Physicochemical and Bacteriological Analysis of Ebe River Water Used for Drinking in Amede Community, Eha-Amufu, Southeast Nigeria

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Abstract. Water is an essential natural resource in maintaining and sustaining life. Drinking water pollution is common in poor societies and seriously challenges public health. Polluted water can contain high levels of heavy metals that can cause critical health problems and serve as vehicles for transmitting several pathogens. Ebe River is the primary source of drinking water in Amede community, and its environment is extensively polluted. This study evaluated some physicochemical parameters and bacteriological quality of Ebe river water using standard methods. A total of 15 samples were taken from five study sites and analyzed during the dry season. The physicochemical parameters analyzed were within the maximum permitted range by the World Health Organization and Nigerian Standard for Drinking Water Quality except turbidity (3.77±0.15-7.10±0.20 NTU), Mg (24.33±0.70-31.60±0.92 mg/l), SO_4 (118.90±2.27-136.17±2.30 mg/l), Zn (2.41±0.02-5.02±0.09 mg/l), Fe (1.14±0.00-2.19±0.18 mg/l), Pb (0.04±0.01-0.13±0.01 mg/l), Cd (0.01±0.01-0.03±0.08 mg/l) and Mn (0.11±0.01-0.19±0.02 mg/l). High concentrations of lead (Pb), cadmium (Cd), and manganese (Mn) in the river water is a serious concern because these chemicals can cause critical health problems. Total heterotrophic bacteria count ranged from 9.1×10^4±2.52-1.16×10^5±7.37 cfu/ml, faecal coliform ranged from 4.33±0.58-10.33±0.58 cfu/100 ml, and total coliform ranged from 17.33±1.16-31.33±4.73 cfu/100 ml. *Pseudomonas*, *Shigella* and *Salmonella* counts ranged from 9.33±0.58-28.67±2.08 cfu/100 ml, 2.33±0.58-5.67±0.58 cfu/100 ml and 2.11±0.01-3.00±1.00 cfu/100 ml. *Vibrio* spp. was not detected. *Pseudomonas* spp. and *Escherichia coli* were isolated in all the 15 samples analyzed (100% occurrence). The percentage of *Salmonella* and *Shigella* spp. occurrence were 60% respectively. The result generally indicates that water from Ebe River, also called Ebonyi River, is of poor quality and unsafe for human consumption.

Keywords: Water; pollution; heavy metals; pathogens; Ebonyi River; coliform.

INTRODUCTION

Water is one of the most essential natural resources plants, animals, microorganisms and humans need to carry out daily activities. Therefore, without water, humans, animals and all living things cannot exist or function well [1–3]. Water occupies about 70% of the earth, maintains the ecosystem by facilitating natural nutrient cycling, and plays crucial roles in sustaining life [4, 5]. It is used daily for different purposes, such as cooking, washing and drinking [6]. The World Health Organization stated that safe drinking water is a human right. One reliable way to promote health and effectively reduce poverty is providing access to safe and adequate drinking water services [7]. Every life on earth depends on water, which is why it is widely said that water is life [8, 9].

The pollution of water bodies, especially those used as drinking water sources, poses a considerable threat to public health. Pollution of drinking water sources is common in rural communities with poor knowledge of sanitation. Water sources like lakes, rivers, and streams should be regularly monitored and protected because they have essential multi-usage components like drinking water, irrigation, fishery, and energy production [10–13]. Generally, drinking water should be clean and safe because of its impact on human and animal health [14, 15]. In developing countries like Nigeria, pollution of water bodies is a significant challenge, and the failure to enforce environmental laws [16, 17] encourages the contamination of water sources with animal, hospital, industrial and domestic wastes [18, 19]. The composition of water is directly dependent on the environment surrounding it, and human activities around water bodies immensely contribute to the physicochemical and microbiological qualities of the water [20–22]. Exposure to some heavy metals in water could cause cardiovascular, neurological and dermatological reproductive diseases in humans [23]. Several studies have shown that water is one of the most important means of transmission of several infectious diseases [24, 25].

