MUNICIPAL WATER SUPPLY AND QUALITY MANAGEMENT IN YENAGOA COASTAL CITY, BAYELSA STATE, NIGERIA

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Abstract

This study assessed the quality of water supplied from municipal water treatment plant to the consumers in Yenagoa, Bayelsa state. Water samples were collected from one sampling point from each of raw water and main water works, three sampling points each from Government house and Civil servant quarters and five sampling point from the community. Samples collected were analyzed for pH, NO_3-N, turbidity, residual chlorine, iron and silica while the results were compared with International (World Health Organization, WHO; European Union, EU) and National (Standards Organization of Nigeria, SON) recommended limits for potable water. Most of the parameters at all the sampling points were within the permissible limits specified by WHO, SON and EU but iron concentration was high. The mean silica values were 46.3±2.5, 21.9±2.3, 28.9±2.7, 14.8±1.1 and 24.3±8.2 mg L^{-1} in raw water, samples from main water works, government house, civil servant quarter and community respectively. The mean turbidity of raw water, treated water at water works and at point of consumptions were above the 5NTU permissible level. The residual chlorine value determined for Government House, Civil Servant Quarters and community were lower compared to the limit set by WHO and SON for public water supplies. Routine water quality assessment and monitoring is essential to prevent the likelihood of heavy metal and bacterial related health problems as Yenagoa is dependent on ground water supply which is prone to flooding during most part of the year.

***Keywords*:** Municipal water, Quality, Residual chlorine, Silica, Management

Introduction

Unsafe water supply is a global public health threat, placing persons at risk of diarrhoea and other infectious diseases as well as illnesses due to chemical toxicity[1]. Potability of water is defined as that which should not contain toxic chemical substances, pathogenic microorganisms and should be aesthetically acceptable[2]. Water is regarded as polluted when it is unfit for its intended use[3]. Around the world, access to improved water sources for drinking can be inadequate, and access to clean water is even more limited since improved access does not always guarantee safety. Unfortunately, 1.1 billion households still do not have access to an improved water source[4] which is defined as one that, by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with faecal matter[5].

However, disease may result from consumption of water containing toxic levels of chemicals. The health burden is most significant for a few chemicals: lead, arsenic, fluoride and others depending on the location. Arsenic contamination of drinking water sources is a serious problem in water supplies world-wide and in Asia in particular. In Nigeria studies carried by Sridhar and Bamigboye (Unpublished data) showed that there are pockets in ten states of the Federation and the levels are within permissible limits. In Bangladesh, between 35 and 77 million people are at potential risk[6]. Fluoride is also a significant global problem and WHO[7] suggest that over 60 million people are affected by fluorosis in India and China and suggest the total global population affected as being 70 million. In Nigeria, Plateau State is known for this problem[8]. Nitrate is also of concern although there remains uncertainty about the scale of adverse health effects from nitrate as few countries include methemaglobinaemia as a notifiable disease[9, 10]. Most of the shallow ground waters in Nigeria have higher levels of nitrate arising from poor sanitary conditions in the vicinity[11]. Methaemoglobin levels among infants in Lagos were shown to be a public health concern[10]. Raised nitrate levels have also been identified as potential public health problems in countries where concentrations in groundwater reach extremely high values[12].

A 2008 study has actually suggested that the condition of water supplies may not be favourable, even in areas that supposedly have access to better water sources[13]. This may be due to a variety of reasons, such as disagreements on the payment of operational costs after construction, poorly engineered boreholes, pressure loss, and damaged taps and pipes[14]. Other possible factors negatively affecting the quality of water being received through these "improved" sources include disputes about or difficulties purchasing the diesel needed to run the pump or to pay for routine maintenance and repair needed for the pump[13]. Hunter et al[14], found that just one day of exposure to unimproved water because of supply failures has significant impacts on the annual risk of enterotoxic *E. coli* infection. This risk continues to increase, and reaches a 99 per cent risk of infection by 34 days of exposure to unimproved sources.

