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Evaluation of Physicochemical Changes and Microbial load in Drinking Water within Keffi Town Before and After Storage

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Authors' contributions

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

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ABSTRACT

The present study aimed at evaluating the physicochemical parameters and microbial load of drinking water in Keffi town, Nasarawa state, Nigeria and the effect of storing the water. Water samples were collected directory from the factories of selected vendors and analyzed for pH, electrical conductivity (EC), dissolved oxygen (DO), total dissolved solids (TDS), turbidity (Tur), chloride ion (Cl^-), alkalinity, sulphate ion (SO_4^-), nitrates (NO_3^-), phosphates (PO_4^-), total hardness (TH) and microbial counts following standard scientific procedures. The results were compared with WHO/NAFDAC recommended standards. Sachet water 1 (SW1), tap water (TW) and bottled water (BW1) had chloride values higher than the standards. TW, SW1, SW2, SW3, SW4, SW5 and SW6 had viable cell counts above the 100 cfu/ml standards recommended by WHO/NAFDAC with isolated organisms. By the 10^{th} week, pH values decreased in all the samples, TDS and $\%DO_2$ increased in all the samples. Alkalinity increased in all the samples with decreased TH, while sulphates values increased in all the samples. Nitrates were not detected in all the samples. Bottled water had total coliform counts within the acceptable values. The results of this study revealed that Bottled water was of best quality for consumption and prolonged storage of all the water samples caused a decrease in PH, TH, $\%DO_2$, BOD and Phosphates.

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1. INTRODUCTION

Good quality drinking water is necessary for healthy life and efforts by water treatment bodies are often targeted at ensuring that a high quality of drinking water is achieved. This is against the backdrop of many water borne diseases that have been identified. Research have shown that about five million deaths a year are caused by polluted drinking water. The World Health Organization estimates that drinking safe water could prevent 1.4 million child deaths from diarrhea each year. According to the United Nations, 884 million people in the world do not have access to safe drinking-water and 2.6 billion people lack access to basic sanitation, 40% of the world's population. Most people need at least 2 litres of safe water per capita per day for food preparation [1].

At standard temperature and pressure, water usually exist as a liquid and as vapour when its temperature rises to 100 ^{o}C while at 0 ^{o}C, it assumes a solid form known as ice. It is tasteless and odourless. The intrinsic colour of water is a very slight blue hue, although both appear colourless in small quantities. Water vapour is essentially invisible as a gas [2]. Water plays an important role in the world's economy as it functions as a solvent for a wide variety of chemical substances and facilitates industrial and transportation, although about 70% of the fresh water used by humans goes to Agriculture [3] due to its necessacity to plants.

Storing water for a long time has been shown to render it unwholesome for human consumption due to inherent changes in physicochemical parameters and microbial load which eventually account for some pathological effects. For instance, diarrheal and its related diseases due to contamination of drinking water during household storage was noted in surveys conducted by the World Health Organization in the 1960s. The WHO team observed that drinking water taken from the pipe supply was stored for cooling in earthen jars, which were without exception faecally contaminated. The observation of water contamination during home storage has since been repeatedly confirmed. Data on in-house water contamination are available from three sources; observational studies of stored water quality, field investigations of the impact of specific behaviours and water vessel characteristics on water quality and on health, and intervention studies using modified water storage vessels.

Just as water may be sourced from different places and in different forms, the level of contamination also vary, consequently, a high degree of public health hazard can be associated with drinking water. The implication therefore is that any drinking water sold to the public must be wholesome and must meet WHO standards [4]. Unfortunately, the quality of drinking water sold to the public in many places in Nigeria may not be wholesome [5]. According to the institute of Public Health Analyst (IPAN), 50% of the 'pure water' sold in the streets of Lagos, a popular commercial city in Nigeria may not be fit for human consumption [6].

