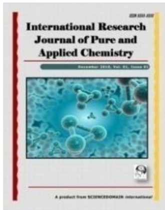

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Determination of Physico-Chemical Parameters, Zinc and Iron Levels in Domestic Waters of Katsina Metropolis, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author LS designed the study, wrote the first draft of the manuscript. Authors BAD and AIY managed the sample collection, laboratory analysis, literature review and performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Physico-chemical parameters, Zinc and Iron levels of sixteen different samples of the domestic waters obtained from some designated areas in Katsina metropolis were determined to ascertain the level of water quality. The parameters investigated were pH: (6.55±0.10-8.34±0.15), turbidity (1.75±0.08-4.86±0.00FTU), DO (1.15±0.03-7.75±3.12mg/L), BOD (22.70±3.44-46.00±8.42mg/L), COD (55.00±4.55-89.25±6.35mg/L), bicarbonate (12±0.00-40±3.86mg/L), chloride (10±2.65-25±1.96mg/L) and nitrate (0.00±0.00mg/L). Zinc and Iron levels were determined using atomic absorption spectrophotometer. Water pH and physico-chemical parameter values investigated were below the WHO safe limit. This indicates that the domestic waters are fit for human

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consumption. The mean concentrations of the metals ranged from 0.75±0.05 to 8.25±0.23ppmZn and from 0.46±0.06 to 0.82±0.03ppmFe. With the exception of rainwater samples, the concentrations of Zn in all samples were below WHO recommended safe limit for Zn in drinking water. High concentrations of Fe were detected in all samples investigated, which were above WHO recommended safe limit. High concentrations of Fe in the water samples are indications that these domestic waters have been polluted, suggesting potential health risk for human consumption. The analysis of variance results computed for this study showed that Zinc contents (F=5.53) of the domestic waters had no significant differences ($p>0.05$) while that of Iron contents (F=133.34) had significant differences ($p<0.05$) with control sample, distilled deionized water (DDW) confirming contamination by Fe. However, it is recommended that there should be monitoring and evaluation of physico-chemical parameters and heavy metal levels in domestic waters to ascertain water quality at regular intervals and maintaining data base. Also, local inhabitants are advised to avoid drinking and utilizing rainwater to prepare herbal concoctions due to high concentrations of Zinc and Iron.

Keywords: Physico-chemical parameters; Zinc; Iron; domestic waters; safe limits; Katsina-Nigeria.

1. INTRODUCTION

Water is a finite resource that is very essential for human existence, agriculture, industry etc. Without any doubt, inadequate quantity and quality of water have serious impact on sustainable development. In developing countries, most of which have huge debt burdens, population explosion and moderate to rapid urbanization, people have little or no option but to accept water sources of doubtful quality, due to lack of better alternative sources or due to economic and technological constraints to treat the available water adequately before use [1,2]. The scarcity of clean water and pollution of fresh water has therefore led to a situation in which one-fifth of the urban dwellers in developing countries and three quarters of their rural dwelling population do not have access to reasonably safe water supplies [3]. Though water as a vital resource in the ecosystem which supports life of all living organisms, occupies about 70% of the earth's surface and provides essential elements and when polluted it may become dangerous to human's health [4]. Safe potable water is essential for healthy living and for water to be regarded as safe for drinking; it must meet certain physical, chemical and microbiological criteria set by international organizations such as World Health Organization [5].

In recent years, because of rapid urbanization, industrialization and growing population, the rate of discharge of pollutants into the environment is higher than the rate of purification [6]. Heavy metals are a group of pollutants that has posed serious concern particularly on drinking water quality and hence their constant monitoring in the environment is of paramount importance [7]. They are metallic elements whose specific gravity is greater than $6.0mg/m^3$ and are non-biodegradable as they are not readily detoxified and removed by metabolic processes once they enter human body [7]. Interestingly, small amounts of these elements are common in our environment and diet and are actually necessary for good health, but large amounts of any of them may cause acute or chronic toxicity. Bioavailability of these metals is very important as this is a gateway for entry of heavy metals into the food chain [7]. However, the most toxic heavy metals are Cr, Ni, Pb, Cd and As. Cr (VI), Ni and Cd are carcinogenic; As and Cd are teratogenic, and the health effects of Pb include neurological impairment and malfunctioning of the central nervous system [8,9]. Although some heavy metals such as Fe, Mn, Co, Cu and Zn are essential micronutrients for fauna and flora, they are dangerous at high levels [9,10,11]. The dearth of information on the water quality in Katsina State necessitates the current work. This research was aimed at determining the levels of physico-chemical parameters and the concentrations of Zinc and Iron in domestic waters of Katsina metropolis in order to ascertain the drinking water quality for human consumption.