Notwithstanding problems associated with improved water supplies, one of the main targets of the United Nations' Millennium Development Goals (MDGs) is to halve the number of people without sustainable access to improved drinking water and sanitation by 2015[15]. Between 1990 and 2006, the percentage of people with access to improved drinking water rose from 76% (4.1 billion) to 86% (5.7 billion). During the same time frame, around 1.1 billion people gained access to improved sanitation in developing regions[5]. Undoubtedly, safe water supply must be maintained to prevent the spread of disease and pathogens especially at the household level. Also, a reliable supply of clean wholesome water is highly essential in a bid to promoting healthy living amongst the inhabitants of any defined geological region[16]. However, it is obvious that following abstraction and treatment water becomes a vulnerable perishable product. It is vulnerable in that the integrity of the system used for the storage and distribution of water can be damaged and contamination through openings can occur. Furthermore, it could be perishable as a result of deterioration in its microbial quality due to the bacterial remaining after treatment growing on the residual nutrient in the water. In Nigeria, most of the studies focused on the assessment of ground water quality with little or no attention to quality of water treated for municipal supply. Therefore, this study evaluated the quality of water supplied from municipal water treatment plant to the consumers in Yenagoa, Bayelsa state. Yenagoa has a projection of providing water for a population of 600,000 by the year 2021 at a projected rate of 180 litres per capita per day. The peak water demand is expected to be 270litres per capita per day[17].

