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Microbiological Assessment of Elechi Creek Receiving Wastewater Effluents from Industrial Operations in Port Harcourt City

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Disposal of wastewater and other effluents into water bodies from activities around water bodies have for long been of major concern and challenge to the environment leading to several infectious diseases. The amount of industrial untreated solid wastes from companies, wastewater from car washing activities, open drainages and agricultural runoffs located close to Elechi creek constitutes the wastewater effluents received by the creek thus resulting in the imbalance of the ecosystem. The study was therefore aimed at determining the microbiology of water quality at different stations of the Elechi creek. Surface water, wastewater and sediment samples were collected during a seven month period and analysed using standard microbiological procedures. Results obtained revealed that the average microbial counts ranged as follows: Total Heterotrophic bacteria $1.12 \pm 0.13 \times 10^8$ to $1.28 \pm 0.09 \times 10^8$ cfu/ml, Total coliform count; 6.4 ± 0.21 to 7.8 ± 0.13 cfu/ml, Total *Staphylococcus* Count**;** 6.9 ± 0.06 to 7.9 ± 0.08 cfu/ml, Total *Shigella* count; 7.9 ± 0.11 to 8.5 ± 0.14 cfu/ml, Total *Salmonella* Count; 5.4 ± 0.13 to 7.9 ± 0.08 cfu/ml, Total *Vibrio* Count; 5.9 ± 0.13 to 7.4 ± 0.09 cfu/ml, and Total *Pseudomonad* Count; 2.5 ± 0.08 to 4.8 ± 0.10 cfu/ml, in surface water, Total Heterotrophic bacteria $1.02 \pm 0.08 \times 10^8$ cfu/ml to $2.68 \pm 0.08 \times 10^8$ cfu/ml, Total coliform count; 4.4 ± 0.10^a to 4.9 ± 0.11^a cfu/ml, Total *Staphylococcus* Count**;**4.7 ± 0.10 to 5.9 ± 0.12 cfu/ml, Total

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Shigella count; 4.0±0.08 to 4.8±0.11 cfu/ml, Total *Salmonella* Count; 3.2±0.16 to 4.6±0.08 cfu/ml, Total *Vibrio* Count; 2.0±0.15 to 4.8±0.11 cfu/ml, and Total *Pseudomonad* Count2.7±0.13 to 3.9±0.09cfu/ml, in wastewater and Total Heterotrophic bacteria 2.16±0.07 x10^9 cfu/g to 2.24±0.09 x10^9 cfu/g, Total coliform count; 1.01±0.13 to 1.36±0.06^b cfu/g, Total *Staphylococcus* Count**;** 6.8±0.11 to 9.1±0.08 cfu/g, Total *Shigella* count; 4.0±0.09 to 6.5±0.06 cfu/ml, Total *Salmonella* Count; 4.1±0.11 to 9.7±0.12 cfu/g, Total *Vibrio* Count; 6.8±0.10 to 9.5±0.09 cfu/g, and Total *Pseudomonad* Count; 4.0±0.16 to 5.9±0.07 cfu/g, in sediment samples. Bacterial isolates belonging to the genera *Bacillus, Staphylococcus*, *Enterococcus, Pseudomonas, Proteus, Klebsiella, Providencia*, *Escherichia coli, Salmonella, Shigella, Vibrio* and *Enterobacter* were isolated and identified. The occurrences of these bacterial isolates as potential pathogens could cause poor water quality through fouling and render the water for various uses and may pose a public health threat to our water resources. Adherence to good hygienic practices and proper treatment of wastewater before discharge into the environment should be encouraged to minimize the spread of infectious diseases and fouling of water bodies. This may also affect the aquatic life in such ecosystems.

Keywords: Microorganisms; surface water; sediment; wastewater; pollution; elechi creek.

