International Scholars Journals

Advanced Journal of Environmental Science and Technology ISSN 2756-3251, Vol. 16 (5), pp. 001-006, May, 2025. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Water Quality Assessment of Shanomi Creek, Niger Delta: Physicochemical Parameters, Heavy Metals, and Bacterial Contaminants

Igbinosa E. O.[1]*, Uyi O. O.[2], Odjadjare E. E.[3], Ajuzie C. U.[1], Orhue P. O.[4] and Adewole E. M.[4]

[1]Department of Microbiology, Faculty of Life Sciences, University of Benin, PMB 1154, Benin City, Nigeria.

[2]Animal and Environmental Biology Department, Faculty of Life Sciences, University of Benin, PMB 1154 Benin City, Nigeria.

[3]Department of Basic Sciences, Faculty of Basic and Applied Sciences, Benson Idahosa University, PMB 1100, Benin City, Nigeria.

[4]Department of Microbiology, Faculty of Natural Sciences, Ambrose Alli University, PMB 14, Ekpoma, Nigeria.

Accepted 23 March, 2025

The physicochemical and microbial qualities of Shanomi creeks in the Niger Delta of Nigeria were assessed between January and October 2011. The temperature across sampling stations ranged between 26 and 27.7°C, while pH varied from 7.49 to 8.74. Turbidity ranged from 176.62-189.96 NTU and conductivity varied between 360.45 and 454.88 µS/cm. The concentrations of other physicochemical parameters were as follows: BOD (6.39-7.64 mg/L) COD (84.25-97.27 mg/L); ammonia (26.83-33.98 mg/L); nitrate (37.25-43.89 mg/L); nitrite (37.35-41.75 mg/L); and phosphate (28.83-37.85 mg/L). The relative dominance of metals in the water followed the sequence: Al > Zn > Cu > Fe > Mn > Cd > Pb > Hg > As. Feacal and total coliform densities ranged from 1.05 × 10^2 to 4.25 × 10^3 (cfu/mL) and 1.56 × 10^2 to 6.40 × 10^4 (cfu/mL) respectively. The study reveals that the water under study was heavily polluted and of serious threat to the aquatic biota and public health.

Key words: Aquatic biota, contamination, pollution, public health, microbial indicators, toxic effects.

INTRODUCTION

Water is absolutely essential for life; it is undoubtedly the most precious natural resource that exists on our planet (Abowei and George, 2009). The quality of water available and accessible to a community has tremendous impact on their living standard and well being; thus global and local efforts are widespread at ensuring adequate provision of clean and safe water to the world's growing population (DWAF, 2003). Although water plays an essential role in supporting human life and biodiversity, it also has a great potential for transmitting diseases when contaminated (Yakasai et al., 2004). Population growth coupled with other factors such as urbanization, agricultural activities, industrial and commercial processes have resulted in the accumulation of wastes and pollutants which ends up in water bodies, thereby altering the water quality, species composition and biodiversity in many aquatic systems (Dike et al., 2004).

Physicochemical parameters such as temperature, pH, DO, salinity, and nutrient loads have been reported to influence biochemical reactions within water systems (Gulson et al., 1997). Such changes in the concentration of these parameters are indicative of changes in the condition of the water system (Gulson et al., 1997); the consequence of such is the compromise of the water quality for beneficial uses. The presence of toxic metals such as lead (Pb) and cadmium (Cd) in the environment has been a source of fret to environmentalist, govern-ment agencies and health practitioners as a result of their health implication which is hazardous and toxic to man (Hacioglu and Dulger, 2009). The presence of these metals in the aquatic ecosystem has far-reaching conse-quences on the biota and man; their toxic effects on man are related to dermal, lung and nasal sinus cancers (Fatoki et al., 2002).

*Corresponding author. E-mail: eigbinosa@gmail.com. Tel/Fax: +234(0) 81 828 68633.

The presence of microbial pathogens in polluted, untreated and treated waters poses a considerable health risk to the general public. Waterborne pathogens infect around 250 million people each year resulting in 10 to 20 million deaths (Anon, 1996). Microbial pathogens that commonly occur in water and wastewater can be divided into four separate groups. These groups are the viruses, bacteria, pathogenic protozoa and pathogenic helminths. The majority of these pathogens are enteric in origin, that is, they are excreted in faecal matter which contaminates the environment, and then gain access to new hosts through ingestion (Toze, 1999). Different microbial patho-gens have different infectious doses. Most enteric viruses and protozoa usually require only ten or less infectious particles or cysts to cause infection. Bacteria, however, do not usually cause infection unless more than 10^3 infectious cells are ingested (US EPA, 1992). Thus, determination of the numbers of different microbial pathogens in a water or wastewater sample is imperative.

