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Determination of Levels of Eight Trace Metals in Ground Water Sources within and around Lafia Metropolis

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ABSTRACT

The levels of eight trace metals (As, Co, Cr, Cd, Pb, Al, Ni and Mn) were determined in ground water sources in Lafia town and its environs using Atomic Absorption Spectrophotometry (AAS). In the wet season(WS), the highest mean concentrations(mg/L) of trace metals from boreholes (BH) was Mn(0.7787 ±0.2389) in Lafia West while the least was Pb(0.0049 ±0.0001) in Lafia South. Similarly for hand –dug wells (HDW) in wet season, the highest was Mn(0.6227 ± 0.0260) in Lafia West while the least was As(0.0106 ± 0.0001) in Lafia East. In dry season(DS), the highest mean concentration of trace metals from BH was Mn(0.3815 ± 0.0907) in Lafia West while the least was Cr(0.0042 ± 0.0001) in Lafia South. Similarly for HDW in dry season, the highest was Mn(0.3588 ± 0.0762) in Lafia West while the least was Ni(0.0065±0.0001) in Lafia Central. The results indicate that these ground water sources were polluted more prominently in wet season.

1.0 INTRODUCTION

In recent years the presence of trace metals in water sources has received considerable and special attention and for which permissible or recommended limits have been set for water for both domestic and industrial applications [1-4]. Trace metal analysis is the determination of metal constituents of a sample where these constituents make up only a small part of sample, generally below or about one hundred parts per million (ppm). The important role of very small amounts of elements in physical, chemical and biological systems has emerged with advances in methods of analyses with increasing sensitivity [5].

The presence of trace metals in ground water and other water sources in general is of serious concern because of the toxic nature of some trace metals particularly at higher concentration [6-11]. On the other hand, some of the metals are commonly required plant micro-constituents which play vital roles in physical, chemical and biological systems. These include Cu, Zn, Mn, and Mo. Animals also require Mn and Co amongst others. Lack of a necessary plant micronutrient in the soil causes plant deficiency disease. Lack of animal micronutrient in the soil may not harm the plants but without them, animals feeding solely on these plants may develop deficiency diseases. For example, Iron is needed for transporting oxygen with its deficiency causing anaemia. Iodine is a constituent of thyroid hormones and its deficiency in diet is responsible for goiter while Fluorine deficiency in diet leads to incidence of dental caries.

In many Nigerian urban centres the per capita consumption of water which is about 80L/d appears quite low compared to 115L/d which is considered more appropriate for urban dwellers in a country like Nigeria [12]. In view of the shortfall in the supply of public treated water in urban centres of the nation, most inhabitants have to look for alternative sources of water especially ground water in form of boreholes and hand- dug wells which are untreated.

The population of Lafia being the state capital of Nasarawa State, Nigeria has increased tremendously since its creation in 1996, with accompanying increase in human activities. One of the economic activities in the state is mining exploration because of the huge mineral potential from which the state is fondly tagged “Home of solid Minerals”. These minerals occur in the soil and no doubt affect the soil and water in which life critical depends. Prominent among the minerals in this area are coal, bartyes, salts, limestones, cassiterite, columbite, clays, glass sand, lead-zinc and hydrocarbon potential [13].
Ground water is water that is found underground in the cracks and spaces in soil, sand and rocks. It is stored in and moves slowly through layers of soil, sand and rocks called aquifers [14].

Water in aquifers is brought to the surface naturally through a spring or can be discharged into rivers, streams and lakes. In other words, these sources of water are sustained by ground waters. Ground water can also be extracted through either a borehole or hand-dug well drilled into the aquifer and this is often withdrawn for agricultural, municipal/ domestic and industrial use.

