PHYSICOCHEMICAL AND TRACE METALS ASSESSMENT OF SOME PACKAGED WATER SOLD IN LOKOJA, KOGI STATE, NIGERIA

Supported by

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Abstract:

Due to the lack of portable drinking water, sachet and bottled water consumption have recently increased in Nigeria's major cities and towns. The intake of packaged water has been linked to an increasing number of ailments, including diarrhea, typhoid, and other waterborne infections. As a result, it is crucial to look into the packaged water quality. As a result, the goal of this study is to evaluate the caliber of packaged water made and sold in Lokoja, Kogi State. It is necessary to look into the likelihood that these waters contain any contaminants that could have a toxicological impact on people when consumed. The result of the physicochemical analysis reveals that all the samples analyzed were within the permissible limit. The result from the analysis of the trace metal revealed that there were some traces of Arsenic in some of the analyzed samples. The results were compared with World Health Organization and Nigerian standards for drinking water quality standards allowable quantities of some of the studied parameters in the water samples from the research region. Finally, this investigation demonstrated a link between human exposure to organic pollutants in packaged water and associated health effects.

Keywords: Packaged water; Lokoja; contamination; permissible limit; diseases; drinking; World Health Organization

Introduction:

'The primary component of the ocean, lakes, and streams on earth is water, an opaque or colorless substance. The majority of living things require it. Since it has the chemical formula H_2O, each of its molecules consists of two covalently bound hydrogen atoms and one oxygen atom. All known forms of life on earth depend on water, which covers 71% of the planet's surface'. 'The planet's crustal water is distributed as follows: 96.5% is in the seas and oceans, 1.7% is in groundwater, and 1.7% is in glaciers. The final 0.001% is found as vapor in the atmosphere. Only 98.8% of this water is found in ice, and only 2.5% of it is freshwater. Despite the fact that it has no calories or natural nutrients, clean drinking water is essential for humans and other life forms. All living things need water to survive and thrive, so it's crucial to regularly check the drinking water's quality because using contaminated water puts the general public at risk for a number of waterborne diseases'.

According to Midrar-Ul-Haq *et al*. (2005), human activities that introduce trace metals into groundwater and surface waters include irregular industrial processes, municipal waste, and excessive and occasionally needless chemical use in agricultural processes. Only in modest doses are some trace metals important for health. A high concentration is harmful to one's health. Despite being in tiny amounts, Health is dependent on copper (Cu) and zinc (Zn) (as quoted in Solomons and Ruz 1998; Fosmire 1990; Singh et al. 2006), the maximum concentration permitted for drinking water by the WHO is Cu_2 mg/L.

Kott (1974), stated that the essential standards for drinking water are that it must be free of pathogenic organisms, include no substances that are harmful to human health, be reasonably transparent, not be salty, have no objectionable tastes or odors, and not corrode. According to Jan *et al*. (2002); water treatment entails transforming "raw water" (water obtained from natural sources) into water fit for home use. Rainwater typically doesn't need as much treatment as surface or groundwater. Also requiring some sort of treatment is harvested water. The elimination of pathogenic organisms is crucial and poisonous compounds like trace metals might harm your health.

The World Health Organization (WHO) is most frequently cited when evaluating the acceptability of public water sources, according to Dada (2009). The physicochemical and trace metals qualities are specified in these regulations (Tables 1).

There is little doubt that the use of agrochemicals, particularly fertilizers and pesticides, has improved food production and disease control, but it also has an impact on agricultural and residential water supply sources. They alter the physicochemical characteristics and microbial diversity of the affected sediment in addition to these effects. According to a 2015 systematic review and meta-analysis by Williams *et al*., (2015), packaged water is typically significantly less likely to be polluted than other water sources, including upgraded water sources like piped water. Despite this, there was a significant amount of heterogeneity between study sites, with more than 40% of studies concluding that bottled water had a similar or worse quality than piped water. Even after accounting for the higher use of sachet water—which is more likely to be contaminated than bottled water among LICs—which is more likely to be contaminated than packaged water, the analysis revealed significant differences in the contamination levels of packaged water between low-income countries (LICs) and upper-middle and high-income countries (UM/HICs).