Materials and Methods

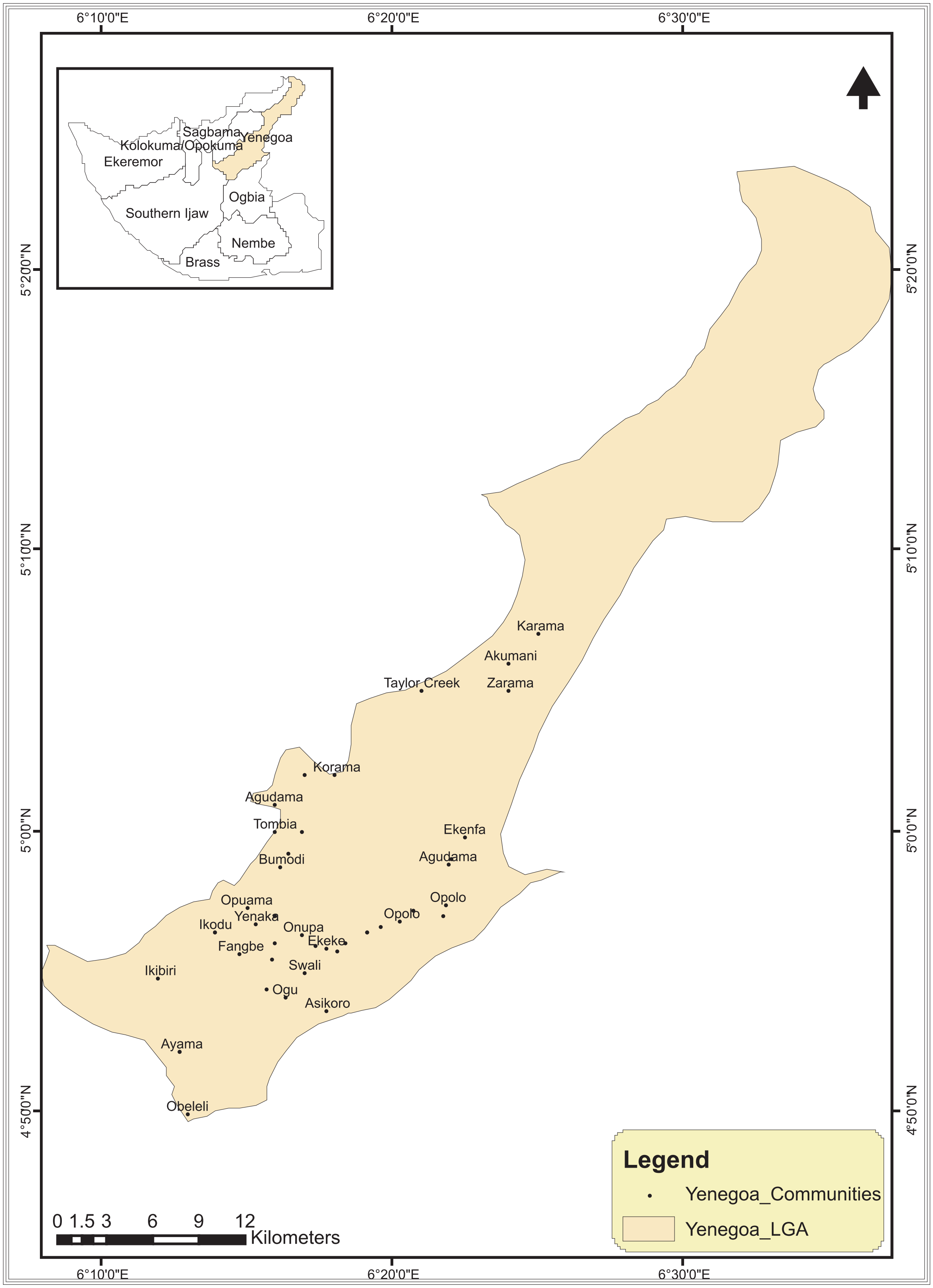
Study Area

The study was conducted in Yenagoa, the capital of Bayelsa State and Yenagoa Local Government Area, Nigeria (Figure 1). The LGA is geographically located within latitudes 4°49'N and 5°23'N and longitudes 6°10' E and 6°33'E (see Figure 1 for detail). It has an area of 706 km² with a population of 353,344[18]. The city is located on the banks of Ekole Creek and Nun River; the latter being one of the major river courses making up the Niger Delta's river. Yenagoa is the northernmost city of the state's significant population centre, located within the lower delta plain believed to have been formed during the Holocene of the Quaternary period by the accumulation of sedimentary deposits. It is situated within the lower floodplain of the Niger Delta. The terrain is poorly drained with a gentle syncline to the Gulf of Guinea in a southwestern direction. The major geological characteristic of the state is sedimentary alluvium. The majority of the communities within the local government area are completely surrounded by wetlands, generally less than 5 m above sea level. The main features of the drainage include the meandering of the distributaries of the River Niger which makes the place to be prone to flooding.

Study design and study location

The study adopted an analytical design which purposively selected the municipal water works; the agency that saddles with the supply of pipe borne water in Yenagoa, Bayelsa state. The raw water used as the source of water, water from the treatment plant and at different point from the users was sampled for analysis.

Figure 1. Map of Yenagoa with locations



Sampling techniques and analysis

A purposively sampling techniques was used in collecting samples from raw water that serves the municipal treatment plant (Raw water), water ready for distribution in the treatment plant (Main water works), Government house, Civil servant quarters and community. Samples were collected from one sampling point from each of raw water and main water works, three sampling points each from Government house and Civil servant quarters and five sampling point from the community. Plastic kegs of 2 litres capacity were used to collect samples for physico-chemical parameters. Polytetrafluoroethylene (PTFE) bottles of 60 ml capacity were used to collect samples for heavy metal analysis. The samples were fixed with concentrated acid to prevent the metals from adsorbing to the walls of the containers. Water samples were collected according to recommended

standard methods described by the American Public Health Association (APHA)[19]. Samples were collected four times in all the sampling points including the raw water. The sample bottles were tightly covered after each collection and transported under 4^0C to the laboratory for physico-chemical (including heavy metal) analysis.

