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Assessment of Microbiological Quality, Heavy Metals, and Petroleum Hydrocarbons in Surface Waters of Abonnema Wharf Waterfront, Niger Delta, Nigeria

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ABSTRACT

This study assessed the impact of anthropogenic activities on microbiological and physicochemical quality of surface water at Abonnema Wharf, Port Harcourt, Rivers State, Nigeria. Five stations along the Wharf River (Transportation, Toilet, Refuse Dump, Ship Deck and Control) were assessed. Enumeration of microorganisms revealed substantial microbial contamination of the water body. Total heterotrophic bacterial counts ranged from 1.01±0.75 × 10^5 CFU/mL to 5.19±3.63 × 10^5 CFU/ml, while total fungal counts ranged from 1.13±0.85 × 10^4 to 1.36±1.25× 105 CFU/mL. Hydrocarbon-utilizing bacteria ranges from 6.00 ±9.06 × 104 to 2.01±2.26 × 105 and Hydrocarbon-utilizing fungi at 0 to 2.63±3.77 × 105 CFU/m, Total coliform count ranges from 7.50 ±2.88 × 103 to 1.26 ±1.16 × 10^5 and faecal coliform counts ranges from 4.25±3.30 × 10^4 to 1.18±2.18× 10^5 CFU/mL at the Transportation station, showing widespread faecal pollution, *Salmonella/Shigella* ranges from 8.50±10.74 × 10^4 to 2.29±1.89× 10^5, Vibrio 1.25±2.50 × 10^3 to 5.13±6.61× 10^4. Physicochemical parameters varied significantly between stations and months ($P < 0.05$). Total dissolved solids rose from 6,480 mg/L in January to 18,590 mg/L in April, and biochemical oxygen demand rose from 0.70–0.90 mg/L to 22.13–25.34 mg/L. Cadmium, copper, zinc and lead ranged from 0.064–0.113, 0.037–0.088, 0.101–0.590 and 0.191–0.326 mg/L respectively, while mercury was below detectable limits. Total petroleum hydrocarbon concentrations exceeded recommended limits at all stations. Bacterial isolates belonging to nine genera were identified, along with fungal isolates of *Aspergillus, Rhizopus, Mucor, Candida* and *Penicillium*. Molecular analysis confirmed selected isolates as *Escherichia coli* strain CEE10, *Salmonella enterica* subsp. enterica serovar Paratyphi B strains F11 and F12, *Pseudomonas fluorescens* strain PM5153, *Pseudomonas aeruginosa* strain BAQVP6 and *Aeromonas caviae* strain A8. The findings demonstrate severe microbiological contamination, faecal pollution, hydrocarbon contamination and heavy metal accumulation in the surface water, highlighting the urgent need for improved sanitation, pollution control and continuous environmental monitoring.

Keywords: Abonnema Wharf, Surface Water Quality, Petroleum Hydrocarbons, Heavy Metals, 16S rRNA, Fecal Coliform.

Introduction

Surface water systems, including estuarine creeks, coastal rivers, and marine jetties, represent critical natural resources that support human livelihoods, maritime commerce, transport, and aquatic biodiversity across developing nations (APHA, 2017; Odeyemi et al., 2023). In the Niger Delta region of Nigeria, surface water channels govern the ecological framework and local economy of riparian communities (Wokem & Lawson-Jack, 2014; Ocheli et al., 2020).

However, decades of intensive oil exploration, illegal artisanal refining, rapid urbanization, and unregulated waste disposal have turned the region's estuarine channels into heavily contaminated wetland ecosystems (Amnesty International, 2018; Jonah et al., 2025).

Anthropogenic activities introduce complex pollutant matrices into receiving waters, disrupting aquatic microbial diversity and natural physicochemical balance (Steffen et al., 2007; Oribhabor, 2016).

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Raw domestic sewage introduces high organic loading, nutrients, and enteric pathogens into water bodies, raising the threat of waterborne disease outbreaks such as cholera, typhoid, and dysentery (Bakare et al., 2003; Guarino et al., 2017; Odeyemi et al., 2023).

