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Physicochemical and Bacteriological Properties of Packaged Water Sold in Imo State, Nigeria: A Case Study of Owerri Municipal Council

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Abstract

Background: The inadequacy of pipe borne water supplies in urban centres is a growing problem. As a result, communities resort to buying water from vendors. Presently, sachet and bottled water are the major source of drinking water in many households and at work. **Aim/Objective**: This study is aimed at assessing the physicochemical and bacteriological quality of packaged water (sachet and bottled) sold in Owerri Municipal Council of Imo State, Nigeria. **Method**: A total number of 24 samples of packaged water (11 sachet and 13 bottled) from several commercial brands sold in the city were selected randomly. These were of two categories: those that are packaged and sealed in bottles by larger factories (13 brands) and those that are sealed in nylon sachets (11 brands) by small scale industries. The samples were subjected to physical, chemical and bacteriological analysis. AAS and analytical quality chemical reagents were used for chemical analyses. Mac Conkey Broth (MB) was used for bacteriological analysis. **Results**: The results showed that while the physicochemical and bacteriological parameters were within standard limits for drinking water quality guidelines values and bacteriological analysis showed that there were no coliform counts in the bottled water samples but 5% of the 11 samples of the sachet water showed coliform growth. **Conclusion**: Thus the bottled waters were more satisfactory compared with the sachet ones. **Recommendation**: The enforcement agencies in the country (e.g. NAFDAC, Ministry of Health) need to get the producers of "packaged water" to comply with the National Drinking Water Guidelines and the communities on their part should be educated and enlightened on the ill effects of patronizing fake vendors of packaged drinking water.

Keywords: *Water, physical, chemical, bacteriological, analysis*

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Introduction

One of the most vital and valuable natural resources is water. All living organisms, from the simplest plants and microorganisms to the most complex living system known as the human body, require it to survive. Water is the most prevalent compound on the earth's surface (70 percent), consisting of hydrogen and oxygen atoms and having the chemical formula H_2O (Reda, 2016). Because of its unusual chemical and physical features, it is significant (Obi and Okocha, 2007; Onifade and Ilori, 2008). Safe and portable water supplies in urban cities in Nigeria are still inadequate compared to the growing population. In Owerri Municipal, a gap still exists in the provision of safe drinking water, so due to complains of inadequacy, shortages of raw water supply and high demand of water supply, hence, the inhabitants have resorted to sourcing drinking of packaged water (i.e. sachet and bottled water) and so many entrepreneurs and companies have gone into the production of packaged water (bottled and sachet).

The sachet water popularly called "pure water" is popular in many wards. These wards are Ikenegbu, Douglas, New Owerri, Tetlow, Wetheral, Eke Ukwu Owerri (the city's main market) and one thing common with this wards is that they are high-density areas where unmet high demand for water will have to be supplemented by other readily available water sources such as packaged water. The water sold at the kiosks and shops is said to be from springs that exists in some local government areas of the state. As at the time of this study a bottle of 50 cl is sold for N50, 75cl is sold for N100 while that of 120 cl is sold for N120, while a pack of 12 bottles is sold for N1200. Some of the producers claim that before it is packaged that it is processed by an ozone machine to make it drinkable. The sachet water costs less than the bottle water, a sachet of 60cl costs N10, while a big nylon bag of 20 sachets costs N100 -N150 (Nwanna, 1998).

The work aimed at assessing physico-chemical and bacteriological properties (quality) of the packaged water (bottled and sachet) sold in Owerri Municipal, Imo State, Nigeria.

Materials and Methods

Source of Material

At the time of the study, the packaged (sachet and bottled) water samples were obtained from owerri municipal council, Imo State, Nigeria.

Laboratory and other facilities were obtained from the Central Services Laboratory of National Roots and Crops Research Institute, Umudike Abia State, Nigeria.

Instruments /Reagents Used
Standard instruments and reagents are of analytical grade were used.

Sample Preparation
Out of 35 brands of packaged water sold in Owerri Municipal council area at the time of study, 24 packaged water samples were selected by simple random sampling methods from various vendors. The 35 brands of packaged water samples comprise of 11 sachets (pure water) and 13 bottled.
These samples were stored in a cool box and carried to the laboratory. For bacteriological analysis, the bottles and sachets were opened aseptically.

pH Determination
The pH measurement was done using a surgifield colomel electrode pH meter. A portion of each water sample was dispensed into a clean glass beaker. The meter was switched on and calibrated with buffered solution at pH 7.0. Thereafter, the electrode was inserted into the sample in the beaker and the pH value read directly from the screen when the figure became steady. The electrode was rinsed in distilled water after each reading before the next one was measured.

