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Research Article

Evaluation of the Microbiology and Some Physicochemical Properties of Bonny River, Rivers State, Nigeria

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Abstract

The continued contamination of rivers by humans is on the increase and such contaminations have resulted to limited supply of safe water for domestic and recreational purposes. The Microbiology and some physicochemical properties of Bonny River was evaluated. Sample locations were designated as: A: refuse disposal point; B: close to oil spill area; C: in close proximity to public toilet, D: away from human activities; E: industrial area, all along the river. The following parameters which include: total heterotrophic bacteria, fungi and microalgae of the surface water samples were evaluated using standard microbiological methods. The microorganisms were identified based on morphological and biochemical characteristics. The physicochemical parameters and heavy metals of the surface water samples were determined using standard methods for the examination of water. Results of the total heterotrophic bacterial counts for A, B, C, D and E are: $1.13 \pm 0.42 \times 10^6$, $5.6 \pm 0.55 \times 10^5$, $1.6 \pm 0.50 \times 10^6$, $6.6 \pm 0.70 \times 10^5$ and $1.02 \pm 0.25 \times 10^6$ cfu/ml, respectively. Results of the coliform counts for A, B, C, D and E are $1.48 \pm 3.08 \times 10^5$, $8.6 \pm 0.73 \times 10^4$, $8.3 \pm 1.04 \times 10^4$, $3.4 \pm 2.63 \times 10^4$ and $8.4 \pm 0.20 \times 10^4$ cfu/ml whereas the results for the fungal counts are: $8.3 \pm 0.43 \times 10^2$, $4.7 \pm 0.48 \times 10^2$, $1.3 \pm 0.45 \times 10^3$, $4.3 \pm 0.45 \times 10^2$ and $1.3 \pm 0.57 \times 10^3$ cfu/ml, respectively. Total heterotrophic bacterial counts were higher in samples collected from location A followed by locations E while the least counts were recorded in location B. Thirty-six bacterial isolates belonging to: *Pseudomonas* sp, *Escherichia coli*, *Enterobacter* sp, *Alcaligenes* sp, *Serratia* sp, *Staphylococcus* sp, *Bacillus* sp, *Shigella* sp, *Salmonella* sp and *Klebsiella* sp were isolated from the different locations. The fungal isolates were *Aspergillus flavus, Rhizopus arrhizus, Aspergillus niger, Rhizopus* sp, *Mucor* sp, *Microsporum* sp, *Cunninghamella* sp and *Candida* sp were isolated. Also, the microalgae identified include: *Closterium* sp, *Scenedesmus* sp and *Oscillatoria* sp. The results showed that the mean range of Physicochemical properties were; pH 8.2 to 8.4, temperature: 26.5-28°C, electrical conductivity: 45600-122000µs/cm, turbidity: 0.71 to 1.45NTU, salinity: 3.06 to 8.18 mg/l, nitrate: 0.02 ± 0.03 to 0.35 ± 0.27 mg/l, phosphate: 0.41 ± 0.52 to 0.72 ± 0.05 mg/l, DO: 1.05 to 2.10 mg/l, BOD: 1.40 to 3.70 mg/l and THC: 8.0 ± 14.14 to 47.0 ± 14.14 mg/l. The results for the heavy metal analyses showed that only the cadmium concentration obtained in locations A, C and E (0.00386 ± 0.00, 0.00249 ± 0.00 and 0.00196 ± 0.00 mg/l) were within the WHO limits (0.005 mg/l). High concentrations of lead, chromium and nickel which exceeded WHO permissible limits were recorded in all the samples. The results of this investigation revealed that the Bonny River is highly contaminated with feacal bacteria, Total Hydrocarbon Content (THC), and heavy metals, which may potentially cause bioaccumulation in organisms. These contaminants have made the water unfit for domestic and other recreational uses. There is need for regular monitoring of these parameters for early detection of any major pollution issues.

Keywords: Human Activities; Microalgae; Coliforms; Total Heterotrophic Bacteria; Physicochemistry; Heavy Metals

Introduction

Water resources are of utmost importance and play very important roles in the sustenance of life in various environments [1]. Akpan and Ajayi [2] described water as a liquid which is needed for metabolism by living things; it is also required for food processing, nourishment of the body, and economic development through its downstream applications. Even though water is abundant on earth, the quality of these water sources is of great concern because its quality is dependent on: natural, human activities, geographical and environmental factors [3]. Water quality is defined by its physical, chemical and biological properties, depending on its end use.

The worldwide degradation of surface water has resulted in decreasing water availability for different specific uses [4]. Biological, chemical and sediment deposits in the rivers have resulted in high levels of pollutant [5]. The United Nations estimated that the wastewater produced globally per annum is about 1500 km^3 [6] and about 70% of the industrial wastewater including the 80% of domestic wastewater from developing countries especially Africa are deposited untreated into the rivers, lakes and coastal areas, polluting existing water supplies [7]. It was estimated that about 28.4 billion US Dollars (5% GDP) annually is lost in Africa due to lack of good water quality [7]. In Africa, the deteriorating water quality has resulted in approximately 3.5 million deaths since the year 2005 [8].

Water availability and quality are of critical concerns due to its importance to humans [9]. High water treatment costs, degradation of the ecosystem and increased production costs (agricultural, industrial and tourism) have been proven to be on the rise in Africa due to deteriorating water quality [7]. Coastal communities of Nigeria, especially the Niger Delta basin have experienced great environmental deterioration and pollution resulting from human activities including: oil production processes, manufacturing operations, industrial and municipal discharges [10]. Industrialization, urbanization and municipal activities have contributed to the quantities of wastes generated which include: solid, liquid and gaseous emissions deposited in the environment that may result in the pollution of our environment [10]. Indiscriminate dumping of raw and untreated waste into surface water and also low quality of health in this region are the results of lack of awareness of proper hygiene practices, contamination of the beaches by washing and bathing, and discharge of waste around the shoreline; is common sights in these coastal communities [11]. The direct release of raw domestic and industrial waste water into the rivers could lead to microbial pollution and impact negatively on the nutrient concentration of the water, destruction of spawning grounds for aquatic organisms and degradation of water quality [11]. Aquatic pollution can occur when the self-purifying powers of water are unable to remove the materials introduced into it and these problems of water pollution which range from chemical, biological, physical to geological effects could lead to public health hazards caused by pathogenic organisms and toxic chemicals [12].

