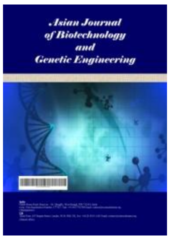

Asian Journal of Biotechnology and Genetic Engineering

5(1): 52-60, 2022; Article no.AJBGE.80597

Assessment of Heavy Metal Contamination and Physicochemical Parameters of Sachet Water Consumed in Bukuru Metropolis of Jos South Local Government Area of Plateau State, Nigeria

Y. Denkok [a*], V. G. Linus [a], U. S. Abara [b] and K. F. Oyebade [c]

[a] *Department of Biochemistry, Faculty of Basic Medical Sciences, University of Jos, Jos, P.M.B.2084, Nigeria.*
[b] *Federal School of Medical Laboratory Sciences, Jos Plateau State, Nigeria.*
[c] *Drug Development Unit, National Veterinary Research Institute, Vom Plateau State, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/80597

Original Research Article

Received 10 November 2021
Accepted 14 January 2022
Published 28 February 2022

ABSTRACT

Aim: The study investigated various concentrations of heavy metals present in some sachet water consumed in Bukuru metropolis of Jos South Local Government Area of Plateau State, Nigeria.
Materials and Methods: Twenty five (25) sachet water were obtained from different selling spots and were grouped into five according to their commercially christened names as: SW1, SW2, SW3, SW4 and SW5 with each of these groups having five samples. Metallic concentrations were analyzed using AAS and standard analytical procedure were used to assay for temperature, conductivity, dissolved oxygen, total dissolved solid and P^H.
Result: The results obtained from this study reveals that lead has a concentration of (0.73± 0.01, 0.75± 0.01, 0.68± 0.01, 0.75± 0.01 and 0.78± 0.01)ppm) for samples of SW1,SW2, SW3, SW4 and SW5 respectively. All of these concentration were relatively higher when compared to the WHO control. Zinc was detected at (0.003±0.2, 0.01±0.4, 008±0.5, 0.003±0.6 and0.005±0.2) ppm for SW1,SW2,SW3,SW4 and SW5 respectively. Iron was detected at (0.002±0.00, 0.03±0.00,

**Corresponding author: E-mail: ydenkok@gmail.com;*

0.05±0.01, 0.03±0.00 and 0.03±0.00) ppm for samples of SW1,SW2,SW3, SW4 and SW5 respectively Iron concentrations were relatively lower in all the samples when compared to the control. Chromium was detected at (0.195 ±0.01, 0.104±0.00, 0.149±0.00, 0.204±0.03 and 0.138±0.00) ppm for samples of SW1, SW2, SW3, SW4 and SW5 respectively. Chromium concentrations were significantly elevated in all the samples relative control. Different concentrations of cadmium were assayed at (0.670±0.01, 0.695±0.01, 0.670±0.00, 0.735±0.01 and 0.628±0.01) ppm for samples of SW1, SW2, SW3, SW4 and SW5 respectively. Cadmium levels were significantly higher in all the groups when compared to the control. Arsenic was detected at (0.160±0.00, 0.120±0.00, 0.320±0.00, 0.060±0.01 and 0.180±0.01) ppm for samples of SW1, SW2, SW3, SW4 and SW5 respectively. They were all significantly higher in concentration relative control. The conductivity, temperature, total dissolved solid and P^H values were lower when compared to the control.The dissolved oxygen concentrations were higher in all the water samples relative control.

Conclusion: The outcome of this investigation shows that the metallic characterization of the various branded sachet water do not meet the recommended standard due to elevated concentration of heavy metals beyond the permissible level. The physicochemical parameters were however, very low in concentration except for dissolved oxygen which was relatively high.

Keywords: Branded water; physicochemical; sachet water; assayed; ground water.

1. INTRODUCTION

Water is one of the most important elements for all forms of plant and animal life [1], and it comes from two main natural sources: Surface water includes freshwater lakes, rivers, streams, and other bodies of water. Borehole and well water are examples of groundwater [2]. Toxic chemicals and heavy metals enter rivers as a result of industrial and anthropogenic activity in metropolitan areas near river drainage basins [3].