Simultaneously, shipping activities, shoreline waste dumping, and fuel handling release persistent petroleum hydrocarbons and toxic heavy metals into the water column (Sin et al., 2001; Ihunwo et al., 2021; Ahmed et al., 2024).

Single-parameter assessments are often insufficient to capture the full scope of ecological risk in multi-pollutant environments; hence, an integrated approach combining microbiological, heavy metal, and hydrocarbon profiling is essential (Nduka & Orisakwe, 2011; Ocheli et al., 2020).

Abonnema Wharf (Kidney Island) in Port Harcourt, Rivers State, is a vital transit and commercial jetty linking urban Port Harcourt with coastal communities in the Niger Delta (Vanguard News, 2012; Nairaland, 2024).

Characterized by high population density, over-water pier latrines, open shoreline refuse dumps, and proximity to oil storage terminals, the Abonnema Wharf waterfront is exposed to severe anthropogenic stress (The Tide, 2012).

While earlier local studies focused on groundwater and domestic well quality (Wokem & Lawson-Jack, 2014, 2015), comprehensive empirical data integrating microbiological enumeration, molecular bacterial identification, heavy metal accumulation, and total petroleum hydrocarbon (TPH) profiling across distinct activity zones at Abonnema Wharf remain limited.

Therefore, this study presents an integrated assessment of the microbiological quality, heavy metal concentrations, and petroleum hydrocarbon levels in surface waters across the Abonnema Wharf waterfront to establish a baseline for pollution control and public health protection.

Materials and Methods

Study Area and Sampling Stations

The study area was Abonnema Wharf, Port Harcourt, Rivers State, Nigeria, within the New Calabar River estuarine environment. Five sampling locations were considered: Transportation/building-materials area, Toilet area, Refuse Dump, Ship Deck/Offloading area and a Control station (upstream). The locations represented areas influenced by different human activities, while the Control station provided a comparative reference within the study area.

Sample Collection

Surface water samples were collected at two-week intervals between January and April 2026. Microbiological samples were collected in 50 mL sterile sampling bottles, while samples for chemical and hydrocarbon analysis were collected in pre-cleaned glass bottles following standard guidelines (APHA, 2023).

Microbiological Analyses

One millilitre each of the water samples were separately added to 9 ml of normal saline (diluents). After thorough shaking, further 10-fold (v/v) serial dilutions were made by transferring 1 ml of the diluted water sample to freshly prepared normal saline diluents to a range of 10^{-3} dilutions.

Enumeration of Total Bacteria

Total Heterotrophic Bacteria and Total heterotrophic Fungi was enumerated on NA (Nutrients Agar). Bacteria Colonies that appeared on the nutrient agar plates which were inoculated in duplicate with an aliquot of 0.1 ml from 10-3 dilutions were counted, the means were calculated and expressed as colony forming unit per millilitre using the formula (Prescott et al., 1999).

$$CFU/ml: \frac{Number\ of\ \ colonies \times Dilution\ factor}{Volume\ Plated\ (ml)}$$

While discrete colonies that developed on the nutrient agar plates were sub-cultured on freshly prepared NA plate in order to isolate pure isolate.