2.0 MATERIALS AND METHODS

2.1 Materials

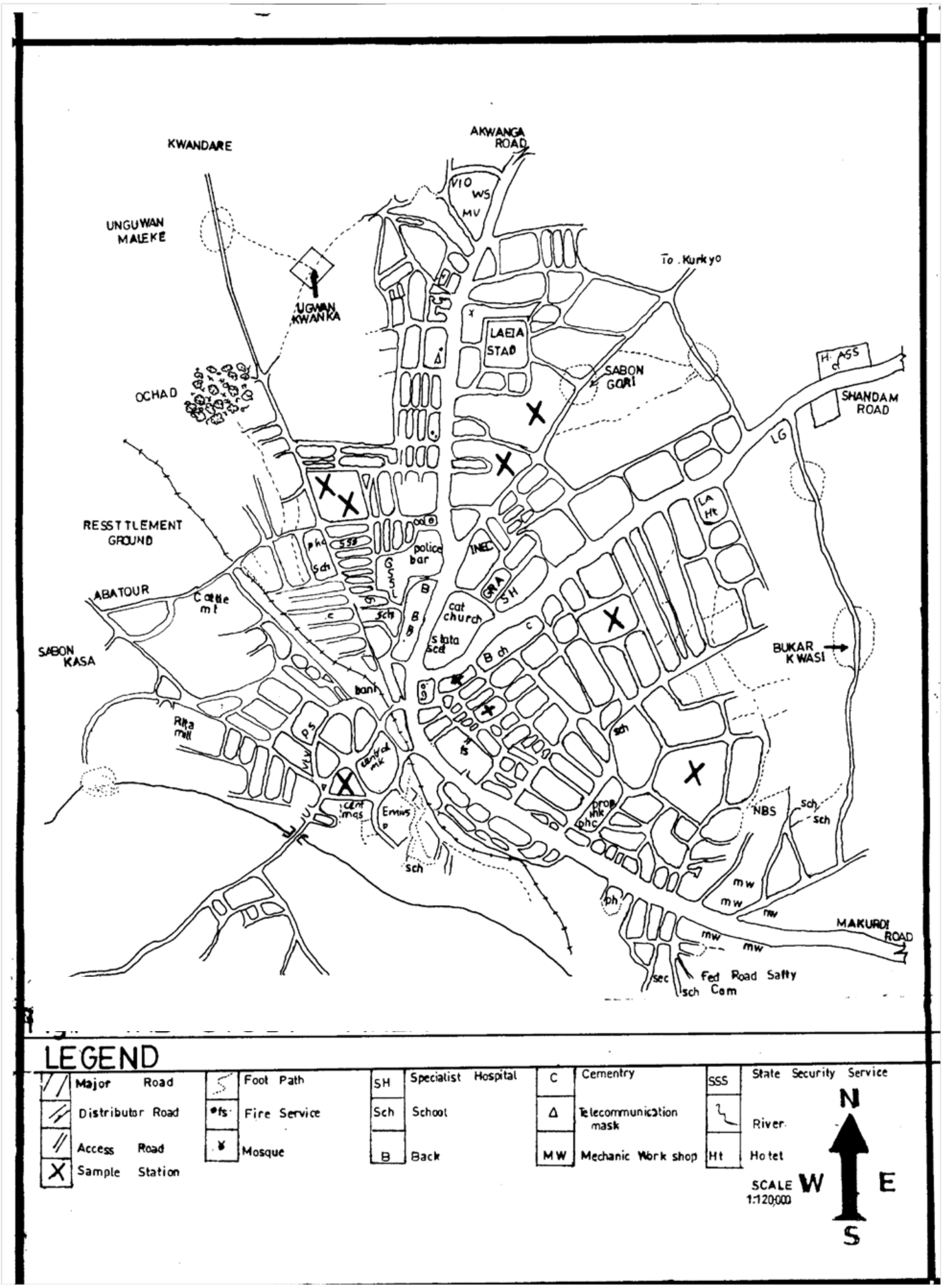
(i) Distilled water
(ii) Methyl Isobutyl Ketone (M.I.B.K.)
(iii) Ammonium Pyrolidine Dithiocarbamate (APDC) from which 5% was prepared.
(iv) Concentrated nitric acid of M & B Analytical Reagent
(v) Trace metals standards
(vi) Atomic Absorption Spectrophotometer(AAS)- SOLAAR 32 AA
(vii) pH Meter- pHep, pH Tester CE of Hanner Instruments Woonsocket: R102895
(viii) Buffer solution (pH 7.0).

2.2 Geology of the study area

The study area is Lafia metropolis (Figure 1) with about fifty neighbourhoods [15]. Lafia is the capital of Nasarawa State which is located in the middle belt region of Nigeria. The state lies between longitudes 7^o and 9^o 37’ E of the Greenwich Meridian and has an altitude of 181.5m above sea level [16].
Lafia is located within the geological Afo Younger Granites complex within the Middle Benue Trough. Afo younger granite complex is the youngest granite complex in Nigeria. The Younger Granites are distinctive series of alkali feldspar granites hosting minerals like cassitterite, columbites as major minerals. Lafia, which is the last segment of the Middle Benue Trough is underlined by basement complex rocks and has appreciable layer of sedimentation notable for water retention [17].

2.3 Sample collection and preservation

The samples for this investigation were collected randomly from various hand-dug wells and boreholes using plastic containers from 10 locations or neighbourhoods to generate 40 samples (10 from hand dug wells, appropriately 12-14m deep and 10 from boreholes, appropriately 45m deep) in each season. The sampling was carried out in the month of September,2011 for wet season and March 2012 for dry season. Samples for the trace metals analyses were preserved by the addition of concentrated nitric acid (HNO_3) to adjust the pH of the sample to below 2 to retard adsorption. The samples were kept in ice packs and transported to the laboratory where they were further preserved in a refrigerator before analysis [18,19].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2.5 Extraction, preconcentration and analysis of trace metals

The most valuable and commonly used procedure for extractive concentration of trace metals is that employing chelation with ammonium pyrrolidine dithiocarbamate (A.P.D.C.) by extraction into Methyl Isobutyl Ketone (M.I.B.K.). The extraction of charged species from an aqueous solution is not possible unless the charge can be neutralized by chelation. Since metals ions do not tend to dissolve appreciably in organic solvents, their charge must first of all be neutralized to make it "organic like". MIBK is widely used as a solvent in this technique because it has quite low solubility in water making it useful for liquid-liquid extraction.

Thus to 100 mL of each sample measured into 250 mL separating funnel, 4mL of 5% APDC was added, followed by 25 mL Methyl Isobutyl Ketone (M.I.B.K). The separating funnel is stoppered and shaken manually for 5 minutes after which the organic phase separated to the bottom leaving the aqueous phase on top. The process was repeated so as to get enough extract. The organic trace metals extract of each sample was analysed using Atomic Absorption Spectrometry (AAS) against standards at the wavelengths of As (248.3 nm), Co (240.7 nm), Cd (309.3 nm), Cr (248.3 nm), Pb (217.0 nm), Al (248.3 nm), Ni (324.7 nm), Mn (422.7 nm). These standards were prepared in different concentrations; 1ppm, 3 ppm,5 ppm or 10 ppm from 1000 ppm standards. Calibration curves were plotted from which the concentrations of the elements in each sample were extrapolated. Quality control was assured because all the determinations were in triplicate in addition to the use of standard reference materials, procedural blanks, relative standard deviations[21, 22, 23].

2.6 Statistical analysis of data

The results obtained were analyzed statistically by using the mean value (X), coefficient of variation $(\overline{CV})$ and standard deviation (S)[24]. Furthermore, correlation tests were used to determine the significant relationship between the mean concentrations of trace metals obtained from BH and HDW using statistical package for social sciences SPSS version 16.

