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Elemental Analysis of Water Samples from Lafia Central, Lafia East andLafia North Areas inNasarawa State, Nigeria

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Abstract:
Aims and Objectives*: The study examined concentrations of sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), lead (Pb), nickel (Ni), arsenic (As) and chromium (Cr) elements in water samples from forty four different locations in Lafia central, Lafia east and Lafia north areas, Nigeria in order to compare them with World Health Organization (WHO) and Standard Oganization of Nigeria (SON) permissible limits so as to highlight the health implications of their various concentrations.*
Methodology: *The Elements of interest were determined using Atomic Absorption Spectrophotometer (AAS) and flame photometer. Analysis of study results were done using Analysis of Variance (ANOVA) and only differences considered significant at $P \leq 0.05$ for each element were stated.*
Results: *The study outcomes specify that the levels of Na (0.001 mg/l to 3.03 mg/l), Ca (5.34 mg/l to 35.02 mg/l) and Zn (0.001 mg/l to 0.35 mg/l) were within WHO and SON permissible limits. Furthermore, K (4.01 mg/l to 24.6 mg/l), Mg (0.25 mg/l to 3.99 mg/l, Mn (0.001 mg/l to 0.15 mg/l), Fe (0.001 mg/l to 0.58 mg/l), Pb (0.002 mg/l to 1.01 mg/l), Ni (0.001 mg/l to 1.324 mg/l) and As (0.0001 mg/l to 3.40 mg/l) were found to be above WHO and SON permissible limits in some of the samples studied, with potential health risks for those who depend on these water sources for drinking and cooking. In addition, Copper and chromium were not detected within the limit of these analyses. The study recommends performing regular testing of different water sources within the study area to ensure that commensurate attention is given in maintaining a healthy population.*
Keywords: *elemental analysis, WHO, SON, water sample, Lafia*

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I. Introduction

Despite comprising two atoms of hydrogen and an atom of oxygen, there are several other elemental components that may be found in any water molecule. Some of these elements occur naturally due to mineralization (Benham, 2011) while others are as a result of anthropogenic activities which may result to pollution and contamination of fresh water sources (Alfarrah&Walraevens, 2018). However, the issues are mostly in terms of the pernicious effects of some of these elements especially when their levels exceed relevant standards, as reported by a number of studies on Nigeria (Omokhodion, 1994; Nriagu, Oleru, Cudjoe, & Chine, 1997; Ololade, L., Olumekun, Ololade, &Ejelonu, 2011; Orisakwe, Blum, Sujak, &Zelikoff, 2014). On that note, groundwater quality evaluation of fifty samples in Delhi, India for various elements using the APHA method shows that while sodium levels were acceptable for most of the samples, magnesium levels were unsuitable in terms of irrigation for over half of the groundwater samples (Acharya, Sharma, &Khandegar, 2018). According to Adegboyega, Olalude and Odunola (2015), assessment of well water quality in Idi-ayunre, Oyo statSe shows that elements like lead and copper are above World Health Organization (WHO) standards for some of the studied samples with potential carcinogenic consequences for those who consume it, especially young children. Similarly, fifty samples of canned and non-canned water-based beverage products, many of which were manufactured in Nigeria were found to have lead levels that are significantly above the EPA standard of 0.015 mg/l maximum, pointing towards malevolent health implications like peripheral neuropathy, skin, bladder and lung cancer for consumers of these products (Maduabuchi, et al., 2006). In the same vein, analyses of water samples from several water sources within the Abakaliki metropolitan area, Ebonyi State Nigeria for lead concentrates indicates that Azuiyiokwu area of Abakiliki had the highest mean lead concentrations among the well water samples while Abakaliki urban and Kpirikpiri areas had the highest mean lead concentrations for samples of borehole water (Ignatius, et al., 2012). Seasonal examination of over 60 groundwater samples from Nanded city, India for chloride, sodium and potassium shows that most of the samples were within WHO acceptable limits in terms of being potable and also suitable for agricultural applications (Sayyed&Bhosle, 2011)