1. INTRODUCTION

Water remains one of the most important natural resources for the sustenance of life on earth. The usefulness of water be it ground water which serves as a source of drinking water or surface water used for different purposes such as transportation, recreation, sanitation (washing) and other domestic activities cannot be overemphasized [1]. Water is a source of life but poorly managed resources in the world today. This is due to increase in human activities and other natural processes such flooding, erosion, runoff or seepages from waste decomposition. Urbanization has shown to be one of the major causes of contamination of water bodies and this poses a threat to all forms of life in the water environment [2]. Most sources of contamination may be described as point or non-point sources in which leachates from domestic wastes, agricultural wastes, Industrial wastes, sewage discharges, among other types of contamination find their way into water bodies [3]. These contaminants affect the aquatic life which exists in the water by depleting available oxygen causing asphyxiation of organisms and other marine forms thereby causing death [4-7]. In Nigeria, there is scarcity of fresh water or potable water supplies as a result of increasing population due to migration of people to urban centres and increase in pollution of the available water resources [8]. Assessment of water resource quality of any region is an important aspect of developmental activities of the region, because rivers, lakes and man-made reservoirs are used for water supply to domestic, industrial, agricultural and fish culture [9]. In recent years, a number of events affecting water quality have resulted in increased public concern about surface water quality [10]. Over the years there has been an increased use of lakes, streams and other small water bodies as dumping grounds for all kinds of wastes, without any consideration of the existing aquatic habitats and the environment. Human activities around the water bodies is also a contributing factor to the pollution of the water bodies, in some cases inefficient waste disposal and dumping of faeces into rivers have contributed to pollution [11]. Elechi creek as brackish water body and receives large amount of effluents from surrounding companies operating within the vicinity. Several studies around the habitats show that the creek is polluted and the aquatic population of the creek is at risk of water borne infections from the water [12- 13]. This raises so much concern to warrant this study in order to assess the microbiological quality of the Elechi creek which produces several sea foods consumed by a large population of people in Rivers State and beyond.

2. MATERIALS AND METHODS

2.1 Description of Study Area

Elechi creek is close to Eagle Island, located on the South-West of Port Harcourt between longitude 04˚46'743"N and 007˚00'557"E; latitude 04˚48'217"N and 006˚48'989"E (Fig.1).It is bounded on the North by the Rivers State University, Nkpolu Oroworukwo area of Diobu. The Elechi creek is a brackish water system influenced by tidal fluxes with amplitude of about 1.20m with minimal current flow velocity of about 3m/s. It has mangrove vegetation with the dominant types being red mangroves *(Rhizophora racemosa*), white mangroves (*Avicennia africana*) and black mangroves (*Laguncularia racemosa*). The area is also inhabited by other plants (e.g. fern, *Achrostichum aureum* and *grass, Paspalum varginatum*). Aquatic habitats found in the area include mud skipper; *Periophthalmus sp., Fidder crabs Uca tangeri and Periwinkles* etc.

2.2 Collection of Samples

A total of five (5) sampling stations were designated along the creek. Sampling stations were chosen approximately 6 to 10 meters from the creek banks and about 50 meters apart from each other (Fig. 1). Surface water, wastewater from industrial activities and sediment samples were collected using sterilized bottles. To collect the surface water and wastewater each of the sample bottles were rinsed three (3) times with the appropriate sample before collection at a depth of about 30cm below the water surface in the opposite direction of the water flow [14]. The sediment samples were collected using a sterilized scoop and transferred into sterilized bottles. After collection of samples, they were appropriately labelled and put in an ice pack cooler and transported to the laboratory for analysis. A total of 210 samples were collected, sampling was done twice a month from February to August, 2019.