2. MATERIALS AND METHODS

Glass ware, plastic containers, crucibles, pestle and mortar were washed with liquid detergent, rinsed with distilled deionized water and then soaked in 10% HNO_3 solution for 24 hrs [12]. They were then washed with distilled deionized water and dried in a drying oven at 80ºC for 5 hrs. Analytical grade reagents and chemicals

(BDH and Sigma-Aldrich chemicals) were used for this study. Distilled deionized water was also used for metal analyses. All digestion and analyses were done in triplicate. Procedural and reagent blanks were used and a clean laboratory environment was ensured during the analysis and preparation of solutions.

2.1 Study Area

The study area covered in this research was Katsina (Fig. 1), a city in North western Nigeria. Katsina is the capital of Katsina State, one of Nigeria's 36 States. It is also the headquarters of Katsina Local Government Area. The global location of the State is between latitude 12^0 $15^'$ north of the equator and longitude 07^0 30' east of the Greenwich Meridian with a total area of 24, 192 Km^2 and a population of 3, 878, 344 as of 1991 census [13].

2.2 Sample and Sampling

A total of sixteen domestic water samples were analyzed in this study and these samples were obtained during the raining season in the year 2013. Four samples each were collected from four designated areas in Katsina metropolis (Fig. 1) using 5.0 litre plastic gallons which were rinsed initially with 20% (v/v) nitric acid. All samples were randomly selected and collected during the month of August in the year 2013.Rainwater samples were collected in clean plastic buckets by placing the container on a raised platform under a roof of a building; which is the normal practice of fetching the said water by the inhabitants in the studied areas. These samples were emptied into clean plastic gallons. The well water samples and others were collected on the same day very early in the morning prior to commencement of water fetching by the inhabitants of the areas. This was done to ensure the water collected was free of sediments. The plastic gallons were tightly covered immediately after collection and in-situ measurements were made for pH, using a digital SB20 pH meter which was calibrated using buffer solution of pH 7. The water samples were then stored in a refrigerator at 40ºC (LG Thermocool) to slow down bacterial and chemical reactions prior to analysis. The samples analyzed were the most commonly consumed in the respective areas.