Total Dissolved Solids (TDS)
The Total Dissolved Solids (TDS) was determined gravimetrically according to James (1995). A measured volume of each water sample was dispensed into a previously weighed evaporation dish. The sample in the dish was evaporated to dryness over a Gallen kamp water bath. The dish was further dried in the oven at 105°C, cooled in a desiccator and re-weighed. The amount of solid was determined by the difference between the dried solid in the evaporation dish and the dried evaporation dish and the formula below was used.

$$\text{Total Dissolved Solids (TDS)(mg/L)} = \frac{1000}{V} xW_1 - W_2 x \frac{1000}{1}$$

Biochemical Oxygen Demand (BOD)
The Dissolved Oxygen (DO) was determined at two different levels and their difference gave the biochemical oxygen demand (BOD).
A measured volume of each test water sample was adequately aerated. The dissolved oxygen in one portion of the aerated sample was determined. The other portion of the aerated water sample was used to fill a screw - capped sterile incubation bottle of capacity 200 mL and sealed. It was incubated at 20°C for 5 days in an environment of reduced light (cupboard). The Dissolved Oxygen (DO) was subsequently determined as follows:
To the water sample in 200ml capacity bottle previously filled to the brim, 1m of 0.2M $MnSO_4$ solution was carefully added to the bottom of the bottle via a pipette in the same manner 1ml of alkali – iodide azide reagent was added. The bottle was stoppered and shaken to mix well. It was allowed to settle leaving a clear liquid above. A ml (1.0 ml) of conc. H_2SO_4 was added to effect dissolution.

Determination of Heavy Metals (Fe, Zn, Mn)
The determination of heavy metals in the water samples was done by the use of the Atomic Absorption Spectrophotometer (Perkin Elmer 6001 AAS) was set up as described in the manufacturer's instructional manual, the monochromator was set at the selected wavelength, standard solutions of the different elements of interest were prepared separately. The instrument was zeroed with deionized water. The blank, standards, and sample digests were run in turns and their reading recorded. Those of the standards were plotted into a curve and used to extrapolate the quantity of the test element. The above procedure was repeated for each test element using the corresponding hollow - cathode lamp and at their various wavelengths.

Determination of Minerals
The water samples for the determination of the mineral elements of interest was subjected to acid digestion and subsequently the different elements were determined using appropriate methods as described below by James (1995).

Digestion
Fifty millilitres (50 mL) volume of each water sample was dispensed into an evaporation dish and treated with 15mL of conc. HNO_3. The mixture was transferred quantitatively to a 100mL standard volume flask. It was made up to volume with deionized water.

Determination of Ca^{2+} and Mg^{2+} (Hardness)
Ca and Mg ions content of the digested water sample were carried out by complexiometric titration as a measure of their respective hardness. A measured aliquot of 50mls was dispensed into separate conical flasks. Pinch doses of the masking agents (Potassium cyanide) were measured into the content of each flask. Twenty millilitres (20 mL) of NH_3 solution was added to one of the flasks to raise the pH to 10.0 while 10ml of NaOH solution was added to the other to raise the pH to 12.0.
To the flask at pH 10.0 (for Ca^{2+} and Mg^{2+}), Erichrome Black T indicator was added and titrated against 0.02N EDTA solution. The other flask at pH 12.0 (for Ca^{2+} alone) Potassium cyanide was added and titrated against 0.02N EDTA solution. At pH 12.0 Ca^{2+} complexes with EDTA while at pH 10.0 both Ca^{2+} and Mg^{2+} form complexes with EDTA. The Ca^{2+} and Mg^{2+} content of the samples was calculated using the standard that 1mL of in EDTA has an equivalence of 12 mg Mg^{2+} and 20.04mg Ca^{2+}.

Test for Acidity
Fifty millilitres (50 mL) volume of the water sample was put in a beaker, 3 drops of phenolphthalein was added and it was titrated against 0.1N NaOH until a stain pink colour appeared which persisted for more than 15 seconds and this was repeated for the other water samples.