Elemental and geochemical analyses of Al-Saad Lake in Saudi Arabia by analyzing 46 samples from different areas of the lake using AAS shows that while iron and sodium levels did not exceed maximum contaminant levels, potassium and magnesium levels were above the permissible limits (Mallick, 2017). Potassium is acceptable when concentration is less than 100 mg/liter of water for drinking. Potassium is an essential element but is rarely a significant water constituent unless except where potassium permanganate is used for water treatment or potassium chloride as a softener (WHO, 2011). A study of drinking water samples from across Canada shows that potassium concentrates ranged up to 8 mg/l except for potassium chloride producing areas where concentration of more than 50 mg/L were identified (Health Canada, 2008). In Flanders area of Belgium, surface water samples were identified to have high concentrations of potassium (up to 190 mg/L in some areas) mainly as a result of contaminated runoff from agricultural point sources (Baert, Loontiens, &Devos, 1996). Calcium and magnesium in water is usually as a result of mineral decomposition; their levels (especially magnesium) in many surface and groundwater samples do not have much pernicious effects when considered as individual elements in water (Kožíšek, 2003). A study of water samples from different sources in Niš, Serbia shows that calcium concentrations ranged from 38 mg/L to over 146 mg/L while magnesium concentrations ranged from 2 mg/L to 16 mg/L, both variables being statistically significant (Stevanovic, Nikolic, &Ilic, 2017).Studies in the Unites States ascertained that the average adult human requires up to 1000 mg/day of calcium and 320 mg/day of magnesium which the body sources from food and water utilization (IOM, 1997). Manganese can be found in many fresh water systems through erosion of manganese containing minerals in the earth crust. Human activities also contribute to manganese concentrations through industrial effluent. In the US, manganese concentrations is lower in surface water than that of groundwater which has been detected at levels as low as 5600 µg/l though with a low median as low as 10 µg/l (WHO, 2011). Assessment of 101 samples gotten from several fresh water sources in Qom, Iran for manganese and iron indicates that while manganese concentrations ranged from 0.09 mg/l to 0.15 mg/L which were above EPA standards for manganese, iron concentrations were within permissible limits as reported by the study (Fahiminia, et al., 2015). Similarly, a review of manganese occurrence in analyzed groundwater samples from different parts of Bangladesh show that out of the six divisions, only one (Barisal division) had manganese mean concentration of less than 0.15 mg/l. Other divisions had mean concentrations as high as 0.73 mg/l which is above the Bangladeshi and WHO permissible limits (Hasan & Ali, 2010).

Elemental evaluation for lead, zinc, copper and cadmium in 365 water samples collected from rainwater in Adelaide area of Australia indicates that about 49%, 14%, 2% and 5% of the 365 samples respectively, were above Australian guidelines on these elements for potable water (Chubaka, Whiley, Edwards, & Ross, 2018). Analyses of water samples from wells in Çorlu, Turkey for copper and cadmium elements using atomic absorption spectroscopy (AAS) indicates that levels of cadmium and copper were 202 ppb and 19 ppb respectively which were below Turkish permissible limits for both elements in household water supply (Ongen, et al., 2008). However, copper and lead analyses in water samples from gold mining areas of Zamfara State, Nigeria shows that lead and copper concentrations in most of the 25 sampled water sources were significantly above WHO limits for these elements with negative health consequences for those that depend on these water sources (Okiei, Ogunlesi, Adio-Adepoju, &Oluboyo, 2016). A two-year examinations of 28 freshwater and groundwater samples in Kowsar dam basin, Iran for nickel element shows that all the samples had nickel levels which were within WHO and EPA permissible limits. The highest nickel level identified by the study was 0.006 mg/l (Boustani, Hojati, &Ebrahimzadeh, 2012). Furthermore, trace metal analysis of water samples from Viti Levu, Fiji for arsenic, cadmium, chromium, copper, mercury, lead and zinc indicates that most of the samples had these trace metals all below WHO permissible limits though arsenic concentration was significant in waters sampled within the vicinity of the a goldmine in the area (Singh & Mosley, 2003). Furthermore, a study on metal pollution in surface water in Kaduna metropolis, Nigeria by analyzing samples collected along river Kaduna showed that most of the samples had arsenic, chromium, copper and lead concentrations that are above the permissible limits which may have serious health implications for those who make use of the water from these sources (Aliyu, Yusuf, &Shehu, 2015). A review of findings on arsenic and chromium in potable water identified that both elements can be found in concentrations above permissible limits in many parts of the world, with potentials for cardiovascular diseases, lungs cancer and natal disorders (Smith &Steinmaus, 2009). On the bases of the fore going review, this study aimed at ascertaining the concentrations of twelve elements (Na, K, Ca, Mg, Fe, Mn, Zn, Cu, Pb, Ni, As and Cr) in water samples from different locations within Lafia metropolitan area of Nasarawa State Nigeria, which were compared with permissible standards so as to elucidate the health implications of consuming water sourced within the study area

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II. Material And Methods

Study Area: The research was conducted in Lafia metropolitan area in Nasarawa State, Nigeria. The study area comprises three sectors: Lafia central, Lafia east and Lafia north. The further segmentation of the area was to facilitate identification of water sampling locations in the study area.

