Water Quality Assessment of the Freshwater Ecosystem at Communities' Points-Of-Use in Yenagoa Metropolis of Bayelsa State, Nigeria

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Abstract
The freshwater ecosystem in the Yenagoa Metropolis of Bayelsa State is characterized by creeks and rivers which most communities rely on for their daily water need. Water is considered safe for consumption when it is free of pathogens, poisonous substances and high concentration of minerals and organic matter. The quality of freshwater at human communities' points-of-use from three geo-referenced sites along the water course (i.e. upstream, midstream and downstream) during the peak of dry and wet seasons of 2014 were determined by conducting a physicochemical and culture-based study. Results obtained were compared to the acceptable limit set by the World Health Organization (2004) for safe water quality. Analyses revealed that the pH readings varied; ranging between slightly acidic to alkaline while values of turbidity, biochemical oxygen demand (BOD) and total hydrocarbon (THC) were above the acceptable limits of water quality. Remarkably, the DO and BOD values at the midstream site of the freshwater were observed to be higher than values from other sites indicating that the midstream site harbors more bacterial community than the upstream and downstream sites. Other tested physicochemical parameters assayed; heavy metals, total dissolved solids, electrical conductivity, and total hardness had values within the permissible limits. Microbiological investigation on the presence and concentrations of total cultivable heterotrophic bacteria (TCHB), total coliform (TC) and fecal coliform (FC) showed that they exceeded the limit of a safe drinking water. Thus, the high values observed for turbidity, BOD, THC, FC, TC and TCHB above the WHO acceptable limits for safe water quality is evident of water contamination which may be attributed to the high anthropogenic activities along the water course within the Metropolis. Although, the midstream site showed the highest DO and BOD levels which reflects the highest bacterial community among sites, more cultivable bacterial species were found at the downstream site. This suggests that the midstream site harbors more uncultivable bacterial species. This uncultivable bacterial species could be of a public health importance.

Keywords: *Freshwater, points-of-use, health risk, Yenagoa, Bayelsa State*

Introduction

Water as a natural resource is one of the most essentials of life. It is commonly referred to as Beni' and 'Mmendi' within the Yenagoa Metropolis of Bayelsa State. The freshwater resource surrounding the Metropolis is commonly relied on by the locals for their daily water needs. Most communities along the water courses use it as their main source of drinking water and for variety of recreational, transportation, agricultural, anthropogenic and human activities which contribute nutrients within the water bodies (8). High anthropogenic activities (e.g. boating, fishing, swimming, washing, bathing, dredging, refuse dumping, effluent and sewage discharge from sewers) along water courses and run-off discharges from roofs, environments (e.g. oil exploration sites, dumpsites, farmlands, settlements, bushes, markets and drainage systems) into water courses during the wet seasons are common in Yenagoa Metropolis (8). Contamination of water is a global public health risk especially as the major cause of diarrheal disease (5). Reports showed that about 2 million persons die every year of diarrheal disease (7); of which 90 % of the deaths were attributed to consumption of contaminated water, lack of access to safe water and sanitation problems (14, 5). Globally, about 663 million people lack access to safe water (15) while in the sub-Saharan Africa, about 300 million people do not have access to safe clean water supply (12). In the Yenagoa Metropolis of Bayelsa State, there are no existing drinking water treatment plants (DWTPs) and drinking water distribution systems (DWDS) that will help to monitor and evaluate the quality of water from raw water (i.e. from the surface water) to treated water (i.e. through stand pipes of the DWDS) meant for consumption. Thus, most communities rely on freshwater from creeks and rivers for their daily water need.

Water is considered safe for consumption when it is free of pathogens or having other pollutants within the regulatory limits. Fecal coliform is a useful indicator in monitoring fecal contamination in water and the estimation of total cultivable heterophic bacteria gives a prediction in the cultivable bacterial community inhabiting the water resource. Physicochemical studies of environmental samples from different compartments explore the environmental factors that affect microbial growth and metabolism. These kinds of studies are less cost intensive, but offer reliable results that can be used for decision-making in executing water resource management, especially in low-income economies. Thus, in this study, physicochemical and bacteriological studies were investigated to determine the drinking water quality of the freshwater at human communities' points-of-use within the Yenagoa Metropolis of Bayelsa State, Nigeria.