2.3 Microbiological Analyses

The surface water, wastewater and sediment samples were aseptically subjected to a 10-fold serial dilution. One mililitre of surface water and wastewater samples were aseptically added to 9ml of sterile normal saline and diluted to 10^{-5} respectively. One gram of sediment samples was aseptically added to 9ml of sterile normal saline and diluted to 10^{-6}. Aliquots (0.1 ml) of 10^{-3}, 10^{-4} and 10^{-5} dilutions for water samples and 10^{-4} and 10^{6} for sediment samples were inoculated onto surface-dried appropriate growth medium such as Nutrient agar, MacConkey agar, Manitol salt agar, Salmonella Shigella agar, Thiocitrate bile salt agar, and Centrimide agar for the cultivation of total heterotrophic bacteria, total coliform bacteria, total staphylococcal, total *Salmonella* and *Shigella*, total Vibrio and total Pseudomonad counts respectively. The inoculation technique was the spread plate method, using a sterile bent glass rod. The inoculated plates were incubated at 37ºC for 24-48 hours after which discreet colonies on plates were counted and expressed as colony forming units and were sub-cultured repeatedly to obtain pure bacterial isolates for subsequent investigations [15-16]. The data obtained were statistically analysed using statistical Package for Social Sciences tool SPSS 22.

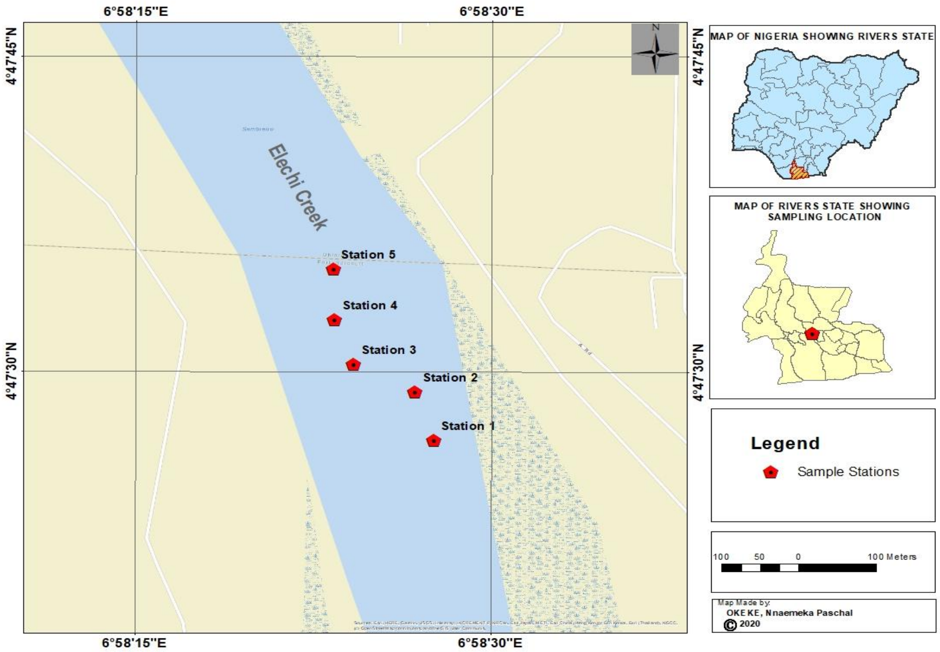

Fig. 1. Map of Elechi Creek showing the Sampling stations

3. RESULTS

The microbial counts obtained in the study showed variations across different stations. The sediment samples recorded higher microbial counts compared to the surface water and wastewater counts respectively.

Table 1 shows variations in the microbial counts for surface water samples at different stations. Total Heterotrophic Bacterial counts recorded high counts with values ranging from 1.17±0.11 $x10^8$ cfu/ml to 1.28±0.09 $x10^8$ cfu/ml; total Coliform counts ranged from 6.4±0.21 $x10^5$ cfu/ml to 7.8±0.13$x10^5$ cfu/ml; total *Staphylococcal* counts ranged from 6.9±0.06 $x10^5$ cfu/ml to 7.9±0.08 $x10^5$ cfu/ml; total *Shigella* counts 7.9±0.11 $x10^5$ cfu/ml to 8.5±0.14 $x10^5$ cfu/ml; total *Salmonella* counts 5.4±0.13 $x10^5$ cfu/ml to 7.9±0.08 $x10^5$ cfu/ml; total vibriod counts ranged from 5.9±0.13 $x10^5$ cfu/ml to 7.4±0.08 $x10^5$ cfu/ml; total Pseudomonad counts ranged from 2.5±0.08[a] $x10^5$ cfu/ml to 4.8 ±0.10[a] $x10^5$ cfu/ml.

