International Research Journal of Pure & Applied Chemistry

21(12): 53-65, 2020; Article no.IRJPAC.60235
ISSN: 2231-3443, NLM ID: 101647669

Appraisal of Public Pipe-borne Water Quality in Jimeta/Yola Adamawa State (Nigeria): From the Treatment-plants to End-user Points

I. B. Bwatanglang[1*], E. Yonnana[2], Lynna D. Ibrahim[3], Abdulrahman I. Kubo[1], B. K. Elijah[1], C. A. Ayagwa[1], J. Abdulkarim[1] and Y. Yerima[1]

[1]Department of Pure and Applied Chemistry, Faculty of Science, Adamawa State University, Mubi, Nigeria.
[2]Department of Geography, Faculty of Science, Adamawa State University, Mubi, Nigeria.
[3]Department of Anatomy and Physiology, Adamawa State College of Nursing and Midwifery, Yola, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. In the experimentation and preparation of the manuscript. Author IBB designed the objectives and carried out the experiments. Author EY supported in the design and interpretation of the experiments. Authors IBB, EY, LDI, AIK, BKE, CAA, JA and YY helped with the writing and data analysis. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IRJPAC/2020/v21i1230234
Editor(s):
(1) Dr. Hao-Yang Wang, Shanghai Institute of Organic Chemistry, China.
Reviewers:
(1) Ihsan Jabbar Hasan, Middle Technical University, Iraq.
(2) Protima Sarker, Noakhali Science and Technology University, Bangladesh.
Complete Peer review History: http://www.sdiarticle4.com/review-history/60235

Original Research Article

Received 07 June 2020
Accepted 12 August 2020
Published 19 August 2020

ABSTRACT

This research aimed at assessing the drinking water quality of piped water distribution in Jimeta-Yola Adamawa State, Nigeria. The strategy was based on establishing the possibilities of contaminants underlying the distribution channels compromising the quality from the treatment source to the consumer point of use. Selected heavy metals and physiological parameters were determined toward establishing the water quality indices (WQI). Though, most of the parameter determined fell below or within the permissible limits (PL) set by WHO for drinking water, the results indicated significant ($p<0.05$) differences in the concentrations determined in the treatment plants (Yola treatment plant (YTP) and Jimeta treatment plant (JMTP)) with those at the consumer

---

*Corresponding author: E-mail: ibbbirma@gmail.com;

endpoints (YTPC and JMTPC). The results showed the WQI at the treatment plants being compromised due to the induction of pollutants across the distribution pipes. The water samples at the treatment point (JMTP) were excellent, having WQI <25 and good quality at YTP (25< WQI<50). However, the water quality on leaving the treatment source was observed to slightly change to poor quality at JMTPC (WQI= 57.00), and further observed to be in moderate-good quality at YTPC (WQI=49.27). Further analysis showed an increase in bacterial counts in the water samples at the consumer points. Escherichia coli concentrations of 565 and 718 cfu /100 mL were detected in samples from YTPC and JMTPC, despite the fact the water was observed to be free from bacteria at the treatment plants.

Keywords: Intermittent piped water; treatment plants; heavy metals; physicochemical; water quality index.

1. INTRODUCTION

Water by its very nature stands out as an indispensable and priceless commodity in the entire biota. Owing to its strategic place in nature, the United Nation through its Sustainable Development Goals (SDG) set a target to ensure global access to safe and affordable drinking water for all by 2030. The cardinal objective is to ensure that drinking water globally is free of pathogens and hazardous contaminants [1]. The decision becomes sacrosanct considering the rising cases of water-related diseases, which accounts for 1.5% of the global disease-related incidences and 5.5 % of the total death-related cases among children [2].

Despite all the developmental goals set in by the SDG, adequate and safe drinking water supply/distribution remains a mirage, increasing water stress especially amongst developing economies [3]. In Nigeria, poorly managed supply and distribution systems create water deficit and were available [4], are channeled through rusted/broken pipes [5,6] at relatively low pressure, and intermittently (at irregular intervals) made available to the consumers [7]. Intermittent or irregular supply of water, coupled with the poorly managed supply and distribution systems are widely considered among the major sources leading to water contamination [7,8]. Waterborne diseases and contamination of water with hazardous materials are reported to have a direct link with intermittent supply patterns from the water plants [9].

According to WHO/UNICEF [10], water supply plants in Africa provide service at irregular intervals, thus leading to water supply deficit, and compromising quality by facilitating the mobilization of microorganism [11] and seepage of contaminates across the low pressure, rusted/ or broken pipelines [8]. A guaranteed and continual flow pressure is required to ensure safe water distribution through pipelines [7,12]. Under this condition, a backflow of water could be prevented and hence the induction of pathogens and contaminants percolating through the distribution system [7,13,14]. Though WHO/UNICEF shows the world achieving its target for drinking water availability in 2010, a further appraisal of the reports suggests that at least 3 billion people or 47% of the global population are exposed to unsafe water in 2010 [15,16]. This discrepancy puts into question possible differential effect in the quality of water from the source with that at the receiving points [17].

Adamawa state in Nigeria has made a giant stride in working down the percentage of households that use unsafe sources of water from 51.38% in 2000 to 30.8% in 2007 [18]. However, this achievement was observed to have declined in recent times as a study conducted by Mohammed and Sahabo [5] shows the daily water supply rate of Jimeta-Yola dropping to about 10ML/D from the estimated 30ML/D based on the projected population of 2015. According to the study, only about 29% of the population in Jimeta-Yola are connected to pipe water that is running at a relatively low pumping supply capacity. The pipe-water supply according to the study was characterized by an irregular flow that runs weekly or twice a week and in some cases, thrice a month [5]. The irregular or intermittent piped water supply was reported to serve as a causative medium through which contaminates entered the water channels, thus increasing the risk to public health [7,19,20].