Despite recognizing the life sustaining importance of water, man's approaches to water usage has always been unsustainable. Studies have shown that most rivers flowing through heavily urbanized and industrialized areas in Nigeria are contaminated with high concentration of some heavy metals of variable and unsuitable physic-chemical characteristics (Peretiemo-Clarke et al., 2009). Warri river with a number of creeks (Shanomi, Miller, Ogbe-Ijoh, Okerenkoko, Benikrukru, Deibiri, Kokodiagbene, Okere, Oporoza) is used for domestic and agricultural purposes, including irrigation and livestock activities. On the other hand, the river also serves as a carrier of major waste load of the industrialized city of Warri in the Niger Delta region of Nigeria and finally flows into the Atlantic Ocean. Over these years some work has been done on the physicochemical parameters of some creeks in Warri river (Peretiemo-Clarke et al., 2009; Ogunlaja and Ogunlaja, 2007), but there has been limited study on the microbial and physicochemical parameters as well as heavy/toxic metal contamination of the Shanomi creek of the Warri river, hence the need for this study.

MATERIALS AND METHODS

Description of study site

Warri river stretches within latitudes 5° 21′ to 6° 00′ N and longitu-des 5° 24′ to 6° 21′ E. Shanomi creek, a major tributary of the Warri river is within this geographical position. The river carries most of the municipal and domestic waste load of Warri metropolis and environs and finally empties them into the sea. Shanomi creek is characterized with industrial activities and other anthropogenic disturbances.

Sample collection

Water samples were collected on monthly basis from Shanomi creek at different sampling stations at 500 m apart from each station: Station A, Station B and Station C, between January and October 2011. Samples were collected in 2 L sterilized plastic containers. During sampling, the containers were rinsed three times with sample water before filling with the samples. The actual samplings were done midstream by dipping each sample bottle at approximately 30 cm below the water surface, projecting the mouth of the container against the direction of flow. After collection, the samples were protected from direct sunlight and transported in a cooler box containing ice packs to the laboratory for analyses. All samples were stored at 4°C and analyzed within 48 h of sample collection.

Physicochemical analyses

All field meters and equipment were checked and appropriately calibrated according to the manufacturers' instructions. The physicochemical parameters of water quality comprising of temperature, pH, turbidity, conductivity, phosphate (PO_4), nitrate (NO_3^-), nitrite (NO_2^-) ammonia (NH_3), biological oxygen demand (BOD_5), chemical oxygen demand (COD), and heavy metal concentrations, including cadmium (Cd); copper (Cu); aluminium (Al); lead (Pb); Zinc (Zn); mercury (Hg); Iron (Fe) and Manganese (Mn) were analysed. Temperature, pH and turbidity were measured using a mercury thermometer, pH meter and portable 2100P Hach turbidimeter, respectively. BOD_5 and COD were determined using the OxiDirect BOD system (Hach) and SpectroQuant Nova 60 COD cell test (Merck), respectively. And heavy metal concentrations were measured using Alpha model-4 atomic absorption spectroscopy (Chemtech Analytical Ltd, PN) with the use of an air-acetylene flame and single element hollow cathode lamp.

Isolation, detection and estimation of bacteria

Water samples were analyzed for the target presumptive bacterial pathogens using internationally accepted techniques and principles (Clesceri et al., 1998). Prior to filtration, samples were diluted 10-fold with sterile distilled water. Fifty milliliters (50 ml) of the appropriate dilution of each sample was filtered through a 0.45 µm pore size membrane filter (Millipore), which was aseptically trans-ferred to Petri dishes containing the appropriate selective media. The isolation of *Escherichia coli* was carried out using Coli-Chromo agar for 24 h at 37°C; while *Salmonella* and *Shigella* were isolated on S-S agar for 24 h at 35°C. Total and faecal coliforms were determined by mENDO agar for 24 h at 35°C and mFC agar for 24 h at 44.5°C, respectively. The estimation of total heterotrophic bacteria, was done on nutrient agar for 48 h at 37°C. Bacterial populations were expressed as colony forming units per milliliter (cfu/ml).