Table 2 shows mean values of the microbial counts for wastewater at the different stations. There were significant differences in the various counts across all sampled stations at a confidence interval of 95%. Total Heterotrophic bacterial counts ranged from 1.02±0.08 $x10^8$ cfu/ml to 2.68±0.08 $x10^8$ cfu/ml; total Coliform counts ranged from 4.4±0.10 ±0.23 $x10^6$ cfu/ml to 4.9±0.11 $x10^6$ cfu/ml; total Staphylococcal counts ranged from 4.7±0.10 $x10^6$ cfu/ml to 5.9±0.12 $x10^6$ cfu/ml; total *Shigella* counts 4.0±0.08 $x10^6$ cfu/ml to 4.8±0.11 $x10^6$ cfu/ml; total *Salmonella* counts 3.2±0.16 $x10^6$ cfu/ml to 4.6±0.08 $x10^6$ cfu/ml; total vibriod counts ranged from 3.4±0.11 $x10^6$ cfu/ml to 4.8±0.11 $x10^6$ cfu/ml; total Pseudomonad counts ranged from 2.7±0.13 $x10^6$ cfu/ml to 3.9±0.09 $x10^6$ cfu/ml.

Table 3 shows variation in microbial counts for sediment samples at different stations. Total Heterotrophic bacterial counts ranged from 2.16±0.07 $x10^9$ cfu/g to 2.24±0.09 $x10^9$ cfu/g; total Coliform counts ranged from 1.01±0.13 $x10^6$ cfu/g to 1.36±0.06 $x10^6$ cfu/g; total Staphylococcal counts ranged from 6.9±0.12 $x10^6$ cfu/g to 9.1±0.08 $x10^6$ cfu/g; total *Shigella* counts 4.0±0.09 $x10^6$ cfu/g to 6.5±0.06 $x10^6$ cfu/g; total *Salmonella* counts 4.1±0.11 $x10^6$ cfu/g l to 9.7±0.12 $x10^6$ cfu/g; total vibriod counts ranged from 7.1±0.09 $x10^6$ cfu/g to 9.0±0.08 $x10^6$ cfu/g; total pseudomonad counts ranged from 4.0±0.16 $x10^6$ cfu/g to 5.9±0.07 $x10^6$ cfu/g.

Table 4 shows the percentage occurrence of bacterial isolates in surface water, wastewater and sediment samples within the sampling period. Surface water recorded *Salmonella* sp and *Shigella* sp as the highest occurring bacteria (66.7%), while the least occurring bacteria was *Enterococcus* and *Enterobacter* (0.00%). In the wastewater samples the highest occurring organism was *Enterococcus* sp (100%) and the least was *Enterobacter* sp (0.00%). In the sediment samples the highest occurring bacteria was *Enterobacter* sp (100.0%) while *Shigella* sp*, Salmonella* sp, *Klebsiella* sp*, Enterococcus* sp and *Staphylococcus* sp (0.00%) respectively occurred least.

4. DISCUSSION

The microbial counts obtained in the study showed variations in the different stations within the period of sampling. Microbial counts for the surface water also varied according to the different stations. Total Heterotrophic Bacterial counts recorded high counts with values ranging from 1.17±0.11 $x10^8$ cfu/ml to 1.28±0.09 $x10^8$ cfu/ml while total Coliform counts ranged from 6.4±0.21 $x10^5$ cfu/ml to 7.8±0.13$x10^5$ cfu/ml. Similar results were obtained for other isolates. The high microbial counts in the surface water and wastewater could be attributed to anthropogenic activities as well as flooding from rainfall, erosion or urban runoff from the activities around the Elechi creek with beehive of industrial activities into the river. These activities could result in accumulation of organic wastes which can equally be a means of contaminating the environments. These microbes could cause fouling of the water body resulting in an ecological imbalance thus causing eutrophication. Flooding or runoff due to torrential rains could increase microbial load washed into the river from the soil and the fact that more nutrients are brought in by this process through leaching of the soil which eventually settles at the bottom of the river, could lead to increased nutrient levels which encouraged rapid multiplication of bacteria. Waste discharges from Elechi creek activities are not treated before disposal which could account for increase in microbial load across the stations [17,18]. This practice is lacking including conventional methods of waste management which have been grossly neglected (Adedipe, 2002; Adeyemi [19] unlike in developed countries where these facilities are adequately provided [20]. Several authors have reported that cities face serious problems of high volume of wastes from different

