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Determination of Seasonal Variability of Heavy Metals Concentration from Drinking Water Using Atomic Absorption Spectrometry in Dutsinma Town, Katsina State, Nigeria

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ABSTRACT

It is an undisputable fact that, many health complications arise as a result of drinking water unsuitable for human consumption. This menace can be minimized drastically through routine monitoring and evaluation of drinking water quality in terms of heavy metals and other physicochemical parameters. This research was carried out to determine seasonal variability and portability of heavy metals concentration from four sources of drinking water in Dutsinma Town, katsina state, Nigeria. The research adopted quantitative research design and purposive sampling technique. Water samples were drawn purposively from eight sampling points selected for the research in both dry and rainy seasons. Water samples were tested for heavy metals (Cu, Zn, Pb, Cr, Hg, As, Cd, Ni, Mn and Al) using atomic absorption spectrometry. All the parameters were detected except Lead and Cadmium. The results obtained were subjected to t-test in order to find out the extent of seasonal variation in the concentration of heavy metals. The result was also compared with WHO (2022) water quality standard to ascertain the suitability of water for human consumption in terms of heavy metals. The result revealed that, the concentration of heavy metals varies slightly with the seasons as all the parameters across all the water sampling points showed insignificant seasonal variation. In addition, most of the heavy metals compared well with WHO (2022) water quality standards for heavy metals. The research concluded that, concentration of all the heavy metals studied varies insignificantly with season and most of the heavy metals tested were within WHO (2022) permissible limits, hence, the water sources are safe for human consumption. One of the recommendations offered was the need to carry out more researches on heavy metals not included in this research.

Keywords: Seasonal, Variation, Heavy Metals, Atomic Absorption, Spectrometry, Dutsinma, Katsina state.

INTRODUCTION

Water quality monitoring and evaluation is one of the key strategies of water resources development worldwide. Continous monitoring and evaluation of drinking water quality is essential in terms of heavy metals and toxic substance as the water quality is subject to change over time. Water is undoubtedly connected to life without which there is no life. This is the reason for which water must be given necessary attention at all times. Good drinking water is not a luxury, it is one of the most essential amenities of life itself (Adetunde and Glover, 2010). According to Egbai, Adaikpoh and Aigbogun (2013), water is an essential element for life and it is used for numerous purposes by man and therefore must be of acceptable quality for human consumption and should be of adequate quantities for livestock and industrial uses.

Water is one of the most vital natural resources for all lives and living creatures on earth. The main availability and quality of water always plays an important part in determining not only where people can live but also quality of life. Even though, there has always been plenty of fresh water on Earth, water has not always been available when and where it is needed, nor it is always of suitable quality for all users, (Federal Ministry of Environment FEPA, 1996).

A heavy metal is any metallic element that has a relatively high density and is toxic or poisonous even at low concentrations (Cobbina et al 2015). Heavy metals exist as natural constituents of the earth crust and are persistent environmental contaminants, because they cannot be degraded or destroyed. While these elements occur naturally they are often bound up in inert compounds. However, their concentrations have increased as a result of human activities. Human exposure to harmful metals can occur in many ways, ranging from the consumption of contaminated food and water, exposure to air borne particles and accumulate over a period of time (Cobbina et al, 2015). Some heavy metals such as copper, selenium iron and zinc are essential to maintain the metabolism of the human body. However at higher concentrations they can lead to poisoning. (lenntech, 2022).

Water quality is a term used in describing the chemical, physical and biological characteristic of water, usually in respect to its suitability for an intended purpose (Kiyawa, 2009). These characteristics are affected by both natural processes and human activities; generally, natural water quality varies from place to place depending on climatic changes, types of soil, rocks and surfaces through which it moves. Human activities such as agriculture, mining, urban and industrial development and re-creation significantly alter the quality of natural water and change the water use potential, (Federal Ministry of Environment FEPA, 1996). The key issue to sustainable water resources is to ensure the quality of water is suitable for an intended use while at the same time maintaining the quality after use. Natural water quality varies from place to place with the seasons, with climate and with the types of soils and rocks through which water moves, when water from rain or snow moves on the land, and through the ground, the water may dissolve minerals in rocks and soils, percolate through organic materials such as roots and leaves and react with algae, bacteria and other microscopic organisms. Water may also carry plants, debris, silt and clay to rivers and streams making the water appear muddy or turbid. When water evaporates from lakes and streams, dissolved minerals are more concentrated in the water that remains. Each of these natural processes changes the quality and potentiality of the natural water. (USDI, 2014).

Toxic and hazardous substances such as heavy metals and pesticides are introduced into the aquatic environment principally from anthropogenic sources, population explosion, hap hazard rapid urbanization, industrial and technological expansion, energy utilization and waste generation from domestic and industrial sources have rendered many water resources unwholesome and hazardous to man and other living resources (FEPA, 1996).

Dutsin-ma town is blessed with both surface and underground water which its inhabitants use for domestic purposes including drinking. The water in the town tends to be contaminated or polluted as water borne disease prevails in the town (Idris, 2011). The water might be contaminated through a number of factors such as disposal of domestic waste into the streams that drain to the main reservoir, pollution from decaying algae, dead leaves, human and animal wastes and agricultural activities. Seepage from septic tanks, pit latrines and waste dump site, leaching processes may lead to ground water contamination in the town. In addition, physical expansion as well as population growth in Dutsin-ma Town also combined to place a lot of pressure on treated water Supplies by the government that is why in some cases the treated water has varied taste and clarity with high level of turbidity (Idris, 2011). The above problem necessitated several researches on water quality studies in the study area including the work of Idris (2011, 2017, 2018, 2020 and 2021), among others, and the researches have not covered heavy metals and all recommended for further studies on heavy metals.

Heavy Metals

Heavy metals refer to any metallic elements that have relative density in toxic or low poisonous concentration. Example of heavy metal includes: Mercury, Cadmium, Arsenic Chromium, Iron Lead, etc. The term heavy metal' has been used extensively to describe a metal that is environmentally pollutant. But some metals are essential when taken up by an organism, there excessive presence will nerve the effect so that the benefit become toxicity. First of all, we want to mention about the heavy metal sources which cause the pollution.