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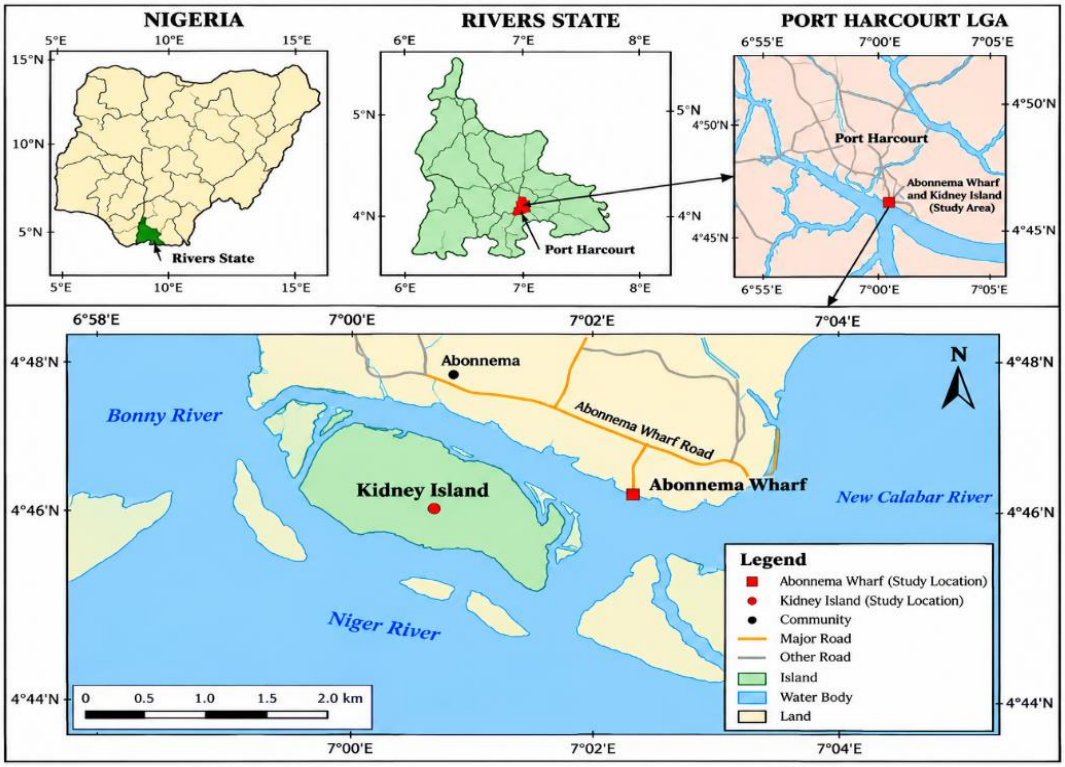


Fig. 1: Map of study area and Location of the study area showing the sampling stations

Total coliform counts

Total Coliform Counts was enumerated. Bacterial Colonies that appeared on the MacConkey agar plates which were inoculated in duplicate with an aliquot of 0.1 ml from 10^{-5} dilutions and incubated 37°C for 24 hours were counted and the mean expressed as CFU /ml.

Faecal coliform counts

Faecal Coliform Counts was enumerated as described by Prescott et al. (1999). Bacterial Colonies that appeared on the Eosin Methylene Blue (EMB) agar plates which were inoculated in duplicate with an aliquot of 0.1 ml from 10^{-4} dilutions and incubated 37°C for 24 hours were counted and the mean expressed as CFU/ml

Total fungal counts

This was determined using Sabouraud Dextrose Agar (SDA) amended with Tetracycline to suppress bacterial growth (Okerentugba and Ezeronye, 2003).

The spread plate technique as described by Prescott et al. (1999) was adopted. An aliquot of 0.1 ml from 10^{-3} dilution of the serially diluted samples was inoculated onto predried SDA agar plates in duplicates.

The inocula were then spread evenly on the surface of the media using a flamed bent spreader. The plates were then incubated at room temperature (25°C) for 5 days after which the colonies that developed were counted and the mean of total Fungi counts were recorded accordingly.

Hydrocarbon-Utilizing Microorganisms

Hydrocarbon-utilizing bacteria (HUB) and fungi (HUF) were enumerated on Bushnell–Haas Agar using the vapor-phase transfer method (Ibiene et al., 2011).

Filter paper discs saturated with of crude oil were placed on the inner lids of inverted Petri dishes and incubated for 5–7 days.

