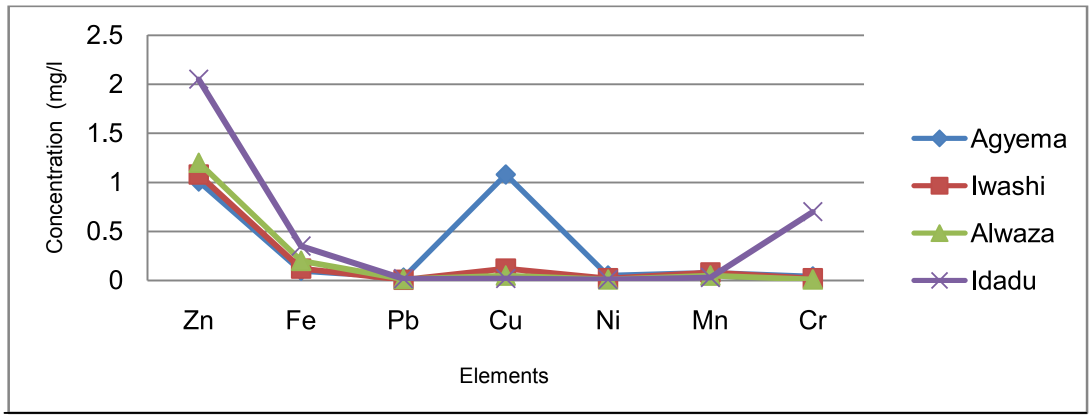


Fig. 4. Variations in heavy metal levels in Doma L.G.A

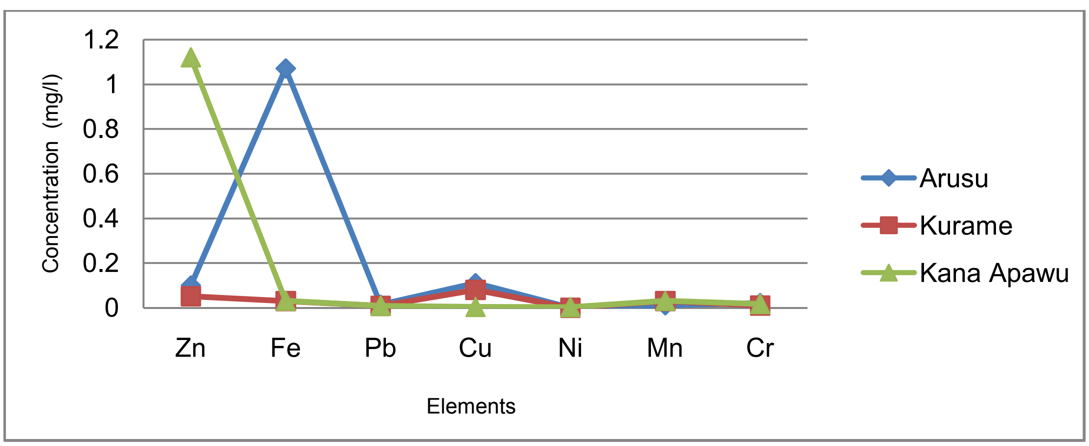


Fig. 5. Variations in heavy metal levels in Garaku L.G.A

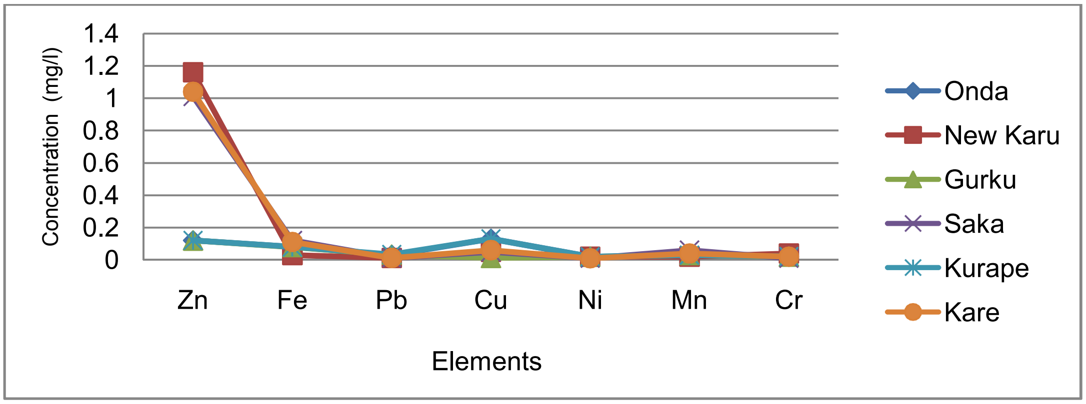


Fig. 6. Variations in heavy metal levels in Karu L.G.A

From Keana (Fig. 7), metal levels were low at Chiata, except for Zn. Concentrations of Fe and Cr were highest at Angbragba. In Keffi (Fig. 8), concentrations of Zn, Mn and Cr at Main market were higher than in Sabo Gari, while Pb, Cu and Ni levels in the areas did not vary. Heavy metal levels at Lafia (Fig. 9) show that concentration of Zn was similar and highest at Agyaragu Yakubu and Akunza Jarmai. Concentrations of Cu and Zn were both highest at Ombi Polytechnic, while the highest concentration of Fe was recorded at Takpah. Results in Nasarawa (Fig. 10), show that the highest levels of Zn and Mn were recorded at Godlonic, while that Fe and Cu was obtained at Zakun Bello. Concentration of Ni was lowest and similar in the areas. The levels of Zn at Ogba, Fe at Kagbu Error and Cu at Galle South were highest (Fig. 11). Concentrations of Pb and Cr were relatively low. Metal levels at Langalaga were genrally low. Heavy metal concentrations at Toto (Fig. 12) varied according to areas. Concentration of Zn and Cu at Kuru, and Fe and Ni at Offu were highest. Low levels metals were recorded at except for Zn at Karmo. Heavy metal concentrations did not vary significantly at Wamba (Fig. 13), except for Zn at Wayo and Cu at Zalli. Heavy metal contents at Waba Kurmi were generally low.