3.0 RESULTS AND DISCUSSION

3.1 Results

Table 1 shows sample stations and their various locations with ten neighbourhoods.
The mean concentrations for the determination of some trace metals in ground water sources from Lafia and environs including coefficient of variations are presented in Tables 2 and 3 Borehole (BH) and Hand-dug well (HDW) water samples respectively for wet season and Tables 4 and 5; BH and HDW water samples respectively for dry season. Their corresponding variations of mean concentrations of trace metals for various locations are presented as Figures; 2A-2F,3A-3F, 4A-4F and 5A-5F. Tables 6 and 7 presents results of pH determination for BH and HDW for wet and dry seasons.

Table 1: Sample stations and their locations

Location	Neighbourhood
Lafia North	Bukan Sidi I
	Ombi II
Lafia Central	Millionaires quarters
	National Supply
Lafia West	Tudun Gwandara (Alhamis)
	Shinge
Lafia Soth	Doma Road
	Emir's Palace (Kofan Fada)
Lafia East	Makurdi Road/Sabon Pegi
	Shemdam Road

Table 2: Mean concentrations of some trace metals from Borehole (BH) water samples for wet season.

Concentration (mg/L)

	As		Co		Cr		Pb		Ni		Mn	
Location	Mean	CV %	Mean	CV %	Mean	CV%	Mean	CV %	Mean	CV %	Mean	CV %
Lafia North	0.0292+0.0001	34.24	0.1877+0.0001	0.0533	0.0283+0.0001	0.3534	0.0111+0.0001	0.9009	0.2190+0.0457	0.0457	0.2894+0.1414	48.86
Lafia Central	0.0430+0.0001	23.26	0.1644+0.0768	46.72	ND	NA	0.0092+0.0001	1.087	0.3729+0.0001	0.0268	0.4072+0.0935	22.96
Lafia West	0.0905+0.0020	2.21	0.1190+0.0001	0.0840	0.5049+0.5871	116.2	ND	NA	ND	NA	0.7787+0.2389	30.68
Lafia South	0.0292+0.0001	34.25	0.1311+0.0001	0.0763	0.0272+0.0001	0.3676	0.0049+0.0001	2.041	0.2129+0.0001	0.0470	0.2141+0.1414	66.04
Lafia East	0.2710+0.0001	0.0369	0.2406+0.2114	87.86	0.4790+0.0001	0.0209	0.0082+0.0027	32.93	0.3292+0.0001	0.0304	0.1709+0.0945	55.30

KEY: BH = Borehole

ND = Not Detected

NA = Not Applicable

CV = Coefficient of variation

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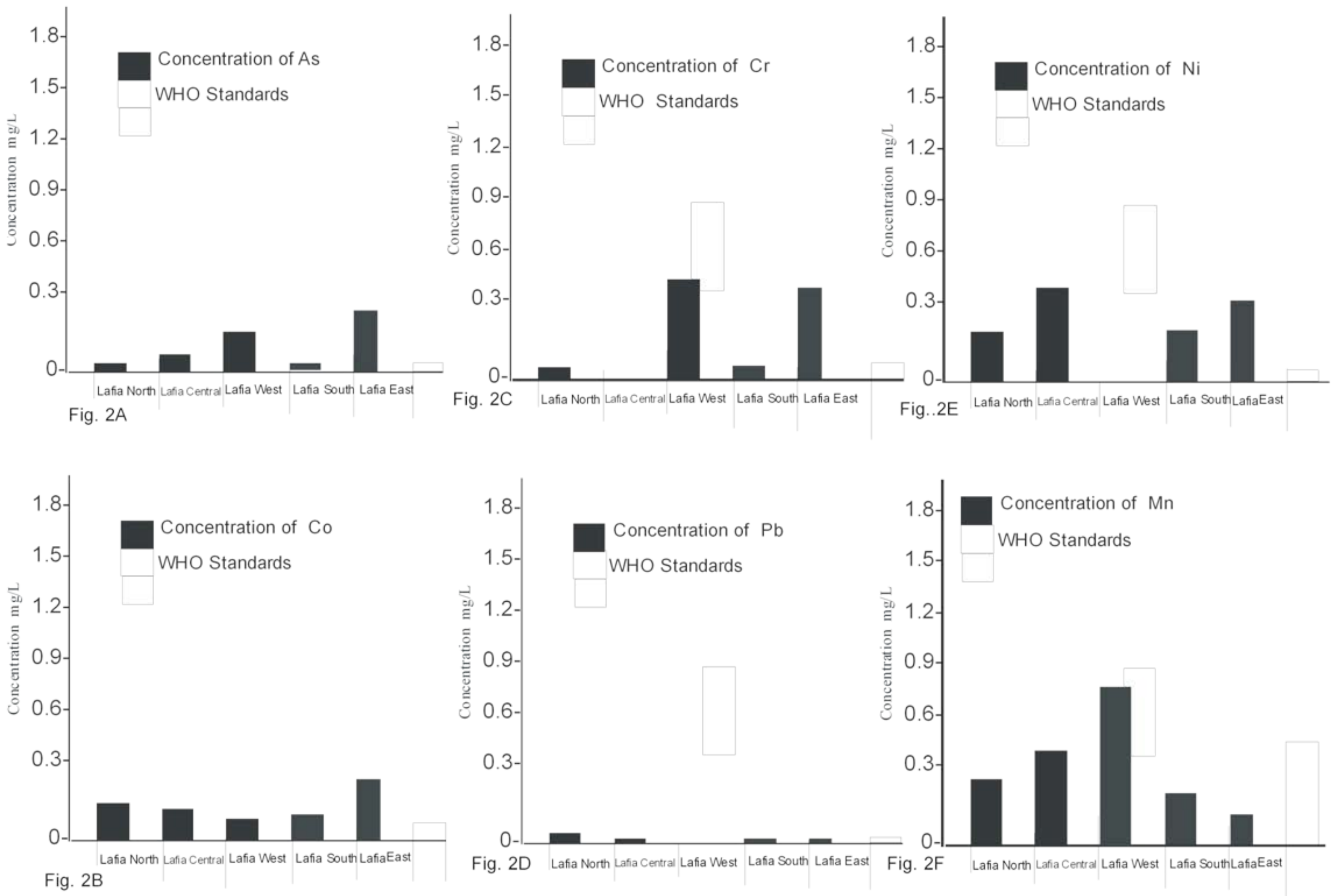

Fig. 2A-2F: Variation of mean concentration of trace metals in Borehole water samples for wet season

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Table 3: Mean concentrations of some trace metals from hand-dug well (HDW) water samples for wet season.