Table 1. Microbial Counts for Surface water samples at the various stations

	Microbial Counts						
Stations	THBC ($x10^8$cfu/ml)	TCC($x10^5$cfu/ml)	TSC($x10^5$cfu/ml)	TSHC($x10^5$cfu/ml)	TSAC($x10^5$cfu/ml)	TVC($x10^5$cfu/ml)	TPC($x10^5$cfu/ml)
Station 1	$1.12±0.13^a$	$6.4±0.21^a$	$7.6±0.12^{abc}$	$8.4±0.08^a$	$7.0± 0.14^b$	$7.0±0.08^b$	$3.9±0.13^a$
Station 2	$1.25±0.09^{bc}$	$7.8±0.13^b$	$7.9±0.08^c$	$7.9±0.11^a$	$7.6±0.11^b$	$7.4±0.09^b$	$3.8±0.12^a$
Station 3	$1.20±0.09^{bc}$	$7.5±0.08^b$	$7.0±0.13^{ab}$	$8.0±0.10^a$	$5.4±0.13^a$	$6.2±0.13^a$	$4.8 ±0.10^a$
Station 4	$1.17±0.11^{ab}$	$7.3±0.09^{ab}$	$6.9±0.06^a$	$8.5±0.14^a$	$7.1±0.14^b$	$5.9±0.13^a$	$4.0±0.08^a$
Station 5	$1.28±0.09^c$	$7.8±0.13^b$	$7.7±0.07^{ab}$	$8.0±0.07^a$	$7.9±0.08^b$	$7.4±0.08^b$	$2.5±0.08^a$

*KEY: THB: Total Heterotrophic Bacterial Count; TCC: Total Coliform Count; TSC: Total Staphylococcal Count; TSHC: Total Shigella Count;TSAC: Total Salmonella Count; TVC: Total Vibrio Count; TPC: Total Pseudomonad Count. *Means with the same superscript along the columns are not significantly different (p<0.05).*Means with different superscript along the columns are significantly different (p<0.05)*

Table 2. Microbial Counts for Wastewater samples at the various stations

	Microbial Counts						
Stations	THBC($x10^8$cfu/ml)	TCC($x10^6$cfu/ml)	TSC($x10^6$cfu/ml)	TSHC($x10^6$cfu/ml)	TSAC($x10^6$cfu/ml)	TVC($x10^6$cfu/ml)	TPC($x10^6$cfu/ml)
Station 1	$1.02±0.08^{ab}$	$4.6±0.23^a$	$5.9±0.12^b$	$4.1±0.09^{ab}$	$4.6±0.08^b$	$3.4±0.11^{ab}$	$2.7±0.13^a$
Station 2	$2.62±0.08^c$	$4.9±0.11^a$	$5.6±0.14^{ab}$	$4.8±0.11^b$	$4.4±0.15^b$	$3.6±0.18^{ab}$	$3.2±0.15^{bc}$
Station 3	$2.04±0.10^a$	$4.7±0.09^a$	$4.8±0.13^a$	$4.4±0.08^a$	$3.2±0.16^a$	$2.0±0.15^a$	$3.9±0.09^c$
Station 4	$2.01±0.07^a$	$4.4±0.10^a$	$4.7±0.10^b$	$4.0±0.08^{ab}$	$4.4±0.08^b$	$4.8±0.11^b$	$2.8±0.13^b$
Station 5	$2.68±0.08^{bc}$	$4.5±0.09^a$	$5.5±0.12^{ab}$	$4.7±0.10^{ab}$	$4.3±0.08^b$	$4.6±0.13^b$	$3.3±0.11^{bc}$