According to Falcone-Dias (2012), the oversight and control of the bottled water industry could present more difficulties with fewer resources. Mineral water that is processed, bottled locally, and sold for consumption is often untreated. Non-mineral water or water from other sources is most usually treated to improve its quality before being bottled or packaged. World Health Organization /United Nations Children's Fund (2011) advises using a variety of disinfection techniques to guarantee an adequate decrease in pathogens in the event that the source water is significantly contaminated or infected with resistant bacteria, such as Cryptosporidium, that are not susceptible to chlorination alone. Regardless of whether they have National Agency for Food and Drugs Administration Control (NAFDAC) Certification, packaged water consumption in Nigeria is rising.

The intake of packaged water has been linked to an increasing number of ailments, including diarrhea, typhoid, and other waterborne infections. This packed water is convenient and reasonably priced, and it is gaining popularity. As a result, it is crucial to look into the packaged water quality. As a result, the goal of this study is to evaluate the caliber of packaged water made and sold in Lokoja, Kogi State.

Materials and methodology:
Chemicals/reagents: Nitric acid, Potassium iodide, Iodine, Arsenic Oxide, Sulphuric acid, Sodium bicarbonate, Starch solution, diphenylthiocarbazone, Sodium Hydroxide, Hydrochloric acid, and deionized water.

Apparatus/Materials: Atomic Absorption Spectrophotometer (AAS) (Thermo-Scientific), HANNA Multi parameter spectrophotometer Nephelometer, conductivity meter (Hach model CO150), pH meter, Weighing Balance and glass wares

Determination of Sample size:

The size of the sample was calculated Cochran's Formula:

$$n = N\,x\,\frac{\frac{Z^2 x\,Px\,(1-P)}{e^2}}{(N-1)+\frac{Z^2 xPx(1-P)}{e^2}} \qquad \text{(Eqn 1.)}$$

Where: N= Population size, Z= Critical value, P= Sample Proportion, e= Margin error

Sampling technique
Before choosing the water to be studied, a preliminary survey was carried out to guarantee enough representative sampling. Research identifies well-known brand names that are primarily used in the research area. The thirty-three (33) samples included ten (10) different brands of bottled water, twenty (20) different brands of sachet water, and three (3) different brands of jar water. Following production, samples from each factory were collected, labeled, and placed in sterile polypropylene sample containers with leak-proof lids. The samples were sent to Sheda Complex (SHETCO) with plainly visible markings for simple identification. The analysis was done after the samples had been stored in the same way.

Sample preparation
To reduce physicochemical changes, these samples were then kept at 4°C for as little time as feasible before to analysis. Temperature, pH, electrical conductivity, turbidity, and other variables with very poor stability were measured right away.

Statistical analysis and quality control
Samples were typically examined twice. All bottles and glassware used for sampling and analysis, respectively, were meticulously cleaned with Teepol before being submerged in 2 M nitric acid for 24 hours and rinsed with de-ionized water. All analyses were checked for reagent impurities using analytical-grade chemicals and reagent blanks. a case Each time there were ten samples, blank digestion was also made.

Physicochemical analysis
Using a mercury-filled thermometer made of glass, the temperature of the water samples is determined in-situ (Sheppard and Socolow 2007). The water samples were normalized with buffers of pH 4.0 and pH 9.2 before the pH was determined using a portable pH meter (Mehta and Burrows, 2001). Using the quality technique recognized by AOAC, we made our decisions based on the conductivity of the water samples (Giddings et al. 2000). It was measured with a conductivity meter (Hach type CO150). To determine the samples' turbidity, a nephelometer was used. Spectrophotometer HANNA multi-parameter logging (HI83399) was employed to digitally analyze water samples to find nitrate, nitrite, phosphate, and sulfate.

Trace metals Analysis
To analyze the samples' minerals (Cr, Pb, Cu, and Cd), an atomic absorption spectrometer was used. Before beginning the studies, the device was calibrated with solutions of metal standards. Using various lamps and the appropriate blanks, the same procedure was used to identify each metal in the samples.

Determination of Arsenic with Iodine
Preparation of Iodine Solution (0.005 mol L^{-1}):
2 g of potassium iodide should be weighed into a 100 mL beaker. Iodine, 1.3 g in weight, is added to the same beaker. Swirl for a few minutes after adding a few mL of distilled water until Iodine is broken down. Transfer the iodine solution to a 1 L volumetric flask, being careful to rinse the volumetric flask completely with distilled water before doing so. Add distilled water to the solution until it reaches the 1 L mark.
In making the Starch Solution, 1 gram of soluble starch should be dissolved in 5 mL of cold, deionized water. 95 mL of quickly boiling water will get a slow addition of the starch suspension. Boil the mixture until it clears. Until room temperature, cool.

