

Water Quality Parameters of some Processed Sachet Water in Ibadan Metropolis, Oyo State, Southwestern Nigeria

Odesola A.F^{1*}, Adekeye D.K², Olatoye R.A², Aremu O.I², Araromi A.A² and Adesoye G.T³

¹Department of Biological Science, Koladaisi University Ibadan, Oyo State

²Department of Chemistry, Ekiti State University Ado-Ekiti, Ekiti State

³Department of Environmental Health Science, Kwara State University Ilorin, Kwara State

*Corresponding author: E-Mail: damilola293@gmail.com

ABSTRACT

The level of contaminants in the environment has been the major focus of most researchers in the area of environmental monitoring and assessment because of their toxicity to organisms. More than a billion people across the globe mostly from developing countries of which Nigeria belong lack safe drinking water. In contribution to the ongoing research on assessing the quality of water consumed by human, this study has investigated quantitatively the physico-chemical parameters of some processed water in Ibadan metropolis, Southwestern Nigeria to ascertain their safety for human consumption. This work involved determination of heavy metals such as cadmium (Cd), copper (Cu), chromium (Cr), manganese (Mn), lead (Pb) and zinc (Zn) in five different processed sachet waters of various factories in Ibadan metropolis using an Atomic Absorption spectrometer (PG 990 model). Physical parameters which include total suspended solids, total dissolved solid, total solid, total hardness, dissolved oxygen (DO), pH, turbidity, electrical conductivity and temperature were also evaluated in the processed water samples using standard methods. Other investigated water quality parameters of the water samples include sulphate (SO₄²⁻), phosphate (PO₄³⁻), nitrate (NO₃⁻) and chloride (Cl⁻). The results obtained were found to conform to International Standards for drinking water except in few cases, where there is close agreement between the results obtained and Standards.

KEY WORDS: Water, Water quality, Water quality parameters, Ibadan, Environmental pollution.

1. INTRODUCTION

It is well known that water is one of the most essential resources required by plants and animal for sustenance of life and well-being. It forms part of the most essential resources for life. All living things require water for life sustenance and survival. Some of its numerous uses include drinking, cooking, washing, irrigation farming etc. (Peter, 2003). Even though water covers more than 70 % of the earth's surface, less than 1 % of it is available as fresh water which is not evenly distributed throughout the world (Nitti, 2011). Aside water scarcity there are some other challenges in providing potable water and reliable water supply in many nations of the world including Nigeria (Olayinka and Alo 2004). The existence of water contaminants poses threats to human life as they are capable of causing diverse diseases and infections. Hundreds of millions of people suffer from short intense diarrhea, cholera, typhoid fever, bacillary, amoebic dysentery and infective hepatitis caused by microorganisms that ruin their lives (Oyedum, 2010; Baldurssons and Karanis, 2011; World Health Organization, 2014). Other water contaminants that are toxic to both human and aquatic organisms above their permissible and recommended levels include sulphate, phosphate, dissolved organics, chloride and heavy metals among others (Ahmaruzzaman, 2011; Adekeye, 2019). Also, physical parameters of water such as pH, total dissolved solid (TDS), suspended solid (SS), total hardness, color and turbidity are parameters that can influence the quality of water and they are capable of posing threats to both human and aquatic organisms when they are present beyond their recommendation level (Asaolu, 1998).

Water plays an important role in determining where people can live. There is abundance of fresh water on earth but high quality water is not yet obtainable by all and sundry and most importantly not always of suitable quality for all uses (Perlman, 2017). Naturally drinking water should be tasteless, odourless and colourless before it can be satisfactory but more importantly, it should be devoid of chemical toxins and disease causing microorganisms (Maheshwari, 2008). However, the role of contaminated water in the transmission of diseases and the importance of water in public health cannot be overemphasized, based on the fact that it is difficult for the general public to distinguish between safe water and potable water, thereby increasing their vulnerability to illness that normally arises from the consumption of contaminated water (Gleick, 1993). It is estimated that several millions of people across the globe mostly from developing countries of which Nigeria belong lack safe drinking water (World Health Organization, 2017).

Several works have been done on processed water in Ibadan metropolis southwestern Nigeria but none has established the pollution load index of the metropolis. Ibadan is the largest city in Nigeria and one of the largest in Africa. It is one of the most industrialized cities in Nigeria with many anthropogenic inputs that are capable of causing environmental pollution (Ogunsola and Yaya, 2019). This research work is carried out to determine the chemical and other physical quality parameters of some processed sachet water in Ibadan as well as to establish the

pollution load index of the investigated processed water in the metropolis in order to ascertain their suitability for consumption. This is further achieved by comparing the results of this study with international and recommended standards.

