ORIGINAL ARTICLE

PHYSICOCHEMICAL AND BACTERIOLOGICAL ASSESSMENT OF HAND-DUG WELLS WATER FROM ILE-OLUJI, NIGERIA

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ABSTRACT

Background- Groundwater is an important source of water for drinking and other purposes in Ile-Oluji, Nigeria. The sources of microbial and chemical contamination of groundwater are diverse and could have serious implications for public health. **Objective**-This study was carried out to determine the physicochemical and microbiological parameters in water samples collected from five hand-dug wells at selected locations in Ile-Oluji, Nigeria. **Materials and Methods**- Five samples (four sources close to filling stations and one control) were collected during the dry season (DS) and rainy season (RS) respectively, and analyzed for relevant physicochemical and bacteriological properties, using standard analytical procedures. **Results-** The data (in mg/L) obtained for the five analyzed samples, including the control were: alkalinity (17.9 – 59.0); total hardness (32.0 – 114); calcium hardness (18.0 – 59.0); magnesium hardness (18.0 – 57.0); chloride (32.0 – 48.0); total dissolved solids (60.0 – 130); free carbon dioxide (70.4 – 132); acidity (3.80 – 10.2), total suspended solids (0.20 – 0.45); nitrates (0.15 – 0.30); phosphates (0.15 – 0.35). The pH ranged from 5.15 – 7.23; temperature, 26.2 – 29.2 ^{o}C; turbidity, 4.00 – 7.00 NTU and conductivity, 38.7 – 84.5 μS/cm. The total bacterial count (TBC) and total fungal count (TFC) ranged from 2.79 x 10^8 to 9.66 x 10^8 and 1.00 x 10^5 to 1.78 x 10^6 cfu/mL respectively. Coliform was not detected from all the samples collected. The average values of physicochemical for all the wells were within the maximum permissible limits (MPL) specified by World Health Organization (WHO), United States Environmental Protection Agency (USEPA) and Nigerian Industrial Standard (NIS) except for turbidity and bacteriological properties. The wells located close to filling stations exhibited varying degrees of contamination and were generally more polluted than the control well. Furthermore, these parameters were observed to be higher in the dry season compared to rainy season. There was a significant difference at $p < 0.05$ in the levels of physicochemical parameters investigated during the (DS) and (RS) seasons. **Conclusion-** water from these wells including the control well is unsuitable for drinking and other domestic applications. It is recommended that the wells must be treated adequately to avoid possible health and other consequences of using the water from these wells. Besides, government should enact appropriate legislation to prohibit location of wells within the proximity of filling stations.

Keywords: *Ile-Oluji Nigeria, groundwater, filling stations, contamination, microbial loads, physicochemical properties.*

1. INTRODUCTION

The quality and quantity of water for drinking purposes is failing in Nigeria due to inadequacy of treatment plants, direct discharge of untreated sewage into rivers and streams, and unproductive management of piped water distribution system [1, 2, 3]. Although, the significance and use of groundwater has increased during the last decades in urban and rural areas of Nigeria [4], pollution from natural and anthropogenic activities is upsetting this vital resource [5, 6]. Groundwater is generally refers to all the water found underground which occupying the void within geological formations. It is the chief components and constitutes about two-thirds of the fresh-water resources, and accounts for nearly 95% in the world today. Groundwater is an important source of water supply throughout the world and almost every living and non-living thing uses water for one thing or the other [7]. Groundwater is generally considered a "safe source" of drinking water and commonly vulnerable to pollution, which may degrade their quality [8].

Pollution is a global dilemma and its potential in influencing health of the human inhabitants is great [9]. The impact of pollution in the vicinity of overcrowded cities and from industrial effluents and automobiles has reached a disturbing magnitude and is arousing public awareness [10]. Excessive levels of pollution are causing a lot of damage to human and animal health, plants including tropical rain forests as well as the wider environment [9]. Pollution is the cause of many diseases, which affect not only the old but also the young and the energetic and all animals and plants [11]. The World Health Organization reported that about twenty million children worldwide suffer from pollution which has become critical because of overpopulation [11, 12]. An estimated 1.2 billion people drink unhygienic water which is the source of water related diseases that are responsible for about five to ten thousand teenage and adult killing around the world today [13]. Water serves as an oracle of life and a major constituent in human physiological appearance, chemical processes taken place in the body system and moral wellbeing.