In light of the above, this study builds on the work conducted by Ankidawa *et al*., [21], Haliru *et al*., [22], Ishaku, [23], and Mohammed and Sahabo, [5]. To assess if any, a differential effect on contamination in the water quality in Jimeta-Yola; from the main source of treatment to the distribution systems, down to the consumers in selected service areas in Jimeta-Yola. Hazardous and microbial contamination as previously discussed above have been linked to the intermittent supply of water. For this purpose, the study examines the quality of water based on the following parameters: the level of heavy metals, the concentration of E.coli, pH, turbidity, total dissolved solids (TDS), total hardness (TH), dissolved oxygen (DO), and electrical conductivity (EC). Other parameters include calcium, sodium, potassium, Fluoride, Chloride, Nitrate, and Phosphate. The outcome of the study is intended toward compiling the stakeholder in the water business to improve on the quality of drinking water from the source, across to the end-users through well managed and effective distribution channels.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

Jimeta and Yola town in Adamawa state are conjoined twice, the former is the administrative city, while the latter houses the Traditional Headship of the state. The two cities are geographically located between latitudes 9° 11^{I} N and 9° 19^{I} N of the equator and between longitudes 12° 12^{I} E and 12° 30^{I} E of the Prime Meridian, covering an area of about 1,213 km^2 [24]. In addition to boreholes and hand-dug wells, the cities received ~30% of its water from the state water treatment plants (TPs) [5]. As described in Fig. 1, the Jimeta water treatment plants (JMTP) established in 1987 extend services to Lugere, Dogerei, and Clack quarters, while Yola treatment plant (YTP) established in 1974 extended extends its services to Shagari, 80 units and Federal College of Education (FCE) Yola. The two water schemes are the major supply points servicing communities within the metropolis. In this work, the communities receiving services from JMTP were designated as JMTPC while those of YTP as YTPC. The supply pattern from the water schemes due to some compounding factors is at irregular intervals and runs weekly or twice a week and in some cases, thrice a month [5].

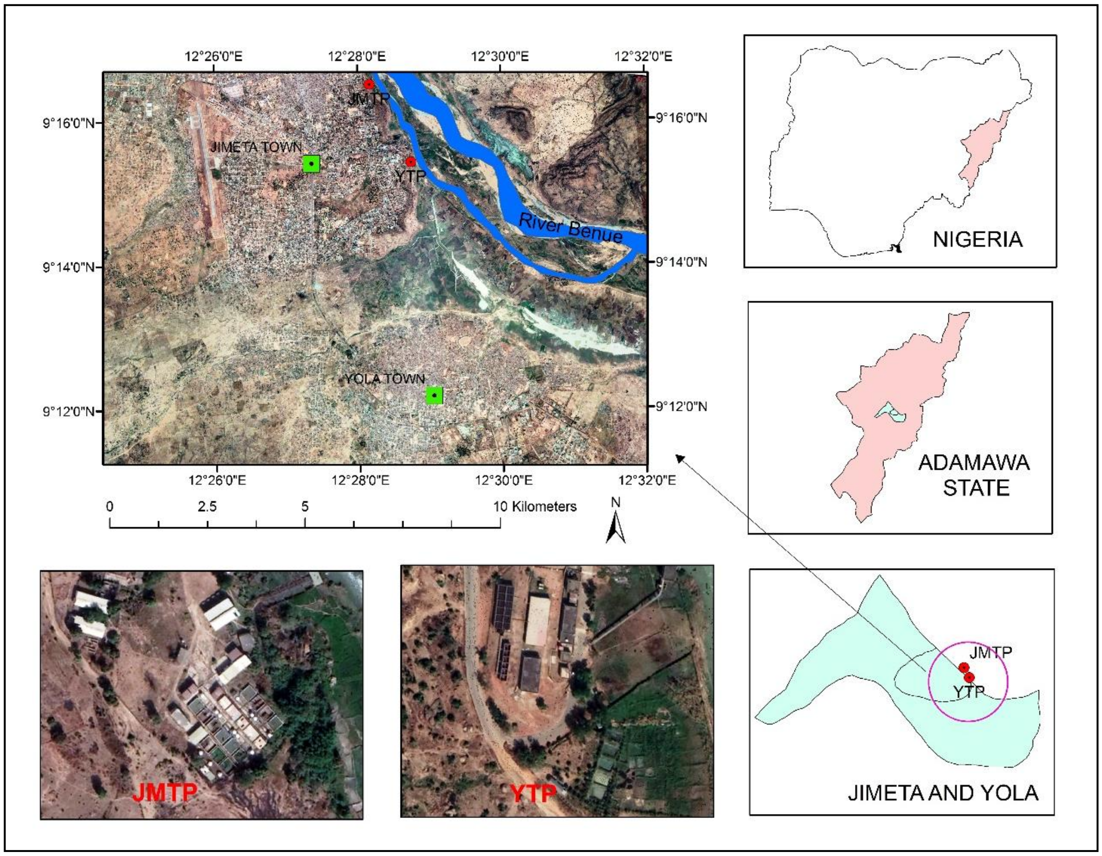


Fig. 1. Map of the study location showing the sampling points

2.2 Sampling and Analysis

For the study, water samples were collected using sterile plastic bottles from the following locations Lugere, Dogerei, Clack quarters, 80 unit, Shagari, and F.C.E weekly for three consecutive weeks. From each location, water samples were collected from six different households at a relative distance from each other and pooled together to make a representative sample for the location. Similar procedures were adopted for the two major treatment plants (JMTP and YTP). For the treatment plants, samples were also collected in triplicate weekly for three consecutive weeks. The samples were collected in a 250-ml sterile polyethylene plastic bottles and stored in a refrigerator before analysis to prevent the induction of contamination and biodegradation. The heavy metals and physicochemical analysis was conducted using standard laboratory methods [25]. Samples were analyzed for Lead (Pb), Calcium (Ca), Zinc (Zn), Copper (Cu), Iron (Fe). Cadmium (Cd) and Magnesium (Mg) using the Atomic Absorption Spectrometer (AAS) (Buck Scientific, VPG 210). Sodium (Na) was carried out using a Flame Photometer. The presence of anion such as chloride was determined using argentometric titration method, acid-base titration using methyl orange as an indicator for the Bicarbonate (HCO3-) ions, Nitrate (NO_3^-), Phosphate (PO_4^{3-})and Sulphate (SO_4^{2-}) using Sci-04 model of water LaMotte Analyzer. The pH was measured using pH meter, while Dissolved Oxygen was determined using DO meter (JENWAY 970). Total Dissolved Solid was determined using a multipurpose JENWAY portable combined TDS/Conductivity meter. The total hardness of the water samples was determined using the titration method with EDTA, while the Turbidity of samples is measured by Nephelometer. Membrane filter method (MF) was adopted using the most probable number (MPN) techniques and standard plate count methods for the determination of E.coli in the water samples [26]. The data were evaluated based on a statistical description using a statistical Package for Social Sciences (SPSS) software (Version 20). The results are expressed as Mean ± SD of three individual experiments. The results are considered significant at $p < 0.05$.