Microorganisms are resident flora of all ecosystems, but microbiological contamination with feacal bacteria due to human activities is considered to be a critical issue for surface waters [13]. Assessment of surface and groundwater quality continues to be of great public interest in the developed world. There is a great need for monitoring water quality [14]; therefore, the assessment for the presence of pathogenic bacteria in water represents a major concern for human and animal health protection [15]. Most enteric pathogens are transmitted from agricultural waste, soil, waste water, and sediments [16].

Other environmental pollutants are trace metals which occurs in water bodies and may be due to anthropogenic and natural sources [17]. Chemical weathering of minerals and soil leaching are the major natural sources of metals in water. Human sources involve domestic and industrial waste water, surface run off, urban storm water, mining of activities, landfill leachate and gaseous emissions [17]. The presence of these trace metals in surface water has resulted in great concerns on their effects on animals and plants, especially at high concentrations which could lead to death of the organisms [18].

The Bonny River is one of most industrialized rivers in the continental rivers in Rivers [19]. Bonny Island is described as a semi-urban area in the Niger Delta region. Due to its rich historical and cultural past, it is recognized as one of the fastest growing urban centers with great significance as the hub of oil and gas export facilities due to its location [19]. The Bonny/New Calabar River Estuary has faced substantial increases in the industrial and agricultural development over the past four decades with attendant population growth. Apparently, these activities have resulted in the direct discharge of organic and inorganic substances including

crude oil and refined products through normal operations (as effluents), operational failures, sabotage to facilities and release into the adjoining water bodies [10]. The aim of this study was to evaluate the microbiological and the physicochemical properties of the Bonny River as a result of anthropogenic activities. Findings of the study would provide empirical data for companies evaluating the impact of their activities on the Bonny River.

Materials and Methods

Description of study area

The study area was the Bonny River also known as the New Calabar River Estuary [10]. The Bonny River is a 127 km long tidal estuary and lies on the eastern flank of the Niger Delta between latitudes 4.25°and 4.50°N and longitudes 7.00° and 7.15°E (Figure a). Bonny is the Local Government headquarters of Bonny Local Government Area of Rivers State. It is the largest of the Niger Delta network of rivers and creeks emptying into the Atlantic Ocean and is also the most environmentally stressed due to intense oil and gas exploitation and production activities [20]. The estuary is characterized by a broad belt of mangrove swamps, which are bordered on the seaward side by sandy barrier islands, and receives an influx of sea water for the majority of the year. The depth varies between 2 m inland and 50 m at the point of discharge into the Atlantic Ocean [21]. Some of the anthropogenic or human activities which is carried out on the water body include: fishing, transportation of humans, petroleum products, recreation, disposal of wastes, including washing activities and dredging. In the study area, five sampling locations were considered, and these locations were designated as A, B, C, D and E representing water samples from: waste disposal points, oil spill area, public toilet area, points away from human activities (control) and industrial area, respectively. The map of the Bonny River is presented in figure 1, while the GPS coordinates of the locations under study are presented in table 1.

Figure a: Map of Bonny River (the area indicated with arrow represent the river under study).

Locations	Coordinates
A	4º26'56.1148N, 7º10'18.01452'E
B	4º26'55.00428''N, 7º10'19.60932'E
C	4º26'53.18844'N, 7º10'16.00752E
D	4º27'60.7104'N, 7º10'70.08384E
E	4º25'37.21872'N, 7º9'25.39116'E

Table 1: Global Positioning System (GPS) Coordinates of the Locations.

Key: A: Waste disposal point; B: Oil spill Area; C: Public Toilet Area, D: Away from human activities; E: Industrial Area.

Sample collection

Surface water samples from the selected locations were collected into sterile bottles once every week in the morning (between 8-9 AM) for a period of one month. Samples were collected a few meters apart, bulked together to form composite. Samples collected were immediately transported in flasks containing ice blocks to the Microbiology Laboratory, Rivers State University, Port Harcourt, Rivers State, Nigeria, for immediate analysis. A total of 20 water samples were collected during the period of investigation.

Microbiological analysis

Enumeration and isolation of total heterotrophic bacterial count

The total heterotrophic bacterial populations of the various samples were enumerated using standard microbiological methods [22]. In this method, ten-fold serial dilutions of the water samples were carried out and this was done in the following manner; nine millilitres (9ml) of the normal saline were transferred into test tubes, stoppered with cotton wool and sterilized by autoclaving at 121°C for 15Psi for 15 minutes. After sterilization, 1ml was withdrawn with the aid of a sterile 1ml pipette from the sample and transferred into sterile normal saline in test tube to make a dilution of 1:10 (i.e., 10^{-1}). Subsequent tenfold serial dilution was carried out until 10^{-4}. Aliquots from the 10^{-3} and 10^{-4} dilutions were transferred into the center of freshly prepared nutrient agar (NA) plates in duplicates and spread gently with sterile bent glass rod and incubated at 37°C for 24-48 hours. After incubation, plates were observed for growth. The colonies that grew in the respective plates for the different samples were counted and recorded. This was used in enumerating the bacterial population while distinct colonies on plates were sub-cultured and purified by streaking carefully on freshly prepared NA plates. Pure isolates obtained were stored in bijou bottles containing agar slant and refrigerated at 4°C for further analysis.