Bacteria can adapt and persist in extreme or harsh environmental conditions and, therefore, constitute one of the primary essential contaminants of water [26, 27]. The World Health Organization [28] noted that diseases associated with the contamination of drinking water make up a significant burden on public health; the primary risk to health comes from the ingestion of water already contaminated with animal or human faeces containing pathogenic bacteria that cause infectious diseases such as dysentery, typhoid fever, diarrhoea and cholera [29, 30].

Ebe River, also called Ebonyi River or Ebenyi River, is the primary and only natural source of drinking water throughout the year in Amede community. Apart from the wet season when the locals can harvest rainwater for drinking, the water from the Ebe River is mainly used for drinking and other purposes. The environment of the Ebe River is extensively contaminated with human excrement and several kinds of domestic, agricultural and industrial liquid and solid wastes. Wastewater from homes, fish farms, and cassava processing plants enter the river water at some points along the river bank. Hence, this study evaluated the physicochemical properties and bacteriological quality of the river water in the dry season to ascertain if Ebe River water is fit for human consumption.

METHODS

Study Area. Amede is one of the most prominent and vibrant communities in Eha-Amufu town. Eha-Amufu town is located in Isi-Uzo Local Government Area of Enugu State and Eha-Amufu is situated between latitudes 6°65'N and longitudes 7°77'E. The elevation is about 140m above the sea level. The vegetation is predominantly rainforest in Amede community where the samples were collected. The study area's respective minimum and maximum temperatures are between 26°C and 30°C. Environmental pollution and degradation in the study area are noticeable. In addition to agricultural activities around the study area, domestic wastewater and wastewater from cassava processing plants and fish farms close to the river bank enter the river water. There are several refuse dumpsites, and open defecation is a norm within the study area.

Figure 1 – Ebe River in the dry season

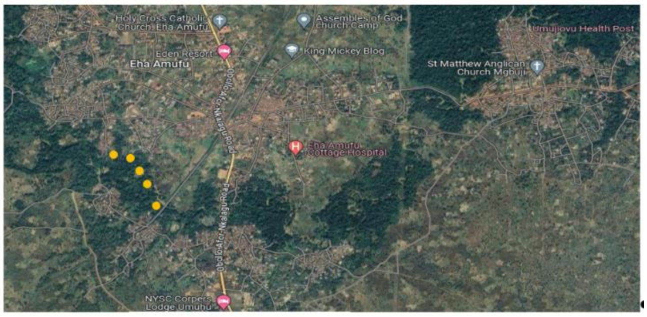

Figure 2 – Location of the study sites (yellow circles). Modified from Google Earth 2024

Sample Sites. Five study sites were selected after conducting preliminary surveys based on human activities in the study area. Site-1 (S1) was the upstream. Site-2 (S2) was where wastewater from a fish farm and cassava processing plant entered the water. Site-3 (S3) was where the villagers bathe, swim, washed clothes and fetch water for drinking and domestic use. Site-4 (S4) was where the largest refuse dump was located, and domestic wastes were discharged. Site-5 (S5) was the downstream.

Collection of Water Samples. A total of 15 samples were collected from five (5) different study sites between December 2023 and February 2024. This was during the dry season. Water samples were collected aseptically into 1L sterilized plastic bottles at each study site. Samples were correctly labelled, indicating the time and point of collection, before being placed in a cooler filled with ice and transported to the laboratory for analysis.

Analysis of physicochemical parameters. The pH, electrical conductivity (EC), and total dissolved solids (TDS) were determined using a waterproof multiparameter meter (HANNA edge EC/Salinity/TDS meter HI2030). Turbidity, acidity, alkalinity, magnesium (Mg), calcium (Ca), Chloride (Cl), sulphate (NO_4), phosphate (PO_4), hardness, nitrate (NO_3), zinc (Zn), chromium (Cr), cadmium (Cd), iron (Fe), manganese (Mn) and lead (Pb) were determined using standard methods. After digestion, heavy metal concentrations in the water samples were analyzed with an atomic absorption spectrophotometer AAS (model AA – 6800) [31, 32].