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Isolation, Biochemical, and Molecular Identification

Pure bacterial cultures were characterized via Gram staining, motility, and standard biochemical tests (catalase, oxidase, indole, methyl red, Voges–Proskauer, citrate, urease, triple sugar iron, starch hydrolysis, and sugar fermentation) (Cheesbrough, 2006). Fungi were identified using cultural morphology and microscopic examination with Lactophenol Cotton Blue.

Genomic DNA was extracted from selected bacterial isolates using the boiling method (Bell, 1998). The 16S rRNA gene was amplified using universal primers 27F (5'AGAGTTTGATCCTGGCTCAG-3') and 1492R (5'TACGGYTACCTTACGACTT-3') on an ABI 9700 Thermal Cycler (Inqaba Biotec, South Africa). Amplified products (~1500 bp) were verified on 1% agarose gels and sequenced using an ABI PRISM 3500xl Sequencer. Sequences were edited in Chromas Lite and aligned against NCBI GenBank using BLASTN (Altschul et al., 1990). Phylogenetic trees were constructed in MEGA (Version 5.2.2) using the Neighbor-Joining method with 1,000 bootstrap replicates (Tamura et al., 2011).

Physicochemical, Heavy Metal and Hydrocarbon Testing

Physicochemical parameters (pH, temperature, conductivity, TDS, turbidity, TSS, salinity, alkalinity, DO, BOD, COD, and TOC) were measured following APHA (2023) standard procedures. Heavy metals (Cd, Cu, Zn, Pb, Hg) were analyzed using an Atomic Absorption Spectrophotometer (AAS; PerkinElmer AAnalyst 700) after acid digestion. Total Petroleum Hydrocarbons (TPH) was extracted with n-hexane and quantified using Gas Chromatography with a Flame Ionization Detector (GC-FID) using the calibrated TPH method. Detector response (pA) is plotted against retention time (min) over about 0 to 23 minutes. After the solvent front at about 1 minute, the baseline settles at roughly 13 to 15 pA. Phytane and the n-alkanes n-C19 to n-C38 are labelled across the 12-to-22-minute window. Total Hydrocarbon Content (THC) was determined gravimetrically.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics (Version 26.0) and R. One-way and two-way ANOVA followed by Tukey's HSD post-hoc test evaluated spatial and temporal variations across stations and days at $P < 0.05$ and Paired t- tests compared seasonal shifts between January and April.

Results

The results of microbial counts; Total heterotrophic bacteria and fungi, Total coliform and Feacal coliform, HUB and HUF, SSA and TCBs counts obtained from the five (5) sampled stations within Abonnema Wharf are as presented in Table 1.

Table 1: Microbial counts (mean ± SD) of the water samples from Abonnema Wharf Waterfront Locations

Microbial Group	Microbial Counts (Mean ± SD) of the Water Samples from the Locations				
	Transportation	Toilet	Refuse Dump	Ship Deck	Control
THB	$5.19 \pm 3.63 \times 10^5$	$4.88 \pm 1.43 \times 10^5$	$2.45 \pm 1.43 \times 10^5$	$1.68 \pm 1.20 \times 10^5$	$1.01 \pm 0.75 \times 10^5$
Total Fungi	$1.36 \pm 1.25 \times 10^5$	$2.63 \pm 2.72 \times 10^4$	$1.38 \pm 0.48 \times 10^4$	$1.63 \pm 0.75 \times 10^4$	$1.13 \pm 0.85 \times 10^4$
Total coliform	$1.26 \pm 1.16 \times 10^5$	$3.88 \pm 2.72 \times 10^4$	$1.25 \pm 0.96 \times 10^4$	$6.00 \pm 6.78 \times 10^4$	$7.50 \pm 2.88 \times 10^3$
Faecal coliform	$1.18 \pm 2.18 \times 10^5$	$7.50 \pm 4.30 \times 10^4$	$4.25 \pm 3.30 \times 10^4$	$7.63 \pm 5.34 \times 10^4$	$6.25 \pm 6.29 \times 10^4$
HUB	$2.01 \pm 2.26 \times 10^5$	$1.76 \pm 1.70 \times 10^5$	$6.63 \pm 9.20 \times 10^4$	$7.25 \pm 10.38 \times 10^4$	$6.00 \pm 9.06 \times 10^4$
HUF	$2.50 \pm 5.00 \times 10^3$	$2.63 \pm 3.77 \times 10^5$	$1.75 \pm 1.50 \times 10^4$	$8.75 \pm 8.54 \times 10^3$	0 ± 0
Salmonella-Shigella	$1.15 \pm 0.66 \times 10^5$	$2.29 \pm 1.89 \times 10^5$	$1.24 \pm 0.52 \times 10^5$	$1.19 \pm 1.11 \times 10^5$	$8.50 \pm 10.97 \times 10^4$
Vibrio	$8.63 \pm 10.77 \times 10^4$	$1.00 \pm 0.82 \times 10^4$	$1.88 \pm 1.44 \times 10^4$	$5.13 \pm 6.61 \times 10^4$	$1.25 \pm 2.50 \times 10^3$