Heavy metals can be critically important to the life process of marine organisms. Aluminum, Arsenic, Cobalt, Copper, Iron, Manganese, Molybdenum, Nickel, Selenium, Tin, Vanadium, and Zinc are essential heavy metals for one or more organisms. Usually they are present in living organisms in trace amount. Copper and Zinc are necessary in trace amounts for functioning of biological systems. The non-essential heavy metals include: Cadmium, Gold, Lead, Mercury, Silver and metals (including radionuclide) of higher atomic weight. Lead and Cadmium are known to interfere with functioning of the biological systems. Due to the fact that even trace amounts of some heavy metals can generally exhibit high toxicity of marine organisms and human, there is an increasing interest in studying of metals in the environments. Among these heavy metals are Cadmium, Lead, Copper, and Chromium. These metals represent the greatest potential concern to the environment and human health (Cobbina et-al, 2015)

Heavy Metals Pollution in Water

Water pollution has many sources and characteristics, human and other living organisms produced bodily wastes which entered rivers, lakes, oceans, and other surfaces water; industries are creating new chemicals each year, all eventually find their way to water, in high concentration these wastes result in bacterial contamination. Inorganic industrial wastes are much trickier to control and potentially more hazardous. Industries discharge a variety of toxic compound and heavy metals and wastes water from industrial process that may also be too hot or too low in dissolved oxygen to support life (Cobinna et-al, 2015).

Brief Description of Study Area

Dutsin-ma city is found within latitude 12º27′10″ N and 12º27′16″ N and longitude 07º29′ 56″ E and 07º30′ 04″ E. Dutsin-ma city is underlain by the basement complex area of Katsina State which is of crystalline origin (Tukur, 2010). There are numerous granitic hills, which rise 60-200meters above the surrounding plains. These hills are probably the result of the intrusion of older granites into the basement complex, which have undergone long period of denudation (Adamu, 2000) in (Tukur, 2010).

The soil of the area is the tropical ferruginous red and brown soil of the basement complex. The soil forming materials are rock and sand materials. Brown to orange color soils consisting of sandy clay loam, overlying lateritic ironstones are found on the interfluves and upper slopes of undulating area, while on the seasonally flooded river valley floors, highly clay content heavier grey soils occur (Oguntoyinbo et al, 1983). The climate of the area is semi-arid classified as tropical wet and dry climate (AW), as classified by W. Koppens. Two major factors influence the climate of the area, latitudinal location and continentality (distance from the sea), According to Adamu (2000) in Tukur (2010) the climate of Dutsin-ma could be described as tropical continental, with annual rainfall of about 800mm. The Temperature in April averages 30.8ºc. In January, the average temperature is about 21.2ºc (Isa Kaita College of Education, Weather Station 2017). Between March and May the area, experience a hot dry season climate. A warm wet season is experience from June to September. Towards the end of the year, the area experience a less marked season after rains, which is characterize by a decreasing rainfall and a gradual lowering of temperature. Dutsinma area is predominantly Hausa-Fulani territory. Majority of the people speak Hausa, but there are small portion of the people that speak Fulani. Large percentages of the people in the area are cultivators, with a few traders .According to the 2006 National Population census, the population figures of Dutsin-ma Local Government reached 169,671 inhabitants. (N P C, 2006). The estimate of 2017 puts the population of Dutsinma local government at 220,756 people. (N P C, 2017).

MATERIALS AND METHODS

Field work. The field work was divided into Pre-field work which involved reconnaissance survey of the study area to identify different water sources in the city for the selection of the sampling points and main field work which involved collection of water samples and laboratory analysis of the samples collected.

Sampling Design. A purposive sampling technique was adopted and water samples were drawn purposively from the surface and ground water sources (treated tap, hand pumps, boreholes and open well water). During reconnaissance survey, eight sampling points were selected; two sampling points for the treated tap water, two for hands pumps, two for boreholes and two others for open wells.

Sample Size. Eight water samples were drawn from eight sampling points selected, two samples from treated tap water, two samples from hand pumps, two samples from boreholes and two samples from open wells. Sampling collection was carried out thrice in the rainy season and thrice in the dry season respectively, making a total of forty eight (48) water samples for the study (24 samples in the rainy season and 24 samples in the dry season).

Sample's Collection. Water samples were collected from two major sources i.e surface (tap water) and ground water (boreholes, hand pumps and open wells). Sample's collection for the dry season was carried out in the month of February, march and April 2023. For the rainy season, the samples were collected in the month of July, August and September 2023. Water samples were collected using sterilized 2-liter plastic containers, thoroughly washed and acidified with nitric acid and clearly marked and labeled after the sampling points, time and date. The containers were further rinsed with the sample water at the sites of the sample collection before collecting the sample to avoid contamination. This is in accordance with Balarabe,Oladimeji and Abubakar (1998), Nirmala et al, (2012), Abed, Hussain and Pradhan (2011), Agbaire, Akporido and Akporhonor (2014), Nwaichi, Monamu and Njoku (2013), Makwe and Chup (2013), Orosun et al (2016) and Idris (2011, 2017, 2018, 2020 and 2021). All samples were collected between 8:00am to 10:00am and were kept in coolers filled with ice blocks before they were finally conveyed to the laboratory where they were analysed for the selected heavy metals.

Laboratory Analysis

Heavy metals tested and analyzed in the laboratory were (Copper (Cu), Zinc (Zn), Lead (Pb), Chromium (Cr), Mercury (Hg), Arsenic (As), cadmium (Cd), Nickel (Ni) Manganese (Mn) and Aluminium (Al). These metallic parameters were tested in standard laboratory using Atomic Absorption Spectrometry (AAS).

Statistical Techniques/Methods

Mean, standard deviation and t-test were used to analyze the results obtained from laboratory so as to determine whether there is significant difference in the quality of drinking water in terms of heavy metals in the study area between the two seasons. Bar graphs were also used to show comparisons on heavy metals concentration between the two seasons.