Unavailability of good quality drinking water is common in many cities in Nigeria and this has serious health implications. It has been shown that 80% of all diseases and 30% of deaths are related to drinking water [7] According to the Federal Ministry of Health, only about 30% of Nigerians have access to portable water. Water is said to be portable when its physical, chemical and microbial properties conform to specified standards. In Nigeria, water standards are set by regulatory agencies which include the World Health Organization (WHO) and National agency for Food and Drugs administration and Control (NAFDAC). To achieve such standards, the water is subjected to purification processes ranging from simple long-term storage to enable suspension of some suspended solid particles to aeration, coagulation, flocculation, filtration and disinfection to more advanced treatments [8].

This research therefore aimed at evaluating the quality of drinking water in Keffi town and the effect of prolonged storage on the physical, chemical and microbial properties with the view to ascertaining compliance to regulatory standards.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Water samples

The water samples from randomly selected vendors were collected and taken in pre-cleaned polyethylene bags, a portion of each was taken for analysis the same day while the remaining

was stored for ten days before analysis. The samples were all labelled appropriately as; BW1, BW2 and BW3 for the three different bottled water samples. The tap water sample, which has its origin from the Nasarawa state water treatment Board was taken at only one point from a tap and labeled as TW and the sachet water obtained from six different vendors of different brands were labeled as SW1, SW2, SW3, SW4, SW5 and SW6.

2.1.2 Instrument/equipments

The instrument/equipments used for the physicochemical parameters and microbial analyses include: Nessler's tube, Sectrophotometer, Measuring jar, Hot water bath, Hot plate, Magnetic stirrer, oxygen – sensitive membrane electrode, BOD bottles, Bunsen burner, pH indicator, hot air oven, autoclave, glasswares, thermometer, refrigerator.

2.2 Methods

2.2.1 Physicochemical and microbial analyses

The collected samples were analyzed for some physicochemical properties; pH, electrical conductivity (COND.), percentage dissolve oxygen (%DO_2), total dissolved solids (TDS), turbidity (TURB.), chlorides (CHL.), alkalinity (ALK.), sulfates (SULF.), nitrates (NIT.), phosphates (PHOS.), and total hardness (TH) as well as for microbial cell counts. These were analyzed using various methods as outlined by [9] [10].

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Physicochemical parameters on Day one of sample collection

As shown in Table 1, none of the samples showed a significant ($p<0.05$) change in pH value when compared with the standard acceptable value on day 1 of sample collection. For TDS, the values were significantly ($p<0.05$) lower in all the test water samples when compared to the standards, Turbidity values were observed to be significantly ($p<0.05$) lower in all the water samples when compared to the standards. The values of %DO_2 values showed non-significant ($p>0.05$) changes in all the samples compared to the standards. NIT was not detected in all samples. Conductivity values were significantly ($p<0.05$) lower in all the samples compared to the standards except SW1 where COND was observed to be significantly ($p<0.05$) higher compared to the standard. Alkalinity values in all the samples were also significantly ($p<0.05$) lower in the samples compared to the standard. TH was significantly ($p<0.05$) higher in all samples except BW2 where the value was significantly ($p<0.05$) lower when compared to the standard. The values of SULP. Were significantly ($p<0.05$) lower in the samples compared to standard. Chloride ions were significantly ($p<0.05$) lower in the samples except BW2, TW and SW5 compared to the control.

3.1.2 Physicochemical parameters on day ten of sample collection

Table 2 which is the result of physicochemical parameters of water samples measured on day ten after sample collection showed that a significant ($p<0.05$) decrease in pH value was observed in the BW1 sample when compared with the standard acceptable value. For TDS, the values were significantly ($p<0.05$) lower in all the test water samples when compared to the standards, Turbidity values were observed to be significantly ($p<0.05$) lower in all the water samples when compared to the standards. %DO_2 values showed non-significant ($p>0.05$) changes in all the samples compared to the standards. NIT. was not detected in all samples. Conductivity values were significantly ($p<0.05$) lower in the samples compared to the standards except SW1 where COND was observed to be significantly ($p<0.05$) higher compared to the standard. Alkalinity values in all the samples were also significantly ($p<0.05$) lower in the samples compared to the standard. TH was significantly ($p<0.05$) high in the samples except the BW samples when compared to the standard. The values of SULP. Were significantly ($p<0.05$) lower in the samples compared to standard. Chloride ions were significantly ($p<0.05$) lower in the samples except in SW5 compared to the control.