Samples: In carrying out the study, water samples were derived from boreholes, wells and streams in various locations within Lafia metropolis. Tables 1, 2, 3 show the various locations within the study area that water samples were collected.

Table 1: Sampling locations in Lafia Central

Sample	Sample Location	Sample Source
Lai	Emir's Palace	Borehole
LAii	Emir's Palace	Well
LAiii	Science School Lafia	Boerhole
LAiv	Railway market Lafia	Well
LAv	Lafia modern market	Well
LAvi	Lafia modern market	Borehole
LAvii	Lafia Water Board	Borehole
LAviii	Mararaba	Well
LAix	Mararaba	Borehole
LAx	Federal University Lafia	Borehole
LAxi	Gandu	Borehole
LAxii	Gandu	Well
LAxiii	Gandu	Stream
LAxiv	Bukwankoto	Borehole
LAxv	Bukwankoto	Well
LAxvi	Bukwankoto	Well

Table 2: Sampling locations in Lafia East

Sample	Sample Location	Sample Source
LBi	Assakio	Borehole
LBii	Assakio	Borehole
LBiii	Assakio	Borehole
LBiv	Assakio	Well
LBv	Adogi	Borehole
LBvi	Adogi	Borehole
LBvii	Adogi	Borehole
LBviii	Adogi	Well
LBix	Ashige	Borehole
LBx	Ashige	Borehole
LBxi	Ashige	Borehole
LBxii	Ashige	Well

Table 3: Sampling locations in Lafia North

Sample	Sample Location	Sample Source
LCi	Shabu	Borehole
LCii	Shabu	Borehole
LCiii	Shabu	Borehole
LCiv	Shabu	Well
LCv	Ombi 1	Borehole
LCvi	Ombi 1	Borehole
LCvii	Ombi 1	Well
LCviii	Ombi 1	Stream
LCix	Ombi 2	Borehole
LCx	Ombi 2	Borehole
LCxi	Ombi 2	Borehole
LCxii	Ombi 2	Well
LCxiii	Azuba	Borehole
LCxiv	Azuba	Borehole
LCxv	Azuba	Borehole
LCxvi	Azuba	Well

Instruments and chemicals: Equipment used in the analysis includesAtomic Absorption spectrophotometer (PG Instrument, Model F-990), Flame Photometer (Jenway, Model P7). All reagents used in this study include Aldrich grade reagents.

Sample collection: Water samples for the analyses were collected from different locations and sources in the months of October through December considered to be dry season period; well, stream and borehole. Selection of locations was based on the population density, and areas of industrial and/or anthropogenic activities. Plastic containers were used to collect the water samples. The containers for sample collections were washed with detergent (except for phosphates, nitrates and sulphates determinations), rinsed with distilled water and also rinsed with the sample to be collected at the point of collection to ensure it was free of contaminants. To collect well water samples, a stone of suitable weight was dried in a desiccator. The stone was tied in an already washed, dried nylon water-proof material. The stone was attached to the sampling container by means of a thread in a manner in which it enhanced the sinking of the sampling container. A dried rope was attached to the handle of the container and used in lowering and drawing the container after it was filled with the sample. The length of the sampling rope was made to correspond to the length of the rope the local consumers use to draw their drinking water. To collect borehole water sample, the tap was disinfected with 50% ethanol solution. The tap was flushed repeatedly by running out portions of the sample to be collected. Afterwards, the sample for analysis was collected. Grab method was used for sampling streams. The sampling container was dipped partially into the stream with the opening in opposite direction to flow of stream. The samples were collected at three different points along the stream. The samples collected were properly sealed and kept in dark environment at a temperature range of 4-10 ◦C using ice block to avoid any contamination and effects of light and temperature variation.

Elemental Analysis: The Determination of elements in water sample was carried out as outlined by APHA (1999) procedures (Method 3111). Five hundred cubic centimeter of the water sample was measured into an evaporating dish. Fifteen cubic centimeter of concentrated nitric acid was added to the sample and mixed thoroughly. The mixture was heated in a steam bath and evaporated to 25 cm3. The mixture was transferred into a 50 cm3 volumetric flask and diluted to mark using deionized water. This solution was used for the analysis of calcium, magnesium, copper, iron, lead, manganese, zinc, arsenic, chromium, and nickel using Atomic Absorption Spectrophotometer, PG Instrument, model F-990; while sodium and potassium, was analyzed using Jenway P7 Flame photometer.