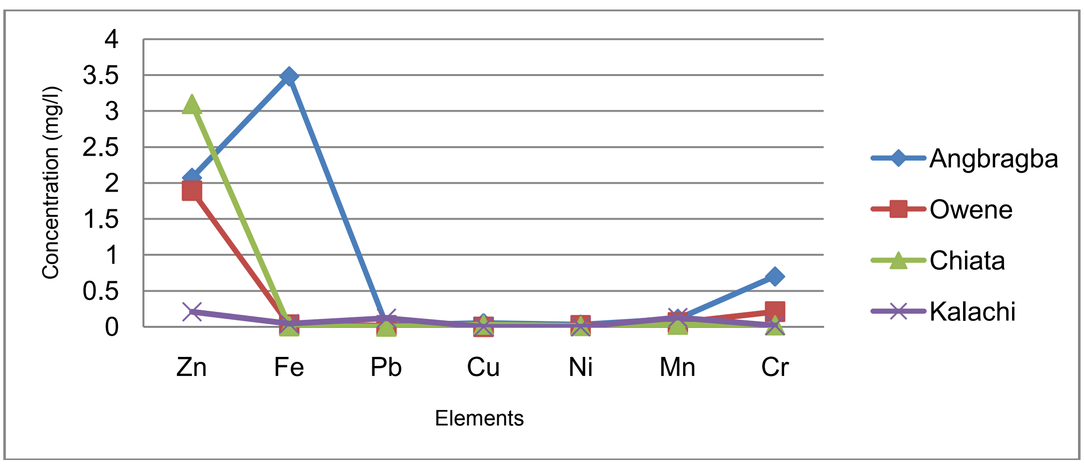


Fig. 7. Variations in heavy metal levels in Keana L.G.A

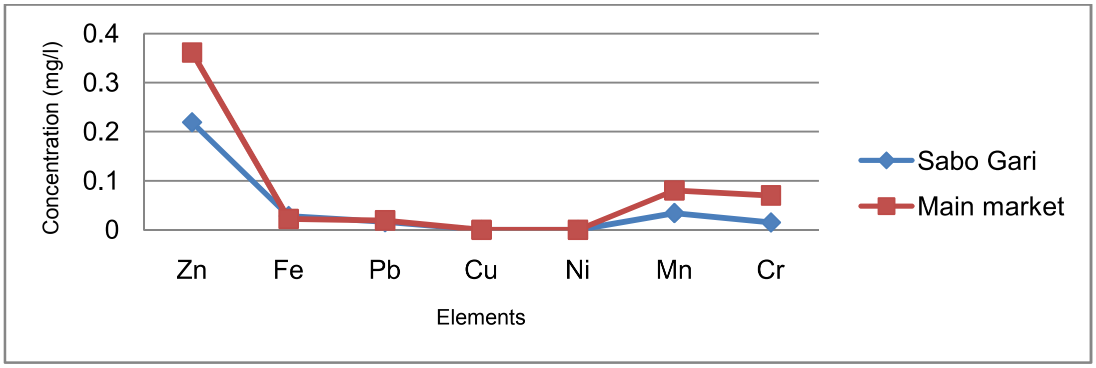


Fig. 8. Variations in heavy metal levels in Keffi L.G.A

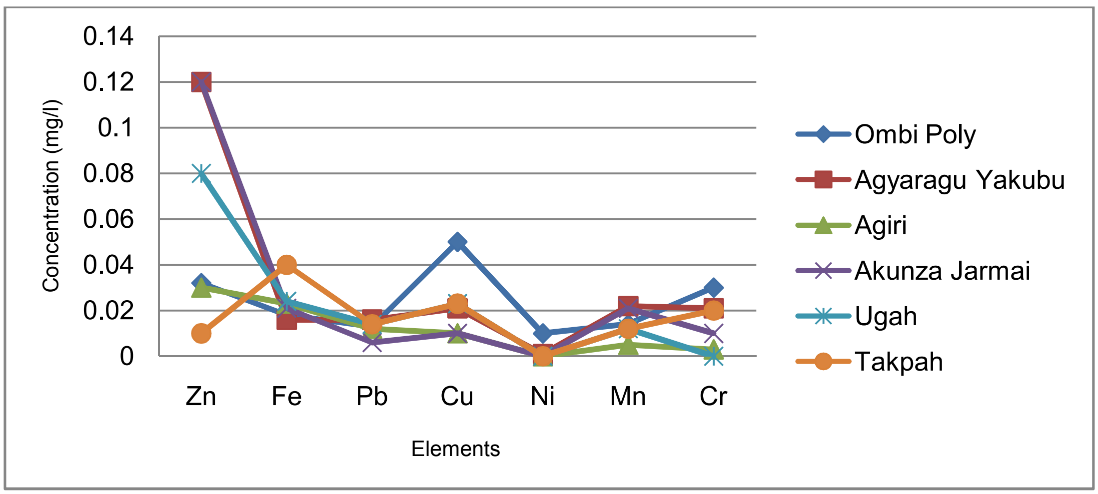