3.1.3 Microbial compositions at week one of sample collection

Table 3 is a presentation of the microbial cell counts for each of the water samples analyzed on day one of sample collection, and only Bacillus species were isolated. According to the

Table 1. Physicochemical parameters on Day one of sample collection

Sample	pH	TDS(mg/l)	TURB. (NTU)	%DO_2 (mg/l)	NIT. (mg/l)	COND. (µS/cm)	ALK. (mg/l)	TH (mg/l)	SULP. (mg/l)	CHLO. (mg/l)
BW1	6.7±.01	13.6±.05	.0±0*	150.1±.01	0.0±.01	23.1±.01*	.6±.01*	130.0±1.0*	5.9±.01*	68.0±.1*
BW2	7.2±.01	93.9±.01*	.0±.0*	130.1±.01	0.0±.0	157.2±.01*	1.2±.01*	91.0±1.0*	6.9±.16*	128.0±1.0*
BW3	7.1±.01	122.6±.01*	.5±.0*	191.6±.01	0.0±.0	202.0±1.0*	1.0±.01*	88.0±1.0*	9.1±.01*	55.3±.01*
TW	7.7±.01	42.3±.01*	14.9±.01*	196.1±.01	0.0±.0	69.8±.01*	1.8±.6*	306.0±1.0*	9.1±.01*	103.0±1.0*
SW1	7.2±.01	18.8±.01*	.6±.01*	159.1±.01	0.0±.0	309.0±1.0*	1.2±.01*	102.0±1.0*	5.3±.01*	53.1±1.0*
SW2	7.0±.01	49.2±.01*	1.2±.02*	145.9±.01	0.0±.0	81.7±.01*	2.2±.01*	150.0±1.0	6.9±.01*	36.0±1.0*
SW3	7.1±.01	5.1±.01*	1.2±.02*	163.1±.02	0.0±.0	84.7±.01*	2.6±.01*	154.0±1.0*	9.2±.01*	26.0±1.0*
SW4	7.2±.01	48.8±.01*	1.1±.01*	187.0±1.0	0.0±.0	82.7±.1*	1.6±.01*	129.0±1.0*	8.6±.01*	76.0±1.0*
SW5	6.9±.01	49.5±.01*	.7±.01*	163.1±.01	0.0±.0	82.7±.1*	.5±.01*	206.0±1.0*	4.8±.01*	109.0±1.0*
SW6	7.1±.01	52.7±.01*	1.1±.01*	144.0±1.0	0.0±.0	88.1±.01*	.7±.01*	140.0±1.0*	2.5±.01*	55.0±1.0*
STDs.	6.5-8.5	500	5	≥ 6	0.02	300	120	100	100	100

*Note: Results are presented as Mean ± SD, (n = 3). The standards (STDs.) quoted in the table are those stipulated by local and international regulatory bodies (NAFDAC) National Agency for Food Drug Administration and Control and (WHO) World Health Organization respectively as sourced from (IPAN, 2005) and (Dimowo, 2013). BW = bottled water, TW = tap water, SW = sachet water. Mean values with * compared to STDs. are considered to be significant at p < 0.05.*