2. MATERIALS AND METHODS

Chemical Reagents: All the reagents used were of analytical grades and the instruments used were pre-calibrated appropriately prior to measurement.

Pre-treatment and Sterilization of Apparatus: All glass wares used (Erlenmeyer flask, conical flask, beakers, measuring cylinder, volumetric flask, and watch glass) and plastic bottles were washed with non-ionic liquid detergent and rinsed with distilled water. They were then soaked in 10% HNO₃ for 48 hours and then rinsed with distilled water followed by oven drying to preclude trace metal contaminations prior to sampling and for further analyses.

Collection and Preparation of Samples:

Water collection and preparation: The processed sachet water samples were collected from five various factories. At each factory, five processed sachet water were collected randomly, pooled and stirred together thoroughly to make a representative sample. All samples were preserved briefly at a temperature of 4°C without adding nitric acid so as to avoid the dissolution of the insoluble metal components by the acid prior to physico-chemical and metal analyses.

The Study Area: The Processed sachet water samples were collected from five different water factories namely: Dayem Aquatic Water, M. Oyee Pure Water, Gbenro Pure Water, Ore-Ofe Standard Pure Water and Everest Aquatic Water. They are all located within Ibadan Metropolis, in Oyo State. Four sachets were collected randomly at a factory and pooled together to make a representative sample of a location. The geographical locations of these sites were determined using global positioning System. Table.1, gives the geographical locations of the sampling sites.

Table.1. Coordinate Points of Sampling Sites

Sample Location	N coordinates	E coordinates	Elevation (m)
Dayem	07° 38' 502"	004° 11' 254"	234.40
M.Oyee	07° 37' 744"	004° 10' 321"	237.03
Gbenro	07° 07' 660"	004° 09' 520"	244.97
Ore Ofe	07° 09' 395"	004° 11' 023"	256.15
Everest	07° 38' 494"	004° 12' 305"	245.06

Determination of Water Quality Parameters:

Determination of temperature: The temperature determination of the water samples was achieved by the use of a digital thermometer following a procedure in a field manual for water quality monitoring (Mark and Williams, 2008).

pH determination: pH of the samples was measured using water proof digital pH meter as described by Hendershot (1993). Prior to use, the pH meter was calibrated using buffer solutions with pH of 4 and 9 respectively. The pH of the water samples was determined by dipping the electrode of the pH meter into each of the samples and allowed to stand for three minutes. The electrode was rinsed with distilled water and cleaned with good quality tissue paper after each determination. The experiment was repeated five times for each sample and the mean pH value ± standard deviation (SD) was recorded as the pH value of each water sample.

Electrical conductivity (EC) determination: EC Testr 11 dual range electrical conductivity meter was used for the determination of EC. This meter was calibrated by using standard potassium chloride (KCl) solution at room temperature after which the conductivities of the samples were measured in µS/cm.

Chloride (Cl⁻) determination: Argentometric method described by Carmen (2005) was used for chloride determination. Approximately 10 mL of each sample was titrated against 0.0141 M silver nitrate (AgNO₃) using 2 drops of potassium chromate (K₂CrO₄) indicator solution to a pinkish yellow end point and calculation was done according to equation (1):

$$\frac{\text{MgCl}}{l} = \frac{(A - B) \times M \times 35450}{V} \dots\dots\dots (1)$$

Where, A = Volume of titrant used for sample; B = Volume of titrant used for blank; M = Molarity of AgNO₃; V = Volume of sample taken.

Sulphate (SO₄²⁻) determination: For the sulphate determination, turbidimetric method was used (Ademoroti, 1996). 20 mL of the water sample was treated with 0.3301 g of barium chloride and 1ml of conditioning reagent (mixture of 50 ml glycerol, 30 ml conc. HCl, 300 ml distilled water, 100 ml 95% ethanol and 75 g NaCl). The colloidal solution formed was measured using an already calibrated Jenway 6305 spectrophotometer (U.K). The sulphate concentrations in the samples were extrapolated from the calibration curve obtained from series of standard solution. The sulphate stock standard was prepared by dissolving 0.0148 g anhydrous sodium sulphate,

(Na₂SO₄) in distilled water and diluted to give 100 mg/L solution using 100ml standard flask. 5 mg/L, 10 mg/L, 15 mg/L, 20 mg/L, 25 mg/L, 30 mg/L, and 40 mg/L series of standards were prepared from the standard solution. These were then treated with 1 mL of conditioning reagent and 0.3301 g of BaCl₂. The solutions were used to plot a calibration curve which reading was taken at 470 nm using a Jenway 6305 UV/visible spectrophotometer.