2.3 Water Quality Assessment

The water quality index (WQI) was assessed mathematically using the HMs concentrations and the physicochemical parameters obtained from the water sample in the study locations. In this study, 20 parameters were chosen for the assessment of the WQI and enabled using the WHO standards for drinking water (Table 1). The assessment was conducted using the expressions in equation 1 [27].

$$\text{WQI} = \sum_{i=1}^{n} \text{SIi} \quad (1)$$

Where SI is the water quality sub-index determined using the equation

$$SI = RWi \times qi \quad (2)$$

Where Wi is the relative weight of each parameter and qi is the rating scale for each parameter obtained from the expressions below

$$RWi = \frac{wi}{\sum_{n=1}^{n} wi} \quad (3)$$

Where Wi is the assigned weight for each parameter, RWi is the relative weight. The results are presented in Table 1.

$$qi = \left(\frac{Ci}{Si}\right) \times 100 \quad (4)$$

Where Ci is the concentration of each parameter and Si is the corresponding standards from WHO.

3. RESULTS AND DISCUSSION

3.1 Physicochemical Parameter Analysis

The pH with a mean value of 6.46±0.07 as shown in Fig. 2 was observed to fall slightly within the 6.5-8.5 ranges set for first-class drinking water [28,29]. The highest value of 6.53 was observed in FCE (6.53) and the least in 80 units (6.39). The values were further observed to be insignificant ($p>0.05$) when compared with the values at the treatment (YTP) plant (6.46±0.11). In the same vein, the pH values in water samples in JMTPC as shown in the figure also fall slightly within the 6.5-8.5 ranges set for first-class drinking water. Mean values of 6.43±0.12 and 6.66 ±0.15 were observed for samples in JMTPC and the JMTP respectively. These results agree with the pH ranges (5.6 and 7.2) reported by Abubakar and Adekola [30] and Ankidawa *et al* [21] in groundwater samples across Yola. In the figure, the value of Turbidity in the respective YTPC areas was observed to be significantly ($p<0.05$) below the WHO (5 NTU), but further observed to be significantly ($p<0.05$) higher compared to the values observed at the YTP (0.60±2.12 NTU). A mean value of 1.17±0.76

NTU was observed at the YTPC. Though the turbidity values were found to be below the WHO (5 NTU), the mean values observed in samples from JMTPC (2.03±1.67 NTU) were found to be significantly ($p<0.05$) higher than the values at the JMTP (0.50±1.02 NTU). The result was found to be lower than the mean value of 6.47 NTU detected in a groundwater sample from Yola as reported by Haliru *et al* [22]. Analysis of the sample as presented in the figure revealed a mean value of 22.00±4.58 mg/l for DO in water samples from the YTPC. The values were observed to be significantly ($p<0.05$) higher than the WHO (6-8 mg/l) and the values at YTP (11.00±0.15 mg/l). Similarly, a mean value of 25.00±1.01 mg/l was detected in samples from JMTPC. The value at JMTPC was found to be significantly ($p<0.05$) higher than the value at JMTP (13.03±2.11 mg/l). The concentration of DO reported in this study was higher than the 6.234 mg/l reported by Haliru *et al* [22] in wells and boreholes water samples in Jimeta-Yola. Water samples with high amounts of DO are observed to facilitate the oxidation of ammonium ion in the water to nitrate [23]. This could probably be an additional source of nitrate observed in this study, showing higher values in samples from the YTPC and JMTPC.

Table 1. The weight (Wi) and relative (RWi) for the water parameters and the WHO standards used in WQI determination

Parameters	WHO	Wi	Rwi
pH	6.6-8.5	2.54	0.05
TDS (PPM)	1000.00	3.36	0.06
Conductivity (µS)	1000.00	3.13	0.06
Turbidity (NTU)	5.00	2.20	0.04
Hardness ($CaCO_3$) (mg/l)	100.00	1.70	0.03
DO (mg/l)	6-8	3.04	0.05
Magnesium (Mg) (mg/l)	30.00	2.25	0.04
Sulphate (SO_4^{2-}) (mg/l)	250.00	3.67	0.07
Sodium (Na) (mg/l)	200.00	2.00	0.04
Calcium (Ca) (mg/l)	75.00	2.25	0.04
Phosphate (PO_3^{-4}) (mg/l)	1.00	0.10	0.00
Nitrate (NO^{-3}) (mg/l)	50.00	2.93	0.05
Chloride (Cl^-) (mg/l)	250.00	2.50	0.05
Floride (F^-) (mg/l)	1.50	4.00	0.07
Pb (mg/l)	0.01	4.00	0.07
Cd (mg/l)	0.00	3.00	0.05
Zn (mg/l)	0.10	2.00	0.04
Cu (mg/l)	1.00	3.00	0.05
Cr (mg/l)	0.05	4.33	0.08
Fe (mg/l)	0.30	3.50	0.06
		ΣWi =55.50	ΣRWi =1.00

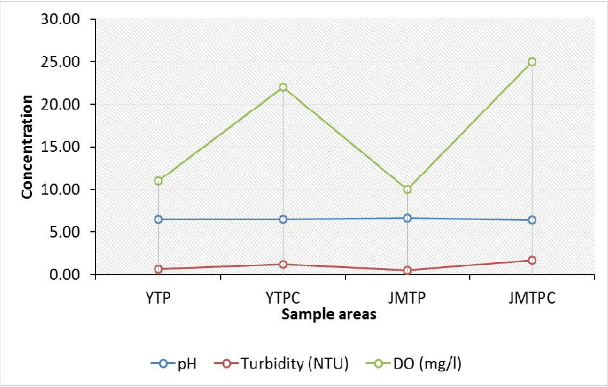


Fig. 2. Showing the pH, Turbidity, and DO values in water samples from the study locations. Results are presented in Mean ±SD of three replicate analysis