Water is an indicator in the existence of life; various purposes associated with water include agriculture, infrastructures, industrialization and other domestic applications. Every activities in the creation attached to water in one way or the other, without water, ability to function and carry out every processes in the body would be residual, stunt and depreciable, all chemical processes would yield no result, this tell importance of water to life.

In the world today, water occupies almost 70% of the Earth crust. The categories of natural substances which cause water contamination includes, gases, soils, minerals, humus materials, waste created by animals and host of other living organisms present in water. Water resources continue to be insufficient and deficient in most areas to meet the growing demands of a rapidly increasing population and because of this scarcity, the resources have continued to be overexploited leading to its salinity, increased pollution and eutrophication due to intensive agricultural practices [14]. Although, several papers have been published on the quality of groundwater from other parts of the state [15] and the country [16, 17, 18, 19, 20], indeed there is paucity of information on the quality of groundwater from Ile-Oluji. Consequently, this study was undertaken to assess the physicochemical and microbiological properties of water from hand-dug wells at selected locations in Ile-Oluji, with a view to determining their suitability for human consumption and other domestic purposes.

2. MATERIALS AND METHODS

2.1 Sample location: Ile-Oluji is the headquarters of Ile-Oluji/Okeigbo Local Government, Ondo State, Nigeria and lies between Longitudes 6° 40' N and 7° 14' N, and Latitudes 4° 38' E and 4° 53' E. It has an area of 698 km² and a population of 172,870 as at the 2006 census (Figure 1). Water samples used for this study were collected from five hand-dug wells at selected locations in Ile-Oluji, Ondo State, Nigeria. Fig. 2 shows a map of the sampling locations. Each sampling site was identified by a hand-held Garmin-GPSMAP 76S-type global positioning system (Table 1).

Table 1: Description of sampling locations

Sampling code	Point of collection	Location
A	Social filling station	7°13'24" N and 4°52'08" E
B	Alfan filling station	7°13'42" N and 4°52'10" E
C	Soka filling station	7°10'52" N and 4°52'07" E
D	Ade Oil filling station	7°11'06" N and 4°52'09" E
E (Control)	GRA, Temidire	7°13'24" N and 4°51'60" E