Statistical analysis

The data obtained were subjected to descriptive statistical analysis (95% confidence limit). The general linearized model (GLM) of SAS (statistical analysis system) was used to generate analysis of variance (ANOVA), means, standard error and range. The coefficient of correlation between microbial density and the physicochemical parameters was calculated by the Pearson correlations test. Statistical significance was set at P values of < 0.05 or < 0.01. All statistical analysis was performed using SAS (SAS version 8, SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

In spite of increasing stress on water resources in both developed and developing countries, understanding of pollutants in these aquatic environments is quite strewn. In addition, chemical pollutants that enter surface waters

Table 1. Physicochemical qualities and heavy metal concentrations of Shanomi creek.

Variable	Stations (mean ±SD)			F-value	Pr > F
	Station A	Station B	Station C		
Temperature (°C)	27.7±1.90^{c}	26.5±0.29^{a}	26±2.03^{b}	54.83	< .0001
pH	7.49±1.12^{a}	8.76±2.2^{b}	8.74± 3.32^{b}	130.59	< .0001
Conductivity (µScm^{-1})	454.88±0.54^{a}	390.28±4.91^{b}	360.45±2.73^{a}	681.75	< .0001
Turbidity (NTU)	189.96±2.50^{a}	177.34±1.0^{b}	176.62± 2.2^{a}	153.75	< .0001
BOD (mgL^{-1})	6.39±2.1$^{b\ a}$	7.64±1.0^{c}	6.74±0.1$^{a\ b}$	102.23	< .0001
COD (mgL^{-1})	97.27±6.92$^{a\ b}$	96.16±7.28$^{c\ b}$	84.25± 6.76^{a}	198.95	0.0013
Ammonia (NH_3(mgL^{-1})	33.02±2.5$^{a\ c}$	26.83±5.2$^{b\ c}$	29.35±0.1$^{a\ b}$	61.281	0.0016
Nitrate (NO_2^-(mgL^{-1})	38.98±4.32^{a}	43.89±0.78^{a}	37.25±2.94^{b}	216.55	0.0009
Nitrite (NO_3^-(mgL^{-1})	40.29±1.05^{b}	41.75±1.00^{a}	37.35±1.04$^{b\ c}$	20.85	0.0007
Phosphate (PO_4) (mgL^{-1})	37.85±0.10^{a}	28.83±3.10^{a}	36.63±1.20^{b}	113.50	0.0035
Pb (mgL^{-1})	0.158±0.11^{a}	0.310±0.00^{c}	0.367±2.03^{b}	40.65	0 .0001
Hg (mgL^{-1})	0.357±1.0^{a}	0.106±0.1^{b}	0.302±1.1^{c}	25.14	< .0001
Cd (mgL^{-1})	0.467±1.15^{b}	0.347± 2.10^{b}	0.284±1.15^{a}	110.59	<.0001
Cu (mgL^{-1})	0.368±1.54^{a}	0.579±1.07^{a}	1.487±0.76^{b}	223.67	0.0006
Al (mgL^{-1})	0.759±1.90^{c}	1.591± 1.40^{c}	1.985±0.01^{b}	73.04	0 .0009
Zn (mgL^{-1})	0.807±0.11^{a}	1.758±1.20^{c}	1.585±2.03^{b}	40.65	< .0001
Mn (mgL^{-1})	0.650±2.1$^{b\ a}$	0.152±1.0^{c}	0.760±0.1$^{a\ b}$	82.85	0.0012
As (mgL^{-1})	0.253±1.3^{a}	0.116±1.1^{b}	0.237±2.1^{c}	112.54	0.0001
Fe (mgL^{-1})	1.485±1.0^{a}	0.163±0.1^{b}	1.288±1.1^{c}	25.14	0 .0015

Values are means of triplicate ± Standard deviations (SD); Means with the same letter are not significantly different ($p >$ 0.005).