Concentration (mg/L)

	As		Co		Cr		Pb		Ni		Mn	
Location	Mean	CV %	Mean	CV %	Mean	CV%	Mean	CV %	Mean	CV %	Mean	CV %
Lafia North	ND	NA	0.0910±0.0001	0.1099	ND	NA	0.0202±0.0001	0.4950	0.0841±0.0001	0.1189	0.3151±0.0288	9.140
Lafia Central	0.0910±0.0717	78.79	0.1398±0.0001	0.0715	0.1663±0.1773	106.6	0.0432±0.0537	124.3	0.1081±0.0001	0.0925	0.3109±0.0662	0.2129
Lafia West	ND	NA	ND	NA	0.0430±0.0001	0.2326	ND	NA	ND	NA	0.6227±0.0260	4.175
Lafia South	0.2077±0.0001	0.0481	ND	NA	0.2077±0.0001	0.0481	ND	NA	ND	NA	0.2529±0.2005	79.28
Lafia East	0.0106±0.0001	0.9434	0.0281±0.0001	0.3559	0.2057±0.0001	0.0486	ND	NA	ND	NA	0.1049±0.0322	30.70

KEY: HDW = Hand –dug-well

ND = Not Detected

NA = Not Applicable

CV = Coefficient of variation

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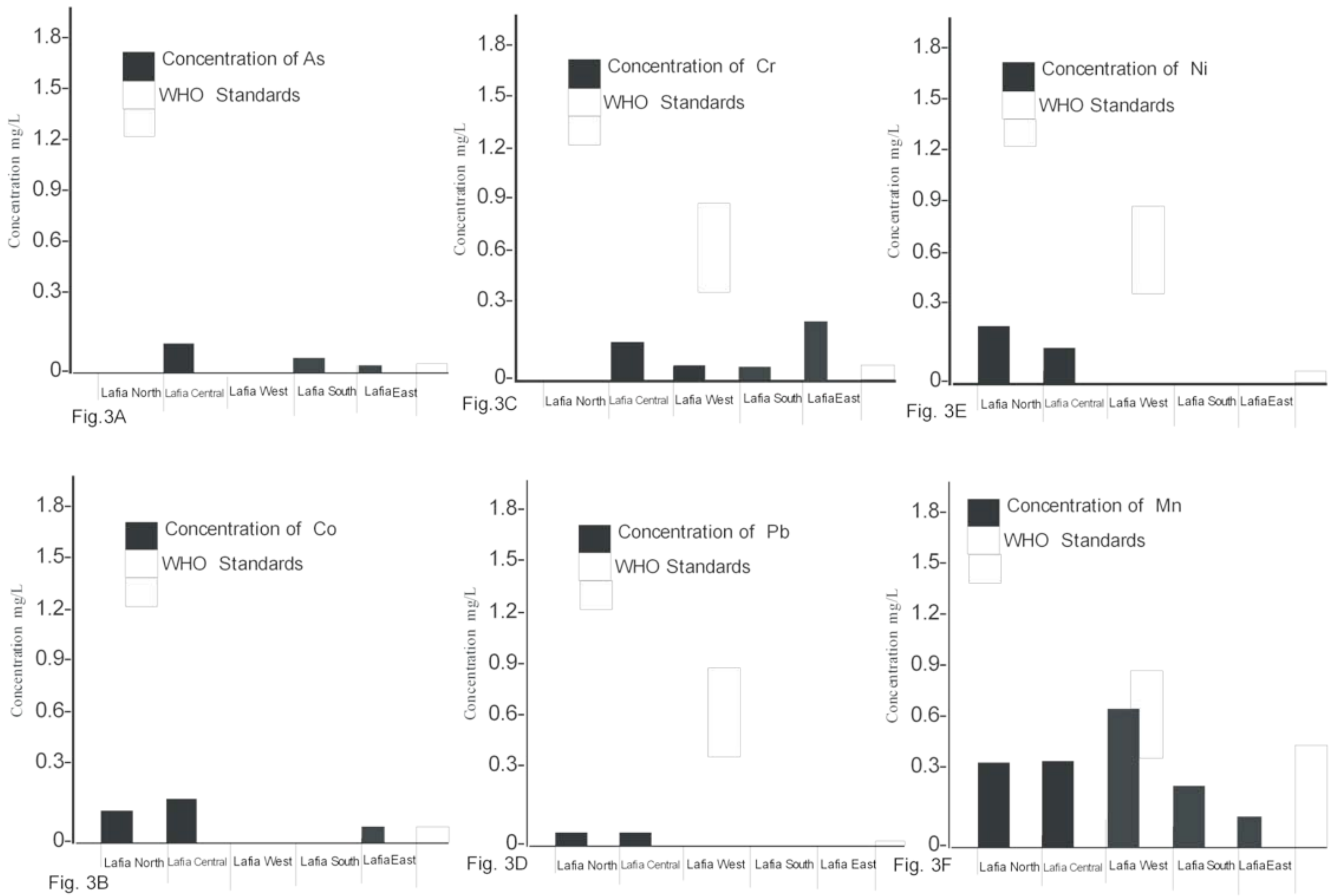

Fig. 3A-3F: Variation of mean concentration of trace metals in Hand dug well water samples for wet season

Table 4: Mean concentrations of some trace metals from borehole (BH) water samples for dry season.