Laboratory Analysis

Temperature and pH of samples were determined on-site. pH was measured using a pre-calibrated pH meter, **while** temperature was measured using a mercury thermometer (range 0^0C to 100^0C). **Turbidity was determined using HACH DR/2000 spectrophotometer at wavelength of 450 nm and expressed as NTU. Titrimetric method (using** disodium dihydrogen ethylenediamine-tetra-acetate) **was used to determine total hardness (using** powdered Eriochrome Black T (EBT) indicator**) and calcium hardness (using powdered murexide indicator)**[19]. A colorimeter (Jenway 6510, England) at 410 nm was used to determine NO_3-N, Nitrite and Ammonia while phosphate and sulphate were determined using Jenway 6405 UV/Visible Spectrophotometer. A colorimeter (Jenway 6510), England) at 515 nm was used to determined Residual chlorine using DPD (N, N-diethyl-p-phenylenediamine) Method while Atomic Absorption Spectrophotometer (Hanna C-100 spectrophotometer (made in UK) was used for the determination of Iron (Fe), Copper (Cu) and Silica (Si)[19]. All reagents used for analysis were prepared from Analar grade chemicals. Appropriate reagent blanks were prepared for each analysis. All analysis was done in triplicates.

Data analysis

Data were analyzed using statistical package for social sciences (SPSS) Windows Version 18 (Chicago, IL). The mean and the corresponding standard deviation were used to summarize the characteristics of the water samples, while the results were compared with Nigerian Industrial Standard (NIS) for drinking water by Standards Organization of Nigeria (SON) and World Health Organization (WHO) Guidelines for drinking water quality (Table 1). ANOVA test was used at 5% level of significance to determine if there were significant differences in the water quality parameters across the sampling points.

Table 1: World Health Organization (WHO), Nigerian Industrial Standard (SON) and European Union (EU) guidelines for potable water

Characteristics	WHO Limits	SON Limits	EU guideline
pH value	6.5-8.5	6.5-8.5	6.5-8.5
Temperature (^{0}C)	25	25	25
Turbidity (NTU)	5	5	5
Total Hardness (mg L^{-1})	100	150	
Calcium Hardness (mg L^{-1})	-	-	
Nitrate (mg L^{-1})	10	10	
Nitrite (mg L^{-1})	1.0	0.2	
Ammonia (mg L^{-1})	-	-	0.5
Sulphate (mg L^{-1})	200	100	
Phosphate (mg L^{-1})	-	-	-
Residual Chlorine	0.2-0.5	0.2-0.25	
Iron (mg L^{-1})	0.3	0.3	
Copper (mg L^{-1})	1.0	1.0	
Silica (mg L^{-1})			

Source: SON[20], WHO[4] and EU[21]