Phosphate (PO₄³⁻) determination: Phosphate (PO₄³⁻) determination acid colorimetric technique (Ademoroti, 1996), was used to determine the levels of phosphate in the samples. 5 mL vanadate-molybdate reagent was used to develop yellow colour in the standards and samples, ten minutes after addition of this reagent to 17.5 mL of sample or standard solutions, which was made up to 25ml mark with distilled water in a standard volumetric flask. The intensity of this yellow colour is proportional to the phosphate concentration after measuring the absorbance at 470 nm.

Vanadate-molybdate reagent was prepared by dissolving 6.25 g ammonium molybdate, (NH₄)₆MO₇O₂₄. 4H₂O in 75 mL distilled water and labelled solution A. Solution B was prepared by dissolving 0.3125 g ammonium metavanadate, NH₄VO₃ via heating to boiling in 75 mL distilled water, cooled and added 82.5 mL concentrated HCl. Solution B was then cooled to room temperature after which solution A was poured into it, mixed and diluted to mark in a 250 mL standard flask. Phosphate stock standard was prepared by dissolving in distilled water 0.0220 g anhydrous KH₂PO₄, and diluted to 100 mL to give 50 mg/L standard solution. 5 mg/L, 10 mg/L, 15 mg/L, 20 mg/L, and 25 mg/L concentrations were used to plot a calibration curve the readings were taken at 470 nm using a Jenway 6305 UV/visible spectrophotometer.

Nitrate (NO₃⁻) determination: Ultra-violet spectrophotometric screening method (APHA, 1998) was used to determine the Nitrate concentration of the water samples. The measurement of ultra violet absorption at 220 nm enabled a rapid determination of NO₃⁻. Since dissolved organic matter also may absorbed at 220 nm and NO₃⁻ does not at 275 nm, a second measurement of the sample made at 275 nm was used to correct the NO₃⁻ values. For the nitrate preparation, potassium nitrate (KNO₃) was dried at 105°C for 24 h in an oven and 0.0722 g of it was dissolved and diluted to mark in a 100 mL volumetric flask to give 100 mg/L standard solution. From the stock solution, 2 mg/L, 4 mg/L, 6 mg/L, 8 mg/L, and 12 mg/L concentrations were prepared and used to plot the calibration curve at 220 nm by treating 25 mL each of the series of standards with 0.5 mL of 1.0M HCl. The absorbance was then determined at 220 nm and 275 nm respectively.

Total Hardness determination: The total hardness of the water samples was determined by titration (EDTA titrimetric method) as described by APHA (1998).

Total solid (TS) determination: The determination involves evaporating 50 mL of each well mixed water samples to dryness in a weighed dish at about 105°C. The increased weight over the empty dish represents the total solid. The weight of each empty evaporating dish used for this experiment was taken and recorded as W₁ after it was allowed to dry in an oven to a constant weight. After drying, the water samples (50 mL of each) were measured into their corresponding labeled evaporating dishes and placed inside the oven to evaporate. After the evaporation, the dishes were brought out of the oven and allowed to cool by placing them inside the desiccators. The weight of the cooled evaporating dishes after evaporation was taken and recorded as W₂. The total solid was calculated using the following equation:

$$\text{Total solid (mg/L)} = W_2 - W_1 \times 10^6 \dots\dots\dots (2)$$

Where, W₁ = weight of empty dishes without the sample (g); and W₂ = weight of dishes after evaporation of water sample (g).

Suspended solid (SS) determination: Whatman No. 1 filter papers were placed in an oven set at 105°C and dried to constant weights. The filter papers were removed from the oven and placed in a desiccators to cool down. The weight was then taken and recorded as W₁. An accurately measured 50mL of each, well mixed water sample was filtered through the weighed dry filter paper. The residue on the filter paper was dried to constant weight in an oven set at 105°C. The dried filter paper containing the residue was then weighed as W₂. The increase in weight of the filter paper represents the suspended solid. Calculations were done according to equation (3)

$$\text{Suspended solid (mg/L)} = W_2 - W_1 \times 10^6 \dots\dots\dots (3)$$

Where, W₁ = weight of dried filter paper before filtration (g); and W₂ = weight of dried filter paper after filtration (g).