Key: THB = total heterotrophic bacteria; HUB = hydrocarbon-utilising bacteria; HUF = hydrocarbon-utilising fungi.

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The Total heterotrophic bacteria count from Abonnema Wharf water samples ranged from 1.01 ± 0.75 × 10^5 CFU/ml at the Control to 5.19 ± 3.63 × 10^5 CFU/ml at the Transportation station which has the highest counts, Toilet station (4.88 ± 1.43 × 10^5 CFU/ml) was close behind, followed by the Refuse Dump (2.45 ± 1.43 × 10^5 CFU/ml) and the Ship Deck (1.68 ±1.20 × 10^5 CFU/ml).

Total heterotrophic Fungi count from Abonnema Wharf water samples ranged from 1.13 ± 0.85 × 10^4 CFU/ml at the Control to 1.36 ± 1.25 × 10^5 CFU/ml at the Toilet station recorded 2.63 ± 2.72 × 10^4. The Ship Deck recorded 1.63 ± 0.75 × 10^4 CFU/ml, while the Refuse Dump stations recorded 1.38 ± 0.48 × 10^4 CFU/ml.

Total coliform counts ranged from 7.50 ± 2.88 × 10^3 CFU/ml at the Control to 1.26 ± 1.16 × 10^5 CFU/ml at the Transportation station, with the Ship Deck (6.00 ± 6.78 × 10^4 CFU/ml), Toilet (3.88 ± 2.72 × 10^4 CFU/ml) and Refuse Dump (1.25 ± 0.96 × 10^4 CFU/ml). The Faecal coliform counts ranged from 4.25 ± 3.30 × 10^4 CFU/ml at the Refuse Dump to 1.18 × 10^5 CFU/ml at the Transportation station Ship Deck (7.63 ± 5.34 × 10^4 CFU/ml) and Toilet (7.50 ± 4.30 × 10^4 CFU/ml) were also higher than the Control (6.25 ± 6.29 × 10^4 CFU/ml).

HUB counts ranged from 6.00±9.06 × 10^4 CFU/ml at the Control to 2.01±2.26 × 10^5 CFU/ml at the Transportation station. The Toilet station followed with 1.76 ± 1.70 × 10^5 CFU/ml, while the Ship Deck (7.25 ± 10.38 × 10^4 CFU/ml) and Refuse Dump (6.63 ± 9.20 × 10^4 CFU/ml).

HUF counts ranged from 0 CFU/ml at the Control, where none were detected, to 2.63 ± 3.77 × 10^5 CFU/ml at the Toilet station.

The Refuse Dump (1.75 ± 1.50 × 10^4 CFU/ml), Ship Deck (8.75 ± 8.54 × 10^3 CFU/ml) and Transportation station (2.50 ± 5.00 × 10^3 CFU/ml).

The results of the physicochemical characteristics of the various locations at the Abonnema Wharf are as presented in Figures 1 to 13.