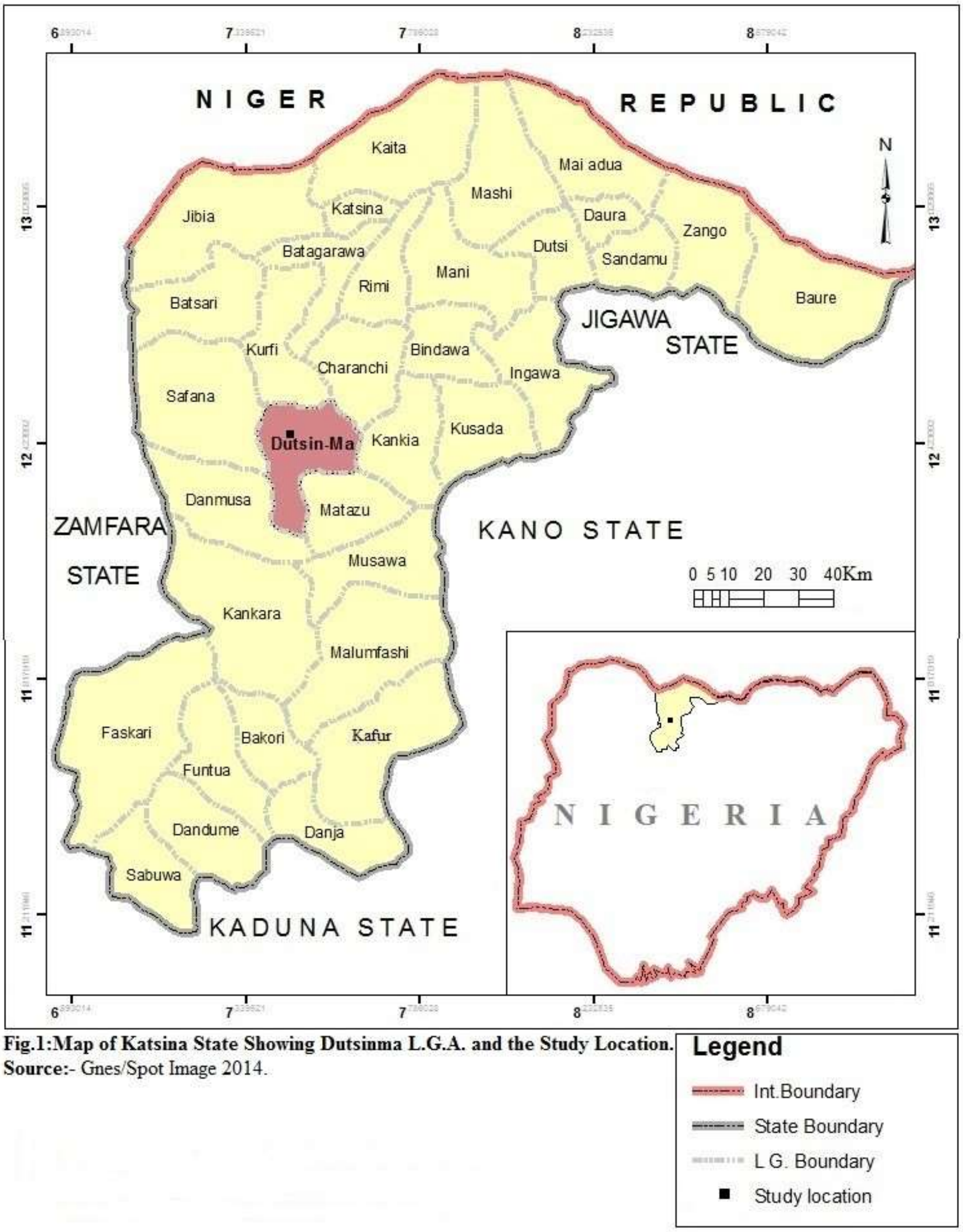


Fig.1:Map of Katsina State Showing Dutsinma L.G.A. and the Study Location.
Source:- Gnes/Spot Image 2014.

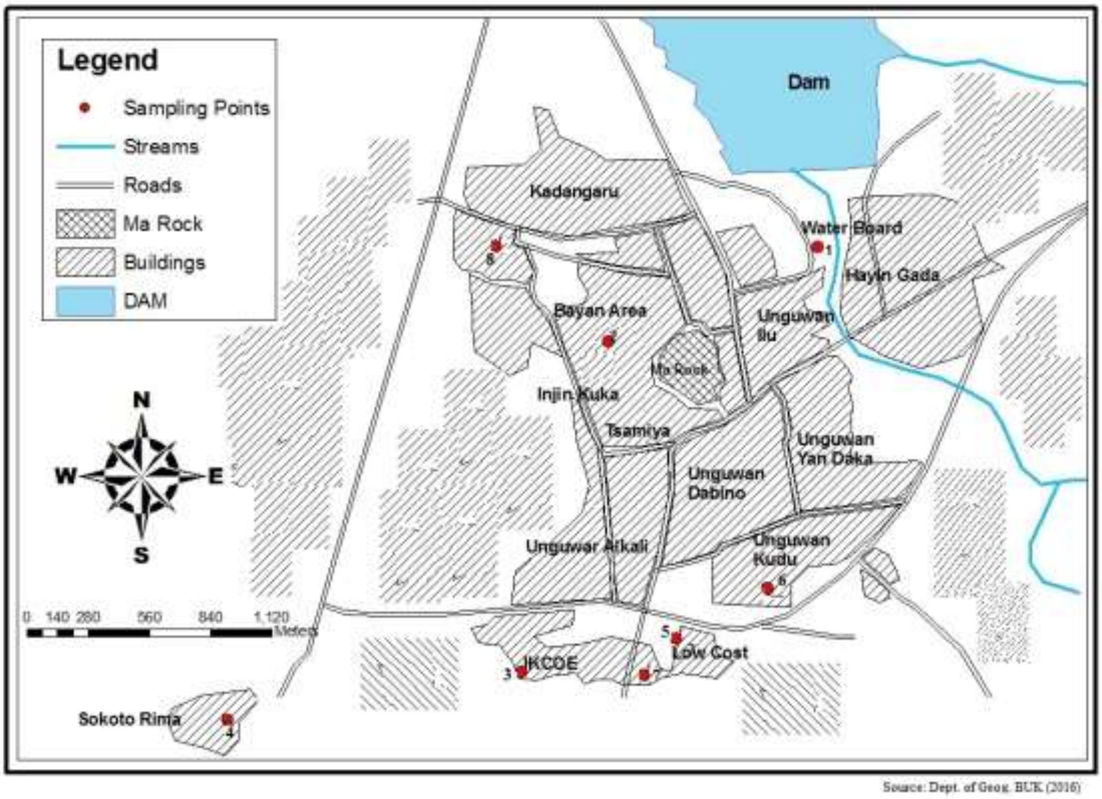


Fig 2: Map of Dutsinma Town showing eight sampling points

RESULTS AND DISCUSSIONS

The averages of the results for the two seasons were taken and presented in the tables below,

Table 1: Concentration of Heavy Metals from Water Samples Collected in Dry Season (February – April, 2023)

	Sampling Points							
Parametres	WSP 1	WSP 2	WSP 3	WSP 4	WSP 5	WSP 6	WSP 7	WSP 8
Copper (Cu) µg/l	1870	1920	1580	1790	1620	1718	2133	2085
Zinc (Zn) µg/l	2334	3013	2722	2981	2499	2645	2860	2565
Lead (Pb) µg/l	9.60	9.90	8.30	8.92	9.02	9.00	7.50	8.20
Chromium (Cr) µg/l	29.00	26.50	27.55	28.30	25.10	33.22	53.20	37.26
Mercury (Hg) µg/l	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arsenic (As) µg/l	9.20	9.63	6.90	7.50	8.25	8.10	9.42	10.10
Cadmium (Cd) µg/l	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nickel (Ni) µg/l	69.00	62.00	53.50	57.30	53.32	54.75	46.80	43.00
Manganese (Mn) µg/l	28.30	33.80	53.10	40.56	55.22	46.25	30.30	28.56
Aluminium (Al) µg/l	193	189	129	143	157	161	123	119