Mining and smelting activities, dumping of untreated and partially treated effluents, metal chelates from various industries, and indiscriminate use of heavy metal-containing fertilizers and pesticides in agricultural fields are the main anthropogenic sources of heavy metal contamination [4]. Some metals are required for proper biological processes, such as calcium, magnesium, potassium, and sodium. Furthermore, cobalt, copper, iron, manganese, molybdenum, and zinc are required as catalysts for enzyme activity at low levels [5], but excessive exposure to heavy metals can cause toxicity.

Chemical and microbiological pollutants commonly pollute water sources, resulting in water-borne illnesses and disorders [6]. Improper industrial effluent disposal, which is ubiquitous in major African urban and rural areas, has resulted in substantial contamination of available fresh water sources, lowering the volume of safe agriculture, residential, irrigation, and drinking water [7].

In Nigeria, the packing of sachet water (packed groundwater), sometimes known as "clean water," has become a burgeoning industry. The sachet water sector is considered as a poverty alleviation industry for many Nigerians without work, according to the Nigerian government, which is preoccupied with poverty eradication [8]. The leaching of some undesired heavy metals into water sources was aided by sachet water packing materials, which can be harmful in high concentrations and cause acute or chronic health effects.

Cadmium and lead are hazardous heavy metals with extended retention periods that can build up in human tissue to dangerous levels. Cadmium has a half-life of 38 years in bone and is known to cause cancer. Its consumption in large quantities can be harmful to human health. Cadmium can build up in the kidneys and liver over time, and because of its long biological half-life, it can induce kidney damage [9]. The hexavalent form of chromium present in water is frequently carcinogenic and very poisonous [10].

Lead is present as metallic lead, lead salts, and lead inorganic ions and has no important function in humans. Food and water are two of the most common sources of lead poisoning. Lead is transported throughout the soft tissue, mineralizing tissue, and blood once it enters the bloodstream. Because of their quick growth and metabolism, children are particularly susceptible to lead [11].

Heavy metals are unbreakable, and the most of them are poisonous to aquatic life, animals, and humans [12]. Heavy metal can have major health consequences, with symptoms varying depending on the type and quantity of metal consumed [13]. They cause toxicity by building compounds with proteins that contain carboxylic acid (–COOH), amine (–NH2), or thiol (–SH) groups. These altered biological molecules lose their ability to operate normally, causing the cells to malfunction or die. Metals that bind to these groups inactivate key enzyme systems or alter protein structure, which is linked to enzyme catalytic characteristics. This type of toxin can also produce radicals, which are hazardous substances that cause biological components to oxidize [14].

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Equipment and reagents

Volumetric flask,conical flask, Beaker, washing bottle,pH meter(PHS-3C pH meter), Conductivity meter(Jenway 4510 conductivity meter), Atomic absorption spectrophotometer(Buck scientific 205 atomic absorption spectrophotometer), Manganous sulfate, Potassium iodide azide, Sulfuric acid.

2.1.2 Study area

The geology of the research region, which is 8600 km2 in size and is surrounded by 300-600m escarpments for much of its circle, falls within the Jos - Bukuru Complex, which is dominated by biotite-granite, according to [15]. The Jos Plateau's geology is dominated by the Precambrian Basement migmatite-gneissquartzite complex, which underpins roughly half of the state and has been intruded by Precambrian to late Paleozoic Pan-African granite (Older Granite), diorite, charnockite, and other minerals. The Jurassic anorogenic alkali Younger Granites are intrusive into these Basement Complex rocks [16]. Volcanic rocks such as basalts and rhyolites, as well as the Basement rocks, are associated with the Younger Granites and overlie or cross-cut this formation. Early Cenozoic (Tertiary) Older Basalts and Quaternary Newer Basalts are thought to have generated these volcanic rocks [17]. The majority of the sediments originated from denuded younger granitic rocks, resulting in rich detrital deposits of commercial minerals such as Cassiterite (tin ore), Columbite, and others (niobite-tantalite).