Table 2. Physicochemical parameters on day ten of sample collection

Sample	pH	TDS(mg/l)	TURB. (NTU)	%DO_2 (mg/l)	NIT. (mg/l)	COND. (µS/cm)	ALK. (mg/l)	TH (mg/l)	SULP. (mg/l)	CHLO. (mg/l)
BW1	6.4±.01*	21.32±.01*	.5±.01*	60.2±.01	0.0±0	15.2±.01*	1.8±.01*	100.0±1.0	4.0±.01*	38.0±.1*
BW2	7.0±.01	102.3±.01*	.9±.01	45.6±.01	0.0±0	102.0±.01*	2.6±.01*	56.0±1.0*	4.3±.16*	86.0±1.0*
BW3	6.8±.01	156.2 ±.01*	1.2±.0 1*	29.0±.01	0.0±0	256.0±1.0*	1.2±.01*	65.0±1.0*	6.2±.01*	49.2±.01*
TW	6.5±.01	33.9±.01*	8.12±.01*	10.0±1.0	0.0±0	56.0±.01*	1.9±.6*	215.0±1.0*	10.2±.01*	70.0±1.0*
SW1	7.1±.01	24.32±.01*	1.2±.01*	23.0±1.0	0.0±0	362.0±1.0*	1.4±.01*	130±1.0*	3.4±.01*	48.3±1.0*
SW2	7.1±.01	56.1±.01*	1.5±.01*	13.0±1.0	0.0±0	94.5±.01*	.8±.01*	114.0±1.0*	4.7±.01*	27.0±1.0*
SW3	6.7±.01	59.4±.01*	.7±.01*	20.5±1.0	0.0±0	97.0±.01*	.9±.01*	121.0±1.0*	7.4±.01*	17.0±1.0*
SW4	6.9±.02	52.1±.01*	1.5±.01*	31.0±1.0	0.0±0	99.4±.1*	.7±.01*	101.0±1.0*	6.9±.01*	66.5±1.0*
SW5	6.6±.01	52.1±.01*	2.0±.01*	48.1±1.0	0.0±0	289.2±.1*	.7±.01*	160.0±1.0*	3.5±.01*	102.0±1.0*
SW6	6.9±.01	68.4±.01*	4.6±.01*	31.5±.01	0.0±0	294.0±.01*	.9±.01*	88.10±1.0*	1.9±.01	48±1.0*
STDs.	6.5-8.5	500	5	≥ 6	0.02	300	120	100	100	100

*Note: The standards (STDs.) quoted in the table are those stipulated by local and international regulatory bodies (NAFDAC) National Agency for Food Drug Administration and Control and (WHO) World Health Organization respectively as sourced from (IPAN, 2005) and (Dimowo, 2013). BW = bottled water, TW = tap water, SW = sachet water. Mean values with * compared to STDs. are considered to be significant at p < 0.05. Results are presented as Mean ± SD, n = 3.*

results, only the bottled water samples (BW1, BW2 and BW3) passed the recommended standards for microbial contents in drinking water with cell counts of ($0.5x10^2$, $0.8x10^2$ and $0.1x10^2$ cfu/ml respectively) compared to the standard ($1x10^2$) while the other samples were said to have failed to meet up with the standards.

3.1.4 Microbial compositions at week ten of sample collection

Table 4 is a presentation of the microbial cell counts for each of the water samples analyzed on day ten of sample storage. The results depict that only the bottled water samples (BW1, BW2 and BW3) passed the recommended standards for microbial contents in drinking water with cell counts of ($0.6x10^2$, $0.8x10^2$ and $0.1x10^2$ cfu/ml respectively) compared to the standard ($1x10^2$), similar to the observation on day one of sample collection.

3.1.5 Isolated organisms on day one analysis

Table 5 is a presentation of the organisms that were isolated in each waster sample on day one of sample collection. While a negligible number of organisms were observed in the bottled water samples, the other samples recorded different microbial species thus; TW; *Bacillus subtillis; Staphylococcus aureus, Escherichia coli*, SW1; *Bacillus subtillis; Staphylococcus aureus, Escherichia coli*, SW2; *Bacillus subtillis; Staphylococcus aureus, klebsiella pneumonia*; *Bacillus subtillis; Pseudomonas aeruginosa, proteus mirabilis*, SW4; *Bacillus subtillis; Staphylococcus aureus, Escherichia coli*, SW5; *Bacillus subtillis; Staphylococcus aureus, klebsiella pneumonia* and SW6 ; *Bacillus subtillis; Staphylococcus aureus, Escherichia coli*.