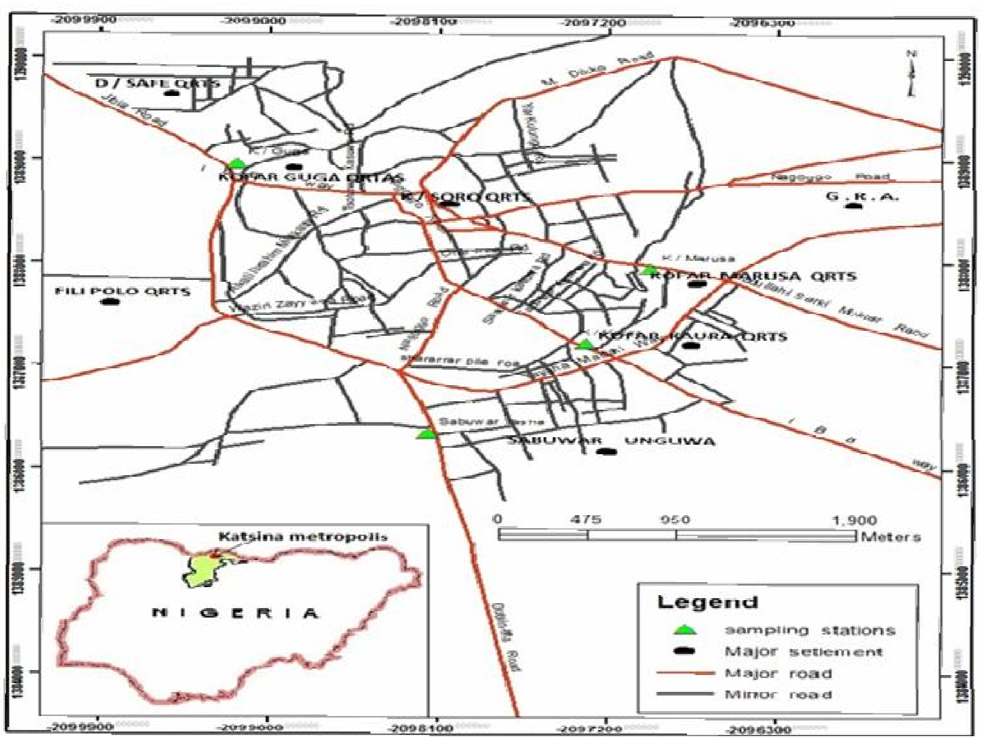

Fig. 1. Map of Katsina metropolis showing the sampling stations (areas)
Source: Cartography unit, Geo. Dept. UMYU 2014

2.3 Sample Digestion and Analysis

Sample digestion and analysis as well as determination of turbidity, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), bicarbonate, nitrate, and chloride were carried out according to American Public Health Association (APHA) standard methods [14]. Serial dilution method was used to prepare the working solutions and the concentrations of the metals in each sample digest were determined using Buck Model 210 VGP Spectrophotometer equipped with digital readout system [15].

2.4 Statistical Analysis

Data obtained were analyzed using Microsoft Excel and results were expressed as mean±standard deviation. The analysis of variance was used to test for significant differences. Statistical variations were considered significant at $p<0.05$.

3. RESULTS

The results of the analysis are shown in Table 1. Water pH values ranged from 6.55±0.10 to 8.34±0.15. The turbidity of the water samples ranged from 1.75±0.08 to 4.86±0.00 FTU. The dissolved oxygen of all samples was low (1.15±0.03 to 7.75±3.12 mg/L). All the water samples were low in BOD which ranged from 22.70±3.44 to 46.00±8.42 mg/L and COD which ranged from 55.00±4.55 to 89.25±6.35 mg/L. All water samples contained low bicarbonate (12.00±0.00 to 40.00±3.86 mg/L). There was zero concentration of nitrate in all samples. Chloride was evenly distributed in all the water samples analyzed and ranged from 10.00±2.65 to 25.00±1.96 mg/L. Highest level of Zinc (8.25±0.23 mg/L) was recorded by rainwater sample SU1 while the least concentration (0.75±0.05 mg/L) was recorded in well water sample SU4. Also, rainwater sample SU1 recorded highest amount of Iron (0.82±0.03 mg/L) while well water sample KG4 recorded least concentration of 0.46±0.06 mg/L.

The mean concentrations of the metals in the domestic waters are presented in Fig. 2. The general trend for the mean concentrations of Zn metal in the drinking waters showed that: rainwater> borehole water> public tap water> well water. Similarly, the general sequence for the mean concentrations of Fe metal analyzed in the samples showed that: public tap water> rainwater> borehole water> well water as shown in Fig. 2.