*KEY: THBC: Total Heterotrophic Bacteria Count; TCC: Total Coliform Count; TSC: Total Staphylococcal Count; TSHC: Total Shigella Count; TSAC: Total Salmonella Count; TVC: Total Vibriod Count; TPC: Total Pseudomonas Count. *Means with the same superscript along the columns are not significantly different (p<0.05). *Means with different superscript along the columns are significantly different (p<0.05)*

Table 3. Microbial counts for sediments at the various stations

	Microbial Counts						
Stations	THBC($x10^9$cfu/g)	TCC($x10^6$cfu/g)	TSC($x10^6$cfu/g)	TSHC($x10^6$cfu/g)	TSAC($x10^6$cfu/g)	TVC($x10^6$cfu/g)	TPC($x10^6$cfu/g)
Station 1	$2.24±0.09^a$	$1.13±0.14^a$	$6.9±0.12^a$	$4.8±0.08^{bc}$	$9.2±0.12^b$	$8.8±0.20^a$	$5.9±0.07^a$
Station 2	$2.24±0.08^a$	$1.01±0.13^a$	$9.1±0.08^{ab}$	$6.5±0.06^b$	$9.7±0.12^b$	$9.0±0.08^b$	$4.0±0.16^a$
Station 3	$2.16±0.07^a$	$1.17±0.09^a$	$6.8±0.10^{bc}$	$5.2±0.09^a$	$9.1±0.09^b$	$7.1±0.09^b$	$5.1±0.09^b$
Station 4	$2.18±0.13^a$	$1.17±0.12^a$	$6.9±0.08^a$	$5.8±0.10^c$	$6.3±0.18^a$	$6.8±0.10^{ab}$	$4.3±0.13^a$
Station 5	$2.20±0.09^a$	$1.36±0.06^b$	$6.8±0.11^c$	$4.0±0.09^{bc}$	$4.1±0.11^c$	$9.5±0.09^b$	$4.9±0.14^a$

*KEY: THBC: Total Heterotrophic Bacterial Count; TCC: Total Coliform Count; TSC: Total Staphylococcal Count; TSHC: Total Shigella Count; TSAC: Total Salmonella Count; TVC: Total Vibriod Count; TPC: Total Pseudomonad Count. *Means with the same superscript along the columns are not significantly different (p<0.05). *Means with different superscript along the columns are significantly different (p<0.05)*

Table 4. Percentage Occurrence of Bacterial Isolates in all the samples

Bacteria Isolates	Surface water n(%)	Wastewater n(%)	Sediment n(%)
Bacillus sp	2(28.6)	3(42.9)	2(28.6)
Staphylococcus sp	2(40.0)	3(60.0)	0(0.00)
Enterococcus sp	0(0.00)	3(100)	0(0.00)
Pseudomonas sp	1(14.3	2(28.6)	4(57.1)
Proteus sp	4(44.4)	3(33.3)	2(22.2)
Klebsiella sp	2(50.0)	2(50.0)	0(0.00)
Providencia sp	2(40.0)	2(40.0)	1(20.0)
Eschericia.coli	4(57.1)	2(28.6)	1(14.3)
Salmonella sp	2(66.7)	1(33.3)	0(0.00)
Shigella sp.	2(66.7)	1(33.3)	0(0.00)
Vibrio sp	2(50.0)	1(25.0)	1(25.0)
Enterobacter sp	0(0.00)	0(0.00)	3(100)

Key: n=number of isolates; %=percentage occurrence of isolates represent values in parenthesis

sources due to inadequate disposal technologies and high cost of waste management [19-22]. The high microbial counts observed in the surface water is in agreement with previous reports by Obire *et al* [12] who stated that the high counts of heterotrophic bacteria and coliform bacteria are attributed to the activities going on around the creek. Also, the high coliform bacteria counts are indication that disease-causing microorganisms may be present in the waters of the creek.