Test for Alkalinity
Fifty millilitres (50 mL) volume of the water sample was put in a beaker, 3 drops of phenolphthalein was added after which 3 drops of methyl orange was also added and it was titrated against 0.5N sulphuric acid to a pink end point.

Microbiological Analysis
This was done using the methods of International Commission on Microbiological Specifications for Foods (ICMSF 1978)

Total Viable Count
Total Viable Count (TVC) was done by direct plate count on nutrient agar medium. Serial 2 – fold dilution of each sample was done prior to inoculation.

Pour – Plate Method
An ml (1 mL) of each diluent from first diluent for the samples was inoculated onto sterile plates in triplicate with a sterile pipette. Molten nutrient agar was poured aseptically over the inoculum. The plates were gently shaken for even mixing and allowed to cool and set. Two plates and one plate of each triplicate samples were incubated at 37°C for 24 to 48 hours. The plates were incubated upside - down to prevent the condensed water vapour from disrupting the surface of the medium, colonies were counted from the triplicate plates.

Statistical analysis: Microsoft Excel version 10 was used for computing the mean and standard deviation.

Results and Discussion

The results of the work are shown in Tables 1 and 2. Table 1 shows the physico-chemical and bacteriological parameters of the sachet water samples sold in Owerri Municipality. While the results of the physico-chemical and bacteriological parameters of the bottled Water samples sold in Owerri Municipality are shown in Table 2.

pH
The results of the pH of the assayed branded packaged water samples (sachet and bottled) ranged from 6.6 -7.3. (Tables 1 and 2). The values are within the stipulated limit recommended by National Standard for Drinking Water Quality (NDWQS), Standard Organization of Nigeria (SON) and WHO: World Health Organization (WHO) (Table 1). This indicates a health drinking water. pH is an important parameter considered in good drinking water. It relates to acidity or alkalinity of water (WHO and UNICEF (2010).

Table 1: Physicochemical and Bacteriological Parameters of the Sachet Water Samples Sold in Owerri Municipality

Sample names	**pH**	**TDS (mg/L)**	**Ca (mg/L)**	**Mg (mg/L)**	**Total hardness (mg/L)**	**Alkalinity (mg/L)**	**Acidity (mg/L)**	**Zn (mg/L)**	**Fe (mg/L)**	**Mn (mg/L)**	**BOD (mg/L)**	**TVC (cfu/L)**
1.	6.7±0.047	43.3±2.357	79.8±3.778	61.5±1.131	78.8 ± 0.047	18.4± 0.117	9.2 ± 0.047	0.4±0.0471	2.5±0.047	0.02±0.0047	0.90±0.047	8.6±0.047
2.	7.1±0.094	51.6±2.357	63.5±3.777	40.5±1.131	63.2± 0.047	33.9± 0.117	8.1 ± 0.047	0.6 ±0.0471	1.9±0.047	ND	1.1±0.047	11.0±0.047
3.	6.8±0.094	38.3±2.357	44.5±3.778	29.5±1.131	44.5±0.047	21.3 ±0.117	8.7 ± 0.047	0.6 ±0.0471	2.8± 0.047	ND	0.8±0.047	9.0±0.047
4.	6.8±0.094	73.3±4.714	55.8±3.778	37.4±1.131	55.8 ±0.047	21.9 ±0.117	8.8 ± 0.047	0.8 ±0.0471	1.4±0.047	0.01±0.0047	0.8±0.047	14.0±0.047
5.	6.9±0.047	83.3±2.357	71.5±3.778	50.7±1.131	71.5 ± 0.047	26.1 ±0.117	8.5 ±0.047	0.3 ±0.0471	2.1±0.047	ND	1.3±0.047	7.6±0.047
6.	7.1±0.094	6.6±2.357	90.6±3.778	67.5±1.131	90.6 ± 0.047	36.6 ±0.117	6.3 ± 0.047	0.2±0.0471	2.0 ±0.047	ND	1.5±0.047	12.0±0.047
7.	6.8±0.094	61.6±2.357	60.8±6.545	40.0±1.131	60.8 ± 0.047	21.4 ±0.117	8.8 ±0.047	0.6±0.0471	3.0 ±0.047	ND	1.2±0.047	10.6±0.047
8.	7.3±0.141	58.3±2.357	61.4±3.778	45.4±1.131	61.4 ± 0.047	43.5 ±0.117	6.0 ± 0.047	0.6± 0.0471	2.1±0.047	0.01±0.0047	1.0±0.047	7.3±v
9.	7.2±0.094	66.6±2.357	79.5±3.778	58.7±1.131	79.5 ± 0.047	40.9 ±0.117	7.8 ± 0.04	0.8± 0.0471	1.3 ±0.047	ND	1.1±0.047	8.3±0.047
10.	7.0±0.047	76.6±2.357	71.8±3.779	53.4±1.131	71.8 ± 0.047	30.4 ±0.117	6.8 ± 0.047	0.7 ±0.0471	1.3±0.047	0.01±0.0047	1.1±0.047	11.3±0.047
11.	7.1±0.047	85.0±4.082	71.5±3.778	50.7±1.131	71.5 ± 0.047	33.8± 0.117	6.4 ± 0.047	0.7 ±0.0471	0.9±0.047	ND	1.2±0.047	8.6±0.047
NSDWQ	6.6-8.5	1000	-	0.20	100	200	--	5.0	0.30	0.05	-	-
SON	6.6-8.5	500	-	0.20	-	200	-	3.0	0.30	0.20	-	10.00
WHO	6.6-8.5	500	100-300	5.0	500	200	-	-	0.30	0.50	6.00	0.00