WSP- Water sampling point

Source: Field and Laboratory Analysis (February– April, 2023

Table 2: Concentration of Heavy Metals from Water Samples Collected in Rainy Season (June – August, 2023)

	Sampling Points							
Parametres	WSP 1	WSP 2	WSP 3	WSP 4	WSP 5	WSP 6	WSP 7	WSP 8
Copper (Cu) µg/l	1984	1998	1730	1799	1670	1833	2120	2083
Zinc (Zn) µg/l	2240	3009	2842	2775	2567	2546	2932	2548
Lead (Pb) µg/l	9.81	10.06	7.99	8.43	9.36	9.63	8.22	8.84
Chromium (Cr) µg/l	33.50	29.38	25.07	28.10	25.30	31.83	49.36	36.62
Mercury (Hg) µg/l	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arsenic (As) µg/l	9.82	9.98	7.10	8.33	8.40	8.98	9.50	10.36
Cadmium (Cd) µg/l	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nickel (Ni) µg/l	59.80	61.33	53.70	60.13	58.61	61.50	45.40	44.60
Manganese (Mn) µg/l	30.84	29.67	48.10	38.68	42.34	43.58	29.93	28.21
Aluminium (Al) µg/l	201	198.5	118	146	141	160	110	113

WSP- Water sampling point

Source: Field and Laboratory Analysis (June – August, 2023)

Table 3: WHO 2022 Water Quality Standards for Drinking Water

S/No	Parametres	WHO 2022 (µg/l)	WHO 2022 (Mg/l)
1	Copper Cu	2000	2.0
2	Zinc Zn	3000	3.0
3	Lead Pb	10	0.01
4	Chromium Cr	50	0.05
5	Mercury Hg	6	0.006
6	Arsenic	10	0.01
7	Cadmium Cd	3	0.003
8	Nickel Ni	70	0.07
9	Manganese Mn	80	0.08
10	Aluminium Al	200	0.2

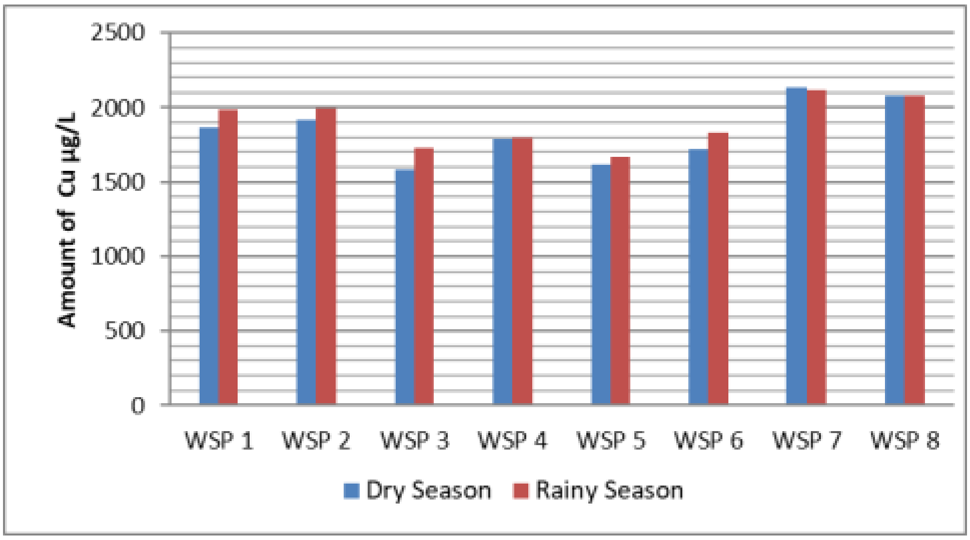
Source: WHO (2022)

Table 4: Result of t-test Showing Seasonal Variation of water Quality in terms of Heavy metals concentration between the two seasons

	Pair	Mean ± Margin of Error	STD. DEV.	N	DF	T	P ≤ 0.05	Remark
Cu µg/l	Dry Season	1839.5 ± 140.2	202.33	8	14	-0.677	0.51	NS
	Rainy Season	1902.13 ± 111.7	166.91					
Zn µg/l	Dry Season	2702.38 ± 165.4	238.62	8	14	0.163	0.873	NS
	Rainy Season	2682.28 ± 175.4	253.18					
Pb µg/l	Dry Season	8.81 ± 0.5	0.78	8	14	-0.609	0.552	NS
	Rainy Season	9.04 ± 0.5	0.79					
Cr µg/l	Dry Season	32.52 ± 6.4	9.23	8	14	0.028	0.978	NS
	Rainy Season	32.40 ± 5.5	7.92					
As µg/l	Dry Season	8.64 ± 0.8	1.12	8	14	-0.766	0.456	NS
	Rainy Season	9.06 ± 0.7	1.08					
Ni µg/l	Dry Season	54.96 ± 5.7	8.16	8	14	-0.177	0.862	NS
	Rainy Season	55.63 ± 4.9	7.01					
Mn µg/l	Dry Season	39.51 ± 7.6	10.96	8	14	0.653	0.524	NS
	Rainy Season	36.42 ± 5.3	7.69					
Al µg/l	Dry Season	151.75 ± 19.8	28.52	8	14	0.211	0.836	NS
	Rainy Season	148.5 ± 18.4	27.7					

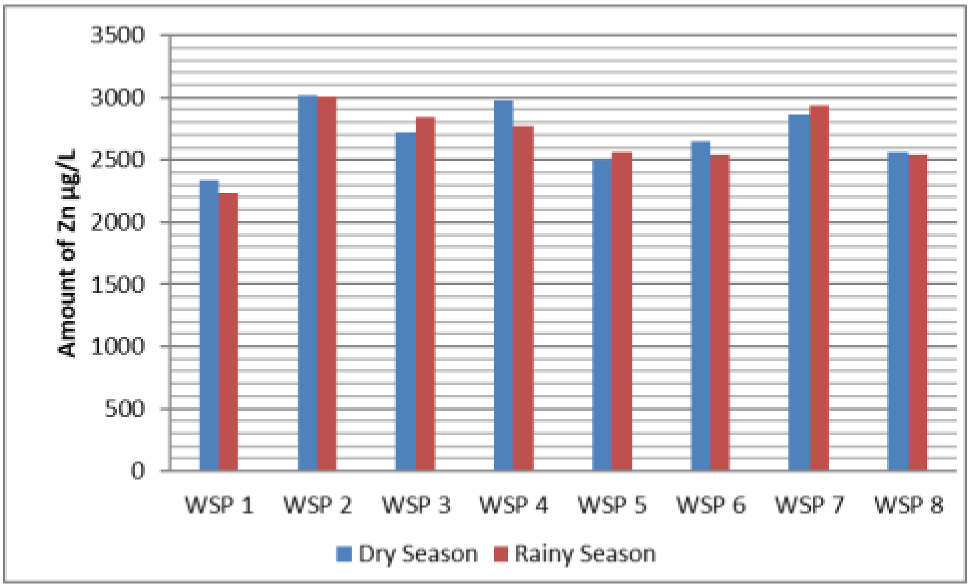
STD DEV. = Standard Deviation, DF =Degree of Freedom, NS = No Significant difference. Decision: If P-Value is greater than significance level (0.05), then there is no significant difference between the two seasons