Enumeration and isolation of coliforms

Coliform count was enumerated by transferring aliquot (0.1 ml) of 10^{-3} dilution into Eosin Methylene Blue Agar (EMB) plates in duplicate. Plates were spread evenly using sterile bent glass rod and were incubated at 37°C for 24-48 hours. After incubation, plates were observed for growth. The colonies in the respective plates for the different samples were counted and recorded. This was used in enumerating the coliform population while distinct colonies on plates were sub-cultured and purified by streaking carefully on freshly prepared NA plates. Pure isolates obtained were stored in bijou bottles containing agar slant and refrigerated at 4°C for further analyses [23,24].

Enumeration, isolation and identification of fungi

The fungal load in the water samples were enumerated by transferring 0.1ml of 10^{-2} dilution into freshly prepared Sabouraud Dextrose Agar (SDA) plates in duplicate. Plates were spread evenly and incubated at 25°C for 3-5 days. After incubation, plates were observed for growth. The colonies in the respective plates for the different samples were counted and recorded. This was used in enumerating the fungal population while distinct colonies on the plates were sub-cultured on freshly prepared SDA plates. Pure fungal isolates obtained were characterized culturally and microscopically. The cultural characteristics examined included: colour, shape, size, spore type and texture while the microscopic characterization was done by transferring fungal spores or piece of mycelium on clean microscope slide containing a drop of lactophenol cotton blue stain, slides were covered with cover slip and were viewed under the microscope at x10 and x40 magnification [25]. Fungal identity was confirmed by referencing fungal characteristics with those recorded in the fungal Identification Manual [26].

Characterization of microalgae in water samples

This was done by viewing water samples under a light microscope; the microalgae in the samples were identified. After vigorously shaking water samples, they were put into Petri dishes, where a drop of the sample was taken out and transferred to the surface of a sterile grease-free glass slide using a Pasteur pipette.

The slide was then covered with a clean cover slip and observed with the x10 and x40 objective lenses under a light microscope. The microalgae were recognized by comparing the morphological features observed under the microscope to those found in Algae biology [27].

Identification of bacterial isolates

Cultural and biochemical identification techniques were used to identify the bacterial isolates. Color, size, texture, shape, and elevation of the colony were among the cultural methods considered, while biochemical methods include: Methyl red test, Voges-Proskaeur test (MR-VP), indole, catalase, oxidase, motility, citrate utilization, and fermentation of glucose, mannitol, sucrose, and lactose. Cheesbrough [28] biochemical assays were carried out exactly as he specified. Bergy's Manual of Determinative Bacteriology [29] and the Automated Biological Identification System (ABIS) were used to identify isolates.

Physicochemical parameters of water samples

The Physicochemical parameters of the water investigated were; temperature, pH, turbidity, electrical conductivity, Phosphate, Nitrate, Salinity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Total Hydrocarbon content. Temperature was taken *in-situ* at the sampling point using mercury in glass thermometer, graduated in degree centigrade (^{o}C). pH was measured using a pH meter D46 (pH/MV/OC meter). The analysis was done based on the method of APHA [30].

Using atomic absorption spectroscopy, heavy metals including: Lead (Pb), Cadmium (Cd), Chromium (Cr), and Nickel (Ni) in water samples were analyzed, after digestion of water sample [31].

Statistical analysis

SPSS was used to calculate the mean and standard deviations of the microbiological counts and physicochemical characteristics (version 26). The Duncan test was used to segregate means in regions where there were significant differences at 95 percent confidence intervals, and the ANOVA was performed to assess for significant differences.

Results

Table 2 showed the total heterotrophic bacterial counts, total coliform counts, and total fungal counts of water samples collected from various sites. The sites: A, B, C, D, and E had total heterotrophic bacterial counts of: $1.1 \pm 0.42 \times 10^6$, $5.6 \pm 0.55 \times 10^5$, $1.6 \pm 0.50 \times 10^6$, $6.6 \pm 0.70 \times 10^5$ and $1.0 \pm 0.25 \times 10^6$ cfu/ml, respectively. The coliform counts for A, B, C, D, and E are$1.5 \pm 3.08 \times 10^5$, $8.6 \pm 0.73 \times 10^4$, $8.3 \pm 1.04 \times 10^4$, $3.4 \pm 2.63 \times 10^4$and $8.4 \pm 0.20 \times 10^4$ cfu/ml whereas the total fungal counts were: $8.3 \pm 0.43 \times 10^2$, $4.7 \pm 0.48 \times 10^2$, $1.3 \pm 0.45 \times 10^3$, $4.3 \pm 0.45 \times 10^2 \pm 0.45$ and $1.3 \pm 0.57 \times 10^3$ cfu/ml, respectively. The highest total heterotrophic bacterial counts were found in samples taken from location A, followed by location E, while the lowest counts were found in samples collected from location B.

Location	Total heterotrophic Bacteria	Total coliform	Total fungi
A	$1.1 \pm 0.42 \times 10^{6a}$	$1.5 \pm 3.08 \times 10^{5a}$	$8.3 \pm 0.43 \times 10^{2a}$
B	$5.6 \pm 0.55 \times 10^{5a}$	$8.6 \pm 0.73 \times 10^{4a}$	$4.7 \pm 0.48 \times 10^{2a}$
C	$1.6 \pm 0.50 \times 10^{6a}$	$8.3 \pm 1.04 \times 10^{4a}$	$1.3 \pm 0.45 \times 10^{3a}$
D	$6.6 \pm 0.70 \times 10^{5a}$	$3.4 \pm 2.63 \times 10^{4a}$	$4.3 \pm 0.45 \times 10^{2a}$
E	$1.0 \pm 0.25 \times 10^{6a}$	$8.4 \pm 0.20 \times 10^{4a}$	$1.3 \pm 0.57 \times 10^{3a}$

Table 2: Microbial Counts of the Various Locations (cfu/ml).

*Mean with same superscript down the column show no significant difference ($P \leq 0.05$).

Key: A: Waste disposal point; B: Oil spill Area; C: Public Toilet Area, D: Away from human activities (control); E: Industrial Area.