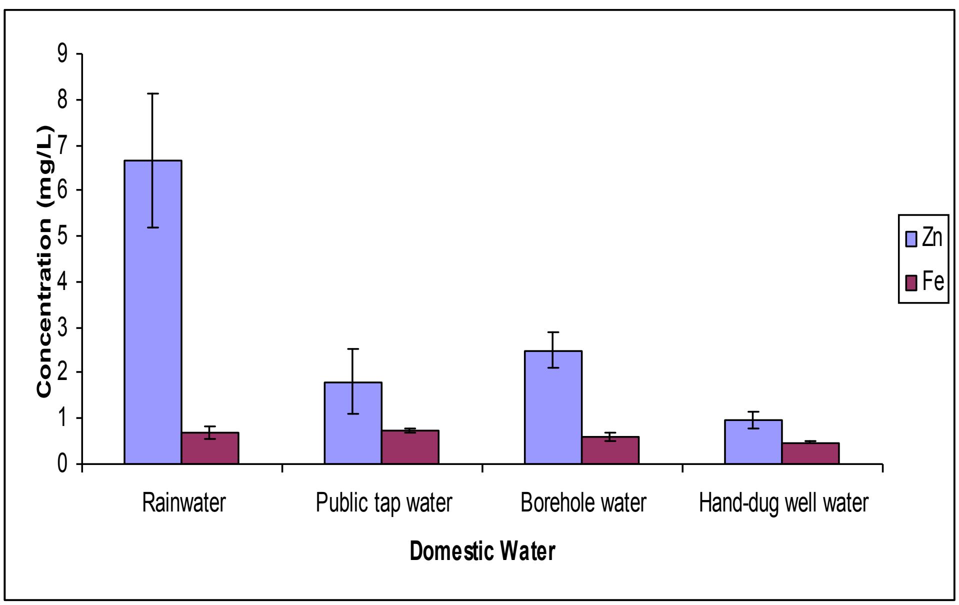

Fig. 2. Mean concentrations of zinc and iron (mg/L) in the various domestic waters
Values represent Mean± Standard deviation of three determinations

Table 1. Table showing the mean physico-chemical parameters and metal concentrations in domestic water samples from four sampling areas in Katsina metropolis

Sample code	pH	Turbidity (FTU)	DO (mg/L)	BOD (mg/L)	COD (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	Nitrate (mg/L)	Zn (mg/L)	Fe (mg/L)
SU1	7.20±0.11	4.50±1.10	6.35±1.96	22.70±3.44	56.25±4.56	32±0.00	25±1.96	0.00±0.00	8.52±0.23	0.82±0.03
SU2	6.55±0.10	3.22±0.13	2.55±0.72	34.50±6.25	55.00±4.55	15±2.55	17±1.45	0.00±0.00	1.93±0.02	0.72±0.04
SU3	6.74±0.14	1.75±0.08	5.75±1.13	29.90±2.50	67.75±6.21	17±4.50	10±2.65	0.00±0.00	2.95±0.75	0.65±0.03
SU4	6.56±0.06	2.32±0.12	6.15±0.00	45.00±8.22	76.50±2.22	12±0.00	16±2.65	0.00±0.00	0.75±0.05	0.49±0.05
KK1	6.94±0.04	4.25±0.25	3.25±0.72	44.35±4.51	87.35±6.34	35±4.50	14±0.00	0.00±0.00	5.56±0.23	0.76±0.06
KK2	8.02±0.12	4.00±0.00	7.20±1.21	28.50±4.85	86.55±8.23	23±6.40	12±1.97	0.00±0.00	2.73±0.92	0.72±0.03
KK3	6.35±0.06	2.75±0.38	4.55±1.21	34.25±0.00	65.85±8.33	28±3.45	11±1.97	0.00±0.00	2.67±0.06	0.64±0.02
KK4	7.03±0.11	4.77±1.76	6.75±1.76	44.50±2.52	89.25±6.35	16±4.55	18±1.96	0.00±0.00	0.98±0.04	0.48±0.02
KM1	7.52±0.07	3.89±0.72	7.25±0.25	43.50±2.52	77.15±5.44	20±0.00	13±1.99	0.00±0.00	5.42±1.21	0.63±0.02
KM2	7.15±0.03	4.86±0.00	2.15±0.92	38.00±4.85	85.65±9.24	40±3.86	15±0.00	0.00±0.00	1.12±0.02	0.66±0.03
KM3	6.85±0.06	2.99±0.72	5.55±1.23	25.30±1.96	57.25±7.21	34±3.86	15±0.00	0.00±0.00	2.20±0.05	0.47±0.08
KM4	6.80±0.04	3.52±0.85	1.15±0.03	32.25±0.00	88.25±4.95	22±4.00	11±1.18	0.00±0.00	0.93±0.02	0.47±0.05
KG1	8.34±0.15	4.55±1.44	7.75±3.12	36.50±2.65	87.25±5.33	36±8.62	19±2.50	0.00±0.00	7.21±0.67	0.53±0.03
KG2	6.88±0.03	3.74±0.00	2.45±0.72	35.25±2.65	66.15±4.51	30±0.00	21±2.50	0.00±0.00	1.45±0.03	0.76±0.05
KG3	6.74±0.05	3.69±1.18	3.25±0.00	46.00±8.42	67.25±5.23	18±0.00	23±0.00	0.00±0.00	2.16±0.02	0.62±0.02
KG4	6.86±0.07	2.88±0.25	7.65±1.44	23.75±3.45	85.75±8.65	21±7.35	22±2.60	0.00±0.00	1.18±0.03	0.46±0.06
DDW	7.02±0.12	1.25±0.06	1.05±0.02	20.50±0.00	42.65±1.21	12.5±2.30	8.5±0.00	0.00±0.00	0.00±0.00	0.00±0.00
WHO STD	6.5-8.5	5.0	-	50.0	-	110.0	400	50.0	5.00	0.30