Iodine Solution Standardization

Weigh out four samples of pure As_2O_3 weighing about 0.20 g each and place them in 250 mL Erlenmeyer flasks. 10% NaOH solution is added in 10 mL. Until all of the As_2O_3 has dissolved, swirl. (If necessary, you might reheat it to speed up the solution.) 50 % dilution mL, let it warm to room temperature, then add 1:5 HCl until the solution turns pink from the addition of methyl red. Small amounts of solid sodium bicarbonate should be added until you are certain that none more will dissolve, and then add an additional 3 g. The chemical reactions involved in this step are:

$$As_2O_{3(s)} + 2OH^- + H_2O \longrightarrow 2H_2AsO^-_3 + 2H^+ \longrightarrow 2H_3AsO_3 \quad \text{(Eqn. 2)}$$

Add extra bicarbonate if the bicarbonate dissolves before the titration is finished. Titrate with the iodine solution right after adding 3 mL of the starch solution. Titrate until you reach the first permanent blue color. Determine the iodine solution's normalcy.

$$H_3AsO_{3(s)} + I_2 + H_2O \longrightarrow H_4AsO_3 + 2I^- + 2H^+ \quad \text{(Eqn. 3)}$$

$$Normality = \frac{(Wt.As_2O_3,g)(1000)}{(Titer,mL)(49.46)} \quad \text{(Eqn. 4)}$$

Titration of Unknown Arsenic

Do not OVERHEAT while drying the unknown for an hour at 105 °C. In a desiccator, cool it. Four 0.4 to 0.5 g samples should be weighed out into 250 mL Erlenmeyer flasks, each. 10% NaOH solution is added in 10 mL. To speed up the solution, it might be essential to warm it. To 50 mL of dilution. Add 1:5 HCl after cooling to room temperature until the solution turns pink with methyl red. Temp again. Until you are certain that no more will dissolve, add the bicarbonate in little amounts; after that, add an additional 3 g. Add extra bicarbonate if the bicarbonate dissolves before the titration is finished. Immediately titrate with the common iodine solution after adding 3 mL of the starch indicator. Determine the unknown's As_2O_3 content in %.

Notes: For the titrations, use 250 mL Erlenmeyer flasks. Avoid using aliquots. Arsenic oxide should be dried from the initial sample for an hour at 100 °C.

Calculation: Determine the molarity of the titrant from the known arsenic titrations, then determine the percentage of arsenic oxide (As_2O_3) present in the sample.

$$As\left(\frac{mg}{L}\right) = \frac{Molarity\,\frac{mol}{L}\,x\,volume\,(L)}{sample\,volume\,(L)}\,x\,RMM\,\left(\frac{g}{mol}\right)x1000\left(\frac{mg}{g}\right) \quad \text{(Eqn. 5)}$$

UV VIS spectrophotometric method for Hg:

Diphenylthiocarbazone (dithizone) 1.56×10^{-3} M: Prepared by dissolving 0.0400 g of diphenylthiocarbazone in 100 mL of 1,4-dioxane in a 100 mL volumetric flask.

Mercury (II) standard solutions: Divalent mercury was produced as a 100 mL stock solution by dissolving 135 mg of mercuric II chloride in deionized water (4.9910-3 M). This is the same as a solution containing 1 mg/mL. Working standard solution: To make a solution containing 1 g/mL of mercury, 100 mL of deionized water were added to 0.10 mL of mercury stock solution.

Procedure:

A 10-mL volumetric flask was used to add varying amounts of the 1 g/mL working standard solution to create the calibration curve. Following the addition of 0.8 mL of the diphenyl thiocarbazone reagent solution, 0.1 mL of the 4.5M sulfuric acid was added. 5 mL of 1,4-dioxane were added after 1 minute, and the mixture was then diluted to the proper consistency with deionized water. It measured the absorbance at 488 nm. 0.1 mL of 4.5M sulphuric acid and 0.8 mL of diphenyl thiocarbazone reagent solution were added to 2 mL of sample solution. 5 mL of 1,4-dioxane were added after 1 min, and the absorbance was measured at 488 nm. The calibration graph was used to determine the amount of mercury in an unknown sample.