Water Supply Distribution in Yenagoa

Results

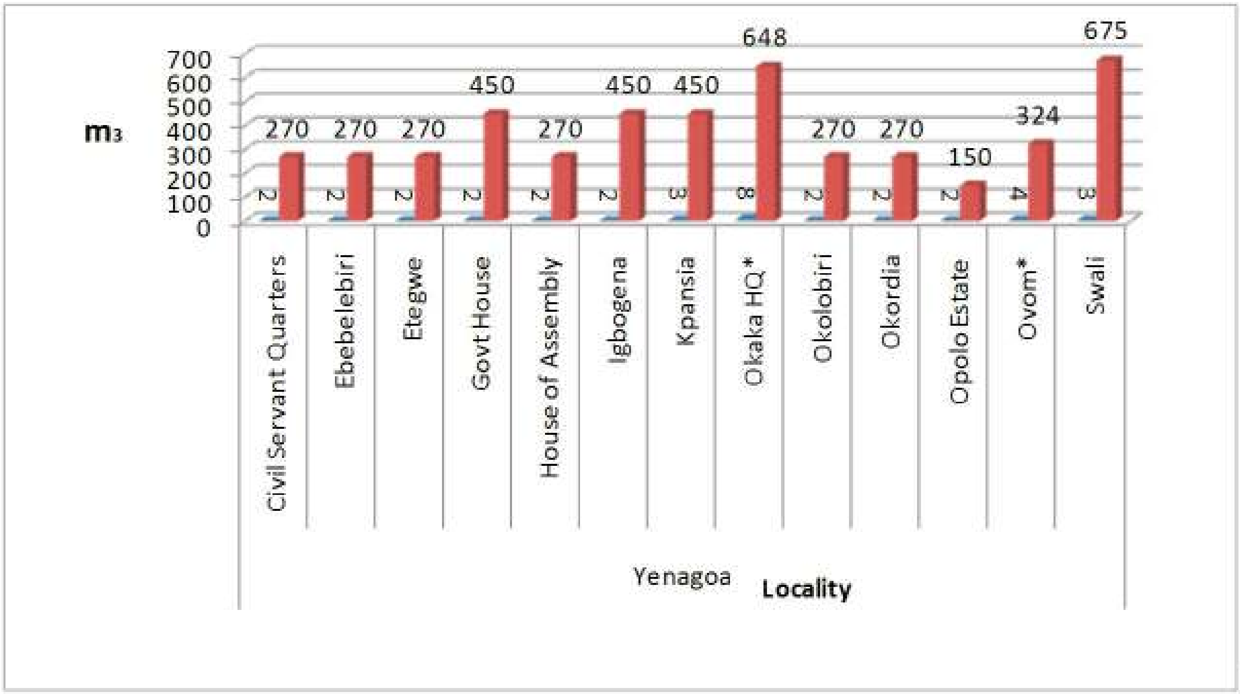


Figure 2: Water supply distribution in various localities in Yenagoa

(left bar number and the right bar volume in m^3, *Volume x 10)

Characteristics of raw water, treated water at water works and at point of consumptions

Table 2 presents the results of physico-chemical quality of the raw water, treated water at water works and at point of consumptions in the study setting. Most of the parameters at all the sampling points were within the permissible limits[21,4, 22] except for iron. The mean silica values were 46.3±2.5, 21.9±2.3, 28.9±2.7, 14.8±1.1 and 24.3±8.2 mg L^{-1} in raw water, samples from main water works, government house, civil servant quarter and community respectively. The mean turbidity of raw water, treated water at water works and at point of consumptions was shown in Figure 3. It was found that mean turbidity of all the water samples were above the 5NTU permissible level[20, 4, 21].

Table 2: Characteristics of raw water, treated water at water works and at point of consumptions

Parameter (Units)	Sampling points				
	Raw water	Main water works	Government house	Civil servants quarters	Community
Temperature (^{0}C)	28.5±0.6	26.0±1.2	28.5±2.4	26.3±2.3	27.5±1.7
pH value	6.5±0.6	7.5±0.3	6.9±0.1	6.6±0.2	7.1±0.3
Total Hardness (mg L^{-1})	1.7±1.3	2.5±0.2	4.9±0.5	2.8±0.2	3.1±0.3
Ca Hardness (mg L^{-1})	0.07±0.01	0.05±0.02	1.7±0.2	0.06±0.01	2.5±0.3
Nitrate (mg L^{-1})	0.04±0.01	1.8±0.5	2.5±0.3	0.7±0.04	0.5±0.3
Nitrite (mg L^{-1})	0.09±0.01	0.9±0.05	0.4±0.07	0.3±0.04	0.09±0.01
Ammonia (mg L^{-1})	0.3±0.02	0.04±0.03	0.1±0.02	0.01±0.0	0.2±0.02
Sulphate (mg L^{-1})	5.8±0.5	0.05±0.01	7.0±0.5	6.7±0.6	3.8±0.4
Phosphate (mg L^{-1})	0.0±0.0	0.2±0.09	0.2±0.08	0.8±0.2	0.08±0.01
Iron (mg L^{-1})	2.9±0.4	1.0±0.5	0.7±0.08	1.3±0.1	1.9±1.1
Copper (mg L^{-1})	0.5±0.04	0.09±0.01	0.2±0.02	0.06±0.01	0.09±0.06
Silica (mg L^{-1})	46.3±2.5	21.9±2.3	28.9±2.7	14.8±1.1	24.3±8.2

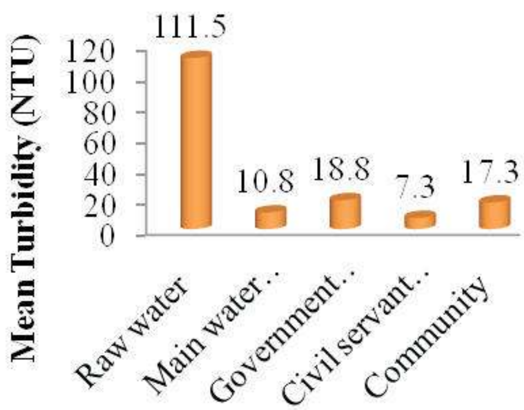


Figure 3: Turbidity (NTU) of raw water and sampling points along treated water distribution