Statistical Analysis: In order to analyze data obtained from the study, the results were subjected to statistical scrutiny so as to verify and evaluate the differences in the quantities of elemental parameters studied. The data was expressed as mean ± standard error of mean. Means were compared using one way analysis of variance (ANOVA) on a statistical program SPSS version 21. Differences were considered significant at $P \leq 0.05$.

III. Results and Discussion

The results on elemental analyses of water samples are presented in the Tables 4, 5 and 6. The results were also presented with WHO and SON standards for the respective elements being studied

Table 4: Results on elemental analyses of water samples from Lafia Central, Nasarawa State Nigeria.

					Elements	(mg/L)						
Sample Location	Na	K	Ca	Mg	Fe	Mn	Zn	Cu	Pb	Ni	As	Cr
LAi	2.10 ± 0.000	5.500 ± 0.060	19.540 ± 0.001	2.500 ± 0.010	0.343 ± 0.004	0.000 ± 0.000	0.000 ± 0.000	0.00	1.050 ± 0.030	1.324 ± 0.001	0.000± 0.000	0.00
LAii	0.10 ± 0.001	5.000 ± 0.030	10.250 ± 0.010	3.460 ± 0.010	0.351 ± 0.003	0.000 ± 0.000	0.000 ± 0.000	0.00	0.920 ± 0.010	0.926 ± 0.001	0.000 ± 0.000	0.00
LAiii	2.000 ± 0.006	8.050 ± 0.010	12.560 ± 0.003	1.000 ± 0.001	0.031 ± 0.001	0.151 ±0.001	0.020 ± 0.001	0.00	1.153 ± 0.002	1.025 ± 0.001	0.000 ± 0.000	0.00
LAiv	0.203 ± 0.003	7.000 ± 0.004	11.30 ± 0.010	0.500 ± 0.001	0.041 ± 0.001	0.001 ± 0.000	0.000 ± 0.000	0.00	1.055 ± 0.003	0.952 ± 0.030	0.000 ± 0.000	0.00
LAv	0.002 ± 0.001	8.000 ± 0.010	9.540 ± 0.010	0.840 ± 0.001	0.432 ± 0.001	0.020 ± 0.002	0.000 ± 0.000	0.00	1.225 ± 0.010	1.151 ± 0.001	0.000 ± 0.000	0.00
LAvi	0.500 ± 0.003	8.500 ± 0.005	21.00 ± 0.060	1.550 ± 0.001	0.028 ± 0.002	0.000 ± 0.000	0.026 ± 0.001	0.00	0.625 ± 0.003	1.001 ± 0.001	0.000 ± 0.000	0.00
LAvii	0.000 ± 0.00	7.500 ± 0.022	35.62 ± 0.012	0.800 ± 0.001	0.025 ± 0.002	0.100 ± 0.003	0.016 ± 0.001	0.00	0.005 ± 0.001	0.026 ± 0.001	0.000 ± 0.000	0.00
LAviii	0.700 ± 0.003	16.50 ± 0.273	14.00 ±0.040	0.762 ± 0.002	0.051 ± 0.002	0.000 ± 0.000	0.000 ± 0.000	0.00	1.251 ± 0.003	0.512 ± 0.013	3.401 ± 0.001	0.00
LAix	1.300 ± 0.010	9.000 ± 0.018	8.000 ± 0.012	1.831 ± 0.013	0.435 ± 0.003	0.001 ±0.000	0.012 ± 0.001	0.00	1.332 ±0.005	1.026 ± 0.003	0.010 ± 0.000	0.00
Lax	0.300 ± 0.002	8.000 ± 0.062	10.55 ± 0.021	1.000 ± 0.016	0.130 ± 0.001	0.052 ± 0.001	0.000 ± 0.000	0.00	1.201 ± 0.010	0.021 ± 0.003	0.015 ± 0.001	0.00
LAxi	0.800 ± 0.010	18.00 ± 0.060	10.01 ± 0.010	2.100 ± 0.051	2.13 ± 0.030	0.028 ± 0.001	0.078 ± 0.005	0.00	1.293 ± 0.005	1.158 ± 0.040	0.011 ± 0.001	0.00
LAxii	0.050 ± 0.002	24.50 ± 0.026	9.140 ± 0.002	0.652 ± 0.004	0.332 ± 0.001	0.015 ± 0.003	0.000 ± 0.000	0.00	1.358 ± 0.005	0.921 ± 0.005	0.003 ± 0.001	0.00
LAxiii	2.510 ± 0.035	12.50 ± 0.051	30.38 ± 0.361	3.479 ± 0.025	0.045 ± 0.003	0.000 ± 0.000	0.000 ± 0.000	0.00	0.152 ± 0.034	0.132 ± 0.004	0.000 ± 0.000	0.00
LAxiv	0.600 ± 0.010	17.00 ± 0.060	10.42 ± 0.015	1.521 ± 0.005	0.335 ± 0.002	0.035 ± 0.002	0.000 ± 0.000	0.00	1.385 ± 0.010	1.253 ± 0.002	1.052 ± 0.001	0.00
LAxv	0.200 ± 0.003	24.00 ± 0.176	11.97 ± 0.100	0.710 ± 0.010	0.432 ± 0.003	0.012 ± 0.001	0.000 ± 0.000	0.00	1.010 ± 0.002	0.087 ± 0.001	0.036 ± 0.001	0.00
LAxvi	0.250 ± 0.002	24.60 ± 0.423	15.18 ± 0.080	0.942 ± 0.004	0.434 ± 0.002	0.005 ± 0.001	0.000 ± 0.000	0.00	1.574 ± 0.001	0.202 ± 0.001	0.273 ± 0.001	0.00
WHO	200.0	12.00	200.00	150.0	0.300	0.100	5.000	1.00	0.010	0.070	0.010	0.05
SON	200.0	12.00	200.00	0.200	0.300	0.100	3.000	1.00	0.010	0.020	0.010	0.05