NSDWQ: National Standard for Drinking Water Quality. SON: Standard Organization of Nigeria. WHO: World Health Organization. Results were presented as mean ± standard deviation of triplicate determinations.

Table 2: Physicochemical and Bacteriological Parameters of the Bottled Water Samples Sold in Owerri Municipality

Sample names	pH	TDS (mg/L)	Ca (mg/L)	Mg (mg/L)	Total hardness (mg/L)	Alkalinity (mg/L)	Acidity (mg/L)	Zn (mg/L)	Fe (mg/L)	Mn (mg/L)	BOD (mg/L)	TVC (cfu/L)
A.	7.0±0.047	45.0±0.047	60.8±0.047	48.5±0.047	12.8±0.047	29.8±0.047	6.7±0.047	0.06±0.047	1.1±0.047	ND	0.4±0.047	4.6±0.047
B.	6.9±0.047	33.3±0.047	45.1±0.047	34.7±0.047	10.4±0.047	22.4±0.047	8.4±0.085	0.42±0.047	1.22±0.085	ND	0.3±0.047	5.8±0.094
C.	7.1±0.094	25.0±0.047	67.0±0.047	53.4±0.047	13.6±0.047	34.9±0.047	8.1±0.085	0.22±0.047	0.8±0.085	ND	0.9±0.047	3.3±0.124
D.	6.6±0.094	38.3±0.047	69.5±0.047	58.7±0.047	10.4±0.047	16.6±0.047	11.4±0.085	0.3±0.047	0.5±0.085	ND	0.7±0.047	4.2±0.047
E.	6.9±0.047	83.±30.047	71.5±0.047	50.7±0.047	20.8±0.047	26.5±0.047	8.5±0.085	0.3±0.047	2.1±0.085	ND	1.3±0.047	4.2±0.047
F.	6.9±0.047	36.6±0.047	69.9±0.047	58.7±0.047	11.2±0.047	22.6±0.047	8.5±0.047	0.1±0.042	1.1±0.047	ND	0.8±0.047	2.2±0.047
G.	6.7±0.094	38.3±0.047	48.6±0.047	37.4±0.047	11.2±0.047	18.5±0.047	9.4±0.085	0.2±0.047	0.9±0.047	ND	0.6±0.047	5.3±0.047
H.	7.1±0.141	46.6±0.047	49.9±0.047	34.7±0.047	15.2±0.047	35.7±0.047	6.3±0.047	0.3±0.047	1.3±0.085	0.02±0.0047	0.7±0.047	5.3±0.047
I.	7.0±0.047	33.3±0.047	55.8±0.047	45.4±0.047	10.4±0.047	30.3±v0.047	6.6±0.047	0.18±0.42	2.0±0.047	ND	0.4±0.047	4.4±0.047
J.	7.3±0.047	35.0±0.047	52.3±0.047	34.7±0.047	17.6±0.047	44.1±0.047	6.0±0.047	0.2±0.047	1.3±0.047	ND	0.3±0.047	4.2±0.047
K.	7.0±0.047	21.6±0.047	45.9±0.047	34.7±0.047	11.2±0.047	30.6±0.047	6.5±0.047	0.16±0.042	0.9±0.047	ND	0.3±0.047	3.2±0.047
L.	6.8±0.047	38.3±0.047	40.3±0.047	26.7±0.047	13.6±0.047	21.3±0.047	8.8±0.085	0.14±0.0429	0.9±0.047	ND	0.5±0.047	3.4±0.047
M.	6.6±0.047	51.6±0.047	48.3±0.047	34.7±0.047	13.60±.047	16.5±0.047	11.4±0.085	0.16±0.0429	1.1±0.047	0.01±0.0047	0.4±0.047	4.1±0.047
NSDWQ	6.6-8.5	1000	-	0.20	100	200	--	5.0	0.30	0.05	-	-
SON	6.6-8.5	500	-	0.20	-	200	-	3.0	0.30	0.20	-	10.00
WHO	6.6-8.5	500	100-300	5.0	500	200	-	-	0.30	0.50	6.00	0.00