MATERIAL AND METHODS

3.2 Study area

The selected study area is Yenagoa, which is the capital city and the most commercial and industrialized part of Bayelsa State (Fig.1). It is located within the lower delta plain with an elevation between 3-7m above mean sea level (13) and drained with rivers and creeks among which are Epie and Taylor Creek, Nun and Ekole Rivers (8).It lies approximately between latitudes 4° 59´N to 5° 15´N and longitudes 6° 15´E to 6° 30´ E within the Niger Delta region of Southern Nigeria. The area has a humid climate with relative humidity of above 80 % and an average annual temperature of 27 °C (9) and vegetation of freshwater swamp and lowland forests (13).

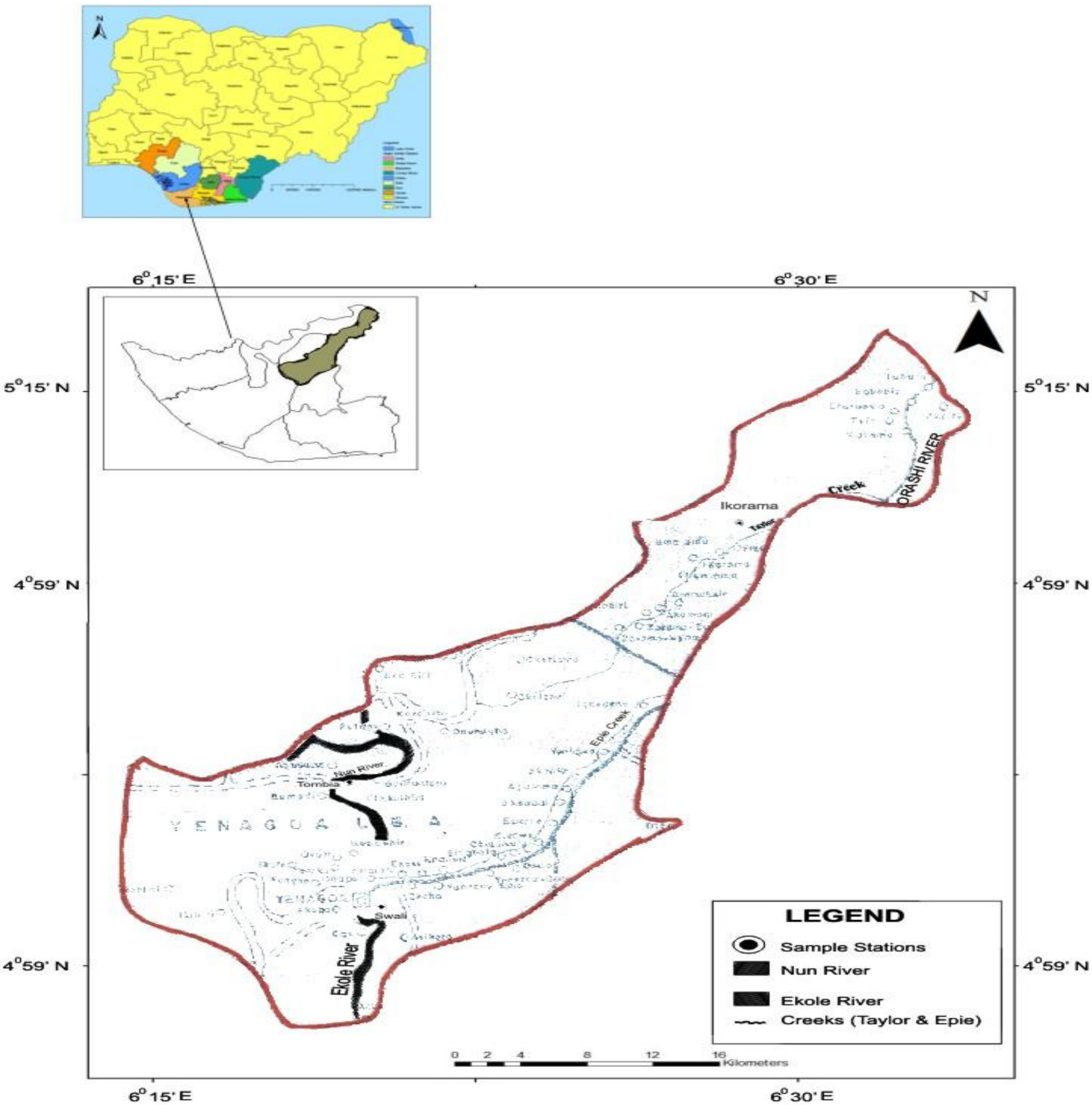

Fig. 1: Map of the study area and sampling points in Yenagoa Metropolis

Sampling

Approximately 1 litre of near-surface river water samples were aseptically collected in a sterile screwed capped containers at three geo-referenced sites (Table 1) along the water course (i.e. upstream at Ikorama community, midstream at Tombia Community and downstream site at Swali community) at human communities' points-of-use. All sample containers were recapped, properly labeled and transported to the laboratory in an iced-packed cooler for analysis within 6 hours of collection. The distance from A to B is about13 km while the distance from B to C is about 3 km.

Table 1 Geo-referenced sites of the freshwater ecosystem within the Yenagoa Metropolis

Sites	Site ID	Longitude	Latitude
Ikorama (Upstream)	A	4^{0} 59' 49'.66 N	6^{0} 15'32.76"E
Tombia (Midstream)	B	4^{0} 59' 57. 47' N	6^{0} 15'46.36"E
Swali (Downstream)	C	4^{0} 59 49.37'N	6^{0} 15'33.94"E

Physicochemical analyses of samples

The physicochemical parameters analyzed in this study include: PH, electrical conductivity, Total dissolved solids, salinity, total alkalinity, total hardness, turbidity, chloride, dissolved oxygen, biochemical oxygen demand, ammonia, ammonium, sulphate, phosphorus, calcium, magnesium, manganese, iron, lead, chromium, nickel and total hydrocarbon.