Sediment recorded high microbial counts because it is generally a reservoir for organic matter, solid and liquid wastes and could serve as a source of food for the microbes [23]. The discharge of wastes into the Elechi creek and the surface run-off into the sites and nearby rivers during the rains are also contributory factors [24]. The presence of these isolates in this study gives credence to these findings. The isolation of *E.coli* and other coliforms is an indication of recent human contamination of the sampling points, and is of great public health concern [25]. Coliforms were isolated from all the samples collected from the water body. The presence of this physiologic group in these samples is an indication of feacal contamination of the samples [26]. This is possible since the faeces is indiscriminately deposited within and around the Elechi creek by residents. Through surface run-off, some of the feacal materials are carried to the nearby water body, leading to the presence of coliforms in such water body. In aquatic ecosystems, sediments play important roles in the growth, evolvement and establishment of aquatic organisms. They are also a sink for pollutants [27-28]. The ability of sediments to act as a sink for pollutants arises from a combination of processes, which include river hydrodynamics, biogeochemical processes, and environmental conditions. However, sediments are useful markers of environmental changes in the aquatic ecosystem and give an indication of the ability of natural mechanism to eliminate them while in their compartment [29]. Within the aquatic food chain, the presence of pollutants in the sediment can lead to a wide range of effects ranging from molecular alterations to deaths of fish populations [30]. These conditions may contribute to loss of water quality functionality resulting in a greater load of contaminants and suspended sediments to downstream receiving waters. It is also possible that in such water columns the sediment-bound pollutants may be suspended and transported to downstream receiving waters, resulting in potential impacts to aquatic biota. For example, the pollutants could kill or impair bottom-feeding (benthic) organisms that comprise part of the aquatic food chain for fish, resulting in less fish for anglers to catch. In addition, these pollutants can also cause external tumors on fish, raising concerns from the public. This situation portends serious danger to populations that depend on such water resources for survival because of the public health risk associated with the entire physiological state.