through various pathways may pose a significant health hazard even at extremely low concentrations, especially persistent chemicals (McMichael et al., 2001). In this study, baseline information on the physicochemical quailties, heavy metals concentrations and microbiological characteristics of Shanomi creek in the Niger Delta of Nigeria, were investigated. The physicochemical variables measured from the Shanomi creek are shown in Table 1. The temperature observed in this study ranged from 26 to 27.7°C and varied significantly with sampling stations (p < 0.01). There was no significant correlation between temperature and other variables tested. This was also seen in a study carried out by Igbinosa and Okoh (2009) which confirmed that the recorded tempera-ture ranged from 15.24 to 24.73°C and did not appear to pose any threat to the homeostatic balance of the rivers. The observed trend could be attributed to the evaporation and decreased flow of water from rivers during the dry seasons and subsequent dilution due to heavy precipi-tation and run-off from the catchment areas during the wet season (Radhika and Ganaderr, 2004). Temperature has a noticeable influence on the chemical and biochemi-cal reactions that occur in water bodies; high temperature increases the toxicity of heavy metals; it also increases the sensitivity of living organisms to toxic substances (Momba et al., 2006).

The pH values in this study (7.49 and 8.76) varied significantly (p < 0.01) with sampling stations. The obser-vation is similar to that reported by Oso and Fagbuaro (2008) as well as Morrison et al. (2001) and suggests that the water quality may not be healthy for the aquatic biota. According to the authors, severe changes in the pH of water bodies can have a drastic effect on aquatic life as these organisms have adapted to life in water of specific pH and even slight changes may result in death. Higher pH in water was attributed to increased photosynthetic assimilation of dissolved inorganic carbon by planktons (Iqbal et al., 2004). A similar effect could also be produced by water evaporation through the loss of half-bound CO_2 and precipitation of mono-carbonate (Wang et al., 2007). There was significant positive correlation between pH and COD (r = 0.635, p < 0.01), and signi-ficant negative correlation between pH and turbidity (r = - 0.587, p < 0.01).

The conductivity of the water samples generally varied significantly (p < 0.01), and ranged from 360.45 to 454.88 µScm^{-1} throughout the study regime. Conductivity exhibit-ted negative significant correlation with turbidity (r = -0.330, p < 0.01). The turbidity profile varied significantly (p < 0.01) amongst the sampling stations throughout the study period and ranged from 176.62-189.96 NTU. The values were higher than the WHO standard of 5.0 NTU (WHO, 2004); suggesting the excessive presence of sus-pended organic materials that promote the growth of microorganisms (Momba et al., 2006) and hence, disqua-lifies the receiving water body for direct domestic use. Excessive turbidity in surface waters, destined for human consumption can cause potential problems for water purification processes such as flocculation and filtration, which may increase treatment costs (Igbinosa and Okoh, 2009). There may also be a tendency for an increase in trihalomethane (THM) precursors, when highly turbid waters are chlorinated (Hacioglu and Dulger, 2009). Elevated turbidity values during the raining period could be attributed to increased surface runoff and erosion, through rain falls. Turbidity negatively correlated with COD (r = -0.437, $p < 0.05$) and positively correlated with NO_2^- (r = 0.597 at $p < 0.05$) and NO_3 (r = 0.792, $p < 0.01$). At higher levels of turbidity, these water bodies lose their ability to support diversity of aquatic life. Suspended par-ticles absorb heat from the sunlight resulting in increased temperature. Barnes et al. (1998) reported that turbidity values should never exceed 100 NTU as the presence of a high degree of suspended solids may clog fish gills, reduce growth rates, decrease resistance to disease and hamper egg and larval development thus disrupting suitable microhabitats.

The BOD_5 and COD profile varied between 6.39 and 7.64 mg/L and 84.25 and 97.27 mg/L respectively (Table 1). BOD_5 is used to indicate the extent of organic pollu-tion in aquatic systems, which adversely affects water quality. The Shanomi creek did not meet the universal water quality index of 3 mg/L BOD (Boyacioglu, 2007) all through the study regime. The high COD values obser-ved in this study are alarming and suggests that both organic and inorganic contaminants from municipal and industrial sources are entering into the water system. This is undesirable as continuous discharge of untreated effluent can negatively impact the quality of these water-sheds and subsequently cause harm to aquatic life. Microorganisms distributed in the marine and brackish environments play an important role in the decomposition of organic matter and mineralization (Hollibaugh et al., 1980). The existing bacterial communities are likely to play very active role in the rapid *in situ* degradative pro-cess. Especially, the salinity, dissolved oxygen, pH, organic matter, nutrients and trace metals play a key role in the biological process. Temperature and pH are limi-ting factors for the survival of bacteria in the environment (Whipple and Rohovec, 1994).