3.1.6 Isolated Organisms on day ten of sample analysis

Table 6 is a presentation of the organisms that were isolated in each waster sample on day ten. While negligible number of organisms were observed in the bottled water samples, the other samples recorded different microbial species thus; TW; *Bacillus subtillis; Staphylococcus aureus, Escherichia coli*, SW1; *Bacillus subtillis; Staphylococcus aureus, Escherichia coli*, SW2; *Bacillus subtillis; Staphylococcus aureus, klebsiella pneumonia*; *Bacillus subtillis;Pseudomonas aeruginosa, proteus mirabilis*, SW4; *Bacillus subtillis; Staphylococcus aureus, Escherichia coli*, SW5; *Bacillus subtillis; Staphylococcus aureus, klebsiella pneumonia* and SW6 ; *Bacillus subtillis; Staphylococcus aureus, Escherichia coli*.

3.2 Discussion

From table 1 above, there was no significant ($p > 0.05$) difference in the $_pH$ values of the samples when compared to the standard $_pH$. This may be due to non-significant ($p>0.05$) alteration in the H^+ concentration in the samples at the time of $_pH$ readings. However, the pH of BW1 decreased significantly ($p<0.05$) on the tenth day of storage indicating that prolonged storage of BW1caused an increase in the number of H^+ ions. This implied that prolonged storage of BW1 up to ten days plunged it in to becoming more acidic. The TDS values were observed to be significantly ($p < 0.05$) lower in all the samples when compared to the standard values, this may be due to unavailability of solid particles in the water

Table 3. Microbial compositions on day one of sample collection

Sample	Narure of Sample	Type of organism	Total viable Observed (cfu/ml)	Std. acceptable count	Remark
BW1	Water	Bacillus species	$0.5x10^2$	$1x10^2$	Pass
BW2	Water	Bacillus species	$0.8x10^2$	$1x10^2$	Pass
BW3	Water	Bacillus species	$0.1x10^2$	$1x10^2$	Pass
TW	Water	Bacillus species	$2.1x10^2$	$1x10^2$	Fail
SW1	Water	Bacillus species	$1.2x10^2$	$1x10^2$	Fail
SW2	Water	Bacillus species	$1.1x10^2$	$1x10^2$	Fail
SW3	Water	Bacillus species	$2.9x10^2$	$1x10^2$	Fail
SW4	Water	Bacillus species	$1.8x10^2$	$1x10^2$	Fail
SW5	Water	Bacillus species	$2.0x10^2$	$1x10^2$	Fail
SW6	Water	Bacillus species	$2.2x10^2$	$1x10^2$	Fail

Table 4. Microbial compositions on day ten of sample collection

Sample	Narure of Sample	Type of organism	Total viable Observed (cfu/ml)	Std. acceptable count	Remark
BW1	Water	Bacillus species	$0.6x10^2$	$1x10^2$	Pass
BW2	Water	Bacillus species	$0.8x10^2$	$1x10^2$	Pass
BW3	Water	Bacillus species	$0.1x10^2$	$1x10^2$	Pass
TW	Water	Bacillus species	$2.1x10^2$	$1x10^2$	Fail
SW1	Water	Bacillus species	$1.2x10^2$	$1x10^2$	Fail
SW2	Water	Bacillus species	$1.1x10^2$	$1x10^2$	Fail
SW3	Water	Bacillus species	$3.9x10^2$	$1x10^2$	Fail
SW4	Water	Bacillus species	$1.9x10^2$	$1x10^2$	Fail
SW5	Water	Bacillus species	$1.9x10^2$	$1x10^2$	Fail
SW6	Water	Bacillus species	$2.2x10^2$	$1x10^2$	Fail

Table 5. Isolated Organisms on day one analysis

Sample	Bacteria Count (cfu/g)	Bacteria species isolated
BW1	$0.5x10^2$	**----**
BW2	$0.8x10^2$	**----**
BW3	$0.1x10^2$	**----**
TW	$2.1x10^2$	*Bacillus subtillis; Staphylococcus aureus, Escherichia coli*
SW1	$1.2x10^2$	*Bacillus subtillis; Staphylococcus aureus, Escherichia coli*
SW2	$1.1x10^2$	*Bacillus subtillis; Staphylococcus aureus, klebsiella pneumonia*
SW3	$2.9x10^2$	*Bacillus subtillis;Pseudomonas aeruginosa, proteus mirabilis*
SW4	$1.8x10^2$	*Bacillus subtillis; Staphylococcus aureus, Escherichia coli*
SW5	$2.0x10^2$	*Bacillus subtillis; Staphylococcus aureus, klebsiella pneumonia*
SW6	$2.2x10^2$	*Bacillus subtillis; Staphylococcus aureus, Escherichia coli*