Copper (µg/L):- The values of Copper were found in the range of (1580 µg/l to 2133 µg/l) in the dry season in the order WSP3 < WSP5 <WSP6< WSP4< WSP1 <WSP2 < WSP8 < WSP7 , with point 7 having the maximum values (2133 µg/l) and point 3 with the minimum values (1580 µg/l). The values ranged between (1670 µg/l to 2120 µg/l) in the rainy season in the order WSP5< WSP3 < WSP4 < WSP6 < WSP1 < WSP2 < WSP8 < WSP7 with point 7 having the maximum value (2120 µg/l) and point 5 having the minimum value (1670 µg/l). Values of Copper were found higher in the rainy season in all the sampling points except sampling points 5, 7 and 8 with values of Copper higher in the dry season. This contradicted the findings of joshua et-al (2017) that observed higher values of Copper in the dry season. The values of Copper across all the sampling points for the two seasons compared well with the WHO (2022) water quality standard of (2000 µg/l) except point 7 and 8 that deviated slightly from the standard. The result of the t-test showed insignificant seasonal variation between the two seasons.



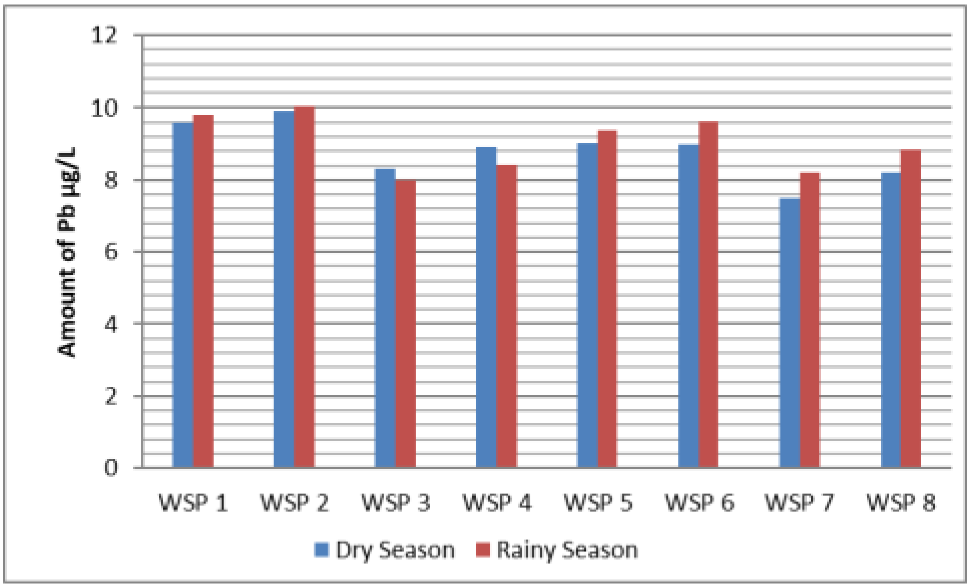
Bar charts showing seasonal variation on Copper

Zinc (µg/L) :- concentration of Zinc from the water samples were found in the range of (2334 µg/L to 3013 µg/l) in the dry season in the order WSP1 < WSP7 < WSP8 < WSP6 < WSP3 < WSP7 < WSP4 < WSP2 with point 2 having the highest value (3013 µg/l) and point 1 having the lowest value (2334 µg/l). The values ranged between (2240 µg/l to 3009 µg/l) in the rainy season in the order WSP1 < WSP6 < WSP8 < WSP5 < WSP4 < WSP3 < WSP7 < WSP1. Maximum values (3009 µg/L) were found from point 2 and minimum values (2240µm/l) were found from point 1. Sampling points 3, 5 and showed higher values of Zinc in the rainy season and lower values in the dry season. On the other hand, points 1, 2, 4, 6 and 8 showed higher values of Zinc in the dry season and lower values in the rainy season respectively. This implied that, concentration of Zinc is higher in the dry season. This finding conformed to that of Joshua et al (2017) and Abdulaziz (2023). With the exception of point 2, all the points revealed Zinc values within the allowable limits of WHO (2022) water quality standard of (3000 µm/l.) The result of the t-test showed insignificant seasonal variation between the two seasons.



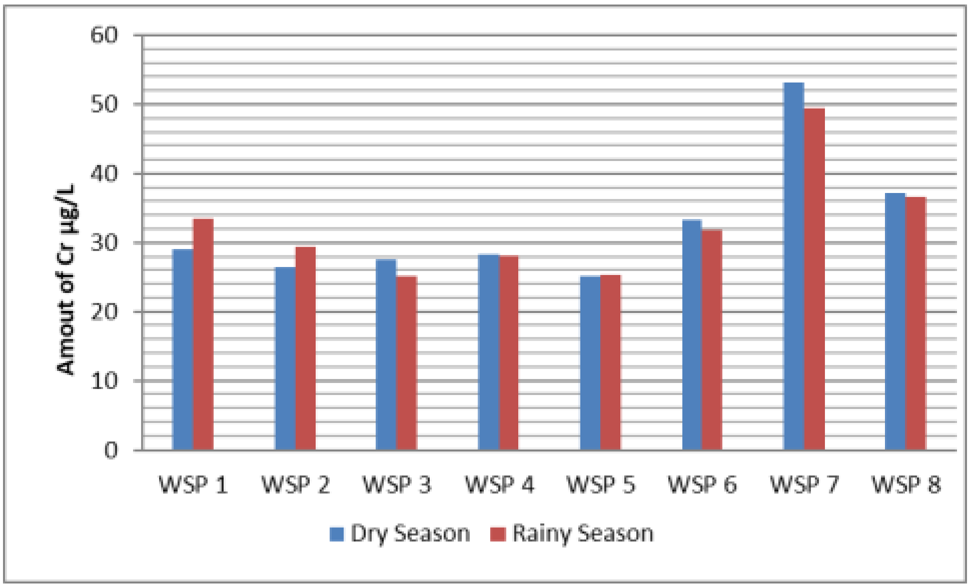
Bar charts showing seasonal variation on Zinc