Thirty-six bacterial isolates belonging to: *Pseudomonas* sp, *Escherichia coli*, *Enterobacter* sp, *Alcaligenes* sp, *Serratia* sp, *Staphylococcus* sp, *Bacillus* sp, *Shigella* sp, *Salmonella* sp and *Klebsiella* sp were isolated from the sites. The distribution of the bacterial isolates is as follows: *Pseudomonas* sp 11.11%, *Escherichia coli* 16.67%, *Enterobacter* sp 8.33%, *Alcaligenes* sp 8.33%, *Serratia* sp 2.78%, *Staphylococcus* sp 13.89%, *Bacillus* sp 22.22%, *Shigella* sp 5.56%, *Salmonella* sp 2.78% and *Klebsiella* sp 8.33% (Figure 1). *Bacillus, Escherichia coli, Staphylococcus and Pseudomonas* spp were more frequent and were identified from all samples. The frequency of occurrence of bacterial isolates showed that *Bacillus* sp were the most predominant bacterial isolates followed by *Escherichia coli* and *Staphylococcus* spp was the third most dominant isolates.

Fungal isolates identified were; *Aspergillus flavus, Rhizopus arrhizus, Aspergillus niger, Rhizopus* sp, *Mucor* sp, *Microsporum* sp, *Cunninghamella* sp and *Candida* sp. Similar to the bacterial distribution, the distribution of the fungal isolates was not uniform, as some isolates like *A. niger* were the most dominant fungal isolate and the most frequently isolated fungal isolate. Percentage occurrence of the fungal isolates were; *Aspergillus flavus* 11.5%, *Rhizopus arrhizus* 7.7%, *Aspergillus niger* 30.8%, *Rhizopus* sp 7.7%, *Mucor* sp 11.5%, *Microsporum* sp 11.5%, *Cunninghamella* sp 11.5% and *Candida* sp 7.7% (Figure 2).

Results of the microalgae identified showed that they belong to: *Closterium* sp, *Scenedesmus* sp and *Oscillatoria* sp. The results of distribution of microalgae showed that *Oscillatoria* sp was the most dominant isolate and it was isolated in location A, B and C, while *Closterium* and *Scenedesmus* spp were rarely isolated in all locations.

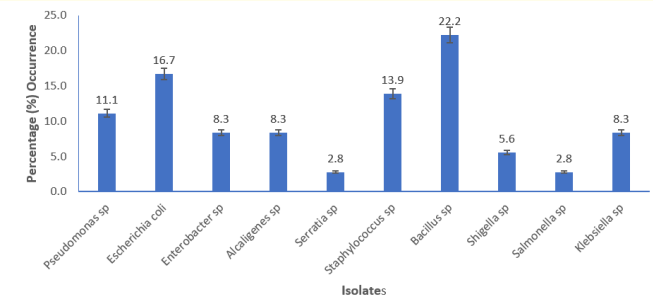

Figure 1: Frequency of occurrence of Bacterial Isolates.

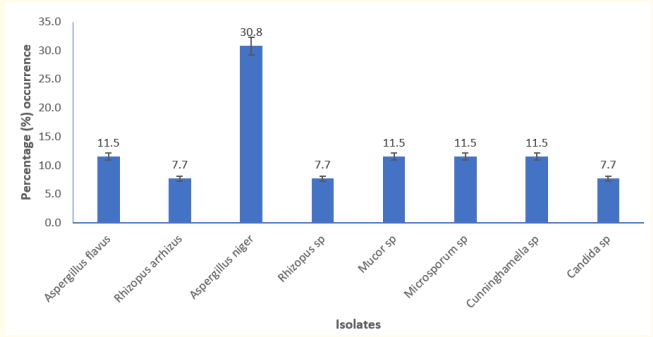

Figure 2: Frequency of occurrence of Fungal Isolates.

Physicochemical parameters

Results of the physicochemical parameters of the water samples analyzed are shown in Table 3. Results showed that the values of Physicochemical properties ranged from : pH, 8.2 to 8.4 with a mean of 8.3 ± 0.20, Temperature, 26.5 to 28°C with a mean of 27.0 ± 1.1°C, Electrical conductivity, 45600 to122000 µS/cm with a mean of 69720.00 ± 39533.90 µS/cm, Turbidity, 0.71 to 1.45 NTU with a mean of 1.13 ± 0.76 NTU, Salinity, 3.06 to 8.18 mg/l with a mean of 5.04 ± 2.20 mg/l, Nitrate, 0.02 ± 0.03 to 0.35 ± 0.27 mg/l with a mean of 0.09 ± 0.16 mg/l, Phosphate, 0.41 ± 0.52 to 0.72 ± 0.05 mg/l with a mean of 0.59 ± 0.31 mg/l, DO, 1.05 to 2.10 mg/l with a mean of 1.35 ± 0.44, BOD, 1.40 to 3.70 mg/l with a mean of 3.01 ± 0.87 mg/l and THC, 31.50 ± 38.89 to 47.0 ± 14.14 mg/l with a mean of 37.90 ± 24.19 mg/l. The outcome additionally showed changes in the various boundaries across the samples in the different Locations. The most noteworthy pH was acquired in Location A followed by Location E. The phosphate concentrations were most elevated in location B (0.78 ± 0.19). The DO was most elevated in location E which was essentially higher ($P \leq 0.05$) than those observed in locations A, B, C and D. The most noteworthy BOD was seen in location D and was significantly higher ($P \leq 0.05$) than the value observed in location A. Results of the THC of the samples across the locations were high: 31.50 ± 38.89, 47.0 ± 14.14, 32.0 ± 38.18, 8.0 ± 14.14 and 40.50 ± 28.99 mg/l for locations A, B, C and E, respectively. The highest hydrocarbon content of 47.0 ± 14.14 mg/l was observed in location B which is close to the oil spill area. THC values obtained from locations A, B, C and E were significantly higher ($P \leq 0.05$) than values obtained in location D, which is the region away from human exercises (used as control).