2.1.3 Collection of sample

In Bukuru, Jos South Local Government, Plateau State, samples (sachet water) for the study were acquired (bought) from various clean water selling spots. They're maintained at 25°C in the fridge until they're ready to be analyzed in the lab.

2.1.4 Sample digestion

The samples were digested with 5% concentrated nitric acid, HNO3, to ensure the elimination of organic contaminants and thus prevent interference in analysis. In a 250ml conical flask, 5ml of nitric acid was added to 250ml of water. In a water bath, the liquid was evaporated to half its volume, then allowed to cool before being filtered using a Whatman Filter Paper. The Buck Scientific 210 VGP Atomic Absorption Spectrophotometer was used to test the digested water samples for the presence of lead, zinc, iron, chromium, cadmium, copper, and arsenic.

2.2 Methods

2.2.1 Analyses of physicochemical parameter of the water samples

Analysis of physical parameters like the pH, conductivity**,** total dissolve solid, temperature and dissolve oxygen were done using the method described by [18].

2.2.2 Analyses of heavy metals

All the heavy metals were detected using atomic absorption photometer (AAS).

3. RESULTS AND DISCUSSION

This work sought to analyze the presence of some heavy metals in commercial sachet water consumed in Bukuru metropolis of Jos South Local Area of Plateau State, Nigeria. Heavy metals are generally toxic to the human body if detected in food or water sample at a certain concentration beyond what the body can tolerate.

The result of this investigation shows that the concentration of lead in SW1, SW2, SW3,SW4 and SW5 were found to be 0.730±0.01, 0.750±0.01, 0.680±0.01, 0.750±0.01 and 0.780±0.01 respectively. SW5 has the highest concentration of lead, whereas SW3 has the lowest. However, as compared to the control, all of these concentrations were shown to

Table 1. Results of some heavy metal analyses of sachet water consumed in Bukuru metropolis of Jos South Local Area of Plateau State, Nigeria

Sample	Pb(ppm)	Zn(ppm)	Fe(ppm)	Cr(ppm)	Cd(ppm)	As(ppm)
CONTROL	0.020±0.00	5.00	3.00±0.00	0.05±0.00	0.003±0.00	0.01±0.00
SW1	0.730 ±0.01[b]	0.003±0.20[a]	0.002±0.00[a]	0.195±0.01[b]	0.670.01[b]	0.160±0.00[b]
SW2	0.750±0.01[b]	0.001±0.40[a]	0.030±0.01[a]	0.104±0.00[b]	0.695±0.01[b]	0.120±0.01[b]
SW3	0.680±0.01[b]	0.008±0.60[a]	0.050±0.01[a]	0.149±0.00[b]	0.670±0.00[b]	0.320±0.00[b]
SW4	0.750±0.01[b]	0.003±0.40[a]	0.030±0.00[a]	0.204±0.03[b]	0.735±0.01[b]	0.06±0.01[b]
SW5	0.780 ±0.01[b]	0.005±0.50[a]	0.030±0.00[a]	0.138±0.00[b]	0.628±0.01[b]	0.180±0.01[b]
P-VALUE	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Values are expressed as mean ± SEM, n = 3. If p value is less than 0.05, there is significant difference in mean values.
a Values are significantly low when compared with control (P= 0.05)
b Values are significantly high when compared with control (P= 0.05)

Table 2. Results of physico-chemical parameters analyses of sachet water consumed in Bukuru metropolis of Jos South Local Government Area of Plateau State, Nigeria

Sample	Conduct. (us)	Temp.(^{0}C)	TDS(mg/L)	pH	DO (ppm)
CONTROL	500±0.00	30.32±0.00	259±0.00	8.5±0.00	7.5±0.00
SW1	4.62±0.11[a]	25.20±0.28[a]	4.21±0.02[a]	5.32±0.21[a]	9.13±0.21[b]
SW2	6.11±0.10[a]	25.50±0.32[a]	4.05±0.05[a]	5.21±0.15[a]	8.40±0.20[b]
SW3	5.61±0.04[a]	25.27±0.22[a]	4.33±0.12[a]	5.22±0.10[a]	13.02±0.06[b]
SW4	2.24±0.04[a]	25.23±0.11[a]	2.97 ±0.26[a]	5.05±0.23[a]	11.07±0.06[b]
SW5	6.235±0.05[a]	25.60±0.20[a]	3.23±0.14[a]	5.45±0.20a	8.44±0.31[b]
P-VALUE	<0.0001	0.4319	0.0027	0.3494	<0.000