Total dissolved solid (TDS) determination: The difference between the values of total solids and suspended solids gives total dissolved solids.

$$\text{TDS} = \text{TS} - \text{SS} \dots\dots\dots (4)$$

Dissolved oxygen (DO) determination: Dissolved oxygen content of the samples was determined by method described by Hassan (2016).

Determination of turbidity (Nephelometric Method): Uniscope Uv-visible spectrophotometer (transmittance mode-No wavelength) was used after the instrument has been properly calibrated with formazin standard solutions. The water sample was thoroughly agitated and waited for a while for air bubbles to disappear. The nephelometer

sample tube was cleaned with soft tissue and put into the sample compartment of the instrument. The readings were taken in NTU unit.

Heavy metals determination: Nitric acid digestion method using the standard method described by Ademoroti (1996), for the determination of concentrations of metals in the water samples was adopted for use. With this technique, 50 mL of each water sample was transferred into 100 mL beaker. After vigorous mixing, 5 mL conc. HNO_3 was then added and brought to a slow boiling and evaporate on a hot plate to about 5 mL, before precipitation. It was finally transferred into 50 mL volumetric flask and made up to mark after cooling. Portion of this solution was used for metal determination after thorough mixing. A blank experiment was carried out for background correction using distilled water and following the procedure described above without sample. Digested samples were analyzed using buck scientific model PG 990 Flame Atomic Absorption Spectrophotometer. All the analyses were done in triplicate and results expressed in $\mu\text{g/L}$.

3. RESULTS AND DISCUSSION

Table.2. Mean Water Quality Parameters of Processed Sachet Water Samples in Ibadan, Metropolis, Oyo State: Temperature, Turbidity and Dissolved Oxygen

Site	Temperature ($^{\circ}\text{C}$)	Turbidity (NTU)	DO (mg/L)
A	27.40 ± 0.71	0.56 ± 10.18	4.90
B	28.00 ± 0.76	0.52 ± 9.32	4.60
C	26.10 ± 0.66	0.76 ± 12.30	4.70
D	27.20 ± 0.70	0.58 ± 10.22	4.50
E	26.40 ± 0.63	0.77 ± 12.44	4.70
Range	26.10 - 28.00	0.52 - 0.77	4.50 - 4.90
(USEPA, 2018)	-	5 NTU	-
(NIS, 2017)	25 $^{\circ}\text{C}$ / Ambient temperature	5 NTU	
(WHO, 2006)	-		5 (mg/L)

Table.3. Mean Chemical Characterization of Processed Sachet Water Metropolis, Oyo State

Sample	pH	EC ($\mu\text{S/cm}$)	TDS (mg/L)	TS (mg/L)	TSS (mg/L)
A	6.90 ± 0.12	110	10.64	10.64	-
B	6.88 ± 0.30	120	11.30	11.30	-
C	6.95 ± 0.25	190	10.82	10.82	-
D	6.80 ± 1.32	200	10.37	10.37	-
E	6.90 ± 0.58	240	6.43	6.43	-
Range	6.80-6.95	110-240	6.43-11.30	6.43-11.30	-
PERMISSIBLE LIMITS					
WHO (2017)	-	-	-	-	-
USEPA (2018)	6.5 - 8.5	-	-	-	-
NIS (2015)	6.5 - 8.5	1000 ($\mu\text{S/cm}$)	-	-	-

Sample	TH ($\text{mg CaCO}_3 \text{L}^{-1}$)	Cl^- (mg/L)	NO_3^- (mg/L)	SO_4^{2-} (mg/L)	PO_4^{3-} (mg/L)
A	3.51	0.20	0.017	0.850	0.010
B	5.46	4.00	0.022	0.800	0.014
C	3.50	5.00	0.038	0.096	0.004
D	3.33	3.50	0.041	0.030	0.018
E	1.59	3.90	0.033	0.091	0.016
Range	1.59-5.46	0.20-5.00	0.017-0.041	0.03-0.85	0.004-0.018
PERMISSIBLE LIMITS					
WHO (2017)	250 (mg/L)	250 (mg/L)	50 (mg/L)	500 (mg/L)	-
USEPA (2018)	250 (mg/L)	250 (mg/L)	10 (mg/L)	250 (mg/L)	-
NIS (2015)	2.93	2.93	50	250 (mg/L)	-