Key: WHO = World Health Organization standard; SON = Standard Organization of Nigeria standard.

Table 5: Results on elemental analyses of water samples from Lafia North, Nasarawa State

Sample Location	Na	K	Ca	Mg	Elements Fe	(mg/L) Mn	Zn	Cu	Pb	Ni	As	Cr
LCi	0.00 ± 0.000	5.500 ± 0.029	9.032 ± 0.004	1.050 ± 0.001	0.012 ± 0.001	0.000 ± 0.00	0.000 ± 0.000	0.000	0.935 ± 0.004	0.162 ± 0.001	0.000 ± 0.000	0.000
LCii	0.00 ± 0.000	4.00 ± 0.010	15.20 ± 0.057	0.851 ± 0.005	0.020 ± 0.001	0.000 ± 0.00	0.002 ± 0.000	0.000	1.318 ± 0.005	0.029 ± 0.002	2.151 ± 0.002	0.000
LCiii	0.50 ± 0.008	7.00 ± 0.011	12.05 ± 0.018	3.011 ± 0.01	0.062 ± 0.001	0.000 ± 0.00	0.350 ± 0.002	0.000	0.154 ± 0.002	0.211 ± 0.005	0.934 ± 0.002	0.000
LCiv	0.30 ± 0.001	9.00 ± 0.027	18.00 ± 0.055	0.250 ± 0.002	0.305 ± 0.003	0.002 ± 0.00	0.221 ± 0.001	0.000	0.115 ± 0.003	0.051 ± 0.003	0.401 ± 0.025	0.000
LCv	0.00 ± 0.000	7.05 ± 0.002	25.12 ± 0.061	2.002 ± 0.001	0.003 ± 0.00	0.000 ± 0.00	0.002 ± 0.000	0.000	0.105 ± 0.010	0.118 ± 0.001	0.001 ± 0.000	0.000
LCvi	0.00 ± 0.000	6.076 ± 0.01	8.350 ± 0.002	3.135 ± 0.002	0.015 ± 0.003	0.003 ± 0.00	0.015 ± 0.001	0.000	1.437 ± 0.002	0.083 ± 0.002	0.000 ± 0.000	0.000
LCvii	0.00 ± 0.000	5.00 ± 0.190	19.35 ± 0.025	1.510 ± 0.010	0.019 ± 0.000	0.015 ± 0.00	0.026 ± 0.001	0.000	1.028 ± 0.002	0.361 ± 0.010	0.000 ± 0.000	0.000
LCviii	0.00 ± 0.000	7.942 ± 0.036	28.00 ± 0.156	0.951 ± 0.010	0.250 ± 0.002	0.000 ± 0.00	0.031 ± 0.002	0.000	1.201 ± 0.005	0.035 ± 0.003	0.000 ± 0.000	0.000
LCix	2.500 ± 0.006	4.00 ± 0.0610	21.00 ± 0.259	1.052 ± 0.010	0.020 ± 0.001	0.000 ± 0.00	0.000 ± 0.000	0.000	0.003 ± 0.000	0.005 ± 0.000	0.051 ± 0.001	0.000
LCx	0.50 ± 0.029	5.024 ± 0.010	11.52 ± 0.047	1.362 ± 0.001	0.024 ± 0.002	0.012 ± 0.00	0.000 ± 0.000	0.000	0.305 ± 0.003	0.013 ± 0.000	0.234 ± 0.002	0.000
LCxi	0.00 ± 0.000	8.001 ± 0.001	8.352 ± 0.003	0.991 ± 0.011	0.006 ± 0.000	0.000 ± 0.00	0.005 ± 0.000	0.000	1.024 ± 0.005	0.130 ± 0.001	1.001 ± 0.001	0.000
LCxii	0.60 ± 0.010	9.103 ± 0.058	13.36 ± 0.026	0.315 ± 0.003	0.021 ± 0.002	0.000 ± 0.00	0.002 ± 0.000	0.000	0.100 ± 0.010	0.019 ± 0.001	2.013 ± 0.010	0.000
LCxiii	0.00 ± 0.000	10.01 ± 0.021	14.75 ± 0.067	2.331 ± 0.005	0.025 ± 0.002	0.000 ± 0.00	0.030 ± 0.001	0.000	1.110 ± 0.050	0.000 ± 0.000	0.000 ± 0.000	0.000
LCxiv	0.05 ± 0.000	9.003 ± 0.001	7.920 ± 0.014	1.023 ± 0.005	0.035 ± 0.002	0.000 ± 0.00	0.000 ± 0.000	0.000	0.902 ± 0.001	0.001 ± 0.000	0.000 ± 0.000	0.000
LCxv	1.00 ± 0.028	6.313 ± 0.010	15.33 ± 0.046	1.200 ± 0.030	0.041 ± 0.001	0.000 ± 0.00	0.015 ± 0.003	0.000	0.513 ± 0.005	0.103 ± 0.001	0.000 ± 0.000	0.000
LCxvi	0.40 ± 0.005	20.05 ± 0.100	35.02 ± 0.064	0.521 ± 0.004	0.024 ± 0.001	0.000 ± 0.00	0.052 ± 0.001	0.000	0.002 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000
WHO	200.0	12.00	200.00	150.0	0.300	0.400	5.000	1.000	0.010	0.070	0.010	0.050
SON	200.0	12.00	200.00	0.200	0.300	0.200	3.000	1.000	0.010	0.020	0.010	0.050