Lead (µg/L):- The concentration of lead were found in the range (7.50 µg/l to 9.90 µg/l) in the dry season in the order WSP7 < WSP8 <WSP3< WSP4< WSP6 <WSP5 < WSP2 < WSP1 , with point 1 having the maximum values (9.90 µg/l) and point 7 with the minimum values (7.50 µg/l). The values ranged between (7.99 µg/l to 10.06 µg/l) in the rainy season in the order WSP3< WSP7 < WSP4 < WSP8 < WSP5 < WSP6 < WSP2 < WSP1 with point 1 having the maximum value (10.06 µg/l) and point 3 having the minimum value (7.99 µg/l). Values of Lead were found higher in the rainy season in all the sampling points except sampling points 5, 7 and 8 with values of Lead higher in the dry season. This finding agreed with that of Raji et-al (2016) that observed higher values of Lead in the rainy season. The values of Lead across all the sampling points for the two seasons compared well with the WHO (2022) water quality standard of (10 µg/l) except WSP 2 that deviated slightly from the standard with (10.06 µg/l). The result of the t-test showed insignificant seasonal variation between the two seasons.



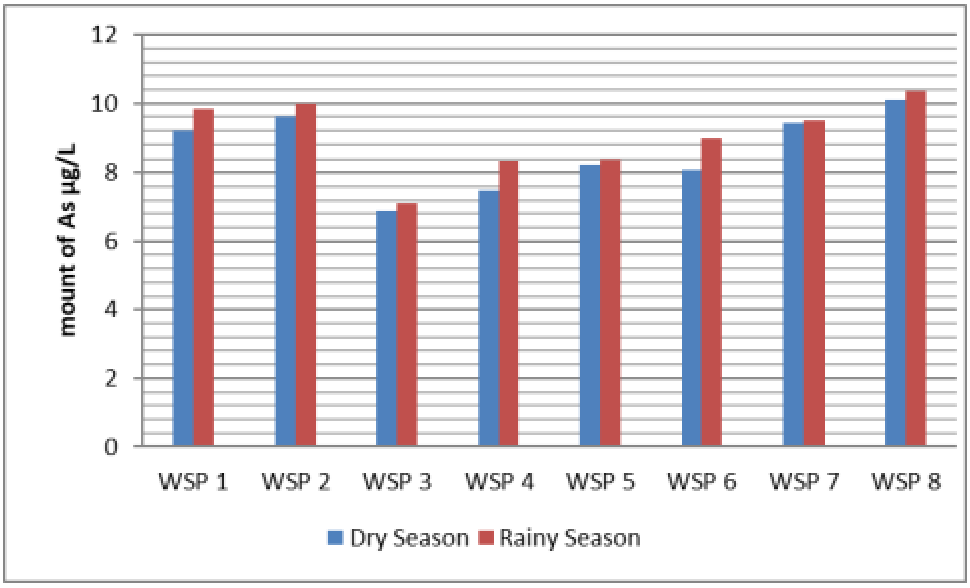
Bar charts showing seasonal variation on Lead

Chromium (µg/l):- The concentration of chromium according to the result varied from (25.10 µg/l to 53.20 µg/l) in the dry season. Point 5 had the lowest value (25.10 µg/l) and point 7 had the highest value (53.20 µg/l). The concentration ranged from (25.07 µg/l to 49.36 µg/l) in the rainy season. Lower values were observed from point 3 (25.10 µg/l) and higher values were observed from point 7 (49.36 µg/l). The values of chromium were slightly higher in the dry season than in the rainy season. However, the result of t-test revealed that, there is insignificant seasonal variation in the quality of water in terms of Chromium between the two seasons. Contrary to the findings of Muyiwa et-al (2016) and Bala, Shehu and Lawal (2008), the results of chromium for all the seasons compared well with WHO (2022) water quality standards for heavy metals in drinking water except for WSP7 that deviated slightly with 53.20 µg/l in the dry season and this conformed to the finding of Abdurrashid and Abdurrahman (2020).



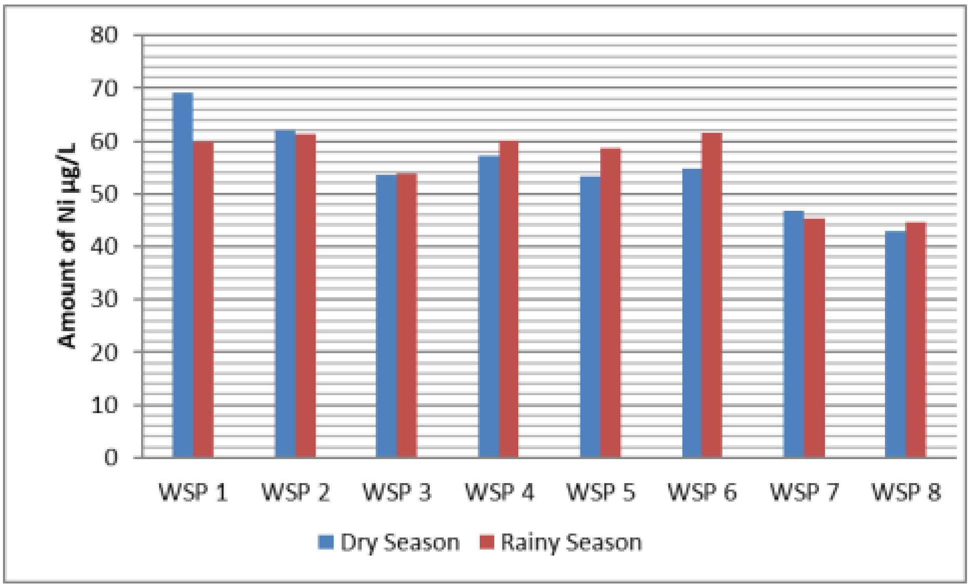
Bar charts showing seasonal variation on Chromium

Arsenic (µg/L):- According to the results obtained, the values of Arsenic ranged from (6.90 µg/l to 10.10 µg/l) in the dry season. Lower values were detected from point 3 (6.90 µg/l) and higher values were detected from point 8 (10.10 µg/l). In the rainy season, the values of Arsenic ranged from (7.10 µg/l to 10.36 µg/l). Highest values were detected from point 8 (10.36 µg/l) and lowest values (7.10 µg/l) from point 3. The results of t test on Arsenic between the two seasons showed insignificant seasonal variation. Comparison of the results of Arsenic with metallic water quality standards revealed that, all the results for both seasons conformed to WHO (2012) water quality standards of (10 µg/l) as observed by Rajeev, Tripathy and Gupta (2014). The only exception was WSP8 that deviated slightly from the standard with 10.10µg/l and 10.36µg/l in the dry and rainy seasons respectively. Contrary to the finding of Pari-Huaquisto et-al (2020), concentration of Arsenic across all the water sampling points was found to be higher in the rainy season.