Table 6. Isolated Organisms on Day ten of sample analysis

Sample	Bacteria Count (cfu/g)	Bacteria species isolated
BW1	$0.5x10^2$	**----**
BW2	$0.8x10^2$	**----**
BW3	$0.1x10^2$	**----**
TW	$2.1x10^2$	*Bacillus subtillis; Staphylococcus aureus, Escherichia coli*
SW1	$1.2x10^2$	*Bacillus subtillis; Staphylococcus aureus, Escherichia coli*
SW2	$1.1x10^2$	*Bacillus subtillis; Staphylococcus aureus, klebsiella pneumonia*
SW3	$2.9x10^2$	*Bacillus subtillis;Pseudomonas aeruginosa, proteus mirabilis*
SW4	$1.8x10^2$	*Bacillus subtillis; Staphylococcus aureus, Escherichia coli*
SW5	$2.0x10^2$	*Bacillus subtillis; Staphylococcus aureus, klebsiella pneumonia*
SW6	$2.2x10^2$	*Bacillus subtillis; Staphylococcus aureus, Escherichia coli*

samples at the times of the analyses; before and after storage, justifying the claim by the water vendors that the water samples were free from solid particle contaminants, hence maybe considered physically pure. Turbidity values were observed to be significantly ($p < 0.05$) lower in all the samples compared to control, except TW which showed turbidity value of 14.9 which was significantly ($p < 0.05$) higher than the standard value of 5 NTU on day one of sample collection, indicating that tap water was turbid at the time of the analysis. $\%DO_2$ which concentration usually is an indication of available oxygen concentration for aerobic activities was found to be within acceptable standard range of ≥6 in all the samples, indicating the likelihood of high survival rate of aerobic organisms in the samples analyzed. Nitrite was found to be absent in all the test samples as the values were all zero and within the acceptable standard value

of 0.02, indicating that Nitrification would unlikely occur in the water samples. The values of conductivity were found to be significantly ($p < 0.05$) lower in all the samples compared to the standard control value of 300 mg/l except for SW1 indicating that the water samples were significantly ($p < 0.05$) devoid of electrolytes, hence electrolytes are responsible for the conductivity of electric current due to accumulation of charged particles therefore the samples collected could not raise the electrolytes concentration of the system which could exacerbate free radical production. Total alkalinity values were significantly ($p < 0.05$) lower in all the samples compared to standard value of 120 mg/l. Too high alkalinity is known to cause green water by depleting chlorine concentration which usually checkmates green algae growth. Too high alkalinity also raises the pH of water beyond control, resulting to alkalosis and accompanying diseases. TW and SW5 samples showed TH values to be significantly ($p < 0.05$) higher than the standard while the values in other samples were significantly ($p < 0.05$) lower when compared to the standard, however, the value was not significant ($p > 0.05$) in SW2 when compared to standard value. Ingestion of 8 g of sodium sulfate and 7 g of magnesium sulfate caused catharsis in adult males [11] Morris and Levy, 1983). Cathartic effects are commonly reported to be experienced by people consuming drinking-water containing sulfate in concentrations exceeding 600 mg/litre [12] [13] although it is also reported that humans can adapt to higher concentrations with time (US EPA, 1985). Dehydration has also been reported as a common side-effect following the ingestion of large amounts of magnesium or sodium sulfate [14]. From the results shown in the table 1 above, sulphate concentration in all the samples were found to be significantly ($p < 0.05$) lower than the standard acceptable value of 150 mg/l. Chloride toxicity has not been observed in humans except in the special case of impaired sodium chloride metabolism, e.g. in congestive heart failure [15]. Healthy individuals can tolerate the intake of large quantities of chloride provided that there is a concomitant intake of fresh water. Chloride is usually produced by ionization of chloride-containing compounds such as sodium chloride. From the results shown in table 1 above, BW2 TW and SW5 showed chloride ion concentration to be significantly ($p < 0.05$) higher compared to the standard acceptable values while in the other samples it was shown to be significantly ($p < 0.05$) lower when compared to the standard acceptable values, indicating that there was probably high ionization of chloride containing compounds in BW2, TW and SW5.