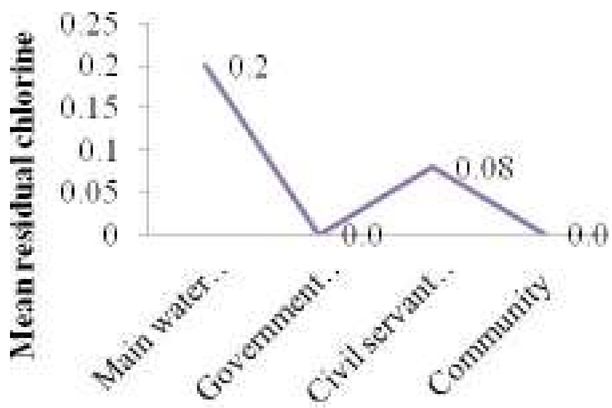


Figure 4: Residual chlorine (mg L^{-1}) in treated water and at point of consumption

Residual chlorine in treated water and at point of consumption

Figure 4 depicted the results of residual chlorine concentration in water samples at the treatment plant (main water works) and the point of consumptions-government house, civil servant quarter and community. The result revealed that the residual chlorine value obtained for sample at the main water works fell within the limit of 0.2-0.5 mgL^{-1}. It was also observed that residual chlorine value determined for Government House, Civil Servants Quarters and community were lower compared to the limit set[20,4,21].

Comparison of water quality between raw water, treated (main water works) and point of consumption

The turbidity and silica values between the raw water, treated (main water works) and point of consumption were compared as presented in Table 3. There was a significant difference between the turbidity values of the raw water, treated (main water works) and point of consumption ($p<0.05$). Though, the turbidity value were reduced at the main water works-treated water, (10.8±0.5) and at the point of consumption (15.7±0.2) compared to the raw water values (111.5±1.7) but were higher than 5NTU permissible limits specified by WHO, SON and EU. Likewise, silica were significantly higher in raw water (46.3±2.5) compared to main water works-treated water (21.9±2.3) and point of consumption (24.2±7.3), $p<0.05$.

Comparison of turbidity, residual chlorine and silica between main water works, government house, civil servant quarters and community was shown in Table 4. The difference between the turbidity values at the treatment plant (main water works) and point of consumption: government house, civil servant quarters and community were not statistically significant ($p>0.05$) though these turbidity values were higher compared to the recommended limit of 5NTU[20, 4, 21]. Likewise, residual chlorine values were not significant ($p>0.05$). The mean silica values among Main Water Works, Government House, Civil Servant Quarters and community were significantly different ($p<0.05$).

Table 3: Comparison of Turbidity and Silica between raw water, treated water from main water works and point of consumption

Parameters	Sampling points	Mean±SD	F-statistics	p-Value
Turbidity	Raw water	111.5±1.7	39.938	0.001
	Main water works	10.8±0.5		
	Point of consumption	15.7±0.2		
Silica	Raw water	46.3±2.5	5.692	0.012
	Main water works	21.9±2.3		
	Point of consumption	24.2±7.3		

Table 4: Comparison of Turbidity, Residual chlorine between main water works and point of consumption

Parameters	Sampling points	Mean -SD	F-statistics	p-Value
Turbidity	Main water works	10.8±0.5	0.232	0.872
	Government house	18.8±0.3		
	Civil servant quarters	7.3±0.6		
	Community	17.3±1.6		
Residual Chlorine	Main water works	0.2±0.03	0.111	0.761
	Government house	0.0±0.0		
	Civil servant quarters	0.08±0.01		
	Community	0.0±0.0		
Silica	Main water works	21.9±2.3	6.841	0.005
	Government house	28.9±2.7		
	Civil servant quarters	14.8±1.1		
	Community	24.3±8.2		