Bacteriological Analysis. The enumeration of total heterotrophic bacterial count (THBC) was done using the pour plate technique. This was done by performing ten-fold serial dilution in test tubes containing peptone water up to 10^{-5}. Exactly 9 ml of peptone water was transferred aseptically into five sterile test tubes labelled 10^{-1} to 10^{-5}. Exactly 1 ml of the water samples was aseptically transferred into the first tube (10^{-1}) with a sterile pipette and then serial dilution. This was repeated until the 5th tube. 1 ml of the samples from 10^{-1} to 10^{-4} of the dilution test tubes was aseptically transferred into the Petri plates and covered with freshly prepared molten nutrient agar medium. This was correctly mixed and incubated at 37°C for 24 hours. The bacterial colonies were then counted and expressed in colony-forming units per millilitre (cfu/ml). The membrane filtration method was performed by passing 100 ml of water sample through a sterile membrane filter with a pore size of 0.45 µm. After filtration, the membrane filter containing the bacteria was carefully unscrewed from the filtration apparatus and transferred aseptically to the surface of MacConkey agar medium for total coliform count (TCC) and incubated at 35 °C for 48 hours. The sterile funnel was carefully and accurately replaced on the filter base and then screwed for another filtration. The process was repeated severally and each time, the membrane filter containing the bacteria was aseptically transferred to the surface of the appropriate agar plates; Eosin methylene blue agar for faecal coliform count (FCC) and incubated at 44.5 °C for 24 hours, Thiosulphate Citrate Bile Salt Sucrose (TCBS) agar for *Vibrio cholerae*, cetrimide agar medium for *Pseudomonas* species, *Salmonella-Shigella* agar medium for *Salmonella* and *Shigella* species. After incubation, pure cultures were obtained by sub-culturing grown colonies [33, 34]. Characterization was based on the morphological and biochemical properties of the isolates. The isolates were tested for Gram reaction (Gram staining) and then subjected to biochemical tests, namely catalase test, coagulase test, citrate utilization test, oxidase test, urease test, indole test, Voges-Proskauer test and methyl red test. A motility test was also carried out. The procedures, including microscopic examination, were done as described by Cheesbrough [35].

Statistical analysis. All data were analyzed statistically using Statistical Package for Social Sciences (SPSS software version 22.0) plus post hoc Duncan's test and presented as mean ± standard deviation (SD). One-way analysis of variance was used to study the significant difference between the means with a significance level of $p < 0.05$.

RESULTS AND DISCUSSION

According to the World Health Organization [7], safe drinking water is a human right. Providing access to safe and adequate drinking water services is one of the most reliable ways to promote health and reduce poverty. The result of physicochemical analysis (Table 1) shows that all the physicochemical parameters evaluated in the dry season were within the maximum permitted range set by the World Health Organization [36] and Nigerian Standard for Drinking Water Quality [37] except turbidity (3.77±0.15-7.10±0.20 NTU), magnesium (24.33±0.70-31.60±0.92 mg/l), sulphate (118.90±2.27-136.17±2.30 mg/l), zinc (2.41±0.02-5.02±0.09 mg/l), iron (1.14±0.00-2.19±0.18 mg/l), lead (0.04±0.01-0.13±0.01 mg/l), cadmium (0.01±0.01-0.03±0.08 mg/l) and manganese (0.11±0.01-0.19±0.02 mg/l).