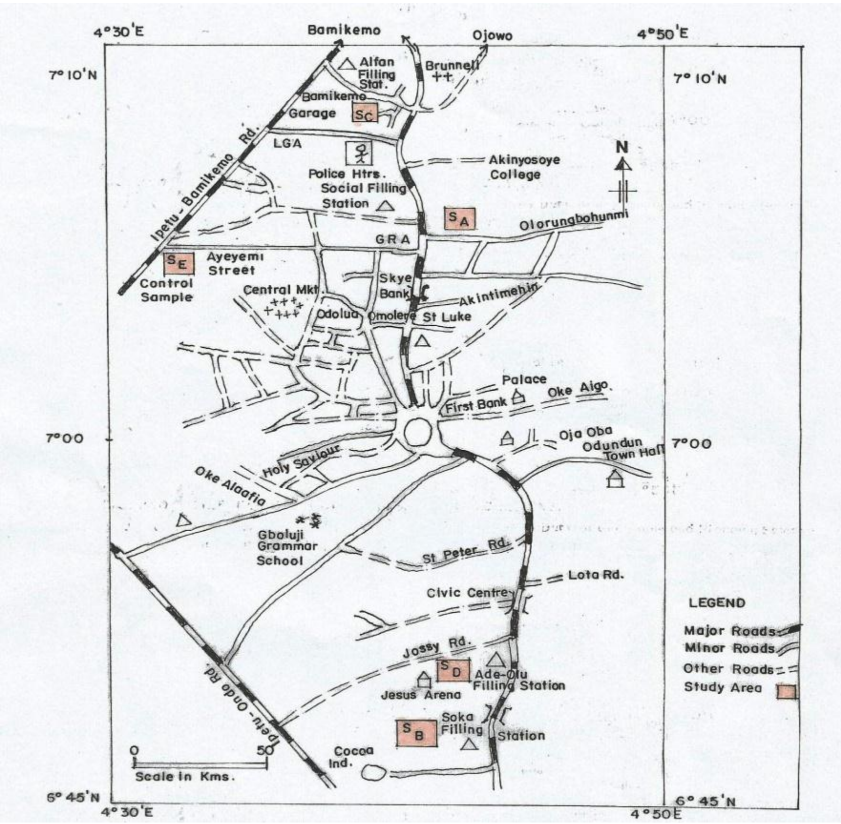

Figure1: The figure presents the map of Ondo State in Nigeria showing Ile-Oluji/Okeigbo Local Government.

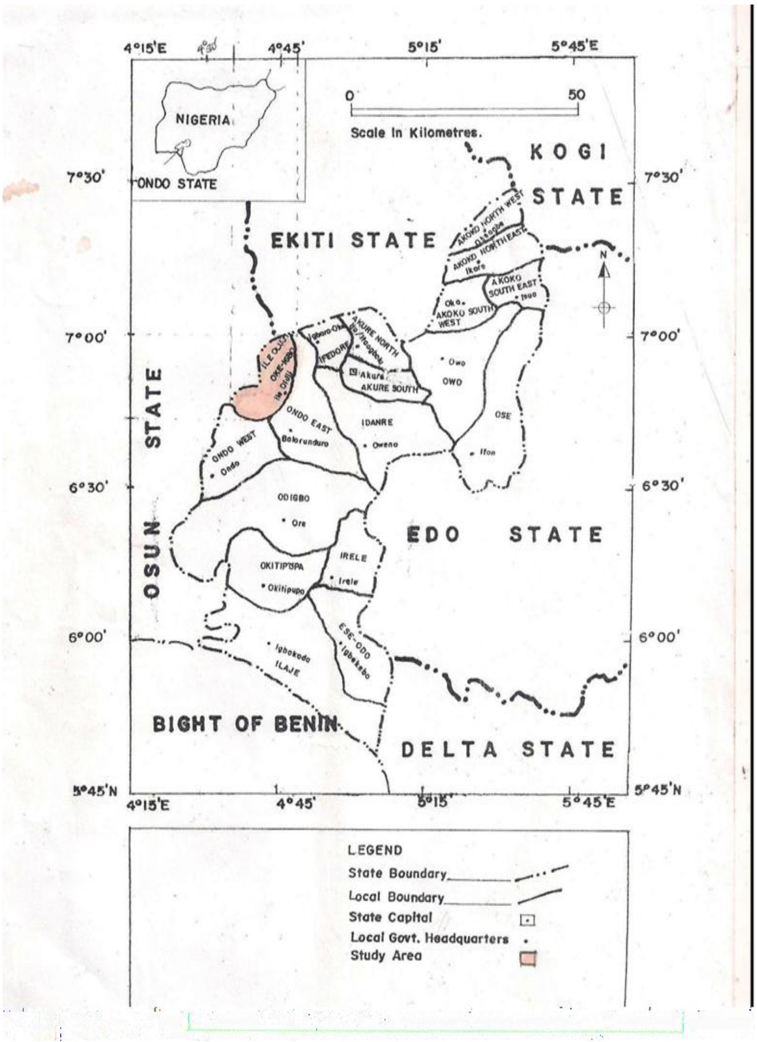

Figure 2: The figure presents the map of Ile-Oluji Township showing Locations for samples A, B, C, D and the Control sample.