Statistical investigation

Excel was used to analyze fundamental statistical analysis, including the mean value, standard deviation, HQ, and HI. Microsoft Office 2016 for Windows was used to carry out all statistical methods.

Results and Discussion:

The result of the physical analysis, chemical analysis and trace metals analysis of the ten brands of bottled water, twenty brands of sachet water and three brands of jar water is presented in Tables 1, 2 and 3 respectively.

Table 1: National and International Standards for Drinking Water (SON 2007)

PARAMETERS	UNIT	NSDWQ	WHO
Trace metals			
Iron (Fe)	mg/L	0.50	0.50
Lead (Pb)	mg/L	0.01	0.01
Zinc (Zn)	mg/L	3.00	0.01
Copper (Cu)	mg/L	1.00	2.00
Chromium (Cr) (trivalent)	mg/L	0.05	0.05
Manganese (Mn)	mg/L	0.20	0.40
Cobalt (Co)	mg/L	NS	NS
Arsenic (As)	mg/L	0.01	0.01
Cadmium (Cd)	mg/L	0.003	0.003
Mercury (Hg)	mg/L	NS	0.006
Physical parameters			
pH	E	6.50e8.50	6.50e8.50
Dissolved oxygen (DO)	mg/L	7.50	NS
Total dissolved solids (TDS)	mg/L	500	500
Temperature	ºC	NS	30
Turbidity	NTU	5.00	5.00
Electrical conductivity (EC)	ds/m	1.0	0.9
Other cations and anions			
Nitrate (NO_3)	mg/L	50.0	50.0
Nitrite (NO_2)	mg/L	3.00	3.00
Phosphate (PO_4)	mg/L	NS	NS
Sulphate ($SO^2{}_4$)	mg/L	100	100
Ammonia (NH_4)	mg/L	5.00	0.50

NS: Not stated

Table 2: Mean values of Physical analysis of the water samples

Sample ID	TDS (mg/L)	EC (ds/m)	DO (mg/L)	pH	Turbidity (NTU)
BW1	5.637	11.45	4.79	5.14	0.29
BW2	23.55	47.95	4.97	6.06	0.21
BW3	59.50	121.4	4.30	6.53	1.74
BW4	1.623	4.424	6.10	6.61	0.34
BW5	114.7	234.3	6.43	6.69	0.22
BW6	117.4	239.7	5.63	6.47	0.34
BW7	2.688	5.331	4.91	5.90	0.37
BW8	10.66	45.67	5.81	6.02	0.28
BW9	67.24	137.2	6.39	5.57	0.23
BW10	6.446	13.35	5.42	5.74	0.36
SW1	15.57	31.65	5.15	7.22	0.44
SW2	55.70	114.0	4.61	7.18	0.48
SW3	30.31	61.89	4.85	7.44	0.57
SW4	69.02	140.8	5.78	7.32	0.46
SW5	7.692	14.90	5.40	7.12	0.36
SW6	82.50	168.4	5.10	7.52	0.59
SW7	7.025	14.23	4.70	6.79	0.47
SW8	55.49	113.1	5.42	7.40	0.73
SW9	51.56	105.3	4.80	7.38	0.39
SW10	6.345	13.02	6.10	6.19	1.63
SW11	55.92	114.1	4.72	7.04	0.64
SW12	10.49	21.44	5.10	6.99	0.51
SW13	23.46	48.23	4.73	7.18	0.52
SW14	75.20	153.4	5.01	7.30	0.80
SW15	48.98	99.91	5.25	6.67	0.80
SW16	22.70	46.51	5.38	7.16	0.95
SW17	80.33	164.1	4.98	7.22	0.29
SW18	49.08	100.1	4.90	7.09	0.89
SW19	53.92	110.0	5.02	7.27	0.41
SW20	49.66	101.3	6.14	6.98	0.70
JW1	424.9	866.9	4.52	7.40	0.33
JW2	165.1	337.4	6.16	7.38	5.55
JW3	483.6	986.8	3.71	7.32	0.82
WHO	1000	1000	5.00	6.5-8.5	5.00
NSDWQ	500	1000	7.50	6.5-8.5	5.00

BW: Bottled Water, SW: Sachet Water, JW: Jar Water, WHO: World Health Organization, NSDWQ: Nigeria Standard for Drinking Water Quality.