Fig. 3 shows the results for TDS, EC, and TH in water samples from YTP and the consumer end (YTPC). The TDS values obtained from YTPC as shown in the figure falls below the WHO PL (1,000 mg/l). Varying within a range of 290-696 mg/l and a mean value of 433.20±28.40. The mean value obtained for the samples at YTPC according to the study is significantly ($p<0.05$) higher to the values at YTP (236.30±5.23 mg/l). Furthermore, the mean values of 538.71±27.70 mg/l were determined for TDS in samples from JMTPC. These values were found to fall within the ranges reported by Haliru *et al* [22]. In their study, the TDS falls within a range of 17 mg/l to 1200mg/l in groundwater and 17mg/l to 220mg/l in borehole water samples across Yola metropolis. A range between 0-560 was also reported by Ankidawa *et al* [21] across Yola. In another work, Ishaku [23] determined a mean value of 368.4 mg/l in samples from Jimeta-Yola. The EC which is a reflection of the presence of dissolved solids was observed to follow the same trend with TDS, showing a significantly ($p<0.05$) higher mean value of 911.67±329.50 µS/cm in samples from YTPC compared to the samples from YTP (457.30±6.76 µS/cm). The values vary within a range of 1288–675 µS/cm, with values at Shagari (1288 µS/cm) exceeding the PL set by WHO (1,000 µS/cm). A mean value of 888.33±14.58 µS/cm was also determined in the sample from JMTPC, also observed to be significantly ($p<0.05$) higher than the values in the JMTP. The EC values in this study were observed to fall within a mean concentration of 667.86µs/cm determined in a groundwater sample from Yola [22] and the value reported by Ankidawa *et al* [21]. Total hardness also reflects the presence of cations and anions in the water body [31]. A TH with a mean value of 113.10±7.25 mg/l were recorded in samples from YTPC. The value was observed to be significantly ($p<0.05$) higher than the WHO PL (100 mg/l) and that of YTP (80.00±2.45 mg/l). A mean concentration of 122.10±1.15 mg/l was also determined in samples from JMTPC. The concentration of TH in water is classified into six categories: ≤50 as soft, moderately soft (50-100), slightly hard (100-150), moderately hard (150-250, hard (250-350), and very hard (>350) [32]. Based on the mean value of 113.10±7.25 mg/l, the water samples from YTPC, having values ranges from 100-150 is classified slightly hard and moderately soft for the sample at YTP. Groundwater samples measured across Yola metropolis by Haliru *et al* [22] show the level of TH ranges from 115-630mg/l. and the study by Ankidawa *et al* [21] shows a range from 31-254 mg/l. A mean value of 153 mg/l was also reported by Abubakar and Adekola in 2012 [30]. The geology of the study areas is characterized by underlying sandstone across the metropolis, influences the dissolution of calcium carbonate across the waterways and hence impacting on the concentration of TH observed in the study locations.

The TDS, EC, and TH observed in samples from treatment plants (YTP and JMTP) are significantly ($p<0.05$) lower when measured against their respective concentrations at the end-user points (YTPC and JMTPC). The increase in this parameters in samples from YTPC and JMTPC observed in this study, shows possible contamination in the distribution channels before reaching the end-user point and could be attributed to the possible inflow of leachable salts, and sewage effluent along the distribution channels seeping through the fragile/worn-out pipes systems in addition to the irregular/intermittent supply pattern.

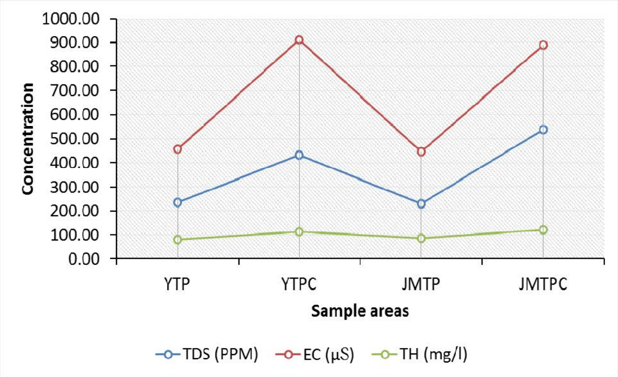


Fig. 3. Showing the TDS, EC, and Hardness values in water samples from the study locations. Results are presented in Mean ±SD of three replicate analysis

Fig. 4 shows the concentration of Mg, Na, and Ca in the water samples. As shown in the figure, a significant ($p<0.05$) increase in the concentration of the cations was observed in samples from YTPC compared to samples from YTP. Magnesium shows a mean value of 30.12±1.01 mg/l, Na has a mean value of 0.90±0.04 mg/l, while 1.94±0.65 mg/l were determined for Ca in samples from YTPC. The values were however observed to be below the PL set by WHO except Mg whose value showed no significant ($p>0.05$) difference with the WHO value. Similarly, when measured against their respective concentrations in JMTP, the results were observed to be significantly ($p<0.05$) higher in samples from JMTPC. Mean values of 36.01±3.61 mg/l, 0.99±0.17 mg/l, and 2.31±0.58 mg/l were measured for Mg, Na, and Ca respectively in samples from JMTPC. The concentrations were found to be relatively lower than the values reported in other studies carried out in groundwater samples across Jimeta-Yola. The work conducted by Haliru *et al* [22] detected Na, Ca, and Mg with a mean concentration range of ~32mg/l, 80.36mg/l, and 40.08mg/l in groundwater samples from Yola. The Na values were found to be lower than the average concentration of 93 mg/l reported by Abubakar and Adekola [30] across Jimeta-Yola. A range of 2.0-42.0 mg/l of Mg was also reported in a sample from Yola by Ankidawa *et al* [21]. The dissolution of carbonate and ferromagnesian, dolomite, and magnesium sulfate minerals underlay the groundwater could be responsible for the higher concentration reported in other studies compared to the concentration found in this present study [33].

The concentration of the anions (Cl^-, SO_4^{2-}, NO_3^-, PO_4^- and F^-) in the water samples are shown in Fig. 5. The anions determined in YTPC were all below the PL set by WHO. Phosphate levels range from 0.50-0.30 mg/l, with a mean value of 0.40±0.10 mg/l. Nitrate was found to have a mean value of 6.13±0.81 mg/l in samples from YTPC and 32.33±2.52 mg/l were determined for sulphate in the same water sample. In the study, nitrate and sulphate were not detected in the water sample from YTP. The concentration of Cl^- and F^- determined in the study were significantly ($p<0.05$) higher in samples from YTPC compared to samples from YTP. Mean values of 120.63±5.01 mg/l and 0.80±0.10 mg/l were determined for Cl^- and F^- in samples from YTPC. The concentration determined in this study falls within values reported in other studies. Ishaku [23] reported a mean value of 269.4 mg/l determined for Cl- in groundwater samples across Yola metropolis. In a separate study conducted by Abubakar and Adekola [30], 176 mg/l were determined in groundwater samples in Jimeta-Yola. Other studies reported the presence of chloride from 4-28 mg/l in water samples from Yola [22]. Fluoride with concentrations ranges of 0.014-0.3mg/l was also detected in boreholes and well water samples in Yola [22]. Phosphate levels ranges between 0.3 and 0.9 mg/l were also reported by Abubakar and Adekola. [30]. In a study conducted by Haliru *et al* [22], the concentration of nitrate (NO_3^-) in the range of 8.85-66.0 mg/l was determined in groundwater samples across Yola. Similarly, an average of 29 mg/l of nitrate in water samples from Jimeta-Yola was also reported in 2012 by Abubakar and Co [30]. Nitrate with mean concentrations of 59.9 mg/l was also determined in samples from Jimeta-Yola [23]. Water samples across Yola metropolis were also reported to contain a mean concentration of 30.6 mg/l of sulphate [30] and about 34.99 mg/l in mean concentration in groundwater samples [22]. Similar trends were observed in samples from JMTPC. Showing mean values of 0.46±0.14, 40.67±2.52, 5.17±0.70, 125.33±3.51, and 0.94±0.15 mg/l determined for PO_4^{3-}, SO_4^{2-}, NO_3^-, Cl^-, and F^- respectively. The level of phosphorus in quality drinking water is recommended at maximum 400ug/l and according to the ranges observed in this study, the water samples for the study locations are in first grade [28,29,31].