Values represent Mean±standard deviation of three determinations, Key: SU=Sabuwar Unguwa; KK= Kofar Kaura; KM= Kofar Marusa; KG= Kofar Guga, 1=Rainwater; 2=Public tap water; 3=Borehole water; 4=Hand-dug well water, WHO STD= World Health Organization Standard Safe Limit, DDW=Distilled deionized water control, FTU=Formazin Turbidity Unit

4. DISCUSSION

The results showed that all the water samples were within the standard pH range approved by the WHO for quality drinking water [16]. The pH values indicated that the water samples are ideal to support aquatic life, and good for human consumption [17] as it has been shown that extreme pH values for water are not suitable for human consumption and can cause stress to aquatic life [18]. Turbidity which measures the cloudiness of water and one of the parameters used to measure water quality has been determined. The low turbidity values indicated the presence of few organic and inorganic solids which can provide absorptive site for certain biological and chemical agents [19]. This observation of low turbidity has confirmed that people in these areas are mostly free of gastrointestinal infections [20]. Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria and dissolved chemicals [21].

The dissolved oxygen of all samples was low (Table 1) indicating that the water samples may not support aerobic organism [22]. All the water samples were low in BOD and COD values indicating low levels of biologically active organic matter [23].

All the water samples contained low bicarbonate and zero concentrations of nitrate. Bicarbonate was present in all the water samples analyzed including the distilled deionized water control. It is present in the rainwater samples probably due to the dissolved carbon (IV) oxide; while in the tap, borehole and well water, the anion might have resulted from the hardness of the water. Water acquires hardness when it dissolves Calcium tetraoxosulphate (VI) dihydrate (gypsum), $CaSO_4.2H_2O$ or Calcium trioxocarbonate (IV) (limestone), $CaCO_3$ from the soil over which it flows [24].

Chloride ion was evenly distributed in all the water samples analyzed. The presence of chloride in the rainwater samples could probably have come from the galvanized roofing sheets and the plastic gallons or plastic containers used in sample collection. On the other hand, chloride in well and borehole water samples may be attributed to the presence of chlorides in the earth's crust which might have been formed from reactions between some metallic ions with hydrochloric acid [24]. Also, tap water samples contained chlorides probably due to chlorine used as a powerful germicide and because of its oxidizing nature has been employed in the treatment of the water [24].

Zinc recorded highest concentrations compared to Iron in all the water samples investigated. With the exception of rainwater samples, the concentrations of Zn in all the samples were below the WHO recommended safe limit for Zn (5.00 mg/L) in drinking water. The higher concentrations of Fe detected in all water samples investigated were above the safe limit for Fe (0.30 mg/L) recommended by WHO [16] as shown in Table 1.

The higher level of Zn (6.68±1.47 mg/L) in rainwater may be due to dissolved metal from the galvanized roofing sheets during rainfall as water is a universal solvent [24]. Water is a polar substance, which can dissolve many things. The lower level of the metal (0.96±0.18 mg/L) observed in well water suggests that soil composition of Zn mineral is poor. Similar to this study, a lower value of Zn (0.50 mg/L) in well water was reported [25]. The substantial amounts of Zn (2.50±0.38 mg/L) and (1.81±0.70 mg/L) recorded in borehole water and public tap water respectively can be attributed to water pipes contamination of Zn. Zinc has its sources ranging from plumbing works, animal wastes, pesticides, metal works, industrial effluents, galvanized roofing sheets, etc. Zn is toxic to many plants at widely varying concentrations, however, it has been found to have low toxicity to man. Prolonged consumption of large doses can result in some health complications such as fatigue, dizziness and neutropenia [26]. Cases of Zn poisoning in humans through inhalation and ingestion of Zn have also been reported [27]. Zinc has gastrointestinal effect on human at higher concentration and causes liver damage [16]. As such prolonged consumption of rain water as is the practice during the rainy season in Katsina due to acute scarcity of good drinking water may lead to health complications in the consumers. Although, Zn is an essential element involved in metabolic functions and is important for both man and plant healthy growth [28].