Figure 1 revealed that Total Suspended Solids (TS) concentrations decreased across all stations from January to April. January values were relatively uniform at approximately 6,480 mg/L across stations, whereas April values ranged from 5440 to 5490 mg/L. The highest TS concentration in April was recorded at the Toilet station (5490 mg/L), while the lowest value (5,440 mg/L) was observed at the Ship Deck station

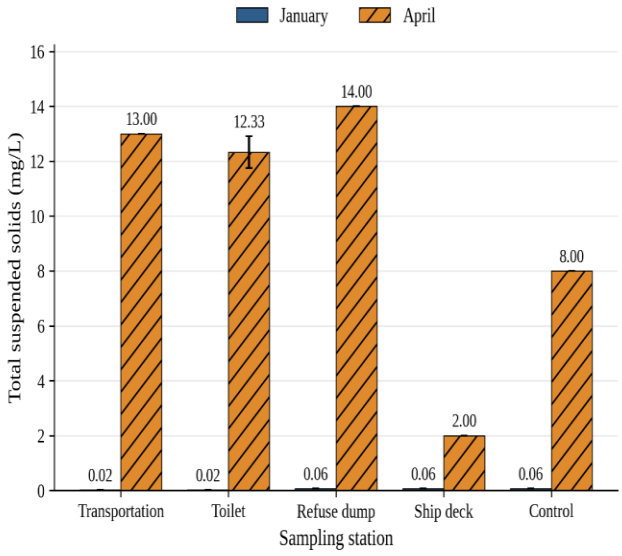


Fig 1: Total Suspended Solids of the Stations.

Figure 2 revealed that Total Solids (TS) concentrations decreased across all stations from January to April. January values were relatively uniform at approximately 6480 mg/L across stations, whereas April values ranged from 5440 to 5490 mg/L. The highest TS concentration in April was recorded at the Toilet station (5490 mg/L), while the lowest value (5440 mg/L) was observed at the Ship Deck station.

Figure 3 revealed that temperature values decreased across all stations from January to April. January temperatures ranged from 30.50°C to 30.70°C, while April temperatures ranged from 28.70°C to 29.23°C. The highest temperature was observed at the Refuse Dump and Ship Deck stations during January, whereas the lowest value was recorded at the Control station during April.

Figure 4 revealed that pH values increased slightly across all stations from January to April. January pH values ranged from 6.37 to 6.56, while April values ranged from 6.70 to 6.92.

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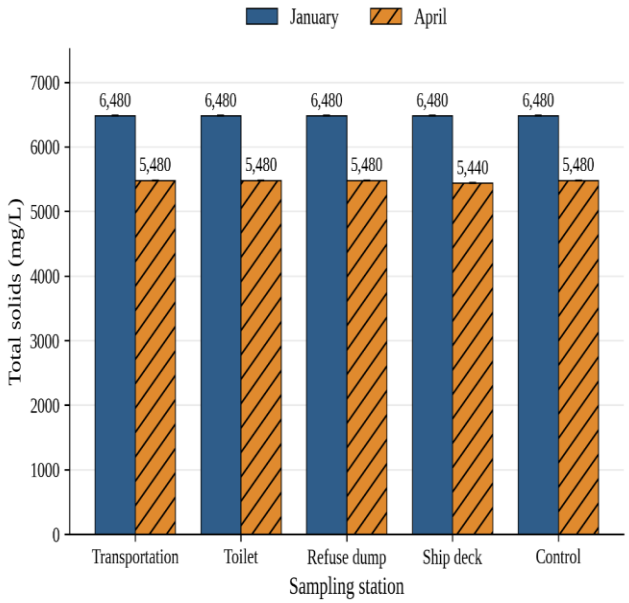


Fig 2: Total Solids of the Stations.