The pH, salinity, electrical conductivity (EC), total dissolved solids (TDS) was conducted in situ using digital Hanna instruments (i.e. HI9024 microcomputer pH meter with the electrode HI1230 and the conductivity and salinity meter HI8033 respectively).

Other physicochemical analyses were done using a Flame photometer (i.e. for the determination of sodium and potassium), UV-Visible Spectrophotometer (i.e. for the determination of the cations), turbidimeter (i.e. for the determination of turbidity), titrimetric measurement (e.g. in determining alkalinity, total hardness e. t. c) and Winkler's method (for the determination of dissolved oxygen and biochemical oxygen demand) following standard methods (2). An Absorption Spectrophotometer (AAS) was used for the determination of heavy metals namely; iron (Fe), manganese (Mn), nickel (Ni), zinc (Zn), chromium (Cr), and lead (Pb).

The reagents employed in the analysis were of AR grade and double distilled water was used for the preparation of solutions

Microbiological analyses

Water samples were screened for total cultivable heterotrophic bacteria (TCHB), total and fecal coliforms bacteria using a pour plate method (2). Nutrient agar medium was used for the analyses of TCHB while Eosin Methylene Blue (EMB) agar medium (Thermo Scientific ^{TM}) was employed for total and fecal coliforms.

Estimation of total cultivable heterotrophic bacteria (TCHB)

The method employed in the estimation of TCHB was the pour plate method (2) using standard methods. In brief, aliquots of approximately 0·01ml of the original water samples were transferred in triplicates in the center of sterile Petri dishes, overlaid with nutrient agar medium (Oxoid) and swirled gently to allow for an even distribution of the cultivable heterotrophic bacterial community on the culture plates. Incubation at an inverted position followed immediately after nutrient agar media (Oxoid) were solidified at 37^{o}C for 48 hours. The colonies were counted after incubation and means of the colony counts of heterotrophic bacteria obtained.