Values are expressed as mean ± SEM, n = 3.
If p value is less than 0.05, there is significant difference in mean values.
[a] Values are significantly low when compared with control (P= 0.05)
[b] Values are significantly high when compared with control (P= 0.05)

be considerably greater. Lead is also used in lead acid batteries, solder, alloys, cable sheathing, pigments, rust inhibitors, ammunition, glazes, and plastic stabilizers, among other things. Because of their widespread use as antiknock chemicals in gasoline, tetraethyl and tetramethyl lead are important [19]. Anemia is caused by the disruption of haemobiosynthesis and the acceleration of red blood cell death caused by lead intoxication. Both are dose-dependent. Lead has also been shown to reduce sperm count [20]. Furthermore, Pb has the potential to harm the kidneys, liver, neurological system, blood vessels, and other tissues [21]. Humans are poisoned by lead, which can enter water by contact with the ground, industrial waste, or water piping. Lead is a cumulative poison, and at a dosage of 10 g/day, it has been known to cause 'plumbism,' or lead poisoning [22]. It has a negative impact on the organs and tissues it comes into contact with. Excess lead in the human body can cause everything from a low IQ in youngsters to high blood pressure in adults, according to [23]. Because of its toxicity, lead entering the food chain is a big problem. The effects of lead on haem biosynthesis and erythropoiesis are significant [24]. It can harm the kidneys and induce chronic poisoning symptoms in humans, such as hepatic dysfunction, decreased intelligence quotient [25], sluggish growth, behavioral abnormalities, hearing difficulties, and cognitive functions. Lead inhibits the activity of three enzymes: indirectly stimulates the mitochondrial enzyme -aminolevulinic acid synthetases; directly inhibits the cytoplasmic -aminolevulinic acid dehydratase; and interferes with the normal functioning of intra-mitochondrial ferrochelatase, which inserts iron (II) into the protoporphyrin ring. Chronic Pb poisoning frequently results in anemia [26].

Concentrations of cadmium in the sachet water samples were discovered to be 0.0670±0.01, 0.695±0.01, 0.670±0.00, 0. 735±0.01 and 0.628±0.01 for samples SW1, SW2, SW3, SW4 and SW5 respectively. These concentrations were statistically higher than that of the control group. This finding is in line with the findings of [27]. Cadmium is primarily utilized as an anticorrosive and is electroplated on steel. In polymers, cadmium sulphide and selenide are often employed as pigments. It's also found in electric batteries, electronic components, and inorganic fertilizers made from phosphate ores, which are a significant source of diffuse cadmium pollution [28]. Furthermore, cadmium accumulates in the colon, liver, and kidneys when consumed by humans. The renal cortex is thought to be the most sensitive organ in the body. Cadmium binds significantly to organic materials and sediments [29]. Cadmium has a number of deleterious physiological impacts on organisms, including slowing growth rates and disrupting embryonic development [30].

Levels of Arsenic were detected at 0.160±0.00, 0.120±0.01, 0.320±0.00, 0.06±0.01 and 0.180 ±0.01 for samples SW1, SW2, SW3, SW4 and SW5 respectively. All of these concentrations were significantly raised compared to that of the control.Arsenic is an extremely hazardous metalloid element discovered in the greatest concentration sample SW3 [31]. Insecticide, herbicide, and weed killer residues are all possible sources of arsenics. Inorganic Weed killers such as sodium arsenite have been routinely utilized in the past. Another possible cause is the burning of construction trash around the river, such as paint cans and processed wood.Because of its germicidal properties and capacity to resist wood rot and decay, arsenic is utilized in antifouling paints and antifungal wood preservatives. These chemicals' abandoned wastes and residues might interact with soil and subsequently be swept into rivers during rainstorms. Fertilizer application to fields near rivers may also be contributing to the higher levels of Arsenic detected [32].