Concentration (mg/L)

	As		Co		Cr		Pb		Ni		Mn	
Location	Mean	CV %	Mean	CV %	Mean	CV%	Mean	CV %	Mean	CV %	Mean	CV %
Lafia North	0.0140±0.0001	0.7143	0.0343±0.0001	0.2915	ND	NA	ND	NA	0.0210±0.0001	0.4762	0.1524±0.0240	15.75
Lafia Central	ND	NA	ND	NA	0.0309±0.0001	0.3236	ND	NA	0.1756±0.0001	0.0569	0.2373±0.0680	28.66
Lafia West	ND	NA	0.1549±0.0001	0.0646	ND	NA	ND	NA	ND	NA	0.3815±0.0907	23.77
Lafia South	ND	NA	0.1451±0.0001	0.0689	0.0042±0.0001	2.381	ND	NA	ND	NA	0.1401±0.0001	0.0714
Lafia East	0.1870±0.0001	0.0535	0.0740±0.0001	0.1351	0.1450±0.0001	0.0690	ND	NA	0.0295±0.0001	0.3390	0.0907±0.0473	52.15

KEY: BH = Borehole

ND = Not Detected

NA = Not Applicable

CV = Coefficient of variation

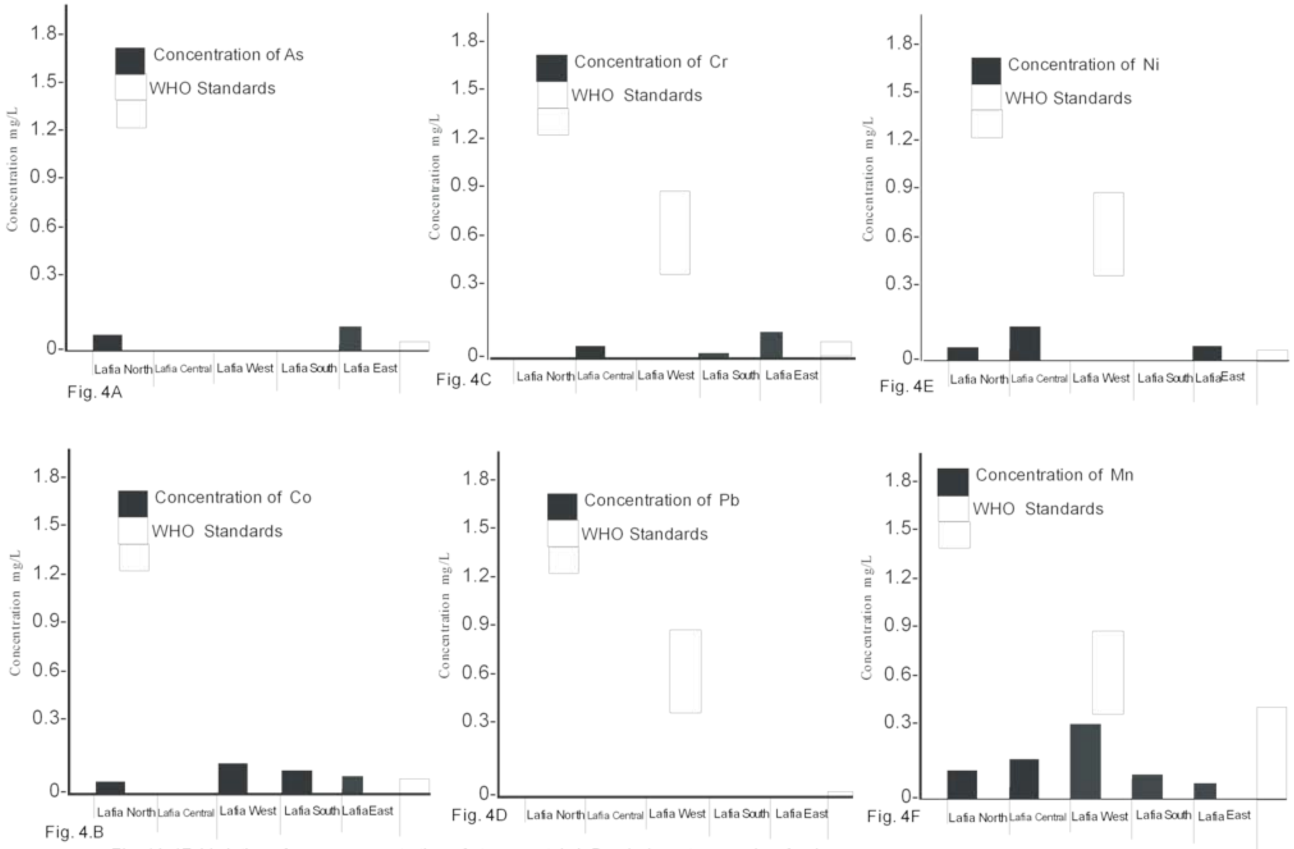

Fig. 4A-4F: Variation of mean concentration of trace metals inBorehole water samples for dry season

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Table 5: Mean concentrations of some trace metals from hand-dug-well (HDW) water samples for dry season.