NSDWQ: National Standard for Drinking Water Quality. SON: Standard Organization of Nigeria. WHO: World Health Organization. Results were presented as mean ± standard deviation of triplicate determinations.

TDS
The total dissolved solid of the assayed water samples is shown in table 1 and 2. TDS for the sachet water ranged from 6.6 -85.0 mg/L and 21.6 – 83.0 mg/L for the bottled water. These values are within the standard limit set by NDWQS, SON and WHO (Duru and Ike, 2017). The inorganic matters and small organic matters in drinking water sample is its TDS. This is an indication of the levels of mineralization (Oluyemi *et al*., 2010) and therefore the value obtained in this work connotes safe drinking water (Olukosi *et al*., 2016).

Hardness
The total hardness obtained (Table 1 & 2) shows that all the branded packaged water samples were below the set limit by NDWQS, SON and WHO (Reda, 2016). The presence of Ca^{2+} and Mg^{2+} are the major causes of water hardness, while $Fe^{2+,}$ Sr^{2+} and Mn^{2+} contribute a little (Ugbaja and Ephraim, 2019). Manganese do not pose any health challenge in drinking water, but its presence may impart a noticeable bitter taste to the water. The Ca^{2+} and Mg^{2+} levels are within the accepted levels. These elements are essentials in the body (Abdomajid and Mehraban, 2014)

Alkalinity
Alkalinity of the assayed water samples (Tables 1 & 2) ranged from 18.4 – 43.50 mg/L for sachet water and 16.5 – 44.1 mg/L for bottled water respectively. This is within the standard limit for drinking water. Alkalinity of drinking water is its acid neutralizing capacity (Reda, 2016).

Fe^{2+}, $Zn^{2+}$and Mn^{2+} (heavy metals)
The iron values obtained (Tables 1 & 2) are above the set limit of 0.3 mg/L. Iron is non- hazardous to health but considered as a secondary or aesthetic contaminant in drinking water (Duru and Ike, 2017).
Generally zinc is non-toxic, but its value in water above the set limit of 5.0 mg/L tend to be opalescent, develops greasy film when boiled and has an undesirable astringent taste (Dada, 2009). Also manganese poses no threat in drinking water, but its presence alters the taste of the water.

BOD
Biological oxygen demand is a measure of the biological or microbiological activities in the water; indicates the organic load of the water. High levels indicate strong contamination. This means oxygen depletion as result of microbial usage in the drinking water (Emmanuel *et al*., 2009). The values obtained were within the accepted limits of 6 mg/L.

Total viable count or Total coliform count
The TVC exceeded the 0.0 – 10 cfu/L stipulated limit. This may be due to the non-aseptic production materials and contamination. TVC is mainly due to the presence of *Escherichia coli* which is often used as indicators of pathogenic infections (Emmanuel *et al.*, 2009; Abdolmajid and Mehraban, 2014).

Conclusion

The physicochemical and bacteriological parameters of the bottled water sample assayed were within the standard set limits unlike the sachet packaged ones. Therefore the bottled ones were more satisfactory compared with the sachet ones.

Recommendation

The enforcement agencies in the country (e.g. NAFDAC, Ministry of Health) need to get the producers of "packaged water" to comply with the National Drinking Water Guidelines and the communities on their part should be educated and enlightened on the ill effects of patronizing fake vendors of packaged drinking water.

• *Thanks for publishing with IPS Intelligentsia.*

Conflict of Interest

Authors declare no conflict of interest.

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