Variations of the Zn level in rainwater may be attributed to differences in the galvanized roofing sheets type. The levels of Zn in rainwater samples SU1 (8.52±0.23 mg/L) and KG1 (7.21±0.67 mg/L) obtained from old metal roofs especially the reddish, rusted roofs recorded highest amounts of Zn whereas samples KK1

(5.56±0.23 mg/L) and KM1 (5.42±1.21 mg/L) obtained from new metal roofed houses had moderate content of the metal. The levels of Zn (2.50±0.38 mg/L) in borehole water reported in this study are higher when compared to that reported in borehole water (0.01 mg/L) by Asia et al. [29]. Zn levels ranging from 8.9 to 107.8ppb in borehole water sources were associated with growth failure, loss of taste and hypogonadism have been reported [30]. This is a clear manifestation of Zn deficiency in the drinking water which showed detrimental effect to human. Adult generally on average scale requires 15 mg/day and about 3 per cent ought to come from drinking water [31]. Hence the need for Zn supplementation in people located in areas in Katsina that uses borehole water for drinking.

The higher concentrations of Fe in the public tap water (0.72±0.041 mg/L) and borehole water (0.69±0.13 mg/L) as shown in (Fig. 2) may be attributed to the presence of various iron salts which are used as coagulating agents for the water treatment as well as cast, steel, and galvanized iron pipes used for water distribution [30]. This finding has confirmed the findings by Oladipo et al. [31] who reported higher Fe levels which ranged from 20.2-83.3 ppm in borehole water sources in Lapai metropolis, Nigeria. The higher Fe contents indicated that these domestic waters had been polluted with iron. Higher Fe levels are associated with lower blood Pb levels, as Fe and Pb occupy similar sites within the human body and so compete for likely binding sites particularly during absorption (http://www.lead.org.au/lanv9n3/iron). The higher amount of Fe in domestic waters is a cause for concern though it may prevent Pb toxicity in the bloods of the consumers. However, a substantial amount of Fe (0.48±0.13 mg/L) in well water as shown in (Fig. 2) though above permissible limit can be attributed to soil composition of the mineral in the areas. Lower value of Fe (0.29 mg/L) in well water has been reported [25]. Although, Fe is found in most tropical soils; it occurs mainly as pyrites or ferromagnesium minerals such as biotite, horn blende and limonite. Small amounts are present in the soil solution or in exchangeable form. Iron is essential for both man and plant healthy growth, but its deficiency may result in severe chlorosis of leaves, while excessive exposure to Fe dust causes respiratory diseases in man [32]. The levels of Fe in borehole water reported in this study are higher when compared to that reported in borehole water (<0.01 mg/L) by Asia et al. [29].

Zn can inhibit Fe absorption and, to a lesser extent, visa-versa, but appears to be dose and ratio dependent [33]. In rats and humans, there is little effect if Fe / Zn ratio is around 2:1 and significant doses are required for their impact [34]. Thus, for this reason, iron supplementation has minimal impact on Zinc levels though an impact is possible [35,36]. However, Zn and Fe have an even more complicated relationship [37] and compete primarily for absorption in the gut [38].

Analysis of variance (ANOVA, p>0.05) showed that there is no significant difference between the Zinc contents of the domestic waters and that of the control sample (Table 2).

Moreover, analysis of variance (ANOVA, P<0.05) showed that there is significant difference between the Iron contents of the domestic waters and that of the control sample (Table 3).

These observations confirmed that Iron has polluted the drinking waters and this need to be addressed since these domestic waters are being utilized for human consumption while in the case of Zinc there is no cause for alarm.