Levels of Chromium were detected to be at 0.195±0.00, 0.104 ±0.00, 0.149±0.00, 0.204±0.03,0 .138±0.00, for samples SW1,SW2, SW3, SW4, and SW5 respectively. Chromium was found to be elevated in samples of SW1 and SW4 when compared to the control group with the least concentration SW2.Chromium and its constituents have been linked to lung, nasalcavity, and paranasal sinus cancers, as well as stomach and laryngeal cancers [33]. Chromium (III) is an essential component that aids the body's utilization of sugar, protein, and fat [34]. However, chromium (III) can easily be oxidized to chromium (VI) compounds, which are harmful to human health, under particular environmental conditions [35] and metabolic transformations. Waste containing lead-chromium batteries, colorful polythene bags, discarded plastic items, and empty paint containers could be sources of Cr in this water sample [36]. Natural Cr compounds are usually trivalent (Cr (III)); they serve as micronutrients for humans and play an important role in lipid and sugar metabolism [37]. However, anthropogenic activities can discharge hexavalent Cr quantities into bodies of water, which have been classified as carcinogenic to human health by many regulatory and non-regulatory organizations [38].

Iron was detected in all the samples of the sachet water at a concentration lower than that of the permissible level of the WHO. Other studies have shown that iron concentration were detected at higher concentration relative control. This studies does not agree with previous studies reported by [39] that reported high concentrations of iron in sachet water.High levels of iron in drinking water can change the appearance, taste, and odor of water, as well as stimulate bacteria development in the water system [40].

The result of this investigations shows that zinc is detected at different concentrations of 0.003±0.20, 0.001±0.40, 0.008±0.60, 0.003±0.40 and 0.005±0.50 for water samples SW1, SW2, SW3, SW4 and SW5 respectively. This contradicts the findings of [41], who found that sachet water in Abuja, Nigeria, contains a significant concentration of zinc when compared to our investigation, but that the concentration is within the SON and WHO permissible levels, and that higher zinc concentrations in water cause stringent tastes in water, which are essentially undesirable.

Electrical conductivity is a measurement of a liquid's ability to conduct an electric current. It is connected to the amount of dissolved minerals in the water, although it does not reveal which element is present. It has something to do with the total amount of ionized compounds in water [42]. The mean electrical conductance of sachet water from our investigations reveals a values of 4.62±0.11, 6.11±0.10, 5.61±0.04, 2.24±0.04 and 6.24±0.05 for samples SW1, SW2, SW3, SW4 and SW5 respectively.The value of E.C is considerably too low when compared to the WHO suggested maximum of 1000 scm-1 for drinking water. According to [43], a low E.C value indicates the presence of a little amount of dissolved calcium, magnesium, and fluoride salts in water. Long-term consumption of packaged water with an E.C value less than 40 scm-1 carries a number of health hazards, including increased fracture risk in children, pregnancy problem (preeclampsia), diuresis, premature or low baby weight at birth, and teeth rot [44].

Temperature values from our investigation were found to be 25.20±0.28, 25.50±0.32, 25.27±0.22, 25.23±0.11 and 25.60±0.20 ^{0}C for samples SW1, SW2, SW3, SW4 and SW5 respectively. Temperature of sachet water in all the groups are within the accepted levels.Temperatures in this range are ideal for the maximal growth of mesophyll bacteria, including those that cause human illnesses. With time, this process has a propensity to encourage the formation of an unpleasant taste and odor in water [45].

The salinity behavior of ground and surface water is determined by total dissolved solids. Vegetable degradation, evaporation, effluent discharge, and chemical weathering of rocks are the principal sources of total dissolved solids in water [46]. The total dissolved solids (TDS) for sachet water were determined to be 4.21±0.02, 4.05±0.05, 4.33±0.12, 2.97±0.26 and 3.23±0.14 for samples SW1, SW2, SW23, SW4 and SW5, respectively, according to this investigation.All the outcome were within the permissible level for consumption in drinking water relative control. Our investigation shows that all the sachet water do not contain any suspension/particle of solid in them, which clearly agrees with the findings of [47].