2.2 Methods: The temperature and pH of the water samples were determined at the time of collection using thermometer and Pocket Digital pH Meter respectively. Other parameters such as TDS, free CO_2, hardness, alkalinity, chlorides, etc., were determined in the laboratory, using standard analytical procedures [21, 22, 23, 24, 25, 26], Ultra-violet spectro-photometer was used for the determination of nitrate and phosphorus concentrations.
Total heterotrophic bacteria in the water samples were enumerated using pour plate method. A five - fold serial dilution (10^{-1} to 10^{-5}) of the samples were prepared using sterile distilled water. MacConkey and Nutrient agar media were prepared in duplicate. 1mLs of each dilution was introduced into sterile petrish-dishes into which 19 mL of the prepared molten media was added. The cultured plates were allowed to cool and solidified. Therefore, they were incubated at 37^0C for 24 hours and the Petrish-dishes containing discrete colonies were counted [19, 27, 28].

2.3 Statistical analysis: The data obtained were subjected to descriptive statistical analysis (95% confidence limit). The general linearized model (GLM) using Turkey test was used to generate analysis of variance (ANOVA). The coefficient of correlation between the physicochemical parameters was calculated by the Pearson correlations test. Statistical significance was set at P values of < 0.05 or < 0.01. All statistical analysis was performed using SPSS (version 17.0).

3. RESULTS

3.1 Physicochemical parameters

The results of physicochemical parameters of the samples (A – D) collected close to filling stations for both dry season (DS) and rainy season (RS) are shown in Tables 2, while the results of the physicochemical parameters of the control samples and the WHO's maximum permissible limits (MPLs) are presented in Table 3 and the results of bacteriological examination are showed in Table 4.

Table 2: The table presents the physicochemical parameters of water samples.

	A		B		C		D	
Parameters	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**
Conductivity (µS/cm)	39.0	38.7	84.5	82.9	45.5	47.6	45.5	49.4
Temperature (°C)	29.5	27.5	28.2	27.3	26.7	27.8	26.2	26.8
Acidity (mg/L)	5.50	5.20	3.80	4.10	10.2	6.80	5.20	4.90
Alkalinity (mg/L)	18.0	17.9	38.0	33.2	59.0	45.0	39.0	31.0
Free carbon dioxide (mg/L)	70.4	72.4	125	116	132	124	106	117
pH	5.15	5.26	7.17	7.19	6.70	7.02	7.02	7.23
Total hardness (mg/L)	36.0	41.0	78.0	83.0	109	114	80.0	88.0
Calcium hardness (mg/L)	18.0	22.0	52.0	54.0	52.0	59.0	48.0	48.0
Magnesium hardness (mg/L)	18.0	19.0	26.0	29.0	57.0	55.0	32.0	40.0
Chloride (mg/L)	32.0	36.5	48.0	48.0	32.0	32.0	48.0	48.0
Total dissolved solids(mg/L)	60.0	70.0	130	120	70.0	80.0	70.0	60.0
Total suspended solids(mg/L)	0.25	0.30	0.20	0.25	0.40	0.45	0.35	0.35
Turbidity (NTU)	7.00	5.00	6.00	6.00	6.00	6.00	4.00	4.00
Phosphate (mg/L)	0.35	0.35	0.25	0.15	0.20	0.25	0.30	0.30
Nitrate (mg/L)	0.20	0.20	0.30	0.30	0.25	0.20	0.20	0.15

A, B, C and D represents sample codes; DS – Dry season; RS – Rainy season

Table 3: The table presents the physicochemical parameters of control sample and WHO's maximum permissible limits (MPLs)