Table 3: Mean values of Chemical analysis of the water samples

Sample ID	Nitrate (mg/L)	Nitrite (mg/L)	Sulphate (mg/L)	Phosphate (mg/L)
BW1	Nil	Nil	56	0.01
BW2	Nil	Nil	72	0.05
BW3	0.23	Nil	102	0.08
BW4	Nil	Nil	35	Nil
BW5	0.20	Nil	169	0.10
BW6	0.40	Nil	198	0.08
BW7	Nil	Nil	18	Nil
BW8	Nil	Nil	52	0.02
BW9	0.02	0.01	71	Nil
BW10	Nil	Nil	63	0.01
SW1	0.32	0.01	102	0.02
SW2	0.02	Nil	142	Nil
SW3	0.11	0.03	89.5	0.03
SW4	Nil	Nil	98	0.01
SW5	Nil	0.01	34	Nil
SW6	0.21	Nil	77	Nil
SW7	Nil	Nil	89.5	Nil
SW8	1.2	0.1	79	0.02
SW9	0.34	Nil	55	Nil
SW10	0.22	Nil	40	0.01
SW11	Nil	Nil	89	0.02
SW12	0.02	0.01	34	0.01
SW13	Nil	Nil	42	Nil
SW14	0.08	0.01	65	0.08
SW15	0.02	Nil	45	Nil
SW16	1.05	Nil	39	0.02
SW17	0.44	0.01	61	Nil
SW18	Nil	Nil	59	0.02
SW19	0.29	0.07	61	Nil
SW20	Nil	0.01	58	Nil
JW1	2.17	0.51	321	1.2
JW2	1.55	0.02	269	0.95
JW3	0.98	0.2	418	1.98
WHO	50.0	3.00	250	6.5
NSDWQ	50.0	3.00	100	NS

BW: Bottled Water, SW: Sachet Water, JW: Jar Water, WHO: World Health Organization, NSDWQ: Nigeria Standard for Drinking Water Quality.

Table 4: Mean concentration of Trace Metal in the water sample

Sample ID	As (mg/L)	Hg (mg/L)	Cr (mg/L)	Cu (mg/L)	Pb (mg/L)	Cd (mg/L)
BW1	Nil	Nil	-0.300	0.294	0.180	0.179
BW2	Nil	Nil	-0.182	0.137	0.230	0.180
BW3	Nil	Nil	-0.236	0.488	0.158	0.207
BW4	Nil	Nil	-0.406	0.735	0.181	0.190
BW5	0.01	Nil	-0.570	0.739	0.048	0.179
BW6	Nil	0.001	-0.077	0.982	0.137	0.189
BW7	Nil	Nil	-0.201	0.818	0.271	0.222
BW8	Nil	Nil	-0.114	1.032	4.276	0.203
BW9	Nil	Nil	-0.501	1.149	0.018	0.212
BW10	Nil	Nil	-0.122	1.086	-0.500	0.227
SW1	0.02	Nil	-1.809	0.223	0.827	0.115
SW2	Nil	Nil	-1.849	0.315	0.942	0.130
SW3	Nil	0.002	-1.794	0.282	0.987	0.159
SW4	Nil	Nil	-1.641	0.570	1.066	0.149
SW5	Nil	Nil	-1.743	0.502	0.890	0.158
SW6	Nil	Nil	-0.158	0.609	1.102	0.158
SW7	Nil	Nil	-0.939	0.898	1.312	0.158
SW8	0.02	Nil	-0.142	0.977	1.041	0.157
SW9	Nil	0.002	-0.212	1.068	1.254	0.162
SW10	0.02	Nil	-0.440	1.091	1.245	0.168
SW11	0.23	Nil	-0.355	1.064	1.307	0.172
SW12	Nil	Nil	-0.463	1.182	1.783	0.174
SW13	Nil	Nil	-0.467	1.212	1.559	0.174
SW14	Nil	Nil	-0.310	1.136	1.706	0.177
SW15	Nil	Nil	-0.323	1.325	1.567	0.166
SW16	Nil	Nil	-0.224	1.380	1.798	0.718
SW17	Nil	Nil	-0.637	1.424	1.921	0.167
SW18	Nil	Nil	-0.175	1.581	1.846	0.178
SW19	Nil	0.001	-0.536	1.625	1.924	0.182
SW20	0.02	Nil	-0.269	1.712	1.979	0.183
JW1	Nil	Nil	-0.264	1.243	Nil	0.202
JW2	0.03	0.001	-0.249	1.241	Nil	0.203
JW3	0.01	Nil	-0.124	1.308	Nil	0.201
WHO	0.01	0.006	0.05	2.00	0.01	0.003
NSDWQ	0.01	NS	0.05	1.00	0.01	0.003

