Original Research Article

Assessment of Heavy Metal Contamination and Physicochemical Parameters of Sachet Water Sold in Bukuru Market of Jos south Local Area of Plateau State, Nigeria

ABSTRACT

Aim: This study investigated various concentrations of heavy metals present in some sachet water sold in Bukuru market 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 (Add the units of these value) 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±0.4,0, 008±0.5,0.003±0.6,and0.005±0.2for SW1,SW2,SW3,SW4 and SW5 respectively. Iron was detected at 0.002±0.00, 0.03±0.00, 0.05±0.01, 0.03±0.00 and 0.03±0.00 for samples of SW1,SW2,SW3, SW4 and SW5 respectively Iron concentrations were relatively lowered 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 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 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 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. However, the dissolved oxygen concentrations were higher in all the water samples relative control. **Conclusion**: The findings of this investigation revealed that the metallic characterization of the various branded sachet water do not meet the recommended standard due to high 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.

Key word: Branded water, physicochemical, sachet water, assayed, ground water.

INTRODUCTION

Water is one of the essentials that supports all forms of plant and animal life [1] and it is generally obtained from two principal natural sources; Surface water such as fresh water lakes, rivers, streams, etc. and Ground water such as borehole water and well water [2]. Toxic chemicals and heavy metals enter rivers through industrial and anthropogenic activities of urban settlement around the drainage basin of rivers [3].

The main anthropogenic sources of heavy metal contamination are mining and smelting activities, disposal of untreated and partially treated effluents, metal chelates from different industries and indiscriminate use of heavy metal-containing fertilizers and pesticides in agricultural field [4]. Some of the metals are essential to sustain life-calcium, magnesium, potassium and sodium must be present for normal body functions. Also, cobolt, copper, iron, manganese, molybdenon and zinc are needed at low levels as catalyst for enzyme activities [5], however, excess exposure to heavy metals can result in toxicity.

Pollution of water bodies are usually caused by chemical and microbial contaminants which leads to water- borne infections and diseases [6]. Improper dispersal of industrial effluents which is most common in major African urban and rural centres have led to heavy contamination of available fresh water sources reducing the volume of safe agriculture, domestic, irrigation and drinking water [7]

The packaging of sachet water (packaged groundwater), popularly known as “pure water,” has become a booming business in Nigeria. In the view of the Nigerian government, whose preoccupation is poverty eradication, the sachet water industry is seen as a poverty alleviation industry for many Nigerians without jobs [8].Sachet water packaging materials contributed to the leaching of some undesirable heavy metals into the water sources which when in high concentration can be toxic and can cause acute or chronic health effect.

Cadmium and lead are toxic heavy metals with long retention times; they can accumulate to a significant extent in human tissue. Cadmium may have a half-life in bone of 38 years and it has carcinogenic properties .Its intake in relatively high amounts can be detrimental to human health. Over a long period of intake, cadmium may accumulate in the kidneys and liver and, because of its long biological half-life, may lead to kidney damage [9].Chromium found in water is usually in the hexavalent form which is carcinogenic and highly toxic [10].

Lead has no essential function in man and it can be found occurring as metallic lead, lead salts and lead inorganic ions. Food and water are some of the major sources of lead exposure. Once in the blood stream, lead is distributed among the soft tissue, mineralizing tissue and blood. Children are more sensitive to lead because of their rapid growth rate and metabolism [11].

Heavy metals are indestructible and most have toxic effects on aquatic organisms, animals and humans [12]. Heavy metal can cause serious health effects with varied symptoms depending on the nature and quantity of the metal ingested [13]. They produce their toxicity by forming complexes with proteins, in which carboxylic acid (–COOH), amine (–NH2), and thiol (–SH) groups are involved. These modified biological molecules lose their ability to function properly and result in the malfunction or death of the cells. When metals bind to these groups, they inactivate important enzyme systems or affect protein structure, which is linked to the catalytic properties of enzymes. This type of toxin may also cause the formation of radicals which are dangerous chemicals that cause the oxidation of biological molecules [14].