Table 2. One-way ANOVA of Zn contents in various domestic waters

Source of variation	SS	Df	MS	F cal.	P-value	F crit.
Between groups	17.85031	1	17.85031	5.529415	0.056944	5.987378
Within groups	19.36948	6	3.228246			
Total	37.21979	7				

Table 3. One-way ANOVA of Fe contents in various domestic waters

Source of variation	SS	Df	MS	F cal.	P-value	F crit.
Between Groups	0.775013	1	0.775013	133.3355	2.54E-05	5.987378
Within Groups	0.034875	6	0.005813			
Total	0.809888	7				

5. CONCLUSION

The results reported here confirm that even though the domestic waters investigated from designated areas in Katsina metropolis contain substantial amount of the metals. They are fit for human consumption as all physico-chemical parameters investigated fall within the WHO safe limit. With the exception of rainwater samples, the levels of Zn in the water samples were below the safe limit as prescribed by WHO. Higher levels of Fe in all samples were recorded. However, the presence of Fe at high level in domestic waters is a cause for concern as this can affect the health status of the consumers upon prolonged consumption. Thus, it is recommended that there should be monitoring and evaluation of physico-chemical parameters and heavy metal levels in domestic waters at regular intervals and maintaining data base. Coagulating agents other than iron salts, such as aluminium salts and polyelectrolytes should be used for water treatment. Galvanized iron pipes, cast iron pipes and steel iron pipes should be replaced with plastic types for water distribution. Also, local inhabitants are advised to avoid drinking and utilizing rainwater to prepare herbal concoctions due to high concentrations of Zinc and Iron.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Calamari D, Naeve H. Review of pollution in the African aquatic environment. CIFA Technical paper. FAO, Rome. 1994;25:118.
2. Aina EOA, Adedipe NO. Water quality monitoring and environment status in Nigeria. FEPA Monograph 6, FEPA, Abuja. 1996;239.
3. Lloyd B, Helmer R. Surveillances of drinking water quality in rural areas. Longman scientific and Technical, Wiley, New York. 1992;34-56.
4. Karavoltsos S. Evaluation of the quality of drinking water in regions of Greece. In Antimicrobial resistance of pathogenic bacteria isolated from tube well water of costal area of Sitakunda, Chittagong, Bangladesh. Open Journal of Water pollution and Treatment. 2008;1(1):1-6.
5. APHA Standard method for examination of water and wastewater. American Public Health Association. Academic Press, Washington, DC 22nd Ed. 1989;90-94.
6. Reza R, Gurdeep S. Pre and Post Monsoon variation of heavy metals concentration of groundwater of Angul Talcher region of Orissa. India Natural and Science. 2009;7(6):52-56.
7. Ganeshamurthy AN, Varalakshmi LR, Sumangala HP. Environmental risk associated with heavy metals contamination in soils, water and plants in urban and periurban agriculture. Journal of Horticultural Sciences. 2008;3(1):1-29.
8. Markus J, McBratney AB. A review of the contamination of soil with lead II: Spatial distribution and risk assessment of soil lead. Environment International. 2001;27:399-411.
9. Nadel M, Schuhmacher M and Domingo JL. Metal pollution of soils and vegetation in area with petrochemical industry. Science Total Environment. 2004;321:59-69.
10. Ochieng EZ, Lalah JO, Wandigo SO. Analysis of heavy metals in water and surface sediment in five rift valley lakes in Kenya for assessment of recent increase in anthropogenic activities. Bulletin of Environmental Contamination Toxicology. 2007;79:570-576.
11. An YJ. Assessment of comparative toxicities of lead and copper using plant assay. Chemosphere. 2006;62:1359-1365.
12. Todorovic Z, Poli P, Djordjeri D, Antonijevi S. Lead distribution in water and its association with sediment constituents of the “Barje” lake (Leskovac, Yugoslavia). Journal of the Serbian Chemical Society. 2001;66(10):697-708.
13. Wikipedia. Available: http://www.en.wikipedia.org/wiki/Katsina_State. Accessed on 10 March, 2014.

14. APHA Standard methods for the examination of water and wastewater. American Public Health Association Academic press, Washington DC 6th Ed. 1985;1-14.

15. Waziri M, Audu AA, Shuaibu L. Assessment of the levels of some heavy metals content in the Glass sand deposit in Kazaure, Nigeria. British Journal of Applied Science and Technology. 2013;3(3):638-646.

16. WHO Guidelines for drinking water quality, Geneva; 2004.

17. Boyd CC, Linchkopper F. Water quality management in pond fish culture. International Centre for Agricultural Experimental Section, Auburn University, USA. 1997;20-25.