Key: WHO = World Health Organization standard; SON = Standard Organization of Nigeria standard.

Table 6: Results on elemental analyses of water samples from Lafia East, Nasarawa State

Sample Location	Na	K	Ca	Mg	Elements Fe	(mg/L) Mn	Zn	Cu	Pb	Ni	As	Cr
LBi	3.050 ± 0.029	5.032 ± 0.015	8.352 ± 0.003	1.037 ± 0.004	0.048 ± 0.002	0.001 ± 0.000	0.00 ± 0.000	0.000	0.350 ± 0.003	0.035 ± 0.002	0.000 ± 0.000	0.00
LBii	2.135 ± 0.006	4.001 ± 0.001	15.37 ± 0.046	3.001 ± 0.001	0.393 ±0.002	0.000 ± 0.000	0.003 ± 0.000	0.000	1.001 ± 0.000	0.041 ± 0.001	0.002 ± 0.000	0.00
LBiii	0.950 ± 0.032	7.213 ± 0.004	10.03 ± 0.041	2.017 ± 0.002	0.019 ± 0.001	0.000 ± 0.000	0.016 ± 0.001	0.000	1.205 ± 0.001	0.074 ± 0.001	0.316 ± 0.002	0.00
LBiv	1.601 ± 0.002	6.005 ± 0.003	12.10 ± 0.061	0.965 ± 0.003	0.582 ± 0.001	0.000 ± 0.000	0.158 ± 0.001	0.000	1.083 ± 0.002	0.121 ± 0.001	1.024 ± 0.002	0.00
LBv	0.000 ± 0.00	5.001 ± 0.001	9.002 ± 0.005	3.998 ± 0.003	0.031 ± 0.001	0.043 ± 0.002	0.000 ± 0.00	0.000	0.938 ± 0.002	0.048 ± 0.001	0.000 ± 0.00	0.00
LBvi	1.042 ± 0.002	9.357 ± 0.004	13.25 ± 0.006	1.931 ± 0.002	0.235 ± 0.003	0.002 ± 0.000	0.021 ± 0.001	0.000	0.412 ± 0.001	0.021 ± 0.001	0.401 ± 0.001	0.00
LBvii	0.863 ± 0.001	14.903 ± 0.20	7.092 ± 0.002	0.984 ± 0.082	0.003 ± 0.000	0.000 ± 0.000	0.008 ± 0.000	0.000	1.030 ± 0.003	0.009 ± 0.000	1.235 ± 0.002	0.00
LBviii	0.005 ± 0.00	8.010 ± 0.005	35.06 ± 0.031	1.402 ± 0.001	0.073 ± 0.001	0.000 ± 0.000	0.000 ± 0.000	0.000	1.015 ± 0.001	0.130 ± 0.001	2.021 ± 0.012	0.00
LBix	2.057 ± 0.002	11.04 ± 0.045	20.85 ± 0.115	0.983 ± 0.002	0.021 ± 0.001	0.000 ± 0.000	0.002 ± 0.000	0.000	0.519 ± 0.003	0.082 ± 0.002	1.317 ± 0.002	0.00
LBx	0.968 ± 0.023	7.325 ± 0.003	10.64 ± 0.029	1.007 ± 0.002	0.003 ± 0.000	0.003 ± 0.000	6.417 ± 0.200	0.000	0.316 ± 0.001	0.110 ± 0.001	0.035 ± 0.003	0.00
LBxi	1.005 ± 0.000	5.001 ± 0.040	5.336 ± 0.005	1.450 ± 0.004	0.001 ± 0.000	0.002 ± 0.000	0.001 ± 0.000	0.000	1.021 ± 0.001	0.015 ± 0.003	0.000 ± 0.000	0.00
LBxii	1.200 ± 0.001	7.901 ±0.001	22.36 ± 0.347	1.362 ± 0.001	0.350 ± 0.003	0.000 ± 0.000	4.820 ± 0.193	0.000	0.281 ± 0.001	0.008 ± 0.000	0.501 ± 0.001	0.00
WHO	200.0	12.00	200.0	150.0	0.300	0.400	5.000	1.000	0.010	0.070	0.010	0.050
SON	200.0	12.00	12.00	0.200	0.300	0.200	3.000	1.000	0.010	0.020	0.010	0.050