Fig. 9. Variations in heavy metal levels in Lafia L.G.A

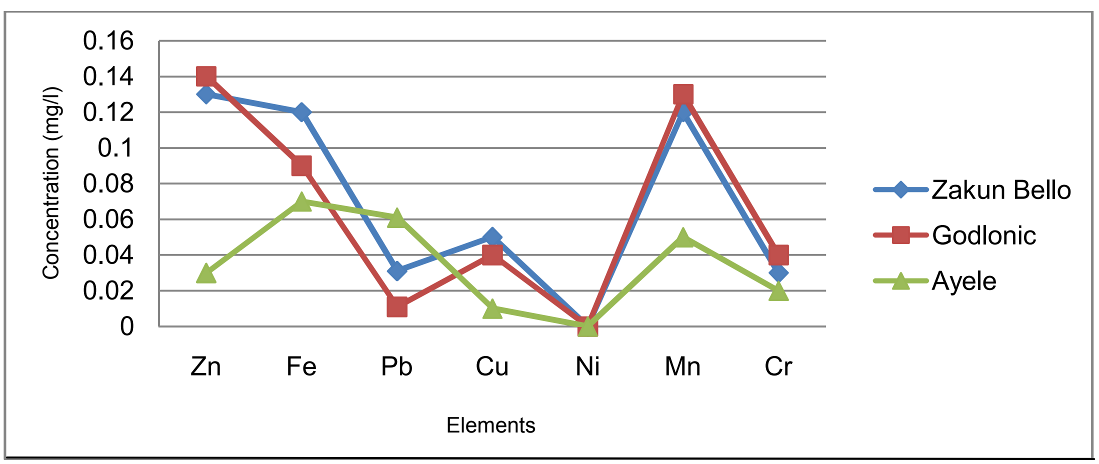


Fig. 10. Variations in heavy metal levels in Nasarawa L.G.A

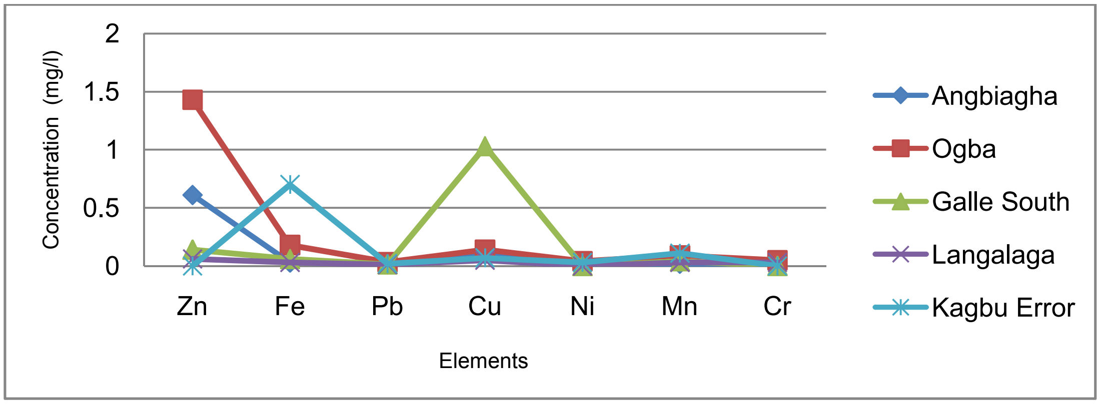


Fig. 11. Variations in heavy metal levels in Nasarawa Eggon L.G.A