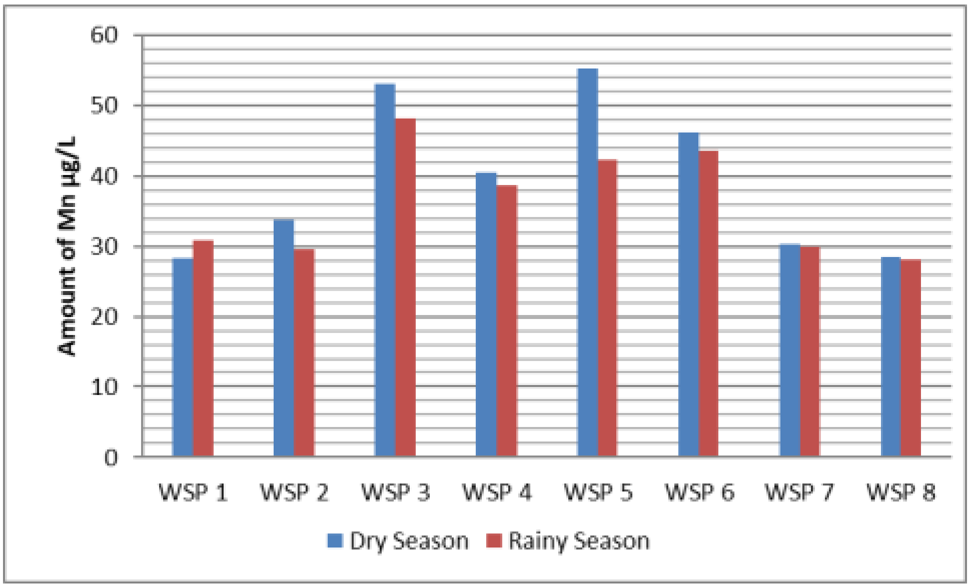
Bar charts showing seasonal variation on Arsenic

Nickel (µg/l):- The results of Nickel were found in the range of (43.00 µg/l to 69.00 µg/l) in the dry season. WSP1 had the higher value of (69.00 µg/l). This was followed by WSP2 (62.00 µg/l), WSP4 (57.30 µg/l), WSP6 (54.75 µg/l), WSP3 (53.50 µg/l), WSP5 (53.32 µg/l), WSP7 (46.80 µg/l) and WSP8 (43.00 µg/l) with the lowest value. The result ranged from (44.60 µg/l to 61.50 µg/l) in the rainy season. WSP6 had the highest value of (61.50 µg/l). This was followed by WSP2 (61.33 µg/l), WSP4 (60.13 µg/l), WSP1 (59.80 µg/l), WSP5 (58.61 µg/l), WSP3 (53.70 µg/l), WSP7 (45.40 µg/l) and WSP8 (44.60 µg/l) with the lowest value. Four sampling points recorded higher values in the dry season (WSP 1,2,4,7) and four sampling points in the rainy season WSP 3,5,6,8) Despite this, seasonal variation between the seasons remained insignificant. This coincided with the finding of Raji et-al (2016). As observed by Mercy and Mary (2021), all the results of Nickel across all the eight sampling points and two seasons were accommodated by WHO (2022) water quality standards.



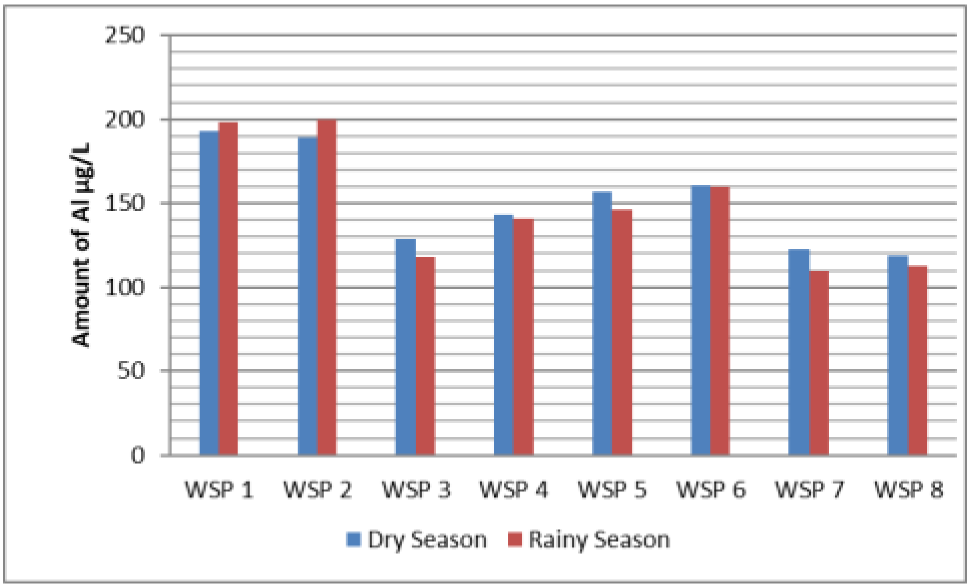
Bar charts showing seasonal variation on Nickel

Manganese (µg/l):- Results of Managanese ranged between (28.30 µg/l to 55.22 µg/l) in the dry season and (28.21µg/l to 48.10 µg/l) in the rainy season respectively. WSP 3,4,5,6,7 and 8 revealed higher values of Manganese in the dry season and lower values in the rainy season, while WSP 1 and 2 revealed higher values of Manganese in the rainy season and lower values in the dry season. This implied that, concentration of Manganese is higher in the dry season. However, the result of t-test showed insignificant seasonal variation between the two seasons. Comparison of Manganese result with the WHO (2022) water quality standards revealed that, all the water samples tested were within the recommended standards of (80 µg/l) in terms of Manganese. This finding coincided with that of Dogara, James and Manasch (2017) and contradicted that of Miftahu et-al (2022).