Chloride, nitrate, and sulphate are the major anions that adversely alter drinking water quality [32] and are found to be significantly ($p<0.05$) higher in samples from Both YTPC and JMTPC compared to the corresponding treatment sources. The presence of chloride ions in the water samples could be anthropogenic related or from the leaching of saline residues in the soil [34]. Seeping of sewage effluent, discharge of household saline containing products along fragile and worn-out pipes could be the possible reason behind the increase in the chloride content at the receiving points [35]. Water from the treatment plants before discharge through the distribution channels often contains not <20 mg/l of residual chlorine and is expected not to exceed 0.5 mg/l before reaching the end-user point under normal distribution systems [36]. Water sample containing ≤25 mg/l of Chloride is considered class-I; and class-II, III, and IV if the chloride concentration in the water is 200 mg/l, 400, and >400 respectively. From the analysis, the water in the study locations could be categorized as class-II [28,29,31].

Furthermore, the concentration of nitrates in the water samples could be from nitrate-based agrochemicals or leaching of human or animal wastes [27]. Water is considered class-I if it contains ≤5 mg/l of nitrate, class-II; if it contains 6-10 mg/l of nitrate, class-III and IV if it contains 11-20 and >20 mg/l of nitrate respectively. According to those limits, the water samples from YTPC having nitrate values from 6.13±0.81 MG/L could be categorized as class-II, while the samples from JMTPC having a mean value of 5.17±0.15 is class-I [28,29,31]. The breakdown of organic materials through soil weathering processes, leaching from sulphate containing fertilizers, atmospheric deposition, and oxidative decomposition of the sulfur compound by bacteria are means of sulphate induction into the water bodies [27,31,34,37]. Sulphate below 200 mg/l in water samples is classified as class-I, class-II if it is 200 mg/l. If 400 or >400 mg/l are categorized class-III and IV respectively [31]. The water samples from all the study locations based on the concentration of sulphate are classified as class-I [28,29,31]. Besides run-off from farmlands [38], Human and animal feces, or sewage water from septic tanks, percolating through defective or worn-out pipelines are possible routes through which contaminants enter drinking water sources. Exposure to nitrate and sulphate through drinking water is linked to health-related complications such as blue (methemoglobinemia), cyanosis, and asphyxia [39,40].

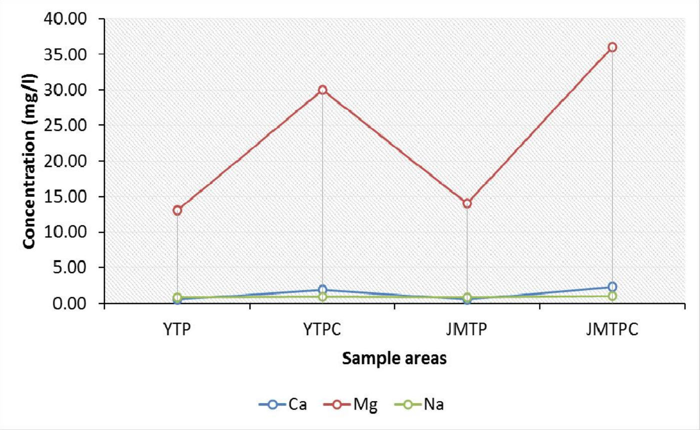


Fig. 4. Showing the Ca, Mg, and Na ions values in water samples from the study location. Results are presented in Mean ±SD of three replicate analysis

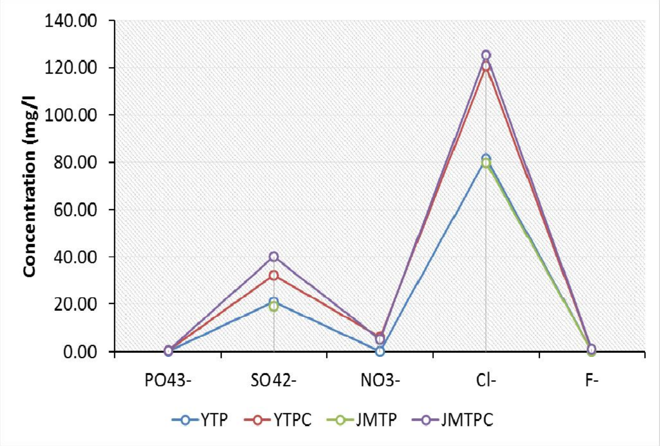


Fig. 5. Showing the PO_4^{3-}, SO_4^{2-}, NO_3^-, Cl^-, and F^- ions values in water samples from the study locations. Results are presented in Mean ±SD of three replicate analysis

The HMs in the samples from YTPC vary in concentration when compared to the WHO and YTP (Fig. 6). The mean concentration of Pb (0.02±0.03 mg/l), Cd (0.004±0.01), Zn (0.004±0.11), Cr (0.004±0.12), and Fe (0.033±0.02) were found to be slightly higher in samples from YTPC compared to the samples from YTP. Copper was not detected in samples from YTP. Cadmium, Zn, and Cu were not detected in samples from JMTP but were detected in samples from JMTPC. Other researchers detected varying concentrations of these ions in groundwater samples from Yola and environs. Iron with a mean concentration of 0.16 mg/l was determined in water samples from Yola by Abubakar and Adekola [30]. Similarly, a range of 0.18-18 mg/l was reported by Ankidawa *et al* [21]. Haliru *et al* in [22] determined the presence of Cu, Pb, Cr, and Fe with a mean concentration of 0.232, 0.390, 0,280, and 1.1 mg/l respectively in groundwater samples from Yola. Other studies reported the presence of Cr and Fe with mean values of 0.016 and 0.356 mg/l in groundwater samples from Jimeta-Yola [23].