	WHO	Control	
Parameters		**DS**	**RS**
Conductivity (µS/cm)	1000	39.0	42.8
Temperature (°C)	-	25.8	26.4
Acidity (mg/L)	-	7.30	6.50
Alkalinity (mg/L)	100	48.0	41.0
Free carbon dioxide (mg/L)	-	176	151
pH	6.5 - 8.5	6.98	6.89
Total hardness (mg/L)	500	40.0	37.0
Calcium hardness (mg/L)	75	20.0	18.0
Magnesium hardness (mg/L)	<50 – 150	20.0	19.0
Chloride (mg/L)	250	40.0	40.0
Total dissolved solids(mg/L)	500	60.0	70.0
Total suspended solids(mg/L)	5	0.45	0.50
Turbidity (NTU)	5	4.00	4.00
Phosphate (mg/L)	0.5	0.40	0.45
Nitrate (mg/L)	50	0.45	0.55

WHO: World Health Organization; DS – Dry season; RS – Rainy season

Table 4: The table presents the levels of microbial loads in the samples (cfu/ml)

	Mean TBC		Mean FC		Total Coliform	
Sample	DS	RS	DS	RS	DS	RS
A	4.80×10^8	4.39×10^8	4.50×10^5	4.00×10^5	0	0
B	9.66×10^8	6.20×10^8	1.58×10^6	7.70×10^5	0	0
C	3.68×10^8	3.54×10^8	1.78×10^6	1.63×10^6	0	0
D	5.53×10^8	5.09×10^8	1.08×10^6	1.00×10^5	0	0
Control	6.23×10^8	2.79×10^8	1.22×10^6	8.03×10^5	0	0

DS – Dry season; RS – Rainy season; TBC - total bacteria count; FC - fungal counts

During the (DS) the highest pH value was observed for sample B (7.17) and the least sample A (5.15). However, during the (RS), the highest pH was observed for sample D (7.23) and the least for sample A (5.26). Comparatively, the results obtained for the control sample were lower than other catchment samples except at sample A. The temperature of samples A to D ranged from 26.8°C to 27.8°C and 26.2 to 29.5 during the (DS) and (RS) respectively. The lowest temperature (25.8°C) was observed during the (RS) for the control sample. Alkalinity values for samples A to D ranged from 18.0 to 59.0 mg/L (DS) and 17.9 – 45.0 mg/L (RS). The control sample had values of 48.0 mg/L (DS) and 41.0 mg/L (RS).Turbidity values of samples A to D ranged from 4.00 – 7.00 NTU during (DS) and 4.00 – 6.00 NTU (RS). The results obtained during the (DS) for samples A to C and for samples B and C (RS) were above the maximum permissible limits (MPL) set by WHO [29]. However, values obtained for samples A and D (RS) and sample D (DS) fell within the MPL. Comparatively, the control sample had lower values of turbidity than other samples except sample D (RS).The results of total suspended solids (TSS) in samples A to D varied from 0.20 – 0.40 mg/L (DS) and