Table.4. Mean Heavy Metal Characterization of Processed Sachet Water in Ibadan Metropolis, Oyo State

Sample	Cd (mg/L)	Cu (mg/L)	Cr (mg/L)	Mn (mg/L)
A	0.0029	0.0400	0.0094	0.0110
B	0.0021	0.0080	0.0164	0.0080
C	0.0035	0.0016	0.0106	0.0440
D	0.0025	0.0028	0.0388	0.6432
E	0.0044	0.0540	0.0082	0.2558
Range	0.0029 – 0.0044	0.0016 -0.0540	0.0082 - 0.0388	0.0440-0.6432
PERMISSIBLE LIMITS				
WHO (2017)	0.003 mg/L	2. 00 mg/L	0.05 mg/L	0.40 mg/L
USEPA (2018)	0.005 mg/L	1.30 mg/L	-	0.05 mg/L
NIS (2015)	0.003 mg/L	1.00 mg/L	0.05 mg/L	0.20 mg/L

Sample	Pb (mg/L)	Zn (mg/L)	Total Metal Load (mg/L)
A	0.0133	0.0300	0.1067
B	0.0072	0.0468	0.1129
C	0.0123	0.0130	0.0739
D	0.0100	0.0474	0.7447
E	0.0070	0.0265	0.3559
Range	0.0070 – 0.0130	0.0130 – 0.0474	0.0739 - 0.7447
PERMISSIBLE LIMITS			
WHO (2017)	0.01 mg/L	0.05 mg/L	
USEPA (2018)	0.00 mg/L	5.00 mg/L	
NIS (2015)	0.01 mg/L	3.00 mg/L	

DISCUSSION

The water quality parameters in water bodies vary in composition and concentration on a diurnal basis. These variations may be related to patterns of water use and replenishment (APHA, 2012). The patterns of distribution of water quality parameters measured for processed sachet water in Ibadan metropolis for this study were generally similar. The mean variation of water quality parameters of sachet water samples are presented in Tables 2 to 4.

Temperature: Temperature ranged from 26.10 ± 0.66 to $28.00 \pm 0.76^\circ\text{C}$. Temperature was highest in sample B ($28.00 \pm 0.76^\circ\text{C}$) while sample C has lowest value of $26.10 \pm 0.66^\circ\text{C}$ (Table.2). The normal recommended temperature of water for drinking by Nigeria International Standard (NIS) for drinking water is ambient temperature (25°C) (Nigerian Industrial Standard, 2015). The results from study were slightly above the recommended temperature and this may be due to the fact that temperature of the city (Ibadan) is usually above 25°C ; it ranges between $25 - 33^\circ\text{C}$ (Abatan, 2018). The high environmental temperature and its variation is usually as a result of global warming as suggested by Abatan (2018). The higher temperature of the water samples above 25°C is thus influenced by the temperature of the environment. Water with temperature at the range of $26 - 28^\circ\text{C}$ is still considered permissible to the body without adverse effect.

Turbidity: Turbidity is a “measure of the relative clarity of water” (WHO, 2006). Turbidity in water is caused by suspended and colloidal matter, like clay, silt, finely divided organic and inorganic matter. Turbidity in the water samples was in the range $0.52 - 0.77$ NTU (Table.2). Sample E has highest turbidity while sample B has lowest turbidity (Table.2). The turbidity of the water samples were within USEPA permissible limit which implies that the water samples contained reasonable or very low amount of both suspended and dissolved solids (United State Environmental Protection Agency, 2018).

Dissolved oxygen: The dissolved oxygen (DO) in mg/L of the water samples was estimated to be in range of 4.50 and 4.90 as shown in Table.2. Dissolved oxygen (DO) was highest in Sample A (4.90 mg/L) while Sample D has the least estimated value (4.68 mg/L). Dissolved oxygen in drinking water as recommended by WHO (2006) should be less than 5 mg/L and the results obtained for the analysed water samples of this study were within this recommended value for DO.

pH: The pH of a substance is the measure of degree of acidity and alkalinity of the substance. The pH of the water samples ranged between 6.80 and 6.95 (Table.3). pH was highest in sample C (7.18) while that of Sample D was the least (6.80). The various pH of the water samples were all within the permissible limit of 6.5 to 8.5 which is acceptable for normal drinking water as recommended by United State Environmental Protection Agency (2018) and Nigerian Industrial Standard (2015). If pH value is lower than the permissible limit, it will affect adversely

acidity of the water which can cause corrosion in pipes and stomach lining causing severe gastro intestinal effects (APHA, 2012).