3.8.2 Estimation of total and fecal coliforms

Membrane filter technique was employed in determining the total and fecal coliforms present in each water samples and this was done in duplicate. A 100 ml volume of the water sample was filtered through a membrane with pore size of 0·45μm that is small enough to retain the bacterial coliforms. The membrane filter was laid on the surface of a freshly prepared solidified Eosin Methylene Blue (EMB) agar medium (Thermo Scientific ^{TM}) and subjected to incubation at 37°C for 24 hours. For total coliforms, dark-blue, purple, dark, metallic green sheen, pink and thick, slimy colonies were identified (i.e. based on their differences in colony color due to their lactose fermentation abilities) and counted. For fecal coliforms, colonies with a greenish metallic sheen on EMB which were suspected to be *E. coli* were picked, subcultured and further confirmed by their ability to ferment lactose at 44.5°C and also turn indole and methyl red positive and Voges Prausker and citrate negative in the IMVIC test.

Statistical analysis

All data collected from the physicochemical studies was statistically analyzed using Statistical Analysis System (SAS) for the analyses of variance (ANOVA).

RESULTS

The physicochemical and bacteriological analysis of the surface water quality

Results obtained from the physicochemical analysis of the freshwater samples were summarized as means ± standard error (Table1). The pH readings during the dry and wet seasons varied slightly; ranging between slightly acidic at the upstream site (A) to alkaline at the midstream (B) and downstream (C) sites respectively. All the heavy metal parameters (i.e. iron, lead, chromium, nickel and manganese) analyzed were within the acceptable limit set by WHO as shown in the table. Furthermore, the values obtained for the total hydrocarbon (THC), turbidity and biological oxygen demands (BOD) were much higher that the permissible limit for safe water quality. Remarkably, the DO and BOD values at the midstream site of the freshwater were observed to be higher than values from other sites (A and C).

For the microbiological analysis of the freshwater samples from the various sites, investigations on the total cultivable heterotrophic bacteria (TCHB), total and fecal coliforms indicated that all exceeded the permissible limits of safe water quality (Table 1).

Table 2. Result of the physicochemical and bacteriological analysis of the freshwater samples

Parameter	Unit	A		B		C		WHO limits
		DRY	WET	DRY	WET	DRY	WET	
pH		6.36±0.02	6.2±0.03	6.6±0.15	6.3±0.5	6.72±0.02	6.3±0.2	6.5-8.5

Turbidity	NTU	31.2± 0.3	30.2±0.2	33.0±3.2	34.5±1.1	33.4±0.5	45.1±0.9	5.0
BOD		4.5±0.01	3.8±0.01	5.2±0.01	5.1±0.02	3.6±0.01	3.6 ±0.01	0.05
Fe	mg/L	0.02±0.1	0.02±0.01	0.0±0.0	0.05±0.01	0.05±0.01	0.08±0.1	0.3
Pb	mg/L	0.00±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.01
Cr	mg/L	0.00±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.05
Ni	mg/L	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±00	0.0±0.0	0.02
Ca	mg/L	7.5±0.01	3.7±0.01	8.7±0.03	3.1±0.1	5.5±0.1	3.6±0.1	75
Mn	mg/L	0.01±0.001	0.01±0.01	0.02±0.01	0.01±0.0	0.0±0.0	0.01±0.0	0.2
Salinity		0.03±0.01	0.01±0.01	0.02±0.01	0.03±0.01	0.03±0.01	0.01±0.01	200-250
EC	µS /cm	73.93±0.2	43.9±0.2	87.0±0.4	42.1±0.3	83.0±1.0	43.0±0.2	1000
TDS	mg/L	37.05±0.05	22.0±0.2	43.7±0.3	21.5±0.5	41.7±0.3	21.3±0.2	500
DO		4.94±0.02	5.69±0.01	6.92±0.1	7.18±0.02	4.2±0.1	3.95±0.01	5.0
CL	mg/L	1.90±0.01	2.09±0.2	3.95±0.02	2.25±0.03	2.9±0.02	2.1±0.1	250
ALK	mg/L	7.50±0.3	8.0±1.0	5.8±0.1	6.5±0.0	5.4±0.1	5.5±0.0	200
TH	mg/L	16.3±0.3	18.5±0.1	7.7±0.1	8.4±0.1	6.3±0.1	6.7±0.1	150
NH_4^-		0.0±0.0	0.0±0.0	0.01±0.0	0.01±0.0	0.02±0.0	0.0±0.0	
NO_3^-	mg/L	0.10±0.01	0.09±0.01	0.12±0.01	0.08±0.02	0.15±0.01	0.06±0.01	50
SO_4^{2-}	mg/L	3.1±0.1	3.1±0.03	1.35±0.01	1.23±0.06	1.68±0.01	1.68±0.02	100
PO_4^{3-}	mg/L	0.2±0.01	0.2±0.02	0.15±0.001	0.06±0.01	0.1±0.001	0.08±0.01	0-5
THC	Mg/L	0.36.0±0.0	0.08.0±0.001	0.35±0.05	0.50.0±0.01	0.66.0±0.01	0.28±0.01	0.007
TCHB	CFU/ml	1.5×10^3	2.5×10^3	2.0×10^3	2.4×10^3	2.0×10^3	2.5×10^3	400
TC	CFU/100 mL	1.0×10^2	1.2×10^2	2.0×10^2	2.4×10^2	2.7×10^2	3.0×10^2	10
FC	CFU/100 mL	1.0×10^1	1.2×10^1	1.4×10^1	$1.8x10^1$	$3.0x10^1$	$3.2x10^1$	0