The mean values of the heavy metal analyses done are shown in table 4. The mean Lead values ranged from 0.06874 ± 0.00 to 0.42841 ± 0.00 mg/L, location B has the highest while location D had the least. Cadmium mean values ranged from 0.00196 ± 0.00 to 0.01517 ± 0.00 mg/L, highest in location B and lowest is in location D. Mean chromium values ranged from 0.81673 ± 0.00 to 2.41851 ± 0.00 mg/L, highest concentration was observed in location C, while lowest in location D. Nickel mean values ranged from 0.17850 ± 0.00 to 1.16912 ± 0.00 mg/L, with location B having the highest and D having the least.

Discussion

The microbiology and physicochemical parameters of the Bonny River, Rivers State, Nigeria, were studied. The total heterotro-

Location	pH	Temperature (°C)	EC (µS/cm)	Turbidity (NTU)	Salinity (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	DO (mg/l)	BODs (mg/l)	THC (mg/l)
A	8.42 ± 0.01[a]	27.0 ± 0.00[a]	122000 ± 48224.68[a]	1.45 ± 1.60[a]	8.18 ± 3.23[b]	0.02 ± 0.03[a]	0.59 ± 0.22[a]	1.20 ± 0.14[a]	3.20 ± 0.14[b]	31.50 ± 38.89[a]
B	8.34 ± 0.05[a]	26.5 ± 2.1[a]	57600 ± 16122.04[a]	1.36 ± 0.64[a]	3.86 ± 1.08[ab]	0.03 ± 0.02[a]	0.78 ± 0.19[a]	1.05 ± 0.07[a]	3.40 ± 0.141[bc]	47.0 ± 14.14[a]
C	8.34 ± 0.03[a]	26.5 ± 0.07[a]	79100 ± 2969.85[a]	0.71 ± 0.45[a]	5.30 ± 0.20[ab]	0.03 ± 0.03[a]	0.41 ± 0.52[a]	1.20 ± 0.28[a]	3.35 ± 0.21[bc]	32.0 ± 38.18[a]
D	8.31 ± 0.00[a]	28.0 ± 1.4[a]	44300 ± 53881.54[a]	0.93 ± 0.88[a]	4.84 ± 0.97[ab]	0.03 ± 0.01[a]	0.48 ± 0.66[a]	1.20 ± 0.28[a]	3.70 ± 0.00[c]	8.0 ± 14.14[b]
E	8.29 ± 0.60[a]	27.0 ± 1.4[a]	45600 ± 13293.61[a]	1.23 ± 0.71[a]	3.06 ± 0.89[a]	0.35 ± 0.27[a]	0.72 ± 0.05[a]	2.10 ± 0.28[b]	1.40 ± 0.14[a]	40.50 ± 28.99[a]
WHO (2011)	6.5-8.5	26-28^{0}C	1000 µS/cm	5 NTU	-	10 mg/l	-	7.5 mg/l	15 mg/l	10

Table 3: Physicochemical Parameters of the Various Locations.

Key: A: Waste disposal point; B: Oil spill Area; C: Public Toilet Area, D: Away from human activities; E: Industrial Area.

*Means with similar superscript down the column show no significant difference (P ≤ 0.05).

Samples	A	B	C	D	E	WHO Limit
Pb (mg/l)	0.17142 ± 0.00	0.42841 ± 0.00	0.10186 ± 0.00	0.06874 ± 0.00	0.26113 ± 0.00	0.01
Cd (mg/l)	0.00386 ± 0.00	0.01517 ± 0.00	0.00249 ± 0.00	0.00196 ± 0.00	0.00831 ± 0.00	0.005
Cr (mg/l)	1.84371 ± 0.00	1.00345 ± 0.00	2.41851 ± 0.00	0.81673 ± 0.00	1.34168 ± 0.00	0.1
Ni (mg/l)	0.36498 ± 0.00	1.16912 ± 0.00	0.96744 ± 0.00	0.17850 ± 0.00	0.52491 ± 0.00	0.1

Table 4: Heavy Metal Analysis of the Water Samples from the Locations.

Key: A: Waste disposal point; B: Oil spill Area; C: Public Toilet Area, D: Away from human activities; E: Industrial Area.

phic bacterial counts and the coliform bacterial counts in all the water samples were very high and exceed WHO recommended limits. The WHO recommended limits for total heterotrophic and coliform bacterial counts in surface water is 10 cfu/ml and 0 –-10 coliforms/100ml of water [32]. The significant bacterial counts seen in site A may be due to the large number of different forms of residential garbage dumped in this area of the river. In this location, wastes such as domestic and other produced wastes are disposed of. Similarly, the second-highest bacterial load at position E may be due to wastes created by industry and other pollutants dumped there. The lowest bacterial count was found in location B, which might be related to the presence of limiting factors such as oils and other chemicals that may have prevented the growth of some species. Furthermore, the high bacteria counts seen at location C might be ascribed to microbial communities of faecal and other wastes, such as the entry of raw or untreated human wastes, especially when a public toilet is located nearby. The high microbial load observed in these locations might be due to the different anthropogenic activities going on around the river. Human activities such as: washing, bathing, direct disposal of untreated faeces or faecal materials and other untreated domestic wastes into water bodies contaminate water and make it unfit for human use.

The highest coliform levels were found in Location A, followed by B and E, while the lowest coliform counts were found in location D. The presence of wastes might explain the volatility and increased coliform counts in these locations. Faecal contamination of water has been reported to cause wide range of diseases such as cholera, typhoid, bacteria dysentery, and minor respiratory sicknesses [33]. Despite the variations in microbial loads across the different locations, there was no significant difference (P ≤ 0.05) in the total heterotrophic bacterial, coliform and fungal counts across the various locations. High bacteria counts in surface water and spring water has been reported in previous studies and human activities such

as open defecation, washing, etc have been attributed as reasons behind the high bacterial load [24]. The high bacteria counts in this study, is in agreement with the results of Obire., *et al*. [24], who evaluated the impact of anthropogenic activities on the microbial quality of Azumini Odumanya stream, Port Harcourt.