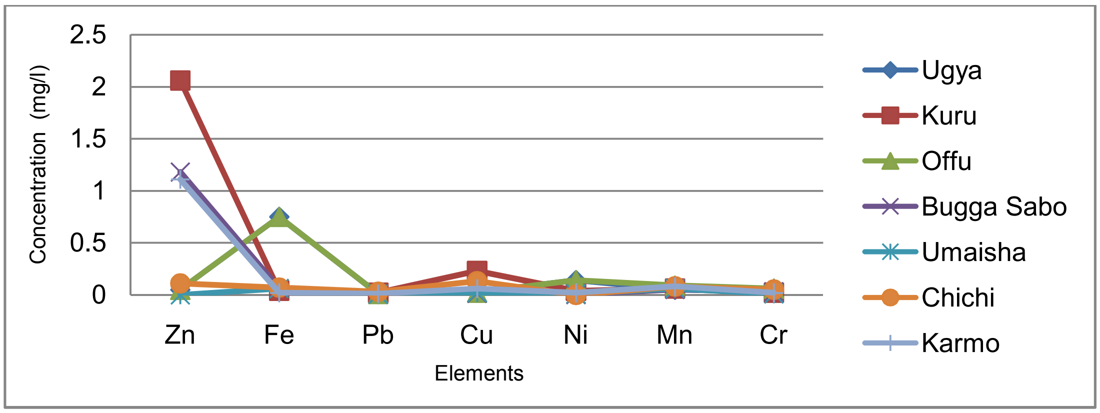


Fig. 12. Variations in heavy metal levels in Toto L.G.A

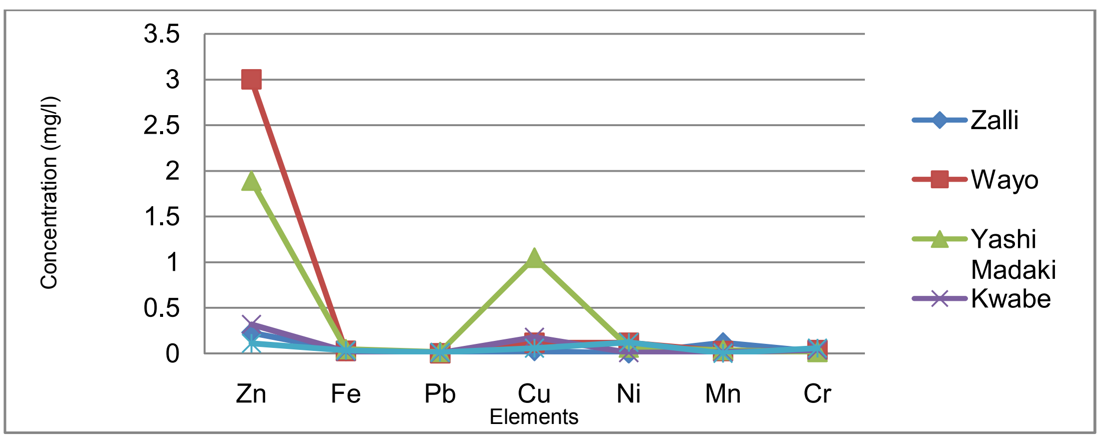
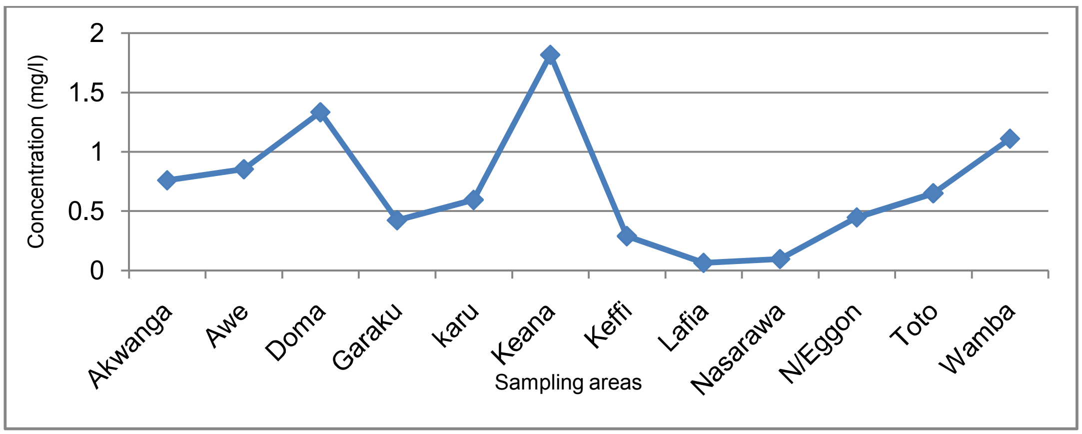
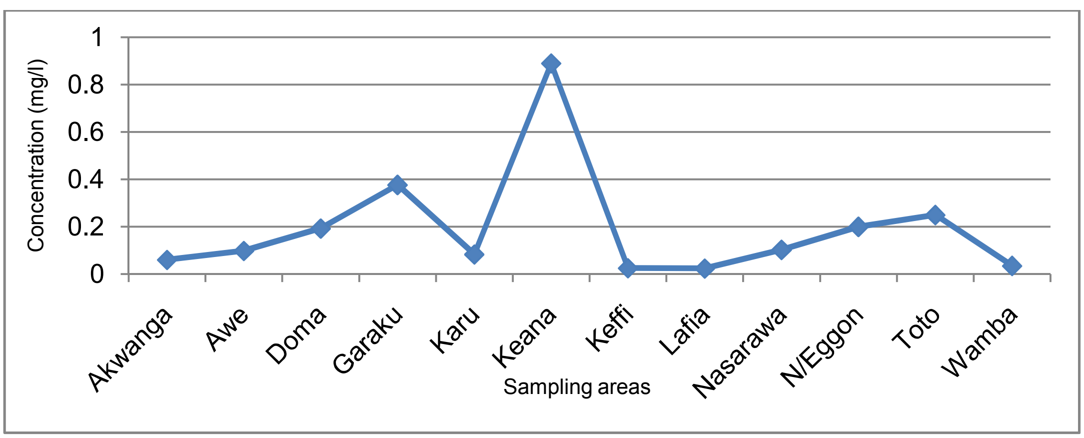