BW: Bottled Water, SW: Sachet Water, JW: Jar Water, WHO: World Health Organization, NSDWQ: Nigeria Standard for Drinking Water Quality, TNTC: Too numerous to count

Discussion:

Total Dissolved Solids (TDS)

Solid particles were found to have dissolved in the samples examined but they were below the permissible level of total dissolved solids (TDS) value (1000 mg/L) of World Health Organization/ National Immunization Strategy. TDS combines the sum of particles of ion that are smaller than 0.0002 cm (Lindsey and Scott 2010). This consists of all the separated electrolytes that makeup concentrations of salinity, as well as other compounds such as dissolved organic matter. In "clean" water, total dissolved solids are approximately equal to salinity (National Oceanic and Atmospheric Administration 2014). In wastewater or polluted areas, total dissolved solids can include organic solutes (such as hydrocarbons and urea) in addition to the salt ions (National Oceanic and Atmospheric Administration 2014). Total Dissolved Solids concentrations outside of a normal range may cause a cell to swell or shrink. This may impact negatively on human life that cannot compensate for the change in water retention.

Electronic conductivity

The conductivity readings for the tested sachet, jar, and bottled water fell within the range of the World Health Organization (WHO)/Nation Standard for Drinking Water Quality (NSDWQ) standard conductivity (0-1000 s/cm). This indicates that all samples were within World Health Organization (WHO) and Federal Ministry of Environment (FME) acceptable limits, supporting the conclusions of Aremu et al. (2011). A measure of water's electrical conductivity is called conductivity. The number of ions present in the water has a direct impact on this ability (Wetzel 2001). Ingredients that dissolve ions are also referred to as electrolytes. The conductivity of water increases with the number of ions that are present.

pH

Both the bottled, jar and sachet water samples that were evaluated for pH fell within the 6.5–8.5 range that World Health Organization (WHO)/Nation Standard for Drinking Water Quality (NSDWQ) recommends for high-quality water. It is crucial to note that water samples with pH values within regulatory guidelines have no chance of posing health risks like acidosis (Asamoah and Amorin 2011). Basically, the pH value is a good indicator of whether water is hard or soft. The pH of pure water is 7. Thus, water with a pH lower than 7 is considered acidic, and with a pH greater than 7 is considered basic. The normal range for pH in surface water systems is 6.5 to 8.5, and the pH range for groundwater systems is between 6 and 8.5.

Turbidity

Most samples fell below the permissible limit of both World Health Organization (WHO)/Nation Standard for Drinking Water Quality (NSDWQ) of 5.0 NTU. Sample JW3 has higher turbidity of 5.5 NTU which does not correlate with the findings of Halder and Islam (2015). Turbidity is known to have impact on odor, taste, and color of water (Ndinwa et al. 2012). The size of particulate matter present in a water sample affects its level of turbidness.

Dissolved Oxygen

Bottled water samples have the highest Dissolved Oxygen. Sample JW3 has the lowest Dissolved oxygen while sample BW5 has the highest dissolved oxygen. The result from this study is within the permissible limit.

Nitrates

The results of the analyzed sample collected in study area shows that bottled water has the lowest amount (0.00 to 0.40 mg/L) of nitrates ions among the others sachet water of sample collected which is 1.21 mg/L which is less than what is recommended by WHO and SON of 50 mg/L (Table 3). Samples from jar water 0.98 to 2.17 mg/L for jar water, has the highest number of nitrates ions with 2.17 mg/L, which is also below what is recommended by World Health Organization (WHO)/Standard Organization of Nigeria. Consequently, bottled water is more suitable for drinking and other domestic usage. These results agree with Jidauna et al. (2013; 2014). Nitrate nitrogen is a commonly used lawn and agricultural fertilizer. It is a chemical formed when waste materials are decomposition. If infants under six months of age drink water (or formula made with water) that contains more than 10 mg/L nitrate-nitrogen, they are susceptible to methemoglobinemia, a disease which interferes with oxygen transport in the blood.

Nitrites

World Health Organization and National Standard for Drinking Water Quality, recommends that water should have nitrite concentration of not more than 3 mg/L. Therefore, all the samples analyzed met the permissible limit.