The frequency of occurrence which showed that *Bacillus* spp were more frequent and dominant in all Locations could be due to their adaptation to extreme environments especially with the presence of endospores [22]. Microorganisms identified in this study varied based on their occurrence and this may be due to the different activities being carried out in the respective sample Locations. For instance, *Bacillus* sp which were more dominant in this study have been reported to thrive in the presence of hydrocarbon, thereby, utilizing it as source of carbon and energy [24]. Moreover, they may have been dispersed to other areas either by water current or direct discharge of wastes. Similarly, *E. coli* which was the second most occurring bacterial isolates was predominant in Locations A and C which are the waste disposal and public toilet points. *E. coli* which is the second most occurring bacterial isolate is used as an indicator organism to check if water body is contaminated with faecal material [33]. Thus, the presence of *E. coli* suggests that the water body may be contaminated with pathogens which could cause gastrointestinal diseases [22]. This explains why there were *Salmonella, Shigella, Klebsiella, Enterobacter* and other bacterial isolates in this water body studied. The microbial genera identified in this study agreed with those reported in previous studies on surface water [24]. The presence of these microorganisms in this water body is of public health concern as these bacterial genera may be pathogenic to those who consume the water or use the water for domestic and recreational purposes. *Salmonella* species are known to be implicated in diseases ranging from salmonellosis to typhoid illness, while *Shigella* sp causes shigellosis. Diseases that may be transmitted by the bacterial isolates identified in this study included: gastroenteritis, skin infections and respiratory infections. This agreed with the reports of Obire., *et al.* [11].

Locations C and E had the greatest fungal counts, followed by location A, while location D had the lowest fungal counts. *Aspergillus niger* had the highest frequency of occurrence while *Candida* sp had the least. The nutrients in the garbage that has collected in these sites might be the cause of the differences in fungus numbers between locations. These organisms get into the environment through decaying wood and produces large amount of spores [34].

Microalgae were also detected in the water bodies. Three microalgae belonging to *Closterium* sp, *Scenedesmus* sp and *Oscillatoria* sp. Microalgae are known as primary producers in water bodies and due to their importance as primary producers, they are usually found in the surface of water especially areas where oxygen is abundant [22]. Thus, the presence of these microalgae in these samples may be due to the high level of solutes or waste which had increased the nutrients concentration such as phosphates and nitrates in the water body. The low diversity of microalgae in this study may be attributed to the different anthropogenic activities as well as ecological factors of the water body. This agreed with previous study which reported that anthropogenic activities could alter microbial balance [33]. The study revealed fluctuations in distribution of microalgae,for instance, *Oscillatoria* sp which was the most occurring microalgae was not found in all the locations. This variation in distribution could be ascribed to differences in nutrient composition of the water samples, anthropogenic activities including other physical and chemical factors. This agreed with reports by Onwugbuta-Enyi., *et al.* [35] who reported that the variations that exist in microalgae distribution within different pond compartments is attributed to the physical, chemical and biological characteristics of the ponds. There are positive and negative effects attributed to the extensive growth of microalgae in water bodies. Some of the negative effects include the deterioration of water quality and health hazards which is as a result of toxin secretion by some species especially the cyanobacteria [36].

The results of the physicochemical parameters showed variations in all samples across the respective Locations. The pH of all the samples despite their fluctuations was all within the WHO limit of 6.5-8.5 [15]. The pH is a vital factor which influences the activities of living organisms [22]. Thus, pH values exceeding the optimum limit of an organism could have a detrimental effect on the organisms by affecting enzymatic activities. This could also cause fluctuations in microbial populations as observed in the various Locations. The pH values in this study (8.29 ± 0.60to 8.42 ± 0.01) were higher than the value of 7.7 reported by Sikoki and Akpiri [37] of same water body.

The temperatures of the water fluctuated across the locations and were within the WHO limits. The fluctuations could also be the reason why there were variations in microbial counts across the locations. Temperature is a factor (abiotic factor) which influences enzymatic activities of microorganisms [22]. The electrical con-

ductivity, turbidity and saltiness were extremely high in Location A and this could be because of much disintegration of particles and squanders around here than other location. Conductivity is a measure of the conductance of an electric current in water. It relates closely to the total dissolved solids (mineral) content of water [8]. The high conductivity observed in location A could be due to additional dissolved solute, erosion, large volumes of waste disposed and large volumes of water from the sea [38].

Turbidity is a measure of suspended minerals, bacteria, plankton, and dissolved organic and inorganic substances and it is often associated with surface water sources. This parameter is important for photosynthetic aquatic organisms, as high turbidity affects light penetration into the water column. The values obtained for turbidity in the locations were within the WHO limits indicating that despite the turbulence of the water influenced by human activities, the water was still within acceptable limits. The presence of salts in the Bonny River may be due to dissolution of wastes, erosion and surface run off, ions and majorly from the proximity of the river to the sea. This agreed with Sikoki and Akpiri [37] who in a similar study attributed the saline nature of the Bonny River to be due to closeness to the sea.

The levels of BOD in the samples are within the WHO limits (15 mg/l). The BOD is the quantity of oxygen needed for microbial decomposition of organic materials [39]. These organic contaminants may enter the water body from municipal and industrial effluents due to urban life and many industrial establishments. These organic materials eventually get broken down by bacteria, which require oxygen for the decomposition process, leading to depletion of DO, hence the low DO content of the water.

Nitrate and phosphate concentrations in all locations were within the WHO limits. These inorganic elements are referred to as nutrient elements and their presence linked to anthropogenic sources such as organic and inorganic wastes associated with the presence of make-shift public conveniences scattered all over the area, soil run-off (as phosphorus bound in the soil will be released, fertilizers from farm lands), synthetic materials which contain organophosphates such as insecticides and livestock waste [22].