Nutrient concentrations revealed considerable varia-tions from Shanomi creek (Table 1) with significant ($p < 0.01$) mean concentration ranging between 26.83 and 33.02 mg/L for ammonia, 37.25 and 43.89 mg/L for nitrate, 37.35 and 41.75 mg/L for nitrite, and 28.83 and 37.85 mg/L for orthophosphate. NO_3^- was positively cor-related with turbidity ($p < 0.01$). NH_3 were positively correlated with NO_2^- and PO_4 ($p < 0.01$), and NO_2 exhi-bited positive correlation with BOD_5, COD, NH_3 and PO_4 ($p < 0.01$ respectively). Ammonia, nitrate and phos-phate are essential nutrients to plant life, but when found in excessive quantities; they can stimulate excessive and undesirable plant growth such as algal blooms. Eutrophi-cation could adversely affect the use of rivers and dams for recreational purposes as the covering of large areas by blue-green algae and/or macrophytes that can release toxic substances (cyanotoxins) could prevent access to waterways (Igbinosa and Okoh, 2009). Ololade and Ajayi (2009) observed the trend of fluctuating phosphate levels during the wet and dry seasons in four major rivers in Nigeria. Other investigators have pointed out that eutro-phication-related problems in temperate zones of aquatic systems begin to increase at ambient total phosphate concentrations exceeding 0.035 mgL^{-1}. The Shanomi creek water samples exceeded the recommended limits for nitrates (<0.5 mgL^{-1}) making this river unsuitable for aquatic life and irrigation purposes (FEPA, 1991). Addi-tionally, the phosphate levels obtained in this study are exceedingly higher than the FEPA limits (<0.05 mgL^{-1}) for aquatic life, irrigation purposes, livestock watering, and recreational activities (FEPA, 1991).

Heavy metal concentrations for the Shanomi creek are shown in Table 1. The respective values were as follows: 0.158 - 0.367 mgL^{-1} for Pb, 0.106 - 0.357 mgL^{-1} for Hg, 0.284 - 0.467 mgL^{-1} for Cd; 0.759 - 1.985 mgL^{-1} for Al, 0.368 - 1.487 mgL^{-1} for Cu, 0.807 - 1.758 mgL^{-1} for Zn, 0.152 - 0.760 mgL^{-1} for Mn, 0.163 - 1.485 mgL^{-1} for Fe and 0.116 - 0.253 mgL^{-1} for As. The relative dominance of heavy metals in the water in terms of concentration was observed in the following sequence Al > Zn > Cu > Fe > Mn > Cd > Pb > Hg > As. Fe, Mn, Zn, Cu, Al and Pb had their highest concentrations in site C, while Hg and Cd had their highest concentrations in site A. The concentra-tions of these heavy metals were well above the WHO (2004) accepted level and pose a serious health risk to people who rely on this creek as their source of domestic water. The high level of Cu observed in this study indi-cate a higher input of organic matter deposition in the creek, which might come from urban and industrial was-tes (Das and Nolting, 1993), while increased Cd concen-tration might be related to industrial activity, atmospheric emission and deposition of organic and fine grain sediments (Khan et al., 1992). Thus efforts need to be taken to ensure that the creek is free from these heavy metals as it serves as a major source of domestic water to the communities in its environ. Trace metal contamina-tions are important due to their potential toxicity for the environment and human (Vinodhini and Narayanan, 2008). Some of the metals like Cu, Fe, Mn, Ni and Zn are essential as micronutrients for the life processes in ani-mals and plants while many other metals such as Cd, Cr, Pb and Co have no known physiological activities (Kar et al., 2008; Aktar et al., 2010). Metals can accumulate in the human body system, causing damage to nervous system and internal organs (Lohani et al., 2008). The main threats to human health from heavy metals are associated with exposure to such element as arsenic. This metals along with other such as mercury and lead have been extensively studied and their effects on human health regularly reviewed by international bodies such as the WHO (Jarup, 2003). The health implications of excess consumption of these non-essential metals have

Table 2. Presumptive microbial indicator and total heterotrophic bacteria from Shanomi creek.