A-Upstream, B-Midstream and C-Downstream

Discussion

Physiochemical studies of the surface water

Despite the fact that Ekole and Nun Rivers in Yenagoa metropolis serve as a sink for multiple anthropogenic effluents from the creeks and surrounding communities, previous studies on the assessment of their physicochemical properties are limited. These studies successfully assessed the physicochemical properties of the Taylor and Epie creeks (6), Ekole River (11) and River Nun (10) during the wet and dry seasons respectively and provided useful information that tested parameters did not exceed the safe limits of drinking water. In our study, investigations on the physicochemical analysis of freshwater samples at human communities' points of use revealed variation in pH, high DO, BOD, turbidity and THC values above the permissible limit which reflects water pollution. This may be attributed to high anthropogenic activities (e.g. boating, fishing, swimming washing, bathing, dredging, refuse dumping, effluent and sewage discharge from sewers) along water courses and run-off discharges (e.g. from roofs, oil exploration sites, dumpsites, farmlands, settlements, bushes, markets and drainage systems) into water courses during the wet seasons (8). Moreover, the highest BOD values noted at the midstream sites of the river during the dry and wet season suggests that the midstream sites and its surrounding environment are driven by more pollution sources. Studies (8) suggested that the community where the midstream site of the freshwater ecosystem (Site B) is situated within the Yenagoa Metropolitan area of Bayelsa State may be driven by both natural and anthropogenic processes. Furthermore, previous studies (4) showed that values for some heavy metals (e.g. iron) exceeded the safe limits of water quality. In our study, all the values for the heavy metal parameters did not exceed the permissible limit of safe water quality.

Bacteriological studies of the surface water

Results of the total cultivable heterotrophic bacteria (TCHB), total coliforms (TC) and fecal coliforms (FC) obtained from the microbiological analysis of the surface water at various sites (Ikorama (A), Tombia (B) and Swali (C) which were all above the permissible limit of safe drinking water suggests that surface water within the Yenagoa metropolis contains high microbial load which is not safe for consumption. Similar results have been reported for other rivers in Nigeria (1, 3).

Conclusion

Consumption of freshwater in Yenagoa Metropolis at points-of-use should be discouraged since this study has revealed high values of BOD, turbidity, THC and the presence of pathogenic bacteria above the acceptable limits for safe water quality. Communities relying on this source for their daily water needs might be prone to infection by waterborne pathogens which have health risk. Furthermore, even though the midstream site showed the highest DO and BOD levels which reflects the highest bacterial community among sites, more cultivable bacterial species were found at the downstream site. This suggests that the midstream site harbors more uncultivable bacterial species. This uncultivable bacterial species at points-of-use could be of a public health importance.

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