The total hydrocarbon content of the water body was high and exceeded the acceptable or permissible limit. Although there was no statistical difference in the THC values of locations: A, B, C and E but slight variations existed in the quantities obtained in the respective locations. The highest THC value which was recorded in location B could be attributed to the contamination of the area by hydrocarbon products due to oil spillage or movement of petroleum products. The low THC value recorded in location D was within the WHO permissible limits (10 mg/l) and this could be attributed to the fact that this area is void of human activities unlike other locations which is constantly under anthropogenic influence. Also, the high THC content obtained in this study could also be attributed to the discharged effluents and disposal of hydrocarbon contents into the water body including surface run offs from mechanic shops, from boats, vessels into the water body. Moreover, the water body serves as a means of transport, thus, leakages from boats could also contribute to the increased THC in the water bodies. This could also influence the microbial populations or the type of organisms especially in regions with higher THC. This observation is so because when oil is released into an environment, it results in selective enrichment of the microbial population, favouring the growth of those organisms that are able to use the pollutant as source of carbon and energy [40]. This statement agreed with the findings in this study which showed an increased bacterial population in Location B which had the highest THC.

The results of the heavy metals analysed showed that lower concentrations of all metals were observed in location D which is away from human activities, while higher concentrations were observed in location B. Only cadmium concentration obtained in locations A, C and E were within the WHO limits of 0.005 mg/l. Higher concentrations of lead, chromium and nickel which exceeded WHO permissible limits of 0.01, 0.1 and 0.1 mg/l, respectively [15], were recorded in all the samples. Adverse effects caused by Pb to aquatic organisms such as algae, benthic invertebrates, and embryos and fingerlings of freshwater fish and amphibians include: loss of sodium, reduced capability, developmental problems, and distorted algal growth. Pb can be absorbed from the skin, digestive and respiratory systems, resulting in adverse effects on the biological, neutrological, cognitive, urinary and cardiovascular functions in the body [41]. Cadmium plays important roles in surface water monitoring studies, due to its toxicity to fish and other aquatic organisms. This metal is widely found in the aquatic environment which bioaccumulates along the trophic levels, building up in the internal organs such as kidneys and livers in fish and has a very high carcinogenic effect on humans [37]. Cadmium can get into human body through the use of contaminated water that could lead

to painful degenerative bone diseases, respiratory and digestive diseases and kidney failure [41,42]. Chromium is naturally occurring heavy metal found in the sea water, earth crust and introduced from industrial activities releasing it to soil, air, surface and ground water; which could cause renal failure, dermal, gastrointestinal, respiratory, neurological and several other cancers when ingested through water and food by humans [43]. The WHO [15] also reported that chromium in its hexavalent form is a known carcinogen in humans, implicated in several health issues. Hence, the high values obtained from this study, may be detrimental to living things in that environment. Nickel is widely distributed in the environment found in soil, air and water. Elevated quantities found as a result of anthropogenic activities mostly from industrial waste, especially battery waste. Exposure to this heavy metal in man can result in respiratory, cardiovascular, renal, and nasal cancer [42].

Conclusion

The findings in this study on the evaluation of microbiological and some physicochemical parameters of Bonny River showed that the water body is polluted with microorganisms, especially bacteria from faecal origin, and the likelihood of the presence of pathogenic organisms. The presence of heavy metals associated with cancer and other health issues were found in high concentrations which is a clear indication of the pollution level. Thus, the water is not safe for both domestic and recreational activities without any form of treatment. Hence, there is need for regular monitoring of the water body and public enlightenment of the populace on the dangers of direct disposal of these wastes into water bodies.

Bibliography

1. Izah S C., *et al*. "A Review on Heavy Metal Concentration in Potable Water Sources in Nigeria: Human Health Effects and Mitigating Measures". *EXP Health* 8 (2016): 285-304.

2. Akpan D and Ajayi O. "Adverse Effect of Water Contamination or Pollution to Human Health and Safety in the Nigeria Delta-Nigeria: An Environmental Case Study". *Journal of Environment and Earth Science* 6.10 (2016): 91-94.

3. Obire O., *et al*. "Evaluation of the Impact of Anthropogenic Activities on the Microbiological Quality of Azumini Odumanya Stream, Port Harcourt, Nigeria". *International Journal of Current Microbiology and Applied Sciences* 10.7 (2021): 143-153.

4. Zhang Z., *et al*. "Surface water quality and its control in a river with intensive human impacts--a case study of the Xiangjiang River, China". *Journal of Environmental Management* 91.12 (2010): 2483-2490.

5. Wandiga SO. "Water Quality Issues in African Rivers, University of Nairobi, Department of Chemistry, Nairobi, Kenya" (2010).

6. Ross N. "World water quality facts and statistics". Annual Water Review, World Water Day 2010, Clean Water for a Healthy World, Pacific Institute (2010).

7. UN-Waters. "World water development report 3, Case study volume: Facing the challenges, Case of Cameron, Sudan, Swaziland, Tunisia and Zambia" 1 (2009): 8-12.

8. Thembeka S N. "Evaluation of the status of water quality of the great Usuthu River, Swaziland". A thesis submitted for the Master of Science Degree in Integrated Water Resources Management at the University of Zimbabwe (2016).

9. Ollis DJ., *et al*. "Bio assessment of the ecological integrity of river ecosystem using macroinvertebrates: an overview with a focus on South Africa". *African Journal of Aquatic Science* 31.2 (2006): 205-227.

10. Onojake MC., *et al*. "Surface water characteristics and trace metals level of the Bonny/New Calabar River Estuary, Niger Delta, Nigeria". *Applied Water Science* 7 (2017): 951-959.

11. Obire O., *et al*. "Impact of Fertilizer Plant Effluent on Water Quality". *International Journal of Environmental Science and Technology* 5.1 (2008): 107-118.

12. Ekpo S. "Environmental Impacts of Petroleum Exploration in Nigeria". *International Journal of Environmental issues* 7 (2010): 1.

13. Bayoumi H A F and Patko I. "Ecological monitoring of Danube water quality in Budapest region". *American Journal of Environmental Sciences* 8 (2012): 202-211.