Bar charts showing seasonal variation on Manganese

Aluminium (µg/L) :- The mean concentration of Aluminium from the water samples were found in the range of (119 µg/L to 193 µg/l) in the dry season in the order WSP8 < WSP7 < WSP3 < WSP4 < WSP5 < WSP6 < WSP2 < WSP1, with point 1 having the highest value (193 µg/l) and point 8 having the lowest value (199 µg/l). The values ranged between (110 µg/l to 198.5 µg/l) in the rainy season in the order WSP7 < WSP8 < WSP3 < WSP5 < WSP4 < WSP6 < WSP1 < WSP2. Maximum values (198.5 µg/L) were found from point 2 and minimum values (110µm/l) were found from point 7. Sampling points 3, 5, 6,7 and 8 showed higher values of Aluminium in the dry season and lower values in the rainy season. On the other hand, points 1, 2 and 4, showed higher values of Alumimium in the rainy season and lower values in the dry season respectively. This implied that, concentration of Aluminium is slightly higher in the dry season. This finding conformed to that of Pari-Huaquisto et al (2020). However, the result of the t-test showed insignificant seasonal variation between the two seasons. With the exception of point 1 (201 µg/l in the rainy season), all the sampling points revealed values of Aluminium within the allowable limits of WHO (2022) water quality standard of (200 µm/l.)



Bar charts showing seasonal variation on total Aluminium

RESULTS

The heavy metals selected for the research (Copper, Zinc, Lead, Chromium, Mercury, Arsenic, Cadmium, Nickel, Manganese and Aluminium) were analysed using standard Atomic Absorption Spectrometry techniques. All the parameters were detected except Mercury and cadmium.

The values of Copper were found in the range of (1580 µg/l to 2133 µg/l) in the dry season and (1670 µg/l to 2120 µg/l) in the rainy season. Values of Copper were found higher in the rainy season in all the sampling points except sampling points 5, 7 and 8. The values of Copper across all the sampling points for the two seasons compared well with the WHO (2022) water quality standard of (2000 µg/l) except point 7 and 8. The result of the t-test showed insignificant seasonal variation between the two seasons. Concentration of Zinc were found in the range of (2334 µg/L to 3013 µg/l) in the dry season and (2240 µg/l to 3009 µg/l) in the rainy season. Sampling points 3, 5 and 7 showed higher values of Zinc in the rainy season and 1, 2, 4, 6 and 8 showed higher values of Zinc in the dry season. Concentration of Zinc is higher in the dry season. With the exception of point 2, all the points revealed Zinc values within the allowable limits of WHO (2022) water quality standard of (3000 µm/l.) The result of the t-test showed insignificant seasonal variation between the two seasons.

The concentration of lead was found in the range of (7.50 µg/l to 9.90 µg/l) in the dry season and (7.99 µg/l to 10.06 µg/l) in the rainy season. Values of Lead were found higher in the rainy season in all the sampling points except sampling points 5, 7 and 8. The values of Lead across all the sampling points for the two seasons compared well with the WHO (2022) water quality standard of (10 µg/l) except WSP 2 that deviated slightly from the standard of (10.06 µg/l.) The result of the t-test showed insignificant seasonal variation between the two seasons. The concentration of chromium according to the result varied from (25.10 µg/l to 53.20 µg/l) in the dry season and (25.07 µg/l to 49.36 µg/l) in the rainy season. The values of chromium were slightly higher in the dry season than in the rainy season. However, the result of t-test revealed that, there is insignificant seasonal variation in the quality of water in terms of Chromium between the two seasons. The results of chromium for all the seasons compared well with WHO (2022) water quality standards for heavy metals in drinking water except for WSP7 that deviated slightly with 53.20 µg/l in the dry season.

According to the results obtained, the values of Arsenic ranged from (6.90 µg/l to 10.10 µg/l) in the dry season and (7.10 µg/l to 10.36 µg/l) in the rainy season. Concentration of Arsenic across all the water sampling points was found to be higher in the rainy season. The results of t test on Arsenic between the two seasons showed insignificant seasonal variation. Comparison of the results of Arsenic with metallic water quality standards revealed that, all the results for both seasons conformed to WHO (2012) water quality standards of (10 µg/l). The only exception was WSP8 that deviated slightly from the standard with 10.10µg/l and 10.36µg/l in the dry and rainy seasons respectively. The results of Nickel were

found in the range of (43.00 µg/l to 69.00 µg/l) in the dry season and (44.60 µg/l to 61.50 µg/l) in the rainy season. Four sampling points recorded higher values in the dry season (WSP 1,2,4,7) and four sampling points in the rainy season WSP 3,5,6,8) Despite this, seasonal variation between the seasons remained insignificant. All the results of Nickel across all the eight sampling points and two seasons were accommodated by WHO (2022) water quality standards.
Results of Manganese ranged between (28.30 µg/l to 55.22 µg/l) in the dry season and (28.21µg/l to 48.10 µg/l) in the rainy season respectively. Concentration of Manganese is higher in the dry season. However, the result of t-test showed insignificant seasonal variation between the two seasons. Comparison of Manganese result with the WHO (2022) water quality standards revealed that, all the water samples tested were within the recommended standards of (80 µg/l) in terms of Manganese. The mean concentration of Aluminium was found in the range of (119 µg/L to 193 µg/l) in the dry season and (110 µg/l to 198.5 µg/l) in the rainy season. This implied that, concentration of Aluminium is slightly higher in the dry season. The result of the t-test showed insignificant seasonal variation between the two seasons. With the exception of point 1 (201 µg/l in the rainy season), all the sampling points revealed values of Aluminium within the allowable limits of WHO (2022) water quality standard of (200 µm/l.)

CONCLUSION

The quality of water varies slightly with the season. Some metals recorded maximum levels in the dry season and others were at their maximum in rainy season. The average values of Copper, Zinc, Lead, Arsenic and Nickel were found slightly higher in the rainy season than in the dry season. Those of Chromium, manganese and Aluminium were found slightly higher in the dry season than in the rainy season. According to the t-test conducted, all the metallic parameters analysed showed insignificant seasonal variation. Comparison of the results of parameters from eight sampling points studied revealed that, most of the parameters studied were found within the recommend levels of WHO (2022). Thus, most of the water sources were safe for human consumption in terms of heavy metals. It may be concluded that, heavy metals concentration in the study area varies insignificantly with the seasons and most of the water sources studied were found suitable for human consumption in terms of heavy metals.

RECOMMENDATIONS

- There is the need for regular monitoring and evaluation of heavy metals in water to ascertain their eligibility for human consumption and other uses.
- More treatment should be given to surface water sources especially during rainy season to meet the required standard.
- Boreholes should be maintained regularly, because many boreholes were not functioning during the research work.
- The research did not cover all the heavy metals in drinking water. There is need to carry out more researches on heavy metals in order to have wider coverage.
- Demand for water is increasing at an alarming rate due to rapid population growth in the town. More boreholes and reservoirs should be drilled or constructed across the study area in order to boost water supply to meet the current demand for water.

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