Fig. 13. Variations in heavy metal levels in Wamba L.G.A

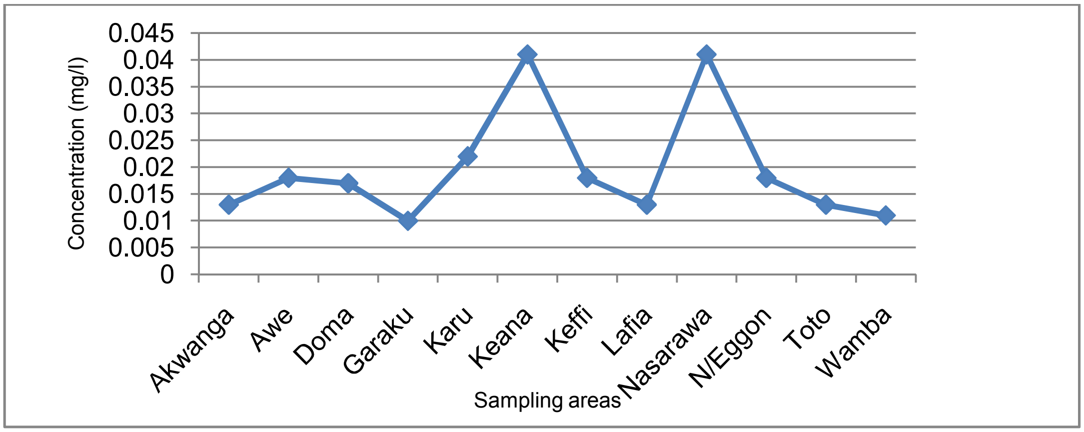
Spatial variations in heavy metal concentrations are presented in Fig. 14(a)–(g). Zn concentration (Fig. 14a) was highest at Keana (1.80 mg/l) and lowest in Lafia. Relatively high concentrations of Zn were recorded at Doma and Wamba. From Fig. 14 (b), Fe level was also highest at Keana and relatively low at Keffi, Lafia and Wamba. High concentrations of Pb (Fig. 14c) were observed at Keana and Nasarawa (0.04 mg/l), and the lowest at Garaku (0.01 mg/l). In Fig. 14(d), Wamba and Doma recorded relatively high levels of Cu. Concentration of Cu wee below detectable limit at Keffi and Lafia. Mn concentrations varied from one study area to the other (Fig. 14e). Mn concentrations show an increase from Akwanga to Doma, Garaku to Keana, and Lafia to Nasarawa. The lowest Mn level was recorded at Lafia and the highest in Nasarawa. Cr levels were generally low (< 0.05 mg/l) and similar (Fig. 14f), except at Doma and Keana, where the concentrations were relatively high. Fig. 14(g) indicated that Ni levels were below detectable limit at Keffi, Lafia and Nasarawa. However, the highest Ni level was recorded at Wamba.