Emissions from vehicles were reported to contain cadmium, zinc, nickel, soot's, and other particulate matter. Runoff containing these HMs from nearby roadside soils could leach through the weak distribution pipes and consequently to the end-users. Cadmium, for example, is mainly generated from the burning of lubricating oil and from wearing of tires. Similarly, wearing of tires in addition to the galvanized components of vehicles are additional sources contributing to Zn buildup in the environment. Copper and leads are a by-product of brake wearing, exhaust gas, and worn-out metal alloys in the engine [41]. Besides this medium, plumbing activities and wearing out of PVC pipes could release residues of Cu, Pb, and Fe into the water, and consequently, the receiving ends. The concentration of Fe as low as 0.3 mg/l will induce color change and increase turbidity in water. Higher amounts of suspended particles associated with a rise in turbidity will provide a culture medium for biofilms; thus increasing the likelihood of microbial contamination in the water body [42].

3.2 Water Quality Assessment

The WQI values were estimated using equations 8. From the result in Fig. 7, the quality of water for drinking purposes is 49.27 and 57.00 in samples from YTPC and JMTPC respectively, which implied that the quality at YTPC is good for drinking but poor in quality at JMTPC even though the quality is good at YTP (26.00) and excellent at JMTP (17.78). The results were accessed using the classification index suggested by Guettaf *et al* [27] and Brown *et al* [43]. WQI values are classified into five types namely, excellent water (0< WQI<25), good water (25< WQI<50), poor water (50 < WQI< 75), very poor water (75< WQI< 100), and water unsuitable for drinking (WQI > 100). Based on these classifications, the good quality measured at the treatment plants (YTP and JMTP) degenerated on transit before reaching the end-user points. Suggesting possible contamination in the distribution channels. The slight shift to poor quality in samples from JMTPC could be from the slight increase in Zn, Cr, Fe, Cl, TDS, TH, and sulphate in the samples from JMTPC. The results in this study, though differ in concept, show some semblance with the study conducted by Ishaku [23]. Reporting a WQI of 96.4 and 138.5 for dry and rainy seasons respectively from groundwater samples in Jimeta-Yola. In the study, WQI of 50-100 signified good water, while poor water quality is from 100-200. According to the study, the higher WQI is mainly due to an increase in the concentration of chloride, nitrate, Cr, EC, and DO.

Though the samples are of good quality in YTPC and not severely poor at JMTPC for drinking purposes, the presence of E.coli in the samples compromised the quality for drinking purposes. As the WHO standards for drinking water suggest zero levels for E.coli. About 565 cfu/100ml and 718 cfu/100ml were detected in samples from YTPC and JMTPC respectively. The presence of E.coli reported in water samples in some parts of Yola by Ankidawa *et al* [21] further supports these findings. Total coliforms and E.coli are important indicators often used to determine water quality for human consumption; measured the degree of pollution more often associated with sanitary conditions. The prevalence of microbial contamination through distribution channels and at point of use is widely observed despite being of good bacteriological quality at the source [44]. Okoko and Idise [45] observed an increase in the bacterial count with distance away from the water source. The presence of E.coli in water is directly associated with fecal contamination and may indicate the likelihood of health risk from disease-causing pathogens, such as bacteria, viruses, and parasites. However, the presence of these indicator organisms doesn't necessarily imply health risk on consumption [46,47]. Most strains of E.coli bacteria are harmless, except strains such as E.coli 0157:H7 which are reported to be associated with several water-borne diseases. Strain other than the 0157:H7 does not have the same genetic signature as those responsible for inducing intestinal infection [48]. This may explain why no available report relating to waterborne disease reported in the study areas. However, further analysis to isolate the bacterial strains is recommended for establishing the presence of disease-causing pathogens to prevent a possible outbreak. The presence of indicator organisms in drinking water follows some risk categories. Zero (O) means it conformed with the WHO guidelines, 1-10 signified Low risk, 10-100 relates to Intermediate risk, 100-1000 signified High risk, while >1000 implies Very High risk [47,49,50]. Since the E.coli counts observed in this study falls between 100-1000, the water samples at the consumer end are therefore signified High risk The main sources of bacterial contamination in drinking water includes: Improperly treated septic and sewage discharges, leaching of animal and human feces, and storm water runoff [47]. In pipe water distribution systems, contamination can occur through multiple pathways. It can occur through defective joints, back siphonage, rusted or worn-out broken pipes, and backflow due to intermittent low-pressure supply pattern [7,19,20,36,45].

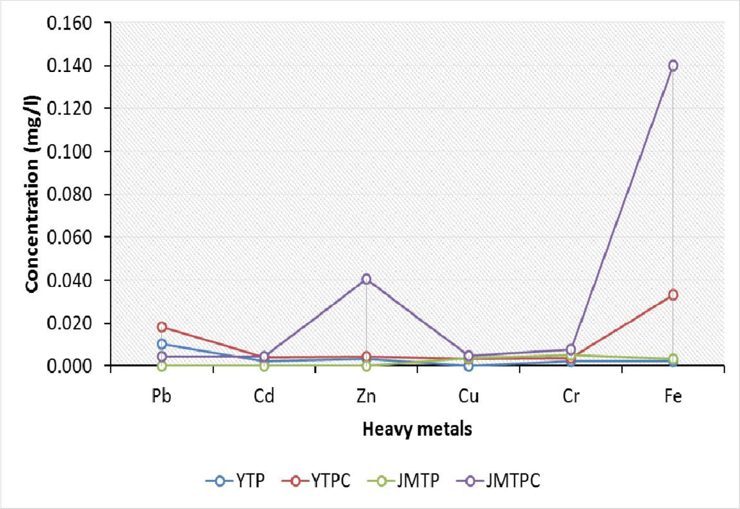
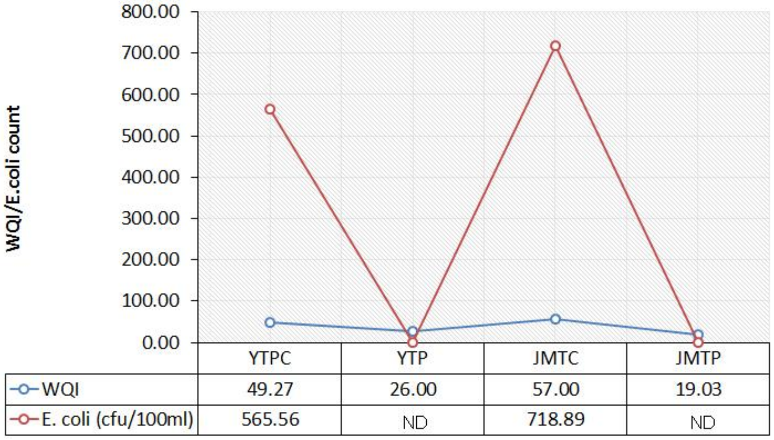