The pH is used to measure the amount of pollution caused by acidic or basic wastes. For samples SW1, SW2, SW3, SW4, and SW5, the mean pH of the various sets of water samples studied was determined to be 5.32±0.21, 5.21±0.15, 5.22±0.10,5.05±0.23, and 5.45±0.20, respectively. All of the sample groups' PH values were within the WHO's suggested range of 6.5 to 8.5. It is critical to emphasize that packed water samples with pH values within regulatory guidelines have no risk of causing health problems such as acidosis [48].

The values of Dissolved Oxygen (DO) were investigated at 9.13±0.21, 8.40±0.20, 13.02±0.06, 11.07±0.06 and 8.44±0.31 for samples SW1, SW2, SW3, SW4 and SW5 respectively. The amount of dissolved oxygen in water is a good predictor of its quality. Its importance as a respiratory gas and its usage in biological and chemical reactions account for this. Oxidation-reduction reactions involving iron, manganese, copper, and nitrogen and sulphur compounds are predominantly affected by dissolved oxygen in water. The amount of dissolved oxygen in water is determined by the source, temperature, and chemical and biological processes occurring in the water distribution system. Large drops in dissolved oxygen in water, on the other hand, could suggest significant levels of microbiological activity and should prompt further microbe sampling [49]. Because the acceptability of low amounts of dissolved oxygen is dependent on the availability of other water constituents, no guideline value is advised [50].

4. CONCLUSION

From the result of this investigation, all the randomly obtained sachet water were contaminated with heavy metals like lead, chromium, cadmium and arsenic. Iron and zinc were detected at levels which were within the permissible level for drinking water all in the sachet water samples. The physico-chemical parameters were detected at a level that is non-toxic to the body. These sachet water should be recommended for proper quality control by the relevant government authorities to reduce the heavy metals to a level that is non -toxic to the body before consumption.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Vanloon GW, Duffy SJ. The hydrosphere. In: Environmental Chemistry: A Global Perspective. 2nd Edn. New York: Oxford University Press. 2005;197-211.
2. Mendie U. The Nature of Water. In: The Theory and Practice of Clean Water Production for Domestic and Industrial Use. Lagos: Lacto-Medals Publishers. 2005;1-21.