Table 1 – Physicochemical parameters of Ebe River water in the dry season

Parameters	Sites of study					NSDWQ (2015)
	S1	S2	S3	S4	S5	
TDS (mg/l)	317.83±5.92^{d}	356.17±5.33^{b}	409.30±5.03^{a}	371.70±2.75^{b}	312.70±4.88^{d}	500
EC (μS/cm)	297.20±1.57^{d}	582.90±3.32^{b}	614.60±1.21^{a}	583.57±5.92^{b}	416.47±3.65^{c}	1000
Turbidity (NTU)	4.93±0.32^{c}	5.73±0.12^{b}	7.10±0.20^{a}	3.77±0.15^{b}	5.23±0.15^{c}	5
pH	6.70±0.10^{a}	6.47±0.12^{b}	6.47±0.06^{b}	6.50±0.00^{b}	6.53±0.58^{b}	6.5-8.5
Acidity (mg/l)	4.13±0.15^{b}	4.43±0.12^{a}	4.40±0.10^{a}	4.43±0.06^{a}	4.27±0.06^{ab}	-
Alkalinity (mg/l)	1.03±0.01^{ab}	0.99±0.03^{bc}	1.06±0.05^{a}	0.95±0.01^{cd}	0.91±0.03^{d}	-
Magnesium(mg/l)	31.60±0.92^{a}	24.33±0.70^{c}	30.40±1.56^{a}	25.77±0.85^{bc}	27.10±1.04^{b}	20
Calcium (mg/l)	5.30±1.11^{c}	16.43±0.65^{a}	17.47±0.96^{a}	12.13±0.38^{b}	6.60±0.78^{c}	-
Chloride (mg/l)	72.13±1.19^{a}	60.27±5.83^{c}	45.60±4.33^{d}	41.63±0.85^{d}	70.42±0.59^{b}	250
Sulphate (mg/l)	118.90±2.27^{d}	132.37±0.98^{b}	136.17±2.30^{a}	129.40±1.39^{b}	123.00±1.04^{c}	100
Phosphate(mg/l)	12.20±0.79^{b}	9.73±0.15^{d}	14.03±0.31^{a}	12.17±0.23^{b}	11.27±0.25^{c}	-
Hardness (mg/l)	37.30±0.80^{c}	40.63±1.10^{b}	49.77±2.89^{a}	37.67±0.40^{c}	33.50±1.00^{d}	150
Nitrate (mg/l)	0.70±0.10^{c}	1.05±0.02^{a}	1.13±0.05^{a}	0.92±0.04^{b}	0.72±0.04^{c}	50
Zinc (mg/l)	2.41±0.02^{c}	2.58±0.03^{d}	5.02±0.09^{a}	4.22±0.06^{b}	3.13±0.05^{c}	3
Iron (mg/l)	1.14±0.02^{d}	1.14±0.00^{d}	2.19±0.18^{a}	1.91±0.02^{b}	1.58±0.04^{c}	0.3
Lead (mg/l)	0.04±0.01^{c}	0.05±0.01^{c}	0.13±0.01^{a}	0.07±0.01^{b}	0.05±0.01^{c}	0.01
Cadmium (mg/l)	0.01±0.01^{b}	0.02±0.01^{b}	0.03±0.08^{a}	0.02±0.01^{ab}	0.02±0.01^{b}	0.003
Chromium (mg/l)	0.01±0.01^{a}	0.01±0.01^{a}	0.02±0.01^{a}	0.02±0.01^{a}	0.02±0.01^{a}	0.05
Manganese(mg/l)	0.13±0.01^{b}	0.14±0.02^{b}	0.19±0.02^{a}	0.12±0.01^{b}	0.11±0.01^{b}	0.2

Notes: Values are presented as mean ± standard deviation of replicated determination (n=3). This means that the same column bearing different letter superscripts differs statistically.

The concentrations of magnesium (Mg), sulphate (SO_4), zinc (Zn) and iron (Fe) do not pose any adverse health implications. Still, high turbidity in drinking water can harbour microbial pathogens and reduce disinfection efficacy [7, 36]. However, the concentrations of lead (Pb), cadmium (Cd), and manganese (Mn) indicate that the water is not safe for human consumption.