0.25 – 0.45 mg/L (RS). Comparatively, the concentration of TSS in the control sample was higher than other samples. From the results obtained, calcium hardness of samples A to D ranged from 18.0 - 52.0 mg/L (DS) and 22.0 - 59.0 mg/L (RS) while the magnesium hardness of samples A to D ranged from 18.0 - 57.0 mg/L (DS) and 19.0 - 55.0 mg/L (RS).The electrical conductivity (EC) of samples A to D ranged from 39.0 – 84.5 µS/cm (DS) and 38.7 – 82.9 µS/cm (RS). Control sample had 39.0 µS/cm (DS) and 42.8 µS/cm (RS). The concentrations of total dissolved solids (TDS) for samples A to D ranged from 60.0 – 130 mg/L (DS) and 60.0 – 120 mg/L (RS). The control sample had 70.0 mg/L (DS) and 60.0 mg/L (RS).The levels of nitrate in samples A to D varied from 0.20 – 0.30 mg/L (DS) and 0.15 – 0.30 mg/L (RS). The values of the control sample (0.45 mg/L (DS) and 0.55 mg/L (RS)) were greater than the catchment samples in both seasons. The phosphate concentration in samples A to D ranged from 0.20 – 0.35 mg/L (DS) and 0.15 – 0.35 mg/L (RS). Comparatively, the control sample had higher values than all other samples. Chloride levels in samples A to D ranged from 32 – 48 mg/L for both (DS) and (RS) respectively. The control sample had values of 40 mg/L for both (DS) and (RS).The concentration of free CO_2 in samples A to D ranged from 70.4 – 132 mg/L (DS) and 72.4 – 122 mg/L (RS); the control sample had values of 176 mg/L (DS) and 151 mg/L (RS). Acidity of samples A to D ranged from 3.80 – 10.2 mg/L (DS) and 4.10 – 6.80 mg/L (RS). The control sample had values of 7.30 mg/L (DS) and 6.50 mg/L (RS). The highest value was observed at sample C in both seasons. The mean total bacteria count (TBC) range between 3.54×10^8 - 6.20×10^8 cfu/ml (RS) and 3.68×10^8 - 9.66×10^8 cfu/ml (DS) while the fungal counts (FC) ranged between 1.00×10^5 and 1.63×10^6 cfu/ml (RS) and 4.50×10^5 and 1.78×10^6 cfu/ml (DS). The minimum FC was observed in site D (RS) and the highest in site C (DS). The minimum TBC was observed in site C (RS), and the maximum or the highest was observed in site B (DS). Coliform was not detected for both seasons. The results obtained for TBC in the control sample were 2.79×10^8 cfu/ml (DS) and 6.23×10^8cfu/ml (RS); the FC in the control sample were 8.03×10^5 cfu/ml (DS) and 1.22×10^6 cfu/ml (RS).

4. DISCUSSION

The pH values, except for sample A were within the WHO's acceptable range for drinking water and liveable range of 5.50 to 10 [30]. Similar trends (6.20 – 7.50 and 6.00 – 8.50) were reported in the Calabar River [31, 32], Cross River [33], New Calabar River [34] and Andoni River [35], all in the Niger Delta area of Nigeria. Variations in the pH are related to seasonal changes of rain and dryness. Relatively higher pH values were observed during the RS. The observed seasonal variation in temperature could be attributed to the climate of the study area which is usually characterized by a hot dry season and cold rainy season [32, 36]. In this study, the temperature ranges for both seasons were within the limits set by WHO [29]. Alkalinity values for all the samples fell within the limits set by WHO [29]. It was observed that alkalinity of the water samples exhibited a seasonal regime; it was higher during the (DS) than (RS). This is in agreement with the results obtained by Adebisi (1981) [37].

The trend might be due to evaporation and concentration of the bases in water in the dry season. Turbidity is an important operational parameter in process control and can indicate problems with treatment processes, particularly coagulation/sedimentation and filtration. Turbidity causes undesired tastes and odours and also affects the process of photosynthesis for algal growth [38]. Generally, a high turbidity values indicates a high concentration of total suspended solids. The higher TSS concentrations may be attributed to accidental discharges entering the water from local drainages. The level of suspended solids have been found to depend on a variety of factors including: substrate type, river flow, tidal height, water velocity, wind reach/speed and depth of water mixing [39]. It has also been reported that high concentration of TSS will cause water to heat up more rapidly and hold more heat. TSS values for all the samples during both seasons were lower than the MPLs stipulated by WHO [29].

The magnesium hardness in all the water samples analyzed fell within MPL set by WHO [29] except in sample C. Water hardness is a property that is defined by the quantity of calcium and magnesium found in water. Hard water does not usually lather enough which makes it unsuitable for domestic purposes. However, several arbitrary classifications of waters by hardness include: Soft, up to 50 mg/L $CaCO_3$; Moderately Soft, 51 - 100 mg/L $CaCO_3$; Slightly Hard, 101 - 150 mg/L $CaCO_3$; Moderately Hard, 151 - 250 mg/L $CaCO_3$; Hard, 251 - 350 mg/L $CaCO_3$; Excessively Hard, over 350 mg/L$CaCO_3$ [38].