14. Peka´rova´ P., *et al*. "Prediction of water quality in the Danube River under extreme hydrological and temperature conditions". *Journal of Hydrology and Hydromechanics* 57 (2009): 3-15.

15. WHO. "Guidelines for drinking-water quality". 4th edn. Geneva, Switzerland (2011).

16. Bonetta S., *et al*. "Development of a PCR protocol for the detection of Escherichia coli O157:H7 and Salmonella spp. in surface water". *Environmental Monitoring and Assessment* 177 (2011): 493-503.

17. Zarazua G., *et al*. "Analysis of total and dissolved heavy metals in surface water of a Mexica polluted river by Total Reflection X-ray Fluorescence Spectrometry". *Spectrochimica Acta Part B: Atomic Spectroscopy* 61 (2006): 1180-1184.

18. Nicolau R., *et al*. "Transfer of nutrients and labile metals from the continent to the sea by a small Mediterranean river". *Chemosphere* 63 (2006): 469-476.

19. Opuenebo BO. "A Partnership Framework for Managing an Emerging Urban Region: The Bonny Experiment in Rivers State, Nigeria". 40th ISoCaRP Congress (2004).

20. Jamabo N and Chinda A. "Aspects of the ecology of Tympanotonus fuscatus var fuscatus (Linnaeus, 1758) in the mangrove swamps of the upper Bonny River, Niger Delta, Nigeria". *Current Research Journal of Biological Science* 2 (2010): 42-47.

21. Bolaji B B., *et al*. "Human Health Impact of Natural and Artificial Radioactivity Levels in the Sediments and Fish of Bonny Estuary, Niger Delta, Nigeria". *Challenges* 6 (2015): 244-257.

22. Prescott LM., *et al*. "Microbiology, (9th Edition)". London: WMC Brown Publishers (2011).

23. Adejuwo J O and Adelakun M A. "Physiochemical and Bacteriological Analysis of Surface Water in Ewekoro Local Government Area of Ogun State, Nigeria: Case Study of Lala, Yobo and Agodo Rivers". *International Journal of Water Resources and Environmental Engineering* 4.3 (2012): 6672.

24. Obire O., *et al*. "Evaluation of the Impact of Anthropogenic Activities on the Microbiological Quality of Azumini Odumanya Stream, Port Harcourt, Nigeria". *International Journal of Current Microbiology and Applied Sciences* 10.7 (2021): 143-153.

25. Douglas S I and Robinson V k. "Indoor Microbiological Air Quality in Some Wards of a Tertiary Health Institution in Port Harcourt, Nigeria". *Journal of Pharmacy and Biological Sciences* 14 (2019): 44-50.

26. Sarah K., *et al*. "Descriptions of Medical Fungi (3rd edn)". (2016): 113-155.

27. Vuuren SJ., *et al*. "Easy identification of the most common freshwater algae: a guide for the identification of microscopic algae in South African freshwaters". ISBN 0-621-35471-6. © North-West University and Department of Water Affairs and Forestry (2006).

28. Cheesbrough M. "District laboratory practice in tropical countries". Cambridge University Press (2006).

29. Holt J G., *et al*. "Bergey's manual of determinative bacteriology" (1994).

30. American Public Health Association, (APHA). "Standard methods for the examination of water and wastewater". 20th Ed, APHA, Washington D.C (2008).

31. Sriadibhatla S S. "Analysis of Water Samples for heavy metal pollutants". *International Journal of Environment, Ecology, Family and Urban Studies (IJEEFUS)* 3.1 (2013): 127-132.

32. World Health Organization. "WHO estimates of the global burden of foodborne diseases. A report by the Foodborne Disease Burden Epidemiology Reference Group 2007-2015". Geneva, Switzerland (2015).

33. Obire O., *et al*. "Bacteriological Water Quality of Elechi Creek in Port Harcourt, Nigeria". *Journal of Applied Science and Environmental Management* 9.1 (2005): 79-84.

34. Douglas S I., *et al*. "Tolerance of Some Soil Fungi to the Content of Deep Cycle Battery and Their Bioremediation Potential". *South Asian Journal of Research in Microbiology* 8.1 (2020): 34-46.

35. Onwubguta-Enyi J., *et al*. "Water quality of Bodo Creek in the Niger Delta Basin". *Advances in Environmental Biology* 2 (2008): 132-136.

36. Hikmet K., *et al*. "Microalgae toxins: characteristics and importance". *African Journal of Biotechnology* 3.12 (2008): 667-674.

37. Sikoki M D and Akpiri O U. "Surface water characteristics and trace metals level of the Bonny / New Calabar River Estuary, Niger Delta, Nigeria". *Applied Water Science* 7.2 (2017): 951-959.

38. Osumanu. "Assessment of the Water Quality Index of Otamiri and Oramiriukwa Rivers". *Physics International* 1.2 (2010): 102-109.

39. Graves R E., *et al*. "Composting in Part 637 Environmental Engineering National Engineering Handbook. United States Department of Agriculture Natural Resources Conservation Service". *Pennysylvania State* 31 (2000): 68.

40. Chikere C B and Ekwuabu CB. "Molecular characterization of autochthonous hydrocarbon utilizing bacteria in oil-polluted sites at Bodo Community, Ogoniland, Niger Delta, Nigeria". *Nigerian Journal of Biotechnology* 27 (2014): 28-33.

41. Nishijo M., *et al*. "Causes of death in patients with Itai-itai disease suffering from severe chronic cadmium poisoning: a nested case-control analysis of a follow-up study in Japan". *BMJ Open* 7.7 (2017): e015694.

42. Balali-Mood M., *et al*. "Toxic Mechanisms of Five Heavy Metals: Mercury, Lead, Chromium, Cadmium, and Arsenic". *Frontiers in Pharmacology* 12 (2021): 1-19.

43. Fang Z., *et al*. "Genotoxicity of tri-and hexavalent chromium compounds in vivo and their modes of action on DNA damage in vitro". *PloS One* 9.8 (2014): e103194.