Key: WHO = World Health Organization standard; SON = Standard Organization of Nigeria standard.

Sodium in the samples varied between 0.00 concentrations in Shabu borehole water (LCi) and 3.03 ± 0.029 mg/L in Assakio borehole water (LBi). Permissible limit for sodium in the drinking water is 200 mg/L (WHO, 2011; SON, 2016). On the account of sodium, all water samples are suitable for human use which is in line with what Acharya et al (2018) reported about sodium in water sampled from Delhi, India. Potassium in water samples ranged from 4.0 ± 0.01 mg/L in Shabu borehole water (LCii) to 24.6 ± 0.423 mg/L in Bukankoto well water (LAxvi). The acceptable limit for potassium in drinking water is 12 mg/L (WHO, 2011; SON, 2016). Some of the samples analyzed were above permissible levels of potassium concentrations which may have come from industrial and agricultural activities contaminated runoff from agricultural point sources (Baertet al., 1996). Similarly, Mallick (2017) reported higher potassium levels in Al-Saad Lake in Saudi Arabia. Calcium in the samples recorded minimum value of 5.336 ± 0.005 mg/L in Ashige borehole water (LBxi) and maximum value of 35.02 ± 0.064 mg/L in Azuba well water (LCxvi). WHO (2011) and SON (2016) made a recommendation of 200 mg/L for calcium in drinking water. All the samples recorded values within the recommended limits. Similar results were obtained for calcium analyses of water samples in Turkey (Kožíšek, 2003) and Serbia (Stevanovic et al., 2017). Magnesium determined for samples varied between 0.250 ± 0.002 mg/L in Shabu well water (LCiv) and 3.998 ± 0.003 mg/L in Adogi borehole water (LBv). Some of the water sources have magnesium levels exceeding the set standards and therefore are not fit for human consumption. Manganese recorded in samples ranged from zero mg/L in most samples to 0.150 ± 0.001 mg/L in Science School Lafia borehole water (LAiii). Similar levels of manganese in some drinking water sources were reported by Fahiminia et al. (2015), which were above the WHO and SON permissible limits for manganese in drinking water, which is 0.1 mg/L. Manganese at higher concentrations is reported to cause neurological disorder in humans (Hasan & Ali, 2010). Iron in the studied samples recorded minimum value of 0.001 ± 0.000 mg/L in Ashige borehole water (LBxi) and maximum value of 0.582 ± 0.001 mg/L in Assakio well water (LBiv). This value is above the tolerance limit for iron in drinking water as recommended by WHO and SON to be 0.3 mg/L. This could be an indication of iron deposits from rust materials and (or) weathering of rock over time in the study area. Zero copper concentration was recorded for all samples. This is an indication that the water sources were not contaminated with copper or copper containing materials or possibly that Cu is below the detectable limit of the instrument used in this study. Zinc in the samples varied between 0.00 mg/L in most samples to 0.35 ± 0.002 mg/L in Shabu borehole water (LCiii). All samples recorded zinc levels within permissible limits similar to water analyses results from Adelaide area of Australia where only less than 15% of all samples studied had values above WHO recommended values (Chubaka et al., 2018). Therefore, zinc concentrations in all the samples are tolerable which may require supplementation by consumers of the water systems studied. Lead in the investigated water ranged from 0.002 ± 0.000 mg/L in Azuba well water (LCxvi) to 1.010 ± 0.002 mg/L in Bukankoto well water (LAxv). The permissible limit for lead in potable water is 0.01 mg/L (WHO, 2011; SON, 2016). Therefore elemental analysis of lead shows that most of the investigated samples are not fit for human consumption. Studies on canned water-based beverages in some parts of Nigeria (Maduabuchi et al., 2006) like Idi-ayunre Oyo State (Adegboyega et al. 2015), Zamfara State (Okiei et al., 2016) and Abakaliki Ebonyi State (Ignatius et al. 2012), had lead concentrations exceeding permissible limits with capability of causing cancer, metabolic disorders, mental health ailments, cardiac arrest and soil infusion of lead by contaminated water sources. Nickel in the samples varied between 0.00 mg/L in Azuba well water (LCxvi) and 1.324 ± 0.001 mg/L in Emir's Palace borehole water (LAi). WHO and SON standards recommend 0.07 mg/L and 0.02 mg/L respectively as limits for nickel in drinking water. This result can be compared to the findings of Boustani et al (2012) which reported permissible levels of nickel in Iran. High nickel levels in some water samples may be attributable to mineable geologic deposits as reported by Singh and Mosley (2003). Arsenic in the studied samples varied between 0.00 mg/L in most samples to 3.40 ± 0.025 mg/L in Mararaba well water (LAviii). Similar arsenic concentrations were recorded by Aliyu et al. (2015) for some surface water sources in Kaduna, Nigeria. The tolerance limit for arsenic in potable water is 0.01 mg/L (WHO, 2011; SON, 2016). Elevated arsenic levels in drinking water can lead to health challenges like cardiovascular diseases and natal disorders (Smith &Steinmaus, 2009) as well as peripheral neuropathy, skin, bladder and lung cancer which can afflict those who consume arsenic-contaminated water (Maduabuchi et al., 2006). Zero levels of hexavalent chromium were recorded for all the investigated samples. Therefore, chromium concentration was not a significant factor in sampled waters from Lafia metropolis, Nigeria.