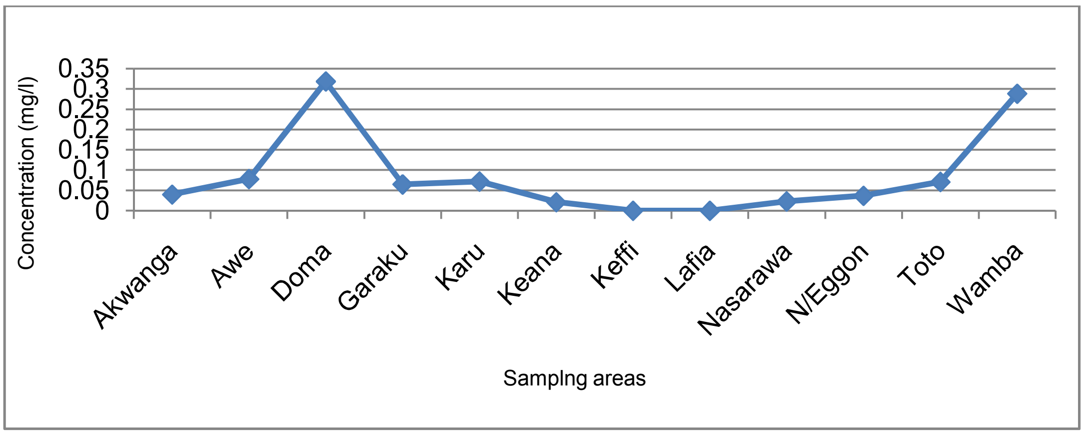
(a) Zinc (Zn)



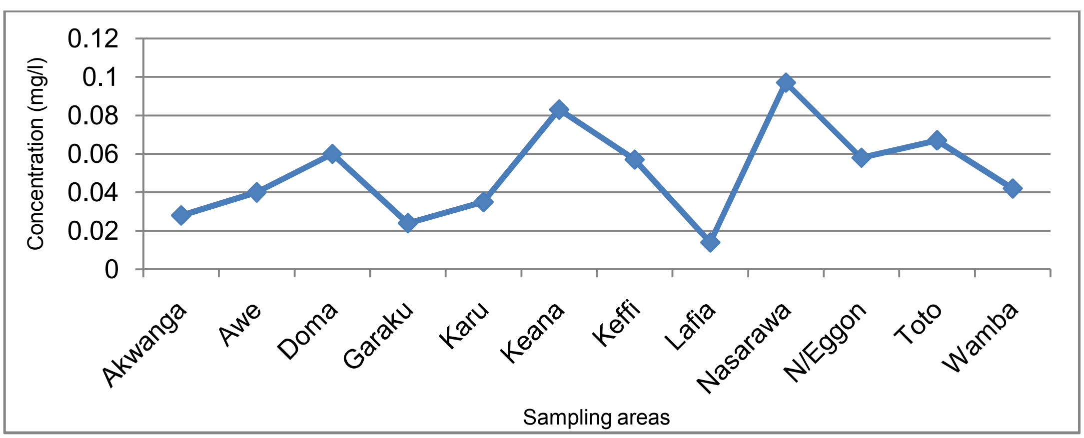
(b) Iron (Fe)



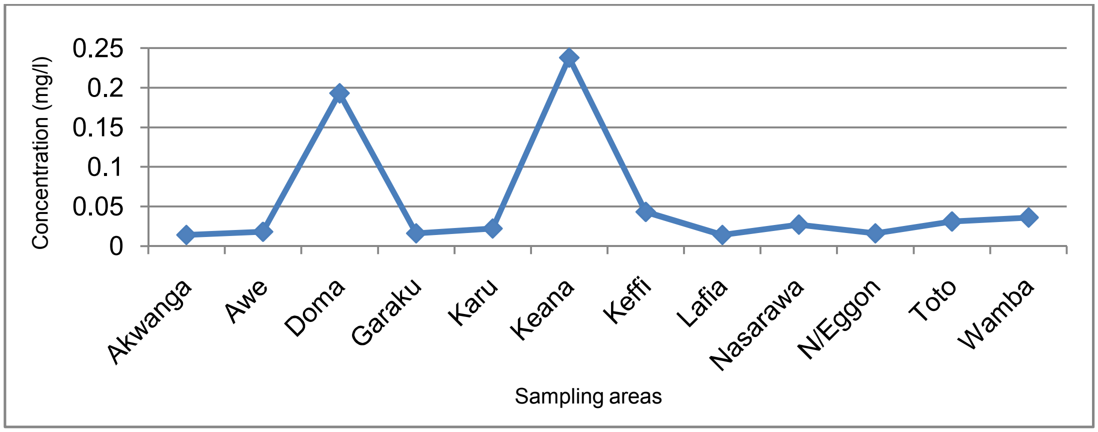
(c) Lead (Pb)