Fig. 6. Showing the Pb, Cd, Zn, Cu, Cr, and Fe ions values in water samples from the study locations. Results are presented in Mean ±SD of three replicate analysis



	YTPC	YTP	JMTC	JMTP
WQI	49.27	26.00	57.00	19.03
E. coli (cfu/100ml)	565.56	ND	718.89	ND

Fig. 7. Showing the concentration of E.coli and WQI in water samples from the study locations. ND signified not detected

4. CONCLUSION

This study brings into light that the water distribution channels in Jimeta-Yola fall short in maintaining quality from the source to the receiving end. The distribution system is characterized by irregular and insufficient pressure to guarantee the delivery of safe drinking water. And due to the irregular/or intermittent supply pattern characterized in the study area, a pool of contaminants underlying the weak, aged and worn-out distribution pipes will backflow into the distribution pipes during low pressure. The result of this study shows a significant (<0.05) increase in the concentration of the physicochemical parameters from the main source of treatment to the consumers. The quality of water for drinking purposes was observed to fall from the WQI that was classified good at YTP (26.00) and excellent at JMTP (17.78) to WQI of 49.27 and 57.00 at the consumer point of use (YTPC and JMTPC) respectively. The study further shows a serious compromise in the water quality due to E.coli infiltration across the weak and fragile distribution pipes, despite the fact the water was observed to be free from bacteria at the treatment plants. About 565 cfu/100ml and 718 cfu/100ml were detected in samples from YTPC and JMTPC respectively. This is considered serious as the WHO standards for drinking water suggest zero levels for E.coli.

5. RECOMMENDATIONS

It is therefore pertinent considering the foregoing for Adamawa State Government without further delay institute reevaluation of the long-aged water distribution schemes in the state. But for the interim, the research work recommends boiling of the water before consumption while further study to establish the E.coli strain for full-scale assessment should be instituted.

ACKNOWLEDGEMENTS

IBB acknowledges Chemistry Department Adamawa State University, Mubi. IBB also acknowledges Geography department, Adamawa State University, Mubi for providing the instrumental facilities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. WHO/UNICEF. Methodological note: Proposed indicator framework for monitoring SDG targets on drinking-water, sanitation, hygiene, and wastewater; 2015. Available:http://www.wssinfo.org/fileadmin/user_upload/resources/Statistical-note-on-SDG-References 67 [accessed 16:04:2020]
2. Prüss-Ustün A, Bartram J, Clasen T, Colford Jr JM, Cumming O, Curtis V, Freeman MC. The burden of disease from inadequate water, sanitation, and hygiene in low-and middle-income settings: a retrospective analysis of data from 145 countries. Tropical Medicine & International Health. 2014;19(8):894-905.
3. Yazdani A, Otoo RA, Jeffrey P. Resilience enhancing expansion strategies for water distribution systems: A network theory approach. Environmental Modelling & Software. 2011;26(12):1574-1582.
4. Onweluzo JC, and Akuagbazie CA. Assessment of the quality of bottled and sachet water sold in Nsukka town. Agro-Science. 2010;9(2). DOI:10.4314/as.v9i2.64804
5. Mohammed AB, Sahabo AA. Water Supply and distribution problems in developing countries: A case study of Jimeta-Yola, Nigeria. Int. J. Sci. Eng. Appl. Sci. 2015;1:473-483.
6. Onugba A, Aboh HO. The tritium content of precipitation and groundwater at Yola, Nigeria. Science World Journal. 2009;4(2). DOI:10.4314/swj.v4i2.51842
7. Kenea M. Assessment of faecal contamination and sanitary risk in intermittent piped water systems in rural Nepal (Doctoral dissertation, UNESCO-IHE); 2016.
8. Kumpel E, Nelson KL. Intermittent water supply: prevalence, practice, and microbial water quality. Environmental science & technology. 2016;50(2):542-553.
9. Lee EJ, Schwab KJ. Deficiencies in drinking water distribution systems in developing countries. Journal of water and health. 2005;3(2):109-127.
10. WHO/UNICEF. Global Water Supply and Sanitation Assessment Report. Geneva, Switzerland; 2000.
11. Coelho ST, James S, Sunna N, Jaish AA, Chatila J. Controlling water quality in intermittent supply systems. Water Science and Technology: Water Supply. 2003;3(1-

2):119–125.