IV. Conclusion

The study analyzed the concentration levels of twelve elements in forty six water samples collected from different locations and water sources within the areas of Lafia central, east and north, Nasarawa State and has elucidated the concentration levels of these elements in terms of their permissible limits as well as their consequences. Sodium and calcium levels (0.001 mg/L to 3.03 mg/L and 5.34 mg/L to 35.02 mg/L respectively) were within permissible range which shows that sodium and calcium content in the samples are generally lower than recommended. Potassium levels (4.01 mg/L to 24.6 mg/L) were above permissible limits for some of the samples examined. Magnesium and manganese levels (0.25 mg/L to 3.99 mg/L and 0.001 mg/L to 0.15 mg/L respectively) were higher than recommended in some of the samples analyzed though manganese level posed more threat given its health implications. In terms of iron levels in the samples (0.001 mg/L to 0.58 mg/L), some samples had concentrations higher than permissible limits. Copper and chromium elements were not found in any of the analyzed samples in the study. This could be that the concentrations of these elements are below the detection limit of the instruments used in these analyses or that they are absent completely. Zinc concentrations in forty four samples studied (0.001 mg/L to 0.35 mg/L) were below permissible limits which may require sourcing zinc elsewhere for the water consumers in the study area. The levels of lead in a number of the water samples were above permissible limits (0.002 mg/L to 1.01 mg/L). The presence of lead in the water samples indicates that urgent measures need to be taken to undiagnosed chronic health ailments in the study area. Nickel concentrations (ranged from 0.001 mg/L to 1.324 mg/L) in some of the water samples studied were significantly above the recommended levels which may be due to geologic weathering. Arsenic levels (0.0001 mg/L to 3.40mg/L) were also significantly higher than permissible limits indicating health risks for consumers of water within the study area. On that note, it is imperative that regular testing of water samples within Lafia metropolitan area become the norm. This will go a long way because dangerous elements like arsenic are odorless and tasteless hence can be effectively detected only by laboratory analysis. Furthermore, sustainable waste management techniques should be imbibed in the populace through sensitization programs to reduce indiscriminate industrial and municipal waste disposal which can be important sources of some of the elements analyzed in this study.

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