18. Stirring P. Chemical and biological methods of water analysis for aquaculturist 1st Ed. Institute of Agriculture Experimental Section, Auburn University, USA. 1985;20:11-17.

19. Chain ESK, Dewalle FB. Evaluation of leachetes treatment, biological and physical-chemical treatment processes, USEPA. 1977;2.

20. Mann AG, Tam CC, Higgins CD, Lodrigues LC. The association between drinking water turbidity and gastrointestinal illness: a systematic review. BMC Public Health. 2007;7(256):1-7.

21. Dinrifo RR, Babatunde SOE, Bankole YO, Demu QA. Physico-chemical properties of rainwater collected from some industrial areas of Lagos State Nigeria. European Journal of Scientific Research. 2010;41(3):383-390. Available: http://www.eurojournals.com/ejsr.htm

22. Adamu GK, Adekiya OA. An assessment of water quality of boreholes around selected landfills in Kano metropolis. African Scientist. 2010;11(2):129-133.

23. Clair NS, Perry LM, Gene FP. Chemistry for Environmental Engineering and Science 5th Ed. McGraw-Hill, New York, USA. 2003;21-30. ISBN 0-07-248066-1.

24. Matthews P. Group IIB Elements in Advanced Chemistry. Cambridge Low Priced Edition, Cambridge University Press. 1998:690-700.

25. Jidauna GG, Dabi DD, Saidu BJ, Ndabula C, Abaje IB. Chemical water quality assessment in selected location in Jos, Plateau State, Nigeria. Research Journal of Environmental and Earth Sciences. 2014;6(5):284-291.

26. Awofolu OR. A survey of trace metals in vegetation, soil and lower animal along some selected major roads in metropolitan city, Lagos. Environmental Monitoring Assessment. 2005;105:431-447.

27. Broadley MR, White PJ, Hammond JP, Zelko I, Lux A. Zinc in plants. New Phytologist. 2007;173(4): 677-702. DOI: 10.1111/j.1469-8137.2007.01996.x

28. Jeffery PK. Environmental Toxicology. Edward Arnold Ltd. London.1992;68-78.

29. Asia IO, Jegede SI, Jegede DA, Ize-Iyamu OK, Akpasubi EB. The effects of petroleum exploration and production operations on the heavy metals content of soil and ground water in the Niger Delta. International Journal of Physical Sciences. 2007;2(10):271-275.

30. WHO. Iron in drinking water. Guideline for drinking water quality, 2nd Ed. 1996;2:1-9.

31. Oladipo MOA, Njinga RL, Baba A, Mohammed I. Contaminant evaluation of major drinking water sources (boreholes water) in Lapai metropolis. Advances in Applied Science Research. 2011;2(6):123-130.

32. Moravic JE, Malik O, Marihlad K, Papayara A. Effects of fumes from welding industry. Journal of Environmental Pollution. 1986;27:77-83.

33. Manju BR, Richard FH, James DC. Meat consumption in a varied diet marginally influences nonheme iron absorption in normal individuals. Journal of Nutrition. 2006;136:576-581.

34. Peres JM, Bureau F, Neuville D, Arhan P, Bougle DJ. Inhibition of zinc absorption by iron depends on their ratio. Trace Elements and Medical Biology. 2001;15(4):237-241.

35. Linda JH, Jack RD, Wendey JH, Victoria JB, Jurien AH, Robert JF et al. Effect of high-dose iron supplement on fractional zinc absorption and status in pregnant women. American Journal of Clinical Nutrition. 2007;85(1):131-136.

36. Brittmaire S. Micronutrient interactions: effects on absorption and bioavailability. British Journal of Nutrition. 2001;85:181-185.

37. Charista FW, Kordas K, Stolthzfus RJ, Black RE. Interactive effects of iron and zinc on biochemical and functional

outcomes in supplementation trials. American Journal of Clinical Nutrition. 2005;82(1):5-12.
38. Freddy JT, Robert-Jan MB, Jack RD, Jurian AH, Vicky JB, Wim HMS. Iron supplements inhibit zinc but not copper absorption in vivo in Ileostomy subjects. American Journal of Clinical Nutrition. 2003;78(5):1018-1023.

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