In table 2, it could be observed that BW1 showed significant ($p < 0.05$) decrease when compared to the standard acceptable pH value, which means that the water sample probably increased in acidity within the period of storage. The TDS values were observed to be significantly ($p < 0.05$) lower in all the samples when compared to the standard values, indicating that storage did not significantly ($p < 0.05$) raise the TDS value in all the samples. TW sample showed turbidity value significantly ($p < 0.05$) higher than the standard acceptable value indicating the likelihood of the TW sample becoming turbid due to storage. The result however showed turbidity value to be significantly ($p < 0.05$) lower in all the other samples compared to the standard values. Percentage dissolved oxygen was shown to be greater than 6 in all the samples and these were in accordance with the standard acceptable value of ≥6 as could be seen in tables 1 and 2 above. Nitrites was not detected in all the samples and were shown to be in accordance with the standard acceptable value of 0.02, indicating that nitrification was unlikely to occur in the water samples within the storage period. Also, Conductivity, Alkalinity, Sulphate and chloride concentrations were shown to remain significantly ($p < 0.05$) lower in all the samples when compared to the standard acceptable values. For total hardness (TH), TW, SW1, SW2 SW3 SW4 and SW5 showed its values to be significantly ($p < 0.05$) higher when compared to the standard acceptable values, which showed that storage was probably responsible for such rise in values in the water samples.

The results obtained for microbial cell counts showed that BW1 increased in microbial load from $0.6X10^2$ to $0.8X10^2$ cfu/ml upon storage while those of BW2 and BW3 remained unchanged. The slight increase noticed may be due to an increase in nutrients and other favourable conditions in the samples, thereby enabling the organisms to multiply. The microbial load in tap water was observed to be constant after storage, and as expected, the values failed to meet up with minimum allowable value set by the regulatory bodies as the value was far beyond the standard minimum value. This could be due to improper treatment methods adopted by the water board. *Bacillus subtillis, Staphylococcus aureus, Escherichia coli* were isolated in BW1, TW, SW4 and SW6 samples.

Pseudomonas auriginosa and *Proteus miribalis* were isolated from SW3. *Klebsiella pneumonia* was isolated from SW3 in addition to *B. subtilis* and *S. aureus,* indicating the possibilities of these water samples been infected by microorganisms. The number of isolates in the bottled water samples were not significant as they were far below the minimum allowable standards, accounting for the 'pass' remark which means they met the minimum standard recommendations for drinking water.

3.3 Statistical Analysis

The data obtained were analyzed using one-way analysis of variance with the help of a software known as IBM statistical product and service solution (SPSS) package, version 20.0 and the results were expressed as mean ± standard deviation followed by LSD and Duncan test for level of significance. The acceptance value of significance was $p < 0.05$ for all the results.

4. CONCLUSION

The results obtained in this research showed that storage could raise the concentrations of some physicochemical parameters as well as the qualitative and quantitative microbial load examination beyond standard acceptable values as manifested by the pH value in BW1, turbidity in TW, and total hardness (TH) in TW, SW1, SW2 SW3 SW4 and SW5 as well as the isolation of pathogenic microorganisms in TW, SW1, SW2, SW3, SW4, SW5 and SW6. However, BW quality was un-altered within the storage period, hence proven wholesome for consumption. Sachet water was also observed to be good for drinking although its quality was observed to depreciate within the ten days of storage. Tap water was observed in the first and second analyses to be unwholesome for drinking.

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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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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