Electrical conductivity: Electrical Conductivity (EC) is a measure of water capability to transmit current. Electrical Conductivity of the water samples ranged between 110.00 and 240.00 $\mu\text{S}/\text{cm}$. Electrical Conductivity was found to be maximum in sample E (240.00 $\mu\text{S}/\text{cm}$) compared to sample A (110.00 $\mu\text{S}/\text{cm}$) which has the minimum value. These results are shown in Table.3. Electrical Conductivity of the water samples collected from the various study areas can be regarded as intermediate/medium according to the Classification of WHO (2006). Electrical Conductivity levels below 50 $\mu\text{S}/\text{cm}$ are regarded as low; those between 50 to 600 $\mu\text{S}/\text{cm}$ are medium while those above 600 $\mu\text{S}/\text{cm}$ are high conductivity (WHO, 2006). Using EC as water quality index, the samples have good quality and can serve domestic applications and diverse species of organisms. The EC of the water samples falls within the range that is acceptable for human consumption (Nigerian Industrial Standard, 2015).

Total Dissolved Solid (TDS) Total Solid (TS) and Total Suspended Solid (TSS): Total dissolved solid (TDS) comprises mainly of inorganic salts and small amounts of organic matter. The results of this study presented in Table.3 showed that the TDS of the water samples ranged between 6.43 to 11.30 mg/L. The total solid contents of the water samples were found to be the same as the total dissolved solid which implies that there are no suspended solids in the water samples. The TS in mg/L ranged from 6.43 to 11.30 mg/L while the value of suspended solid for all the water samples was 0.00 mg/L. These values fall within recommended value for drinking water as they did not exceed 500 mg/L (APHA, 2012; United State Environmental Protection Agency, 2018; Nigerian Industrial Standard, 2015), as well as the range for other uses such as freshwater aqua-culture (0 to 1000 mg/L), domestic use (0 to 450 mg/L) and livestock watering (0 to 1000 mg/L).

Total Hardness (TH): Hardness in water is due to natural accumulation of salts containing hardness ions such as Ca^{2+} and Mg^{2+} from contact with soil and geological formation or it may enter from direct pollution by anthropogenic activities (Asaolu, 1998). Hardness of the water samples was in the range 1.59 to 5.46 mg $\text{CaCO}_3 \text{L}^{-1}$. The highest value was recorded in sample E (5.46 mg $\text{CaCO}_3 \text{L}^{-1}$) while sample C has the lowest value (1.59 mg $\text{CaCO}_3 \text{L}^{-1}$) as shown in table.3. In all water samples, hardness was found within permissible limit for soft water in accordance to Nigerian Industrial Standard (2015) guidelines for drinking water.

Chloride (Cl): Chloride usually occur as NaCl, CaCl_2 and MgCl_2 in widely varying concentrations, in all natural waters. It was initially reported that there is no health-based guideline value proposed for chloride in drinking-water; however, when chloride reaches concentration above 250 mg/L, it imparts an unacceptable taste to water (WHO, 2017). Chloride concentration of the water samples was in the range 0.20 to 5.00 mg/L (Table.3). All the water samples showed satisfactory level within WHO guideline limit which implies that the water is acceptable for domestication in this respect (WHO, 2017).

Nitrate (NO_3^-): Nitrate (NO_3^-) ions usually occur in water as a result of used fertilizers or biocides washed into water bodies (Obiefuna and Orazulike, 2010). The excessive use of nitrogenous preservatives, and the presence of poultry faeces in any area, could initiate NO_3^- leakage into surface and ground water of the area (Olkowski, 2009). Nitrate has health effect when ingested above its recommended level as it can cause blue-baby syndrome for infants (WHO, 2006). The NO_3^- concentrations of the investigated water samples in this study ranged from 0.017 to 0.041 mg/L, where the highest concentration was recorded in Sample A and the lowest in Sample D (Table.3). Additionally, the NO_3^- values in this study was within the optimum recommended level for drinking as stated by WHO (2017); United State Environmental Protection Agency (2018); Nigerian Industrial Standard (2015).