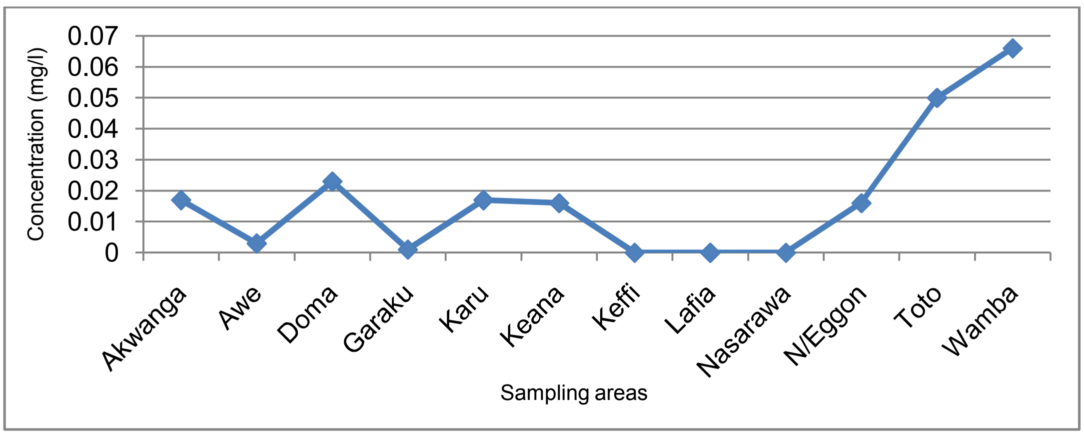
(d) Copper (Cu)



(e) Manganese (Mn)



(f) Chromium (Cr)



(g) Nickel (Ni)

Fig. 14. Spatial variations in heavy metal concentrations (mg/l) in the studied L.G.A

Analysis of variance (Table 1) at $P<.05$ indicated that Zn levels at Doma, Keana and Wamba were significantly different from other areas. Concentrations of Fe at Akwanga, Karu, Keffi, Lafia and Wamba were not significantly different. Cu and Ni levels were not significantly different in the study areas, except at Wamba, for Cu. Concentrations of Mn at Keana, Nasarawa and Toto were significantly different compared to other areas. Cr levels were not significantly different, except at Doma and Keana.

Table 1. Analysis of variance (ANOVA) for heavy metal concentrations (mg/l) in ground water

L.G.A	N	Metals						
		Zn	Fe	Pb	Cu	Ni	Mn	Cr
Akwanga	7	0.76±0.81a	0.06±0.15[a]	0.01±0.01[a]	0.04±0.04[a]	0.02±0.02[a]	0.03±0.03[a]	0.01±0.01[a]
Awe	4	0.85±0.93[a]	0.10±0.06[b]	0.02±0.01[a]	0.08±0.05[a]	ND	0.04±0.02[a]	0.02±0.02[a]
Doma	4	1.33±0.48[b]	0.19±0.11[b]	0.02±0.01[a]	0.32±0.51[b]	0.02±0.02[a]	0.06±0.02[a]	0.19±0.34[b]
Garaku	3	0.42±0.60[a]	0.38±0.60[b]	0.01±0.00[a]	0.07±0.06[a]	ND	0.02±0.01[a]	0.02±0.01[a]
Karu	6	0.59±0.52[a]	0.08±0.03[a]	0.02±0.01[a]	0.07±0.05[a]	0.02±0.01[a]	0.04±0.02[a]	0.02±0.01[a]
Keana	4	1.81±1.19[b]	0.89±1.73[b]	0.04±0.05[a]	0.02±0.02[a]	0.02±0.01[a]	0.08±0 05[b]	0.24±0.32[b]
Keffi	2	0.29±0.10[a]	0.03±0.00[a]	0.02±0.00[a]	ND	ND	0.06±0.03[a]	0.04±0. 04[a]
Lafia	6	0.07±0.05[ab]	0.02±0.03[a]	0.01±0.00[a]	ND	ND	0.01±0.01[a]	0.01±0.01[a]
Nasarawa	3	0.10±0.06[a]	0.10±0.02[b]	0.04±0.01[a]	0.02±0.02[a]	ND	0.10±0.04[b]	0.03±0.01[a]
N/Eggon	5	0.45±0.60[a]	0.20±0.27[b]	0.02±0.01[a]	0.04±0.02[a]	0.02±0.02[a]	0.06±0.04[a]	0.02±0.02[a]
Toto	7	0.65±0.80[a]	0.25±0.34[b]	0.01±0.01[a]	0.07±0.81[a]	0.05±0.06[a]	0.07±0.02[b]	0.03±0.02[a]
Wamba	5	1.11±1.2[8b]	0.04±0.01[a]	0.01±0.001[b]	0.29±0.43[b]	0.07±0.06[a]	0.04±0.05[a]	0.04±0.02[a]
*WHO		3.0	0.5	0.01	2.0	-	0.4	0.05
[z]SON		3.0	0.3	0.01	1.0	-	0.2	0.05