12. National Research Council (NRC). Drinking water distribution systems assessing and reducing risks. The national academies press. Washington, D.C; 2006.
13. Besner MC, Gauthier V, Servais P. Explaining the occurrence of coliforms in distribution systems. American Water Works Association. 2002;94(8):95-109.
14. Trussell RR. An overview of disinfectant residuals in drinking water distribution systems. Wat. Suppl. 1998;16(3):1-15.
15. Onda K, LoBuglio J, Bartram J. Global access to safe water: accounting for water quality and the resulting impact on MDG progress. International journal of environmental research and public health. 2012;9(3):880-894.
16. Shields KF, Bain RE, Cronk R, Wright JA, Bartram J. Association of supply type with fecal contamination of source water and household stored drinking water in developing countries: a bivariate meta-analysis. Environmental health perspectives. 2015;123(12):1222-1231.
17. Boisson S, Stevenson M, Shapiro L, Kumar V, Singh LP, Ward D, Clasen T. Effect of household-based drinking water chlorination on diarrhoea among children under five in Orissa, India: a double-blind randomised placebo-controlled trial. PLoS medicine. 2013;10(8). DOI:10.1371/journal.pmed.1001497
18. Adewusi OA. An Assessment of the Strategies Adopted by Adamawa State Government towards Achieving Millennium Development Goals (MDGS) in Water Supply. International Journal of Business and Social Science. 2012;3(17):265-271.
19. Mokssit A, De Gouvello B, Chazerain A, Figuères F, Tassin B. Building a Methodology for Assessing Service Quality under Intermittent Domestic Water Supply. Water. 2018;10(9):1164. DOI:org/10.3390/w10091164
20. Tosi RD, Schertenleib A, Kunwar BM, Shrestha R, Bhatta M, Marks SJ. Assessing the impact of a risk-based intervention on piped water quality in rural communities: the case of Mid-Western Nepal. International journal of environmental research and public health. 2018;15(8):1616. DOI:10.3390/ijerph15081616
21. Ankidawa BA, Balla SK, Tankoz JA, Muhammad AA. Assessment of water quality of Yola metropolis, Adamawa state-Nigeria. Journal of Engineering Science and Technology. 2010; 5(3):79-82
22. Haliru HA, Ling LP, Suleiman OS, Mboh ABS. Groundwater quality assessment for domestic and irrigation purposes in Yola, Adamawa State Northeastern Nigeria. American Journal of Engineering Research. 2013;2(6):34-41.
23. Ishaku JM. Assessment of groundwater quality index for Jimeta-Yola area, Northeastern Nigeria. Journal of geology and mining research. 2011;3(9):219-231.
24. Adebayo AA, and Tukur AL. Adamawa State in Maps. Paraclete publishers. Yola; 1999.
25. APHA. Standard Methods for Examination of Water and Wastewater. 18th Edition. American Public Health Association; 1992.
26. Shen Q, Wang X, Chen E, Ma Z. Comparative Study on Test Methods of Total Coliforms in Domestic Drinking Water. In IOP Conference Series: Earth and Environmental Science. 2019;310(4):042002.
27. Guettaf M, Maoui A, Ihdene Z. Assessment of water quality: a case study of the Seybouse River (North East of Algeria). Applied Water Science. 2017;7(1):295-307.
28. Şen F, and Aksoy A. Chemical and Physical Quality Criteria of Bulakbaşı Stream in Turkey and Usage of Drinking, Fisheries, and Irrigation. Journal of Chemistry; 2015. DOI:10.1155/2015/72508
29. Tebbutt THY. Principles of Water Quality Control, 1998; 5th edition, chapter 2, Butterworth-Heinemann Elsevier, Oxford, UK.
30. Abubakar B, Adekola O. Assessment of borehole water quality in Yola-Jimeta Metropolis, Nigeria. International Journal of Water Resources and Environmental Engineering. 2012;4(9):287-293.
31. Dirican S. Assessment of water quality using physico-chemical parameters of Çamlıgöze Dam Lake in Sivas, Turkey. Ecologia. 2015;5(1):1-7.
32. Şener Ş, Davraz A, Karagüzel R. Evaluating the anthropogenic and geologic impacts on water quality of the Eğirdir Lake, Turkey. Environmental earth sciences. 2013;70(6):2527-2544.
33. Singh AK, Mahato MK, Neogi B, Tewary BK, Sinha A. Environmental geochemistry and quality assessment of mine water of Jharia coalfield, India. Environmental Earth

Sciences. 2012;65(1):49-65.

34. Chatterjee R, Tarafder G, Paul S. Groundwater quality assessment of Dhanbad district, Jharkhand, India. Bulletin of engineering geology and the environment. 2010;69(1):137-141.
35. Yisa J, Jimoh T. Analytical studies on water quality index of river Landzu. American journal of Applied sciences. 2010;7(4):453-458.
36. Awopetu MS, Coker AO, Aribisala JO, Awopetu SO. Water quality in a pipe distribution network: a case study of a communal water distribution network in Ibadan, Nigeria. WIT Transactions on Ecology and the Environment. 2013;171:175-186.
37. Varol S, Davraz A. Evaluation of the groundwater quality with WQI (Water Quality Index) and multivariate analysis: a case study of the Tefenni plain (Burdur/Turkey). Environmental Earth Sciences. 2015;73(4):1725-1744.
38. Fawell J, Nieuwenhuijsen MJ. Contaminants in drinking waterEnvironmental pollution and health. British medical bulletin. 2003;68(1):199-208.
39. Fan AM, Steinberg VE. Health implications of nitrate and nitrite in drinking water: an update on methemoglobinemia occurrence and reproductive and developmental toxicity. Regulatory toxicology and pharmacology. 1996;23(1):35-43.
40. Knobeloch L, Salna B, Hogan A, Postle J, Anderson H. Blue babies and nitrate-contaminated well water. Environmental health perspectives. 2000;108(7):675-678.
41. Bwatanglang IB, Alexander P, Timothy NA. Vehicle-derived heavy metals and human health risk assessment of exposure to communities along Mubi-Yola highway in Adamawa State (Nigeria). Journal of Scientific Research and Reports. 2019;1-13. DOI:10.9734/jsrr/2019/v23i130110
42. Nemade PD, Kadam AM, Shankar HS. Removal of iron, arsenic and coliform bacteria from water by novel constructed soil filter system. Ecological Engineering. 2009;35(8):1152-1157.
43. Brown RM, McClelland NI, Deininger RA, Tozer RG. A water quality index-do we dare? Water Sew Wks. 1970;339–343
44. Tadesse D, Desta A, Geyid A, Girma W, Fisseha S, Schmoll O. Rapid assessment of drinking-water quality in the Federal Democratic Republic of Ethiopia: country report of the pilot project implementation in 2004-2005. Geneva: WHO/UNICEF; 2010.
45. Okoko FJ, Idise OE. Assessment of chemical and bacteriological quality of pipe-borne water from various locations in Delta State University, Abraka, Nigeria. African Journal of Microbiology Research. 2014;8(21):2137-2143.
46. Chowdhury S. Heterotrophic bacteria in drinking water distribution system: a review. Environmental monitoring and assessment. 2012;184(10):6087-6137.
47. Edition F. Guidelines for drinking-water quality. WHO chronicle. 2011;38(4):104-8.
48. Warburton D, Harrison B, Crawford C, Foster R, Fox C. A further review of the microbiological quality of bottled water sold in Canada: 1992-1997 survey results. International journal of food microbiology. 1998;39(3):221-226.
49. Howard AG. Water Quality Surveillance: A practical guide, Loughborough University, UK and WHO. Guideline for drinking water quality. 2002;1.
50. Kassie G, and Hayelom D. Bacteriological quality of drinking water from source to point of use among rural communities of Farta Woreda in North West, Ethiopia. African Journal of Microbiology Research. 2017;11(26):1069-1074.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/60235