MATERIALS AND METHODS

2. 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 study area which is 8600 km² and bounded by 300-600m escarpments around much of its circumference, falls within the Jos - Bukuru Complex which is predominantly of biotite- granite type as exhaustively studied by [15], The geology of the Jos Plateau is made-up of the Precambrian Basement migmatite-gneissquartzite complex which underlies about half of the entire State and in some places has been intruded by Precambrian to the late Paleozoic Pan-African granite (Older Granite), diorite, charnockite etc. Intrusive into these Basement Complex rocks are the Jurassic anorogenic alkali Younger Granites [16]. In association with the Younger Granites are volcanic rocks such as basalts and rhyolites that overlie or cross-cut this formation as well as the Basement rocks. These volcanic rocks are believed to have been formed during the early Cenozoic (Tertiary) Older Basalts and Quaternary Newer Basalts [17]. Most of the sediments were formed from denuded younger granitic rocks which brought about the rich detrital deposits in economic minerals like; Cassiterite (tin ore), Columbite (niobite-tantalite).

2.1.3 Collection of Sample

Samples (sachet water) for the study were collected (purchased) from various pure water selling spots in Bukuru, Jos South Local Government,Plateau State. They are kept in the refrigerator at 25^{O}C Temperature for onward analysis in the laboratory.

2.1.4 Sample Digestion

To ensure the removal of organic impurities from the samples and thus prevent interference in analysis, the samples were digested with 5% concentrated nitric acid, HNO3. 5ml of nitric acid was added to 250ml of water in a 250ml conical flask. The mixture was evaporated to half its volume in a water-bath after which it was allowed to cool and then filtered using a Whatman Filter Paper. The digested water samples were analyzed for the presence of Lead, Zinc, iron, Chromium, Cadmium, Copper and arsenic using the Buck Scientific 210 VGP Atomic Absorption Spectrophotometer.

2.2 METHODS

2.2.1 Analyses of Physicochemical Parameter of the Water Samples.

2.2.1.1 Determination of pH

The pH of the water samples was measured by using a pH meter (model PHS-3C pH meter). The pH meter was calibrated, with a known standard solutions of (pH 4.0, 7.0, and 10.0), before taking the measurements. The value of each sample was taken after submerging the pH probe in the water sample and holding for a couple of minutes to achieve a stabilized reading. After the measurement of each sample, the probe was rinsed with deionized water to avoid cross contamination among different samples.

2.2.1.2 Determination of Conductivity.

The conductivity of the samples was measured using a conductivity meter (model Jenway 4510 conductivity meter). The probe was calibrated using a standard solution with a known conductivity. The probe was submerged in the water sample and the reading was recorded after the disappearance of stability indicator (**Indicate the stability indicator used?).** After the measurement of each sample, the probe was rinsed with deionized water to avoid cross contamination among different samples.

2.2.1.3 Determination of Total Dissolve Solid.

The conductivity of the samples was measured using a conductivity meter (model Jenway 4510 conductivity meter.). The probe was calibrated using a standard solution with a known conductivity. The probe was submerged in the water sample and the reading was recorded after the disappearance of stability indicator. After the measurement of each sample, the probe was rinsed with deionized water to avoid cross contamination among different samples.

2.2.1.4 Determination of Temperature.

The conductivity of the samples was measured using a conductivity meter (model Jenway 4510 conductivity meter.). The probe was calibrated using a standard solution with a known conductivity. The probe was submerged in the water sample and the reading was recorded after the disappearance of stability indicator (**Repetition**). After the measurement of each sample, the probe was rinsed with deionized water to avoid cross contamination among different samples.