This is because high levels of lead (Pb), cadmium (Cd) and manganese (Mn) in drinking water can cause critical health problems such as cancer, toxicity to central and peripheral nervous systems, kidney dysfunction and neurological disorders [36, 37]. The result is consistent with the results of previous studies by [5, 38–40], who found that the concentrations of iron (Fe), cadmium (Cd), lead (Pb), zinc (Zn), manganese (Mn) and the mean value of turbidity in Otamiri river, Haraz river, Orashi river and well waters were higher than the maximum permitted range set by the World Health Organization. The numerous anthropogenic activities within the Ebe River environment and the refuse dumpsites along the river's bank make it easier for liquid and solid wastes to enter the river water. Hence, the direct and indirect contamination of the river water could be the source of heavy metals detected in the river water.

The isolation of pathogenic bacteria from the river water shows that the water is unsafe for consumption and poses a critical public health problem (Table 2).

Table 2 – Bacterial parameters of Ebe River water in the dry season

Study sites		(CFU/100ML)					
	THBC (CFU/ML)	FCC (*E. coli*)	TCC	*Pseudomonas* Spp.	*Shigella* Spp.	*Salmonella* Spp.	*Vibrio* Spp.
S1	9.8x10^{4}±2.65^{b}	5.33±0.58^{cd}	17.33±1.16^{b}	11.67±0.58^{d}	5.67±0.58^{a}	0.00±0.00^{b}	0.00±0.00^{a}
S2	1.11x10^{5}±4.04^{a}	4.33±0.58^{d}	19.33±1.53^{b}	9.33±0.58^{d}	0.00±0.00^{d}	2.11±0.01^{a}	0.00±0.00^{a}
S3	1.16x10^{5}±7.37^{a}	10.33±0.58^{a}	31.33±4.73^{a}	28.67±2.08^{a}	3.33±0.58^{b}	3.00±1.00^{a}	0.00±0.00^{a}
S4	9.1x10^{4}±2.52^{b}	7.33±1.16^{b}	30.67±2.89^{a}	24.00±1.73^{b}	2.33±0.58^{c}	2.33±0.58^{a}	0.00±0.00^{a}
S5	9.6x10^{4}±2.0^{b}	6.33±0.58^{bc}	19.33±1.53^{b}	15.67±0.58^{c}	0.00±0.00^{d}	0.00±0.00^{b}	0.00±0.00^{a}

Notes: Values are presented as mean ± standard deviation of replicated determination (n=3). This means that the same column bearing different letter superscripts differs statistically.

The total heterotrophic bacteria count (THBC) ranged from $9.1x10^4$ ±2.52 to $1.16x10^5$ ±7.37 cfu/ml, faecal coliform count (FCC) ranged from 4.33±0.58 to 10.33±0.58 cfu/100 ml, total coliform count (TCC) ranged from 17.33±1.16 to 31.33±4.73 cfu/100ml, *Pseudomonas* spp. count ranged from 9.33±0.58 to 28.67±2.08 cfu/100 ml, *Shigella* spp. and *Salmonella* spp. counts ranged from 2.33±0.58 to 5.67±0.58 cfu/100 ml and 2.11±0.01 to 3.00±1.00 cfu/100 ml in the dry season. *Vibrio* spp. was not detected in all the samples.

The result indicates that the river water is unsafe to drink without proper treatment as it contains pathogenic bacteria. *Escherichia coli* and *Pseudomonas* spp. were detected in all 15 samples (100% occurrence). *Shigella* spp. had 60% occurrence, while *Salmonella* spp. also had 60% (Figure 3).