Microorganisms isolated from the water body belong to the genera *Bacillus*, *Staphylococcus*, *Enterococcus*, *Pseudomonas*, *Vibrio*, *Proteus*, *Salmonella*, *Shigella*, *Escherichia coli*, *Enterobacter*, *Klebsiella* and *Providencia*. Similar studies on the Elechi creek and other related creeks have recorded the abundant existence of these isolates [12] [31-33]. The abundance and occurrence of the microbial populations obtained in this study varied in different samples. *Vibrio* was isolated from most of the samples. This indicates that the sampling points were impacted by human activities. It is equally possible that the samples were contaminated with organic wastes that contained *Vibrio* species. The percentage occurrence of bacterial isolates in surface water, wastewater and sediment samples showed that surface water recorded *Salmonella* sp and *Shigella* sp as the highest occurring bacteria (66.7%), while the least occurring bacteria were *Enterococcus* and *Enterobacter* (0.00%). In the wastewater samples the highest occurring organism was *Enterococcus sp.* (100%) and the least was *Enterobacter sp.* (0.00%). In the sediment samples the highest occurring bacteria was *Enterobacter* sp (100.0%) while *Shigella* sp*, Salmonella* sp*, Klebsiella* sp, *Enterococcus* sp and *Staphylococcus* sp (0.00%) respectively occurred least. The presence of *Pseudomonas*, *Enterobacter*, *Proteus*, *Escherichia coli* and *Klebsiella* in different samples is in agreement with findings reported by Wilcox *et al* [34] who in their study of a related creek observed these microbes from surface water of the creek in Rivers State. Occurrence of *Pseudomonas* sp as a hydrocarbon utilizing bacteria has been reported [35]. *Pseudomonas* sp is wide spread in the environment and they could contribute to the oxidation of hydrocarbons in the environment. Larger quantity of these microbes enter the marine environments from wastewater discharges as urban run-off, domestic wastes, industrial discharges and also from vessels as ballast waters, emissions from engine and bilge pumping. They enter the aquatic environment at times as leachates carrying these microorganisms thereby contributing to marine biodiversity [36]. *Proteus* sp, *Shigella* sp and *Enterobacter* sp are enteric pathogens associated with the faeces of animals including humans. However, in most cases the storm water arising from erosion or urban runoff from the various factories may fill up with sediment, adversely impacting water quality and increasing public concerns about mosquito-borne diseases and other microorganisms as reported in this study. In addition, these marshy storm water runoff may harbor toxic blue-green algae and other nuisance algae and duckweed as they discharge into the river. Recreational activities and socioeconomic values in such waters include fishing, sailing, swimming, water sporting and pleasure cruises amongst others are lost in the process because its catchment area in the Elechi creek receives fairly large influx of wastes [37-38]. Also wastewater is a potential source of many human pathogenic bacteria which poses a serious health risk to the general public. When wastewater percolate into the soil, the transport of pathogenic bacteria from surface water to ground water increases the vulnerability of ground water [39] which is the source of drinking water in many parts of the world. This contributes significantly to the spread of diseases such as cholera, diarrhoea, dysentery, malaria and typhoid fever [40-43] [11] in which many of the isolates obtained in the study are carriers of these diseases [44]. The presence of *Proteus, Shigella* and *Enterobacter* in the samples of Elechi creek is an indication of faecal contamination of the creek. This is supported by reports of Ihejirika *et al*. [45] However, *Enterobacter* sp was more predominant in the sediment samples from the creek. The presence of *Vibrio* sp in the surface water samples can be due to contamination from birds, frogs, fishes and shell fish present in aquatic environments [46] [45]. *Vibrio* species especially *V. cholerae* is responsible for the disease namely cholera in humans [47]. In Rivers state, Nigeria, wastes generated from some companies around the Trans Amadi Industrial Layout are channeled directly into one of the tributaries of the River Niger. This act could introduce enteric pathogens e.g. *Bacillus* sp, *Escherichia* sp*,* etc and excess nutrients into the river, may result to eutrophication [48] [17]. These consequences of anthropogenic pollution during such operations can lead to the transmission of diseases by water borne pathogens, eutrophication of water bodies, accumulation of toxic or recalcitrant chemicals in the soil, destabilization of ecological balance and negative effects on human health [49] [33]. Abu-Ashour *et al* [50] revealed that some bacteria also possess the ability to attach to substrate surfaces by electrostatic hydrogen bonding and hydrophobic interactions. After attachment, they secrete slimy materials that can attract other organisms and nutrients to the interface. Attachment to surfaces benefits microorganisms in several ways both on nutritional and survival basis which invariably enhances bioremediation [50-51]

5. CONCLUSION

Results obtained in this study revealed that the water quality of Elechi creek is polluted with various waste products because it appears that the wastewater from industries operating around the Elechi creek are not treated before disposal which is critical to the survival of aquatic life in the receiving waters. Isolation of various bacteria genera namely *Bacillus sp. Staphylococcus sp. Enterococcus sp., Pseudomonas sp., Klebsiella sp., Proteus sp., Providencia sp., Escherichia coli, Salmonella* sp*, Shigella* sp*, Vibrio* sp*,* *Enterobacter* sp, in the receiving water studied is an indication that the water is not potable for domestic use and therefore not recommended for consumption as it poses a threat to human health. Potential health risks from waterborne pathogens can exist in such water contaminated environments by untreated wastes which might lead to destruction of primary producers and this in turn may lead to diminishing consumer populations in water. The direct repercussion of this may result to suffocation of fish and other aquatic life resulting in asphyxiation hence human diet suffers. Therefore, continuous monitoring and treatment of wastes should be maintained in order to promote and maintain a safe working environment as well as water resources and ensure detection when abnormalities that could endanger both workers and environment occur.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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