Sulphate (SO_4^{2-}): Sulphate (SO_4^{2-}) is mostly derived from gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) and oxidation of sulphide ore (Obiefuna and Orazulike, 2010). According to Akanni and Benson (2014), the primary causes of SO_4^{2-} in water bodies are rock weathering, volcanoes and human activities like livestock keeping, refuse discharge and fossil fuel combustion process. More than 250 mg/L of SO_4^{2-} in water imparts bitter taste, purgative effects for some people, corrosion of water pipes and distributing systems (Obiefuna and Sheriff, 2011). The SO_4^{2-} level in water samples ranged between 0.030 and 0.850 mg/L (Table.3). The optimum SO_4^{2-} level in all the water samples was recorded for Sample A, while the minimum value was found in Sample D. Moreover, the SO_4^{2-} values of the water samples studied are within the acceptable limit of WHO (2017); United State Environmental Protection Agency (2018); Nigerian Industrial Standard (2015).

Phosphate (PO_4^{3-}): The mean concentrations of PO_4^{3-} in the investigated water samples varied from 0.004 to 0.018 mg/L. The highest value of PO_4^{3-} in the water samples was recorded for Sample D, while the least phosphate value was observed in Sample C (Table.3). These values generally were below the recommended values set by NESEREA which is 2 mg/L (National Environmental Standards and Regulations Enforcement Agency, 2009). The presence of PO_4^{3-} in the studied water samples may be due to leaching of phosphate preservatives in various industrial and agricultural wastes within the vicinity of the water industries into soil and finally into underground water used for production. Reports by Edet (2014) also showed that anthropogenic activities may result into leaching of contaminants including phosphate into underground water.

Heavy metals: Cadmium (Cd) concentration of the water samples during the study period ranged from 0.0029 to 0.0044 mg/mL. Cadmium in mg/mL was highest in Sample E (0.0044 mg/mL) juxtaposed with Sample D (0.0029 mg/mL). The determined Copper (Cu) concentration of the samples ranged between 0.0016 and 0.054 mg/mL. Copper was highest in Sample E (0.0540 μ g/mL) and lowest in Sample C (0.0016 mg/mL). The assessed Chromium (Cr) chromium concentration was found to be in the range of 0.0082 (sample E) and 0.0388 mg/mL (sample D). The concentrations of Manganese (Mn) in all the samples varied between 0.0080 and 0.6432 mg/mL. Manganese in mg/mL was highest in Sample D and the concentration (0.6432 mg/mL) recorded was a little bit above NIS, WHO and USEPA recommended level for manganese as shown in table 4. This value of Mn in drinking water is thus unacceptable for the reasons of safety and preservation of human health. Manganese concentration was within permissible level in other water samples as recommended by WHO (2017); United State Environmental Protection Agency (2018); Nigerian Industrial Standard (2015). The results of this research showed that lead (Pb) was mostly concentrated in Sample A with value of 0.0133 mg/mL while Sample E has the least concentration value (0.0070 mg/mL). Lead concentrations in sample A (0.0133 mg/mL) and C (0.0123 mg/L) are slightly above the NIS and WHO recommended level for drinking water and this can pose a threat to human health. The high concentration may be due to improper treatment of water before packaging. Concentration of Zinc (Zn) in the water samples measured in mg/mL was found to be within the recommended level by WHO. Maximum and minimum concentrations were recorded for sample B and D respectively. Water sample D has the concentration value of 0.0130 mg/mL while sample B has the value of 0.0474 mg/mL all within the limit of international standard recommended by WHO (2017); United State Environmental Protection Agency (2018); Nigerian Industrial Standard (2015) for drinking water quality (Table.4).

4. CONCLUSION

This study has provided information on the quality of some processed sachet water in Ibadan metropolis. Analytical results of this study revealed that most of the studied parameters varied significantly among the water sources. The data obtained from this study can be used by the industry of concern for management, pollution control and monitoring. Most of the investigated parameters with exception of few occurred within the range of water quality standards for most uses (domestic, aquatic ecosystem, recreation, industrial, livestock watering and irrigation). This study therefore concludes that the processed sachet waters are suitable for consumption with respect to their physicochemical properties while areas with values above recommended value could be looked upon by the production industry and individuals. The microbial profile of the water samples are therefore encouraged to be understudied for a better recommendation of the water samples for consumption.

Conflicts of Interest: The authors declare that there are no conflicts of interests

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