Concentration (mg/L)

	As		Co		Cr		Pb		Ni		Mn	
Location	Mean	CV %	Mean	CV %	Mean	CV%	Mean	CV %	Mean	CV %	Mean	CV %
Lafia North	ND	NA	0.0428±0.0001	0.2336	ND	NA	ND	NA	ND	NA	0.0283±0.0003	0.1059
Lafia Central	0.0721±0.0001	0.1387	0.0091±0.0001	1.099	0.0102±0.0001	0.9804	0.0432±0.0537	124.3	0.0065±0.0001	1.358	0.1489±0.0407	27.33
Lafia West	ND	NA	ND	NA	ND	NA	ND	NA	ND	NA	0.3588±0.0762	21.24
Lafia South	0.0987±0.0001	0.1013	ND	NA	0.0773±0.0001	0.1294	ND	NA	ND	NA	0.2304±0.0236	10.24
Lafia East	0.1102±0.0001	0.0907	ND	NA	ND	NA	ND	NA	ND	NA	0.1574±0.0002	0.1271

KEY: HDW = Hand-dug well

ND = Not Detected

NA = Not Applicable

CV = Coefficient of variation

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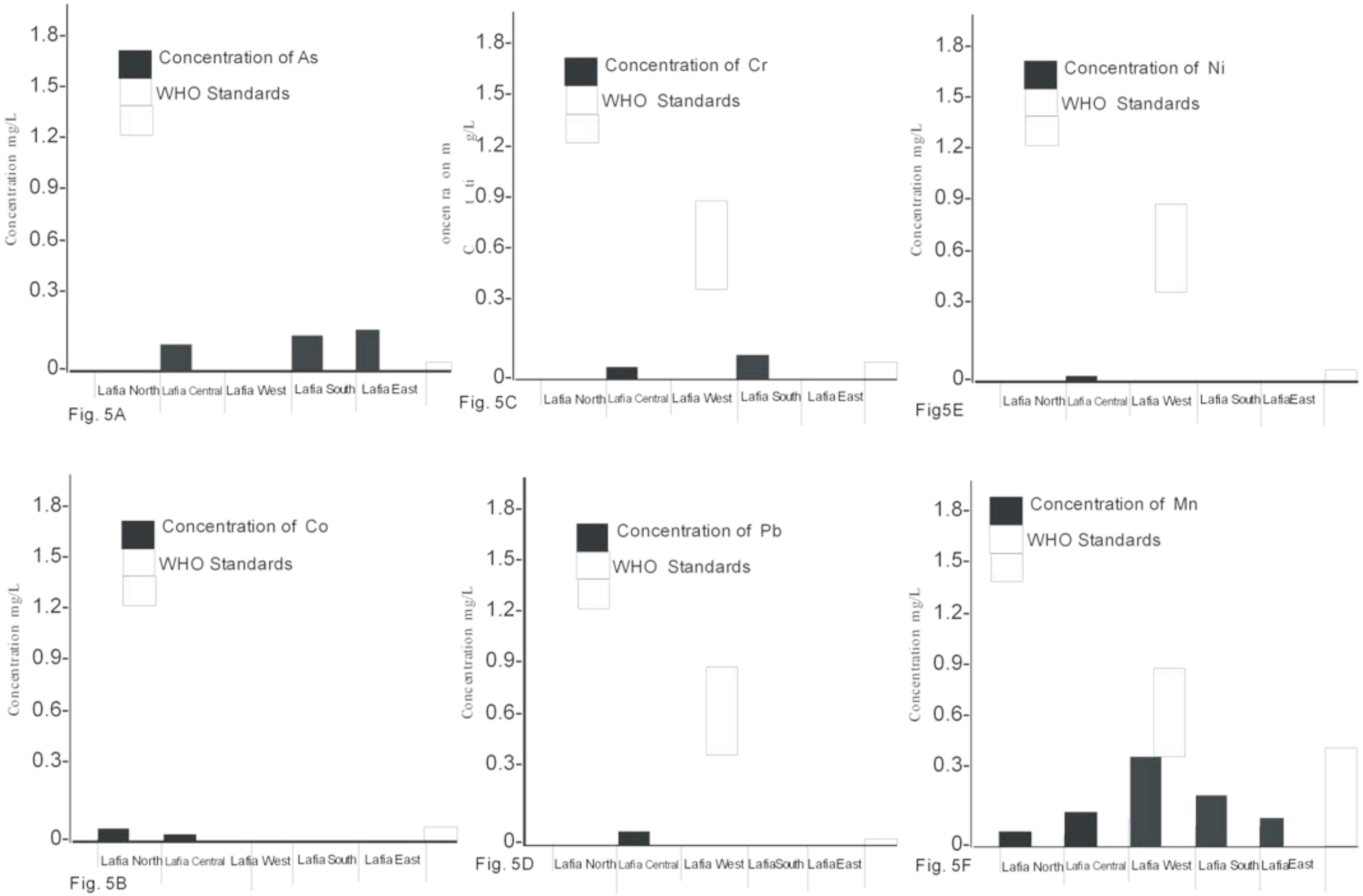

Fig. 5A-5F: Variation of mean concentration of trace metals inHand dug well water samples for dry season

Table 6: Mean values of pH of water samples from Borehole and hand –dug-well for wet season

	pH(BH)		pH(HDW)	
Location	Mean	CV %	Mean	CV %
Lafia North	6.050±0.9192	15.19	5.800±0.9899	17.07
Lafia Central	5.300±0.1414	2.668	5.100±0.7071	13.86
Lafia West	5.450±0.2121	3.892	4.850±0.3535	7.289
Lafia South	5.300±0.4243	8.006	4.850±2.000	41.24
Lafia East	4.750±0.3536	7.444	4.800±1.697	35.35

KEY: BH = Borehole

HDW = Hand-dug-well

CV = Coefficient of variation

Table 7: Mean values of pH of water samples from Borehole and hand dug well for dry season

	pH(BH)		pH(HDW)	
Location	Mean	CV %	Mean	CV %
Lafia North	6.600±0.8485	12.86	6.500±0.1414	2.175
Lafia Central	5.750±0.2121	3.689	5.450±1.060	19.45
Lafia West	5.700±0.1414	2.481	5.350±0.6364	11.87
Lafia South	5.300±0.4243	8.006	5.200±1.838	35.35
Lafia East	5.650±0.2121	3.750	5.40±2.404	45.52