3. Ibukun MA , Mary BJ, Omolara T A, Anthony O. Concentrations and human health risk of heavy metals in Rivers in Aderemi Okunola OgunfowokanSouthwest Nigeria. J Health Pollut. 2018 Sep; 8(19):180907.
4. Reza R, Singh G. Assessment of heavy metal contamination and its indexing approach for river water. Int J Environ Sci Technol. 2010 Sep;7(4):785–92.
5. Adepoju-Bello, AA, Ojomolade OO, Ayoola GA, Coker, HAB. Quantitative analysis of some toxic metals in domestic water obtained from Lagos metropolis. The Nig. J. Pharm. 2009;42(1): 57-60.
6. United States Environmental protection Agency, Is your drinking water safe? Office of water (WHO-550), Washington D.C. 2001;37:31-91.
7. Ezeh E, Okeke O, Aniobi CC, Okeke MU. Comparative assessment of the physicochemical and heavy metal contents of borehole and sachet water consumed In Aba Metropolis, Abia State. Journal of Chemical, Biological and Physical Sciences. 2019; 9(3):181-189.
8. Orish EO, Innocent OI, Onyenmechi, JA, John-Moses EO, John CN. Heavy metal hazards of sachet water in Nigeria. Archives of Environmental & Occupational Health. 2006;61(5):220-235
9. Lauwerys RR. Health effects of cadmium. In: Di Ferrante E, ed. Trace Metals: Exposure and Health Effects. Oxford, England: Pergamon Press. 1979;43–64.
10. WHO. Evaluation of certain food contaminants. 61st report of the Joint FAO/WHO Expert Committee on Food Additives. WHO Technical Report Series, 2004;922. World Health Organization, Geneva.
11. ATSDR – Agency for Toxic Substances and Disease Registry. Draft Toxicological profile for cadmium. United States Department of Health and Human Services, Public Health Human Services, Centre for Disease Control, Atlanta; 2008.
12. Aladesanmi OT, Adeniyi IF, Adesiyan IM. Comparative assessment and source identification of heavy metals in selected fishpond water, sediment and fish tissues/organs in Osun State, Nigeria. J Health Pollut. 2014;4(7):42–53.
13. Adepoju-Bello AA, Alabi OM. Heavy metals: A review. The Nig. J. Pharm. 2005;37:41-45.
14. Falconer JD: The geology and geography of northern Nigeria. Macmillan, London; 1921.
15. Falconer JD. The geology of the plateau tin fields. Bull. Geol. Survey Nigeria Kaduna.1921;4.
16. MacLeod WN, Berridge NG. Geology of the Jos Plateau. Bull. Geol. Surv. Nigeria. 1971;2(32).
17. Bakare-Odunola, MT. Determination of some metallic impurities present in soft drinks marketed in Nigeria. The Nig. J. Pharm.2005; 4(1): 51-54.
18. APHA. Standard for the examination of water and waste water, 18th Edition. American Public Health Association (APHA).American Water Works Association (AWWA) and Water Pollution Control Federation (WPCF) Washington, D.C. 1998;10-195.
19. WHO.Guidelines for Drinking Water Quality. 3rd Edn. World Health Organization, ISBN: 92- 4-154638-7. 2004;516.
20. Anglin-Brown B, Armour-Brown A, Lalor GC. Heavy metal pollution in Jamaica 1: Survey of cadmium, lead and zinc concentrations in the Kintyre and hope flat districts. Environ. Geochem. Health.1995;17: 51-56.
DOI: 1 0.1007/BF00146708.
21. Sanders MJ, Preez HH, Van vuren, JHJ. Monitoring cadmium and zinc contamination in fresh water systems with the use of the freshwater crab, *Potamanautius warrenii*. Water SA. 1999; 25(1): 91-98.
22. Odum HT. Back ground of published studies on lead and wetland. In: Howard T. Odum (Ed), Heavy metals in the environment using wetlands for their removal, Lewis Publishers,New York USA. 2000;32.
23. Ottaway JH. The biochemistry of pollution. Come Lot Press London. 1978; 231.
24. Tadele E. Ariyala H. Health risk assessment of heavy metals in locally produced Beer to the population in Ethiopia.J of Bioanal Biomed. 2014;6(6):12-16.
25. Silva ALO, Barrocas PRG, Jacob SC, Moreira JC. Daily intake and health effects of selected toxic elements. Brazilian Journal of Plant Physiology. 2005;17:79-93.
26. Schwartz, J. Low-level lead exposure and children’s intelligence Quotient: A Metal

analysis and search for a threshold. Environmental Research. 1994;65:42-55.