Sulphates

Water should have a sulfate concentration of no more than 200 mg/L or 100 mg/L, according to the World Health Organization and Standard Organization of Nigeria. In comparison to the other sample sources, jar water had the highest concentration of sulfate ions (418 mg/L), exceeding both World Health Organization and Standard Organization of Nigeria recommendations. In contrast, samples from sachet water had the lowest concentration of sulfate (34 mg/L), falling just short of both World Health Organization and Standard Organization of Nigeria recommendations. These indicate that the sulphate concentration in jar water is not safe for safe for drinking.

Phosphate

The analyzed samples were below the World Health Organization permissible limit of 6.5 mg/L.

Trace metals composition of bottled, sachet and jar water:

The presence of trace metals such as cadmium (Cd) and lead (Pb) were not detected in all the analyzed water samples. The results showed that the level of metals in all the brand of sampled water was within the recommended range set by World Health Organization (WHO) and Nigeria Standard for Drinking Water Quality (NSDWQ). The implication of this result is that the manufacturers of these brands of sachet, jar and bottled water obtained raw water from chemically good sources.

Arsenic

Some of the analyzed samples does not meet the World Health Organization (WHO)/National Standard for Drinking

Water Quality (NSDWQ) recommended range of 0.01 mg/L. Sample SW11 has the highest arsenic contamination. Bottle water was least contaminated with Arsenic.

Mercury (Hg)

All the analysed samples where below the recommended World Health Organization standards. Therefore, the samples as safe from mercury contamination.

Chromium (Cr)

The analysed samples where far below the World Health Organization (WHO)/National Standard for Drinking Water Quality (NSDWQ).

Copper

Only a trace amount of copper (a few milligrams per liter) naturally appears in drinking water. The maximum copper concentration in drinking water that meets World Health Organization (WHO) guidelines is 2 mg/L. In all the sachet, jar and bottled water samples studied, none of the samples analyzed was detected to contain this trace element higher than the permitted concentration. These findings make it clear that sachet water typically contains more copper than bottled water. A higher copper concentration is not preferred.

Lead (Pb)

Sample BW8 has the highest concentration of lead 4.276 mg/L. Most of the samples analysed are far above the recommended World Health Organization (WHO)/National Standard for Drinking Water Quality (NSDWQ). The result revealed that Jar water is safe from lead contamination. Sachet water samples contains more of the lead contamination.

Cadmium (Cd)

All the analysed samples exceeded the World Health Organization (WHO)/National Standard for Drinking Water Quality (NSDWQ) recommended limits of 0.003 mg/L. Sample SW16 is highly contaminated with lead (0.718 mg/L). This could be attributed to the environment from which the water was sourced i.e the geological setting, climate, topography, etc, water composition and the type of treatments used during their production. More changes in the water chemistry might also occur during storage and transportation, when bottles and nylon become exposed to direct sunlight (Ghrefat, 2013).

Conclusion

Potable water is crucial for human health, thus every industry involved in producing water should do a thorough investigation to identify any sources of impurities and get them removed. Numerous laxity chemical contaminants can be influenced by packaging and bottling. According to discoveries, packaged water standards in Nigeria are prone to problems with public health. The commercially available water in Lokoja, Nigeria, tested positive to some trace metals at remarkable levels over the World Health Organization's highest permissible standard, rendering water unsafe for human consumption. It was discovered that source of water had a notable impact on the water's quality. It is possible to attribute the cause of these contaminants to the careless and intentional dumping of animal waste likewise human waste. Meningitis, diarrhea, and urinary tract infections are only a few of the significant health issues caused by particular components found in specific places that are exceedingly harmful to human health and society.

Recommendation

Regulatory agencies should step up their efforts at regulating packaged water producers more aggressively, and plants should undergo regular hygienic inspections. Despite the fact that there is a legal structure in place for this goal, corruption and other irregularities have significantly reduced its efficacy. Producers of packaged water should place a strong emphasis on good management practices (GMP), particularly with regard to the location of the factories and upholding a high standard of hygiene within the production facilities. Regulations governing water quality should be upheld by regulatory organizations.

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Conflicts of Interest

All authors declare no conflicts of interest.

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Data availability statement

The data that support the findings of this study are openly available in NIS at https://rivwamis.riversstate.gov.ng/assets/files/Nigerian-Standard-for-Drinking-Water-Quality-NIS-554-2015.pdf

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