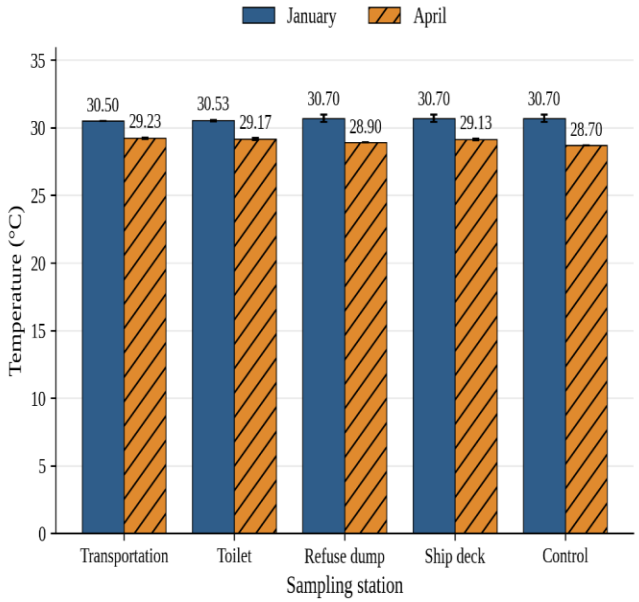


Fig. 3: Temperature values of the Stations.

The highest pH was recorded at the Transportation station in April (6.92), whereas the lowest pH was observed at the Transportation station in January (6.37).

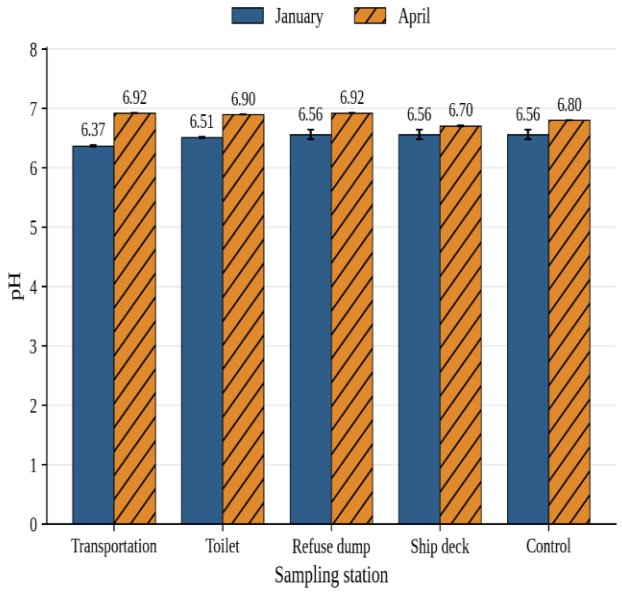


Fig. 4: pH values of the Stations.

Figure 5 revealed that hardness values were generally high across all stations. Concentrations ranged from 1280 mg/L to 1395 mg/L at most stations, although the Transportation station recorded a comparatively lower value in January. The highest hardness value was observed at the Transportation station in April (1395 mg/L), while the lowest value occurred at the Transportation station in January.

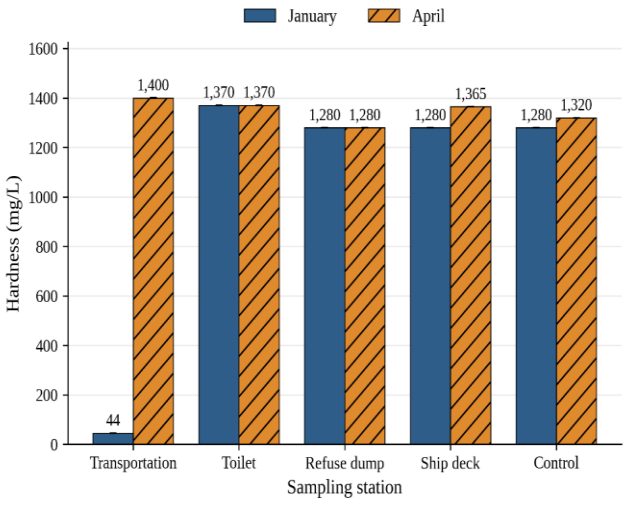


Fig. 5: Hardness values of the Stations.