The results of total hardness in this study revealed that the samples A to D were moderately soft while the control sample was soft. The results obtained in this study fell within the permissible limits of 500 µS/cm set by World Health Organization [29]. Comparatively, the values obtained for the control sample in both seasons were lower, except for sample A (RS). During hot weather high EC concentrations are an indication of high dissolved solids in the water [40]. The EC levels recorded during both seasons for all the samples were lower than the MPL stipulated by WHO [29]. Similar trend was observed by Tawari-Fufeyin *et al.* (1999); Akujieze and Oteze (2006) on groundwater quality of Benin City urban Aquifer [41, 42]. Egborge (1994); Ogbeibu and Victor (1995) reported that conductivity is an index of the total ionic content of water, and therefore indicates freshness or otherwise of the water [43, 44]. Warm weather, evaporation and loss of water increase electrical conductivity [45]. The result was relatively low and fell within the MPL set by WHO [29]. TDS represents the amount of inorganic substances (salts and minerals) such as calcium ion (Ca^{2+}), Magnesium (Mg^{2+}), hydrogen trioxocarbonate (IV) (HCO_3^-), trioxocarbonate (IV) (CO_3^{2-}), trioxonitrate (V) (NO_3^-) and tetraoxophosphate (VI) (PO_4^{3-}). High TDS in water samples commonly give objectionable or offensive taste [46]. TDS concentrations greater than 10,000 mg/L usually result in unusual health conditions in human [47]. The concentration of nitrate in water samples depends on the nitrification activities of micro-organisms. The values obtained in this study were well below MPL set by WHO [29]. Water that is contaminated with nitrate is harmful especially to infants causing methaemoglobinaemia, otherwise called infantile cyanosis or blue baby syndrome if consumed [48]. Oxidation of ammonia form of nitrogen from animal and human wastes to nitrite is a possible way of nitrate entry into the groundwater aquifer [49]. Excessive levels of nitrate in drinking water may cause serious illness and sometimes death due to shortness of breath and increase in starchy deposits [46, 50]. However, the results in all cases fell within the MPLs of 0.50 mg/L set by WHO [29] and FEPA [51] respectively. An excess of phosphate in the water makes algal and aquatic plants to grow wildly, choke up the water way, and use up large amounts of oxygen. This condition is known as eutrophication or over-fertilization of receiving waters. Solubility is responsible for phosphates finding their way into water from animal waste, runoff from agricultural land due to fertilizer use, and detergent-filled domestic wastewater [52]. In this study, the chloride values of all the samples for both seasons were lower than the MPL of 250 mg/L [29]. High concentrations of chloride make water unpalatable and unfit for drinking and livestock watering [53]. Chlorides occur in natural water at varying concentrations depending on the geographical condition. It may also get into surface water from several sources including: rocks containing chlorides, agricultural run-off, waste water from industries, oil well wastes, and effluent waste water from waste water treatment plants. Small amounts of chlorides are required for normal cell functions in plant and animal life [53]. Free CO_2 reacts with carbonate or hydroxide to form hydrogen carbonate [54]. The results obtained in this study were similar to results reported by [55]. The alarming increase in microbial loads may be as a result of increasing nutrients and aeration during the decomposition of organic matter [56, 57]. The microbial load observed in these well water samples are much higher than that reported by Akinyeye and Ogunlade (2016) [58] for a flowing river water sample.

5. CONCLUSION AND RECOMMENDATIONS

On the basis of the physicochemical and bacteriological properties of the water samples examined in this study, the results of bacterial loads were higher in all the samples including the control sample, compared to the values recommended by WHO, NIS and USEPA. Turbidity values were observed to be higher at site A, B and C as opposed to values at site D and the control sample. This point to the fact that users especially children are exposed to serious health risk. Hence before consumption, treatment should be seriously considered, so as to eliminate possible risk factors associated with sourcing water for drinking and other domestic applications from hand-dug well close to filling stations. Because of the high levels of bacteriological properties observed from this hand-dug well water close to filling stations, it is recommended that water from these sources should be treated before consumption to ensure public health safety.

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