N: Number of sampled boreholes; ND: below detection limit; mean values within the same column with different alphabets are significantly different at P<.05; * WHO, 2004; [z]SON, 2007.

Results in this study indicated that Ni concentrations in Awe, Garaku, Keffi, Lafia and Nasarawa were similar to values reported by [18,22,23], while values for Fe were higher than the values reported by [23]. Pb levels were less than the values reported by [8,17], while concentrations of Mn were lower than those reported by [22]. Comparing the results of this study with WHO (2004) and SON (2007) standards for drinking water, Fe levels (0.70 mg/l) at Kagbu Error (N/Eggon), and Offu and Ugya (0.75 mg/l) both at Toto, where higher than the SON [24] and WHO [25] limits. At Idadu (Doma), concentration of Fe (0.35 mg/l) was higher than the SON but within the WHO standards. Concentrations of Pb in borehole water from Tide, Nidan, and Towship at Akwanga were observed to be greater than the WHO standard; and also at Arusu (0.014 mg/l) in Garaku, Keana except at Chiata, Keffi, Karu, Lafia, Nasarawa, and Yashi Madaki (0.02 mg/l) at Wamba. Cr levels at Idadu (0.70 mg/l) in Doma, Angbragba (0.7 mg/l) and Owene (0.21 mg/l) at Keana, and Main market (0.07 mg/l), were also above the SON and WHO acceptable limits for drinking water. Concentrations of Cu at Galle South (1.03 mg/l) in N/Eggon and at Yashi Madaki (1.05 mg/l) in Wamba were higher than the SON standard but within the acceptable WHO standard (2.0 mg/l).

CONCLUSION

The highest concentrations of Zn (1.81±1.19 mg/l) and Fe (0.89±1.73 mg/l) were recorded at Keana, while the lowest levels of these metals were observed at Lafia. Pb levels ranged from 0.01±0.00 - 0.04±0.05 mg/l in the areas. The highest Cu (0.32±0.51 mg/l) and Ni (0.07±0.06 mg/l) contents were obtained at Doma, whileNasarawa recorded the highest concentration of Mn (0.08±0.04 mg/l) and the lowest at Lafia (0.01±0.00 mg/l). Water Cr contents was highest at Keana (0.24±0.32 mg/l) and lowest at Lafia and Akwanga. Ni levels were low. ANOVA shows that except for Zn, concentrations of other metals were not significantly different ($P < .05$). Fe levels (0.70 mg/l) at Kagbu Error (N/Eggon), Offu and Ugya (0.75 mg/l) at Toto, where higher than the SON and WHO acceptable limits for drinking water, except at Idadu, where the value (0.35 mg/l) was within the WHO acceptable limit. Concentrations of Pb in borehole water from Tide, Nidan, and Towship (Akwanga), Arusu (0.014 mg/l) in Garaku, Keana except at Chiata, Keffi, Karu, Lafia, Nasarawa, and Yashi Madaki (0.02 mg/l) at Wamba, were above the WHO threshold value for drinking water. Cr levels at Idadu (0.70 mg/l) in Doma, Angbragba (0.7 mg/l) and Owene (0.21 mg/l) at Keana, and Main market (0.07 mg/l), were also above the SON and WHO acceptable limits. Concentrations of Cu at Galle South (1.03 mg/l) in N/Eggon and Yashi Madaki (1.05 mg/l) at Wamba were higher than the SON standard but within the acceptable WHO standard (2.0 mg/l). Higher levels of some metals compared to the standards might be contributions from anthropogenic and geological sources.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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