Discussion

This study evaluated the quality of water supplied from municipal water treatment plant to the consumers in Yenagoa, Bayelsa state. It was found that mean turbidity of all the water samples, both before the treatment and after were higher that the 5NTU permissible level[4, 21]. Though the turbidity values were not statistically significant, these high values could have been as a consequence of the treatment procedure being either inefficient/ineffective enough or the storage container was not in hygienic condition. Furthermore, ingress of rain water run-off cum turbid source into the distribution channel might occur during the supply to the consumer. Koinyan et al[22] observed in a study that the nitrate and sulphate concentrations in ground and surface water were generally low but higher in the latter. This study however, found that nitrate and sulphate concentration were low in the raw water, main water works (treated water) and at the point of consumption, these values were within the WHO and SON limit for potable water. The low value may be attributed to the use of chemical containing this parameter on either agricultural farmland or at an industrial level.

Although the concentration of copper was found to be lower in all the sample water but iron concentration was higher in both the raw water, treated water and water distribute to the consumers. A study carried out by Nwankwoala[23] heavy metal concentrations in the groundwater sources in the area is high in majority of the locations, with iron (Fe) values ranging from 0.06mgL-1 to 43.09mgL-1 while manganese (Mn) ranges between 0.12mgL-1 to 2.34mgL-1. Zinc (Zn) ranges between 0.15mgL-1 to 10.09mgL-1 with Nickel (Ni) concentration ranging from Below Detectable Limit (BDL) to 0.02mgL-1. Chromium (Cr) concentration ranges from 0.01mgL-1 to 0.18mgL-1, with Lead (Pb) ranging from 0.21mgL-1 to 0.42mgL-1. Arsenic (As) levels ranges from BDL to 0.01mgL-1. Cadmium (Cd) concentrations also ranges from BDL to 0.03mgL-1, with

Mercury (Hg) ranging between 0.07mgL-1 to 0.78mgL-1. Copper (Cu) also ranges from

0.01mgL-1 to 1.31mgL-1.

These results contradict the findings of a study which observed a low concentration of heavy metal including iron in ground water in yenagoa[22]. Furthermore, Shell Petroleum Development Company (SPDC)[24] in 2006 confirmed in an Environmental Impact Assessment study that the concentration of these heavy metals in the ground water is still within acceptable levels. The silica values were high in raw water, samples from main water works, government house, civil servant quarter and community respectively but higher in former. This may be as a result of geological features of the area cum by-product of some industries where the raw water is located. This is similar to the findings of Horsfall et al[25]. and Abia et al[26] that many of the industrial operations release various toxic heavy metals in their effluents into both the surface and ground water body. Heavy metals, arsenic and arsenical compounds, barium, chromium, lead, cadmium, manganese, zinc and other harmful materials are known to cause serious health effects. Such health problems includes but not limited to acute and chronic respiratory problems, gastro-intestinal tract infection, cardiovascular system disorder, nervous system and blood forming organisms malformation cases of skin and lung cancer[22].

The WHO and SON recommended value for residual chlorine in treated water with chlorine/chlorine derivatives disinfectant is in a range of 0.2-0.5 mgL^{-1} and values below this limits is an evident that bacterial might grow within a very short period in the treated water[4, 21]. Data from this study revealed that the residual chlorine concentration in water samples at the point of consumption at Government House, Civil Servants Quarters and community lower compared to the limit set[21,4]. Although the residual chlorine concentrations were not significant, water supplied to government house and community had extremely low residual chlorine compared to main water works and civil servant quarter.

Conclusion

Quality of water supplied from municipal water treatment plant to the consumers in Yenagoa, Bayelsa state has been evaluated and the iron concentration was high in all the sampling points. Also, silica values were high and residual chlorine of water from the point of consumption-government house, civil servant quarter and community were lower than the recommended limit by WHO and SON. These low residual chlorine concentration might create a conducive environment for bacterial growth, thus causing health challenges to the consumers. Routine municipal water quality assessment and monitoring is essential to prevent the likelihood of heavy metal and bacterial induced health problem.

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