KEY: BH = Borehole

HDW = Hand-dug-well

CV = Coefficient of variation

3.2 Discussion

The results of analyses of 8 trace metals studied are shown in Tables 2, 3 for wet season (WS) and Tables 4 and 5 for dry season (DS). The trace metal with the highest mean concentration during WS was Mn(0.7787 ±0.2389 mg/L) for BH in Lafia West while the least concentrated metal for the same season is Pb(0.0049± 0.0001 mg/L) for BH water samples in Lafia South. Similarly for HDW water samples in wet season, the highest mean concentration was Mn (0.6227± 0.0260 mg/L) in Lafia West while the least was As (0.0106 ±0.0001 mg/L) in Lafia East. In the case of DS, the highest concentrated metal was Mn(0.3815 ±0.0907 mg/L) for BH in Lafia West while the least concentrated metal was Cr(0.0042 ±0.0001 mg/L) for HDW in Lafia South. Similarly for HDW in dry season, the highest was Mn(0.3580 ± 0.0762 mg/L) in Lafia West while the least was Ni(0.0065 ±0.0001 mg/L) in Lafia Central.

The following metals were not within the detection limit in both seasons namely Cd, Al. When compared, the level of trace metals for BH and HDW for WS, with the highest variation was found in Cr(116.2%, BH) in Lafia West and Pb(124.3% HDW) in Lafia Central while the least were Ni(0.0268% BH) in Lafia Central; As(0.0481% HDW) and Cr(0.0481% HDW) all in Lafia South. Similarly, the highest variation during the dry season (DS) occurred for Mn(52.15% BH) in Lafia East and Pb(124.3%, HDW) in Lafia Central while the least were As(0.0535% BH and As(0.0907% HDW) all in Lafia East.

Looking at the various locations; Figures 2A-2F, 3A-3F, 4A-4F and 5A-5F; during wet season, Lafia West recorded the presence of four metals; As, Co, Cr, Mn for BH water samples followed by Lafia South with three metals detected namely; As, Cr, Mn while for HDW, Lafia West had only two metals; Cr and Mn.

Similarly, during dry season, Lafia West recorded the presence of only two metals; Co, Mn, detected for BH followed by Lafia South with three metals namely; Co, Cr, and Mn. While in HDW during dry season, Lafia West recorded only Mn followed by Lafia North with two metals; Co, Mn and Lafia East; As, Mn. In all, the proportion of metals detected in all the locations is in the order; BH (WS)> HDW(WS)>BH (DS)>HDW (DS). During the wet season for BH all the locations (Fig 2A-2F) indicated high presence of the trace metals investigated especially of Mn, Cr in Lafia West. However Pb recorded very low presence below the permissible limit in all the locations. Similarly during the wet season for HDW, Mn, Cr exhibited the same trend that is very low presence or none at all for all the metals especially Pb.

During the dry season for BH, the metals recorded very low presence or none at all, especially Pb. Similarly during the dry season, the same pattern was exhibited. Since Lafia town does not have any serious industrial activities apart from Barytes processing plant in Lafia North and Rice mills in Lafia South, these variations may be due to run-offs and recharge of wastes from urban activities such as waste disposal, vehicular emissions, construction works, metal works containing trace metals into the ground and geological formations of the soil at different locations [25].

In Tables 6 and 7 Lafia North had the highest mean pH 6.050 ± 0.9192 (slightly acidic) for borehole (BH) during the wet season (WS), while the least pH of 4.750 ±0.3536 (moderately acidic) occurred at Lafia East for Borehole (BH). Similarly during, the Dry Season (DS), Lafia North had the highest pH of 6.600 ±0 .8485(slightly acidic) for BH while the least pH of 5.200 ± 1.838 was recorded for HDW in Lafia South.

These mean pH values, except for BH in Lafia North are not in agreement with the standard guidelines by WHO, NAFDAC (pH 6.5-8.5) indicating that the BH and HDW water samples are not suitable for drinking and other purposes. These values are consistent with the works of Mcbride (1994) which warned that levels of certain soluble metals particularly Al^{3+}, Mn^{2+} at such pH 5.0-5.5 would be high enough to be biologically toxic [26].

The reason may be due to the level of minerals in the area and run-offs of various wastes. Soil pH plays a major function in the sorption of trace metals as it directly controls the solubility and hydrolysis of metal hydroxides, carbonates and phosphates. It also influences ion-pair formation, solubility of organic matter as well as surface charge of Fe, Mn and Al-oxides, organic matter and clay edges [27].

The mean values of As for BH and HDW range from 0.2710 ± 0.0001 to 0.0106 ± 0.001 mg/L respectively for WS in Tables 2 and 3 and exceeded the set standards of drinking water for As (0.01 mg/L). Similarly, the same

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trend occurred during the DS in Tables 4 and 5 (0.1102$\pm$ 0.0001 to 0.0140$\pm$ 0.001 mg/L). Arsenic has been implicated in lung cancer, especially when the arsenic compound inhaled is of low solubility. It has also been found to have an effect on the liver by causing a disease termed cirrhosis and a rare form of liver called hemangioendothelioma [28].

The mean values (WS) in Tables 2 and 3 for BH and HDW for Co range from 0.2406 $\pm$ 0.2114 to 0.0281 $\pm$ 0.0001 mg/L, all but one were well above the maximum permissible levels of 0.05 mg/L. Similarly during the DS, the mean values for BH and HDW in Tables 4 and 5 range from 0.1549 $\pm$ 0.0001 to 0.0091 $\pm$ 0.0001 mg/L. Though the toxicity potential of Co is quite low compared to many other trace metals, however, the water samples polluted with the Co may have taste and other aesthetic problems [29].