2.2.1.5 Determination of Dissolve Oxygen.

The dissolve oxygen (DO) was measured using wincler? titration method. (Kid model Lamotte dissolve oxygen 5860-01). Sample bottle was filled with the water sample making sure that no air bubbles trapped inside. Eight drops of manganous sulfate solution (4167 **What is this number ?)** and eight drops of alkaline potassium iodide azide (7166 **What is this number ?)** were added. The bottle was cap and mixed by inverting several times, a precipitate was formed. The solution was allowed to settle below the shoulder of the bottle. Eight (8) drops of sulfuric acid 1:1 (6141WT) was added. The bottle was cap and gently mixed the content by inversion until the precipitate and the reagent were totally dissolved. The solution turned orange which indicates that dissolve Oxygen was present. The titration tube was filled to 20mL line with the fixed sample and caped, the cap was removed and the titrator was inserted to the top of sodium thiosulfate, 0.025N (4169) titrating solution. The Bottle was inverted and the solution was withdrawn slowly until it reached zero mark on the titrator. The tip of the titrator was inserted into the opening of the titration tube cap, slowly depressed the plunger to dispense the titrating solution until the yellow-brown colour? changes to very pale yellow. The tube was gently swirled during the titration to mix the contents. Eight drops of starch indicator solution was added and the sample turned blue. The tip of the titrator? was inserted into the opening of the titration tube and the titration continues until the blue colour? disappeared and the solution turned colour? less. The results were read directly from the scale where the large on the titrator? meets the titrator ? barrels. Results were recorded in part per million (ppm).

2.2.2 Analyses of Heavy Metals

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

RESULTS AND DISCUSSION

3.1 RESULTS

Table 1: Results of Some Heavy Metal Analyses of Sachet Water Sold in Bukuru Market 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 sold in Bukuru Market of Jos South Local Government Area of Plateau State, Nigeria.

Sample	Conduct. (Us)	Temp.(^{O}C)	TDS(mg/L)	P^H	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)

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±0.01and0.780±0.01 respectively. Lead has the highest concentration in SW5 and least concentration in SW3. However, all these concentrations were found to be significantly higher when compared to the control .Lead is also used in the production of lead acid batteries, solder, alloys, cable sheathing, pigments, rust inhibitors, ammunition, glazes and plastic stabilizers. Tetraethyl and tetramethyl lead are important because of their extensive use as antiknock compounds in petrol [18]. Lead toxicity leads to anaemia both by impairment of haemobiosynthesis and acceleration of red blood cell destruction. Both are dose related. Lead also depresses sperm count [19]. In addition, Pb can also produce a damaging effect on the kidney, liver and nervous system, blood vessels and other tissues [20].Lead is toxic to humans and may originate in water from contact with the ground, industrial wastes and from water piping itself. Lead is a cumulative poison (**add one or more references to the accumulation and availability of lead in humans) add one or more references to the accumulation and availability of lead in humans)** and has been known to cause ‘plumbism’ or lead poisoning at a concentration of 10 g/day (**Add a reference**). It produces damaging effects on the organs and tissues to which it comes into contact. The consequences of excess lead in the human body range from low intelligent quotient in children and high blood pressure in adults by [21].

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 [22].Cadmium metal is used mainly as an anticorrosive and electroplated on steel. Cadmium sulphide and selenide are commonly used as pigments in plastics. It is also used in electric batteries and in various electronic components and inorganic fertilizers produced from phosphate ores which constitute a major source of diffuse cadmium pollution [23]. Moreover, when ingested by humans, cadmium accumulates in the intestine, liver and kidney. The kidney cortex is regarded as the most sensitive organ. Cadmium adsorbs strongly to sediments and organic matter [24]. Cadmium has a range of negative physiological effects on organisms such as decreased growth rates and negative effects on embryonic development [25].

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 a highly toxic metalloid element [26] and is found to occur in the highest concentration sample SW3. Possible sources of Arsenics include residues from insecticides, herbicides and weed killers. Inorganic As compounds such as sodium arsenite have been widely used as a weed killer. Another probable source is from the burning of construction wastes such as paint cans and processed woods around the river. Arsenic is used in antifouling paints and in antifungal wood preservatives due to its germicidal power and ability to resist wood rot and decay. The discarded wastes and residues from these chemicals can interact with soil and then be washed into the rivers during rainfall. Fertilizer application to farmland around the rivers may also contribute to the increased level of observed Arsenic [27].