Presumptive microbial indicator	Mean of microbial density cfu/ml		
	Station A	**Station B**	**Station C**
E. coli	$1.65 \times 10^2 \pm 2.10$	$2.54 \times 10^3 \pm 0.5$	$8.56 \times 10^5 \pm 0.1$
Salmonella spp	$7.15 \times 10^1 \pm 0.15$	$1.36 \times 10^2 \pm 0.1$	$2.65 \times 10^2 \pm 1.0$
Shigella spp	$6.89 \times 10^1 \pm 1.05$	$1.27 \times 10^1 \pm 0.28$	$1.08 \times 10^2 \pm 1.15$
Feacal coliform	$1.05 \times 10^2 \pm 1.10$	$4.25 \times 10^3 \pm 1.2$	$2.15 \times 10^2 \pm 1.07$
Total coliform	$6.40 \times 10^4 \pm 0.1$	$1.56 \times 10^2 \pm 0.8$	$3.45 \times 10^2 \pm 0.1$
Total heterotrophic bacterial	$1.26 \times 10^4 \pm 0.1$	$5.62 \times 10^4 \pm 0.3$	$8.261 \times 10^6 \pm 0.1$

Values are means of triplicate ± Standard deviations (SD).

been noted to result in neurological, bone and cardiovascular diseases, renal dysfunction and various cancers, even at low levels (Calderon, 2000; Watt et al., 2000; Jarup, 2002).

Pollution of water such as high nutrient concentrations and high turbidity, promotes bacterial growth thus resulting in a substantial increase of these naturally occurring organisms. Feacal and total coliforms densities varied significantly ($p < 0.05$) with sampling site and ranged from 1.05×10^2 to 4.25×10^3 cfu/mL and 1.56×10^2 to 6.40×10^4 cfu/mL, respectively (Table 2). *E. coli*, *Samlonella* and *Shigella* counts ranged from 1.65×10^2 to 8.56×10^5 cfu/mL, 7.15×10^1 to 2.65×10^2 cfu/mL and 1.27×10^1 to 1.08×10^2 cfu/mL, respectively (Table 2). Population densities of *E. coli*, *Samlonella* sp and *Shigella* varied significantly ($p < 0.05$) with sampling station. The total heterotrophic bacterial counts ranged from 1.256×10^4 to 8.261×10^6 cfu/mL (Table 2). Total coliforms are frequently used to assess the general hygienic quality of water (Ashbolt et al., 2001). The microbial population distribution observed in this study is similar to range reported by many researchers (Anwar et al., 2004) especially in relation to aquatic environment. The *E. coli* count was observed to be more in station C than other stations; this could be attributed to rainfall resulting in the washing of debris and faecal contamination from other non-point source pollution. The occurrence of coliform bacteria in this watershed can be viewed as an indicator of faecal contamination especially in cases where *E. coli* and Salmonella was observed. Similar observations were made by other authors (Kara et al., 2004).

In some instances they may indicate the presence of pathogens responsible for the transmission of infectious diseases such as gastroenteritis, salmonellosis, dysentery, and typhoid fever (Ashbolt et al., 2001). According to DWAF, the maximum limit for no risk (domestic and recreational use) for total coliform and feacal coliform is 10 and 0 cfu/100 mL, respectively (DWAF, 1996). This suggest that the water quality under study fell short of recommended standard and could pose health risk (especially of contracting gastrointestinal illnesses) to both humans and animals that use these water bodies. According to the United States Environmental Protection Agency (US EPA) criteria for *E. coli* density (<33 CFU 100 mL^{-1} for freshwater) (US EPA, 2004), all sampling stations in Shanomi creek were of poor microbial quality.

Heterotrophic bacterial biomass and production in coastal waters have been reported almost from all parts of the world away from the immediate influence of rivers, the heterotrophic microorganism and autotrophic microorganism are the major agents shaping the organic composition of aquatic milieu. The heterotrophic bacterial distribution, diversity and activities are controlled by various hydro biological factors and nutrient levels present in the aquatic environment and have been well studied in aquatic environment (Azam et al., 1983; Ducklow and Hill, 1985). Distribution of bacteria depends on changes in water temperature, salinity and physico-chemical parameters.

The current study has revealed that there was an undesirable impact on the physicochemical and microbial characteristics of the Warri river at the Shanomi creek axis as a result of the discharge of untreated waste entering into the watershed from ambient industries and municipalities. This poses a health risk to several rural communities that rely on the water body for domestic and recreational purposes. The information generated in this study can assist local authorities to gain further insight into the state of rivers located within the community. Furthermore, the information can be utilized to revise the established microbiological water quality assessment procedures thereby assisting water resource managers in restoring these impaired water resources.

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