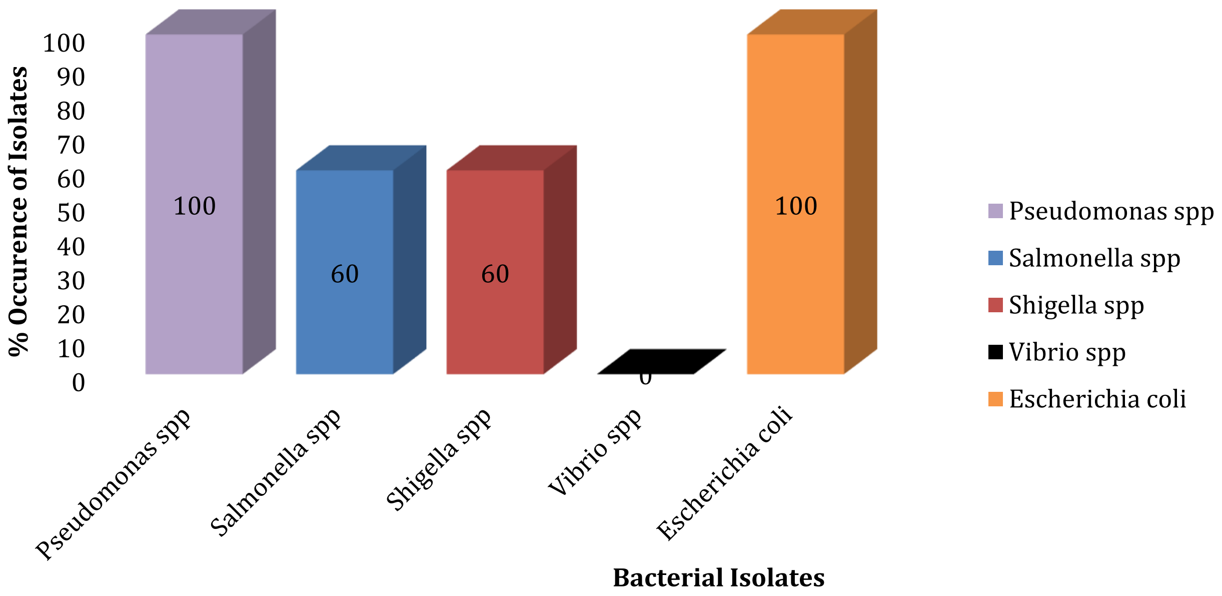

Figure 3 – Percentage occurrence of the isolates in dry season

The river water quality was poor as it failed to meet the standard for drinking water quality set by the WHO and NSDWQ [36, 37]. *E. coli* in the river water indicates faecal contamination, while other bacterial isolates show that the river water has been contaminated. This study's results align with a previous study by [9], who isolated *E. coli* and *Salmonella* spp. from river water in Ikwo, Ebonyi State. Similarly, the findings of [41] align with this current study's result, except that the researchers isolated *Vibrio cholerae* in dry-season water samples.

CONCLUSIONS

Water used for drinking should be clean and safe. However, Ebe River water, the primary source of drinking water in Amede community, is unsuitable for human consumption. The high Pb, Cd and Mn levels are a serious concern since these chemicals can cause critical health problems. Moreover, the THB, FC, TC, *Pseudomonas* and *Salmonella* counts were highest at S3, where people bathe, swim, wash clothes and fetch water for drinking and domestic use. *Shigella* spp. was highest at S1. These bacterial species in the river water make it unsafe for consumption and domestic use. This study suggests that effective measures should be implemented to stop further river contamination. Wastewater from homes, fish farms and cassava processing plants should not be transported or channelled into the water body. Disposing of domestic refuse and wastewater along the river bank should be prohibited. Open defaecation around the water environment and siting of cassava processing plants within the water environment should be stopped. There is a need to regularly monitor the river water and its environment to protect it from further contamination. This present study also recommends that raw water from Ebe River should not be consumed or used without proper treatment. It further calls on the Government, capable individuals and groups and Non-Governmental Organizations to intervene urgently by providing clean and safe drinking water to the people of Amede community.

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