27. Denkok Y, Adesina O, Gurumtet I, Kopdorah SW. An evaluative study on metallic concentration in different ground and industrial water sources in Jos South Local Government Area of Plateau State, Nigeria. Asian Journal of Biochemistry, Genetics and Molecular Biology. 2001;7(1):25-33.
28. Eaton AD. Standard Methods for the Examination of Water and Waste Water. 21st Edn. American Public Health Association, Washington. 2005;343-453.
29. Sanders MJ, Preez HH, Van vuren, JHJ. Monitoring cadmium and zinc contamination in fresh water systems with the use of the freshwater crab, *Potamanautius warrenii*. Water SA. 1999; 25(1): 91-98.
30. Newman MC, Mcintosh AW. Metal ecotoxicology: Concepts and applications. Lewis Publishing, Michigan. 1991; 399.
31. Pizzaro I, Gomez M, Camara C, Palacios MA. Arsenic speciation in environmental and biological samples –Extraction and stability studies. Anal. Chim. Acta. 2003;495:85-98.
32. Chung JY, Yu SD, Hong YS. Environmental source of arsenic exposure. J Prev Med Public Health. 2014 Sep;47(5):253–257
33. ATSDR, Agency for Toxic Substances and Disease Registry. Toxicological Profile for Chromium. Atlanta, GA: U.S. Department of Health and Human Service, Public Health Service. 1600 Clifton Road N.E, E-29 Atlanta, Georgia. 2000;(6-9):95-134.
34. Hati SS, Joseph CA, Ogugbuaja VO. Comparative assessment of chromium discharge in Tannery wastewater in Kano State, Northern Nigeria. Proceed. of the 28th Ann. Int. Confer. CSN. 2005;2(1):137-13.
35. Awan AM, Baigl MA, Igbal J, Aslam MR, Ijaz N. Recovery of chromate form tannery waste water. Electron. J. Environ. Agric. Food Chem. 2003;2(5):543-548.
36. Jung H, Katayama I, Jiang Z, Hiraga T, Karato S. Effect of water and stress on the lattice-preferred orientation of olivine. Tectonophys. 2006;421:1–22.
37. Oliveira H. Chromium as an environmental pollutant: insights on induced plant toxicity. J Bot. 2012;1–8.
38. Tchounwou PB, Yedjou CG, Patlolla AK, Sutton DJ. Heavy metal toxicity and the environment. 2012;101:133–64.
39. Chaitali VM, Jayashree D. Review of heavy metals in drinking water and their effect on human health. International Journal of Innovative Research in Science, Engineering and Technology. 2013;2(7):1-8.
40. Ling MP, Hsu HT, Shie RH, Wu CC, M Hong YS. Health risk of consuming heavy metals in farmed Tilapia in Central Taiwan. Bull Environ Contam Toxicol. 2009;83:558 564.
41. Hati SS, Joseph CA, Ogugbuaja VO. Comparative assessment of chromium discharge in Tannery wastewater in Kano State, Northern Nigeria. Proceed. Of the 28th Ann. Int. Confer. CSN. 2005;2(1):137-13.
42. SO Adewoye, AO Adewoye, OA. Opesila and JA. Elepede. Physicochemical parameters and heavy metal analysis of water samples from hand dug wells in Gambari, Ogbomoso, Oyo State, IOSR Journal of Environmental Science, Toxicology and food Technology. 2013;5(1):22-30.
43. Ndinwa CCG, Chukumah OC, Edafe EA, Obarakpor KI, Morka WPN. Osubor-Ndinwa, Journal of Environmental Management and Safety. 2012;3(2):145 – 160.
44. Guler C, Alpaslan M. Mineral content of 70 bottled water brands sold on the Turkish market: Assessment of their compliance with current regulations, Journal of Food Composition and Analysis. 2009;22:728–73.
45. Isikwue MO, Chikezie A. Quality assessment of various sachet water brands marketed in Bauchi Metropolis of Nigeria. International Journal of Advances in Engineering & Technology. 2014;6(6) 2489-2495.
46. Okoro N, Omeje EO, Osadane PO. Comparative analysis of three borehole water sources in Nsukka urban area, Enugu State, Nigeria. Resources and Environment. 2017;7(4):110-114.
47. Mustapha D, Ibrahim MU, Akindele A. Qualitative assessment of sachet and bottled water marketed in Bauchi Metropolis, Nigeria. Chemical and Process

Engineering Research. 2015;37. ISSN 2224-7467.
48. Asamoah, DN, R. Amorin. Assessment of the quality of bottled/sachet water in the Tarkwa-Nsuaem municipality (TM) of Ghana. Res. J. Appl. Sci. Eng. Technol. 2011;3(5):377-385.
49. Sunday OO, Adewale SA, Adeleke WO. Determination of Shelf Life of Selected Sachet Water in Ogbomoso, Oyo State Nigeria. Journal of Engineering and Technology. 2016;1(!):2579-0625.
50. Horne AJ, Goldman CR.Limnology, 2nd edition. McGraw-Hill, Inc. 1994;576.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/80597