The mean concentration (WS) in BH and HDW for Cr range from 0.5049$\pm$ 0.5871 to 0.0272 $\pm$ 0.001 mg/L. which are not in agreement with the permissible level of 0.05mg/L with exception of two BH water samples. Similarly the mean concentration of Cr in BH and HDW during DS range from 0.1450 $\pm$ 0.001 to 0.0042 $\pm$0.0001 mg/L; with the latter in agreement with those recommended limits (0.05 mg/L). Chromium concentration in natural waters including drinking water are usually very small and is generally found in the hexavalent form (Cr^{6+}). The concentration of Cr in water bodies may give cause for concern, biomagnifications of it may lead to serious condition which could cause adverse health effects to consumers such as renal disease and cancer [30]. However Cr metal is essential for life; its deficiency results in diabetes mellitus and increases the toxicity of lead [31].

The mean concentrations during WS for Pb in BH and HDW range from 0.0423 $\pm$ 0.0537 to 0.0049 $\pm$ 0.0001mg/L and exceeded the maximum permissible level of 0.01mg/L with the exception of one BH water sample.

Similarly during DS, Pb was not detected in all but one HDW sample 0.0432 $\pm$ 0.0537. These values compare well with similar works done in Surulere, Lagos by Anyakora and Momodu (2009). Lead even at low concentration is known to be toxic and has no known function in biochemical process. It can impair the nervous system and affect the foetus, infants and children resulting in lowering of intelligent quotient (Iq) even at its lowest dose[32].

Pb sticks to soil particles and enters drinking water only if the water is acidic or soft and from the results of pH presented in Tables 6 and 7 strengthened this statement. Lead in the form of tetra-ethyl lead, Pb $(C_2H_5)_4$, is the most common additive to petrol to raise its octane number. Upon the combustion of the petrol in the engine, the organic lead is oxidized to lead oxide viz; $Pb(C_2H_5)_4+13O_2$ $Pb + 8CO_2+10H_2O$

This lead can oxidize further to give species such as lead (II) oxide. The Lead (II) oxide, PbO, formed reacts with the halogen carriers (the co-additives) or lead scavengers (1,2—dibromoethane and 1,2- dichloroethane) to form particles of lead halides $PbCl_2$,PbBrCl, $PbBr_2$- which escape into the air through the vehicles exhaust pipes. By this about 80% of lead in petrol escapes through the exhaust pipe as particles while 15-30% of this amount is air borne.

Human beings, animals, vegetation and soil are the ultimate recipients of the particulate. The Lead level in Nigeria supergrade petrol is in the range 210-520mg/L[33].

The mean concentrations during WS for Ni in BH and HDW range from 0.3729 $\pm$ 0.0001 to 0.0841$\pm$ 0.0001 mg/L and exceeded the permissible level of 0.02 mg/L. Similarly the mean concentration during DS for Ni in BH and HDW range from 0.1756 $\pm$ 0.0001 to 0.0065 $\pm$ 0.0001 mg/L which are higher than the maximum contaminant level except for one sample . The occurrence of Ni is clearly connected with alkaline magma rock as well as silty sedimentary rock. A considerable part of nickel finds its way into the environment as a result of the burning of diesel oil containing nickel [34].

The average extent of Ni content at the surface levels of various soils is from 4-50 mg/kg. Soils usually contain more nickel in an organically combined form to a considerable degree in the form of mobile chelates. Ni alongside Cr and Co due to their ever increasing technological significance for toxicity in the environment have become factors destructive of ecosystem, pathogens to living organisms and worse mutagenic or carcinogenic factors for animals and people [35].

The mean concentration values during WS in BH and HDW for Mn range from 0.7787 $\pm$ 0.2329 to 0.1049 $\pm$ 0.0322 mg/L, with only two samples exceeded the guideline value of 0.5mg/L. Similarly during the DS, that of Mn in BH and HDW range from 0.3815 $\pm$ 0.0907 to 0.0283 $\pm$ 0.0003 mg/L which fell below the guideline value. The mean pH values of water samples between 4.8 -6.1 , WS, 5.2 -6.6 for DS determined, are in agreement with literature reports which warn of the potential level of Mn at pH values 5.0-5.5. Manganese is an essential element with moderate toxicities. At levels exceeding 0.1 mg/L, Mn in water causes an undesirable taste in beverages and stains sanitary ware and laundry. The presence of Mn in drinking water, like that of iron, may lead to the accumulation of deposits in the drinking water system. Concentrations below 0.1 mg/L are usually acceptable to consumers. The health-based value for Mn is 4 times higher than this acceptability threshold of 0.1 mg/L and has been implicated in neurological problems especially when inhaled [36].

In summary, the mean concentrations of trace metals in the BH and HDW water samples were higher during the wet season than dry season. This is most likely due to leaching from already weathered materials which is enhanced during rainy season. Another reason could be due to geological formation (solid minerals) status of Lafia town and increased run-offs of wastes into source waters [37].

4.0 CONCLUSION

The study presented data on the concentration of trace metals (As, Co, Cr, Pb, Ni, Mn) in ground water sources; Boreholes and Hand dug wells collected from various locations within and around Lafia metropolis. The results revealed that there were indications of trace metals in the following proportion As 40%, Co 40%, Cr 37.5%, Pb 25%, Ni 25%, Mn 97.5% of the total water samples and their contents were found to be higher in some cases than the recommended guideline values by WHO, NAFDAC, NSDWQ (borehole monitoring unit of Federal Ministry of Water Resources). These levels of trace metals could be due to contribution by the geology of Lafia metropolis, which hosts minerals like Columbite, Tantalite, Cassiterite, run-offs of wastes from anthropogenic activities. This means that water sources from BH and HDW are polluted by these metals and will pose danger to consumers. It is well known that minerals are necessary for life performing important function in the metabolism of living organism. On the other hand, when taken in excess both toxicity and necessity vary from element to element and from species to species. For over millions of years, men and other living creatures have become tolerant to these small concentrations of heavy metals and it is more than likely that some forms of life may now be dependent on these poisonous metals as trace elements. Therefore information on the levels of intake of trace metals through water is important in assessing risk to human health arising from increasing environmental pollution.

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