Levels of Chromium (**Cr^{III} ? Or Cr^{VI}? Their existence depends on the pH of the water Explain the stability of Cr^{III} ? Or Cr^{VI} ?**) 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 compounds are known to cause cancer of the lung, nasalcavity and paranasal sinus and suspected to cause cancer of the stomach and larynx [28]. Chromium (III) had been described as an essential nutrient that helps the body use sugar, protein, and fat [29]. However, under certain environmental conditions [30] and certain metabolic transformations, chromium (III) may readily be oxidized to chromium (VI) compounds that are toxic to human health. Sources of Cr in this water sample could be due to waste consisting of lead-chromium batteries, colored polythene bags, discarded plastic materials and empty paint containers [31]. Natural Cr compounds are generally in the trivalent state (Cr (III)); they function as micronutrients for humans and play a vital role in the metabolism of lipids and sugars [32].Nevertheless, anthropogenic activities can release the hexavalent form of Cr concentrations into bodies of water, which are declared carcinogenic for human health by different regulatory and non-regulatory agencies [33].

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 [34] that reported high concentrations of iron in sachet water. High levels of iron in drinking water may alter the appearance, taste, odor of water and may even promote the growth of bacteria in the water system [35].

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 does not agree with the findings of [36] which reported that sachet water in Abuja metropolis of Nigeria contains a significant concentration of zinc when compared to that our investigation but however having a concentration within the permissible level of SON and WHO and that higher concentrations of zinc in water are responsible for stringent tastes in water which are essentially not desirable.

Electrical conductivity is a measure of waters ability to conduct an electric current and is related to the amount of dissolved minerals in the water, but does not give an indication of which element is present. It is related to the total concentration of ionized substances in water [37]. 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 far too low compared to the maximum of 1000 µscm-1 recommended for drinking water by WHO standard. [38] has reported that low E.C value denotes the presence of minimal amount of dissolved salts (mineral elements such as calcium, magnesium and fluoride) in water (**Reformulate this sentence**). The long term drinking of packaged water with E.C value of less than 40 µscm-1 constitute a number of health risks such as higher probability of fracture in children, **(Specify the minimum duration of accumulation of these metals (Zinc Chrome Arsenic Iron) in the body to cause risks to public health and give references? Group all this in a table ?)** pregnancy disorder (preeclampsia), diuresis, premature or low baby weight at birth and increased tooth decay [39].

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 within this range are favorable for maximum growth of mesophyll bacteria including human diseases causing agents. This phenomenon has the tendency to promote the development of undesirable taste and odour? in water with time [40].

Total dissolved solids indicates salinity behavior of ground and surface water. The total dissolved solids of water are mainly due to vegetable decay, evaporation, disposal of effluents and chemical weathering of rocks [41].This investigation reveals that the total dissolved (TDS) solid for the sachet water were found 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. 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 [42].

The pH serves as an index to denote the extent of pollution by acidic or basic wastes The mean P^H of the various groups of the water samples analyzed were found to be 5.32±0.21, 5.21±0.15, 5.22±0.10,5.05±0.23 and 5.45±0.20 for samples SW1, SW2, SW3, SW4 and SW5 respectively. Values obtained in all the sample groups were within the WHO recommended for P^H that ranges from 6.5-8.5. It is very important to state that the packaged water samples with pH within the regulatory guideline values do not have any probability of posing health issues like as acidosis [43].

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. Dissolved oxygen is an important indicator of water quality. This is due to its importance as a respiratory gas, and its use in biological and chemical reactions. Dissolved oxygen in water primarily affects oxidation-reduction reactions involving iron, manganese, copper and compounds containing nitrogen and sulphur. The dissolved oxygen content of water depends on its source, temperature, chemical and biological processes taking place in the water distribution system. However, large declines in dissolved oxygen in water could indicate high levels of microbiological activity, and should trigger further sampling for microorganisms **(Confirm by other research work (References)?).** No guideline value is recommended because the acceptability of low levels of dissolved oxygen depends on the presence of other water constituents [44].

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.

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Your manuscript falls within the realm of water quality control, so that is why it is interesting to publish this kind of research.

1) Please answer the questions **in red** in the manuscript?
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