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Figure 6 revealed that alkalinity increased at all stations from January to April. January values were relatively uniform at approximately 36.29 mg/L, whereas April values ranged from 70 mg/L at the Toilet station to 85 mg/L at the Refuse Dump station. The highest alkalinity was therefore recorded at the Refuse Dump station during April.

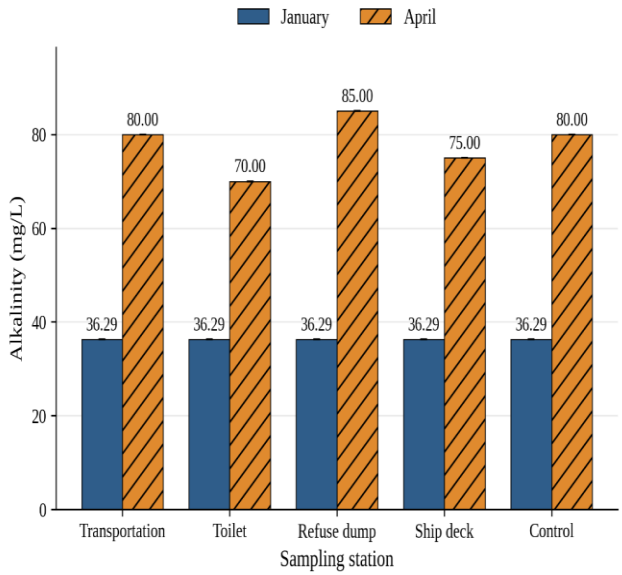


Fig. 6: Alkalinity values of the Stations.

Figure 7 revealed substantial increases in dissolved oxygen (DO), biochemical oxygen demand (BOD) and chemical oxygen demand (COD) between January and April. Dissolved oxygen increased from approximately 1.89 mg/L in January to 6.05 mg/L in April. Similarly, BOD increased from 0.83 mg/L to 24.33 mg/L, while COD increased from 1.45 mg/L to 37.80 mg/L.

Figure 8 revealed a marked increase in electrical conductivity across all stations from January to April. January values ranged from 3500 to 3800 µS/cm, while April concentrations increased substantially to values between 33300 and 33800 µS/cm. The highest conductivity was observed at the Refuse Dump station in April (33800 µS/cm).

Figure 9 revealed that salinity values decreased from January to April across all stations. January salinity ranged from 18000 mg/L at the Transportation station to 26000 mg/L at the Refuse Dump and Ship Deck stations.

In April, values declined to between 11760 mg/L and 16800 mg/L. The highest salinity level was observed at the Refuse Dump and Ship Deck stations in January.

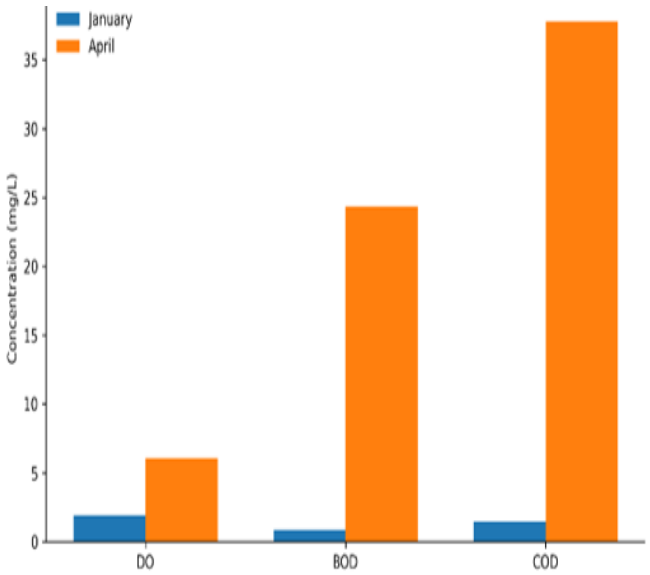


Figure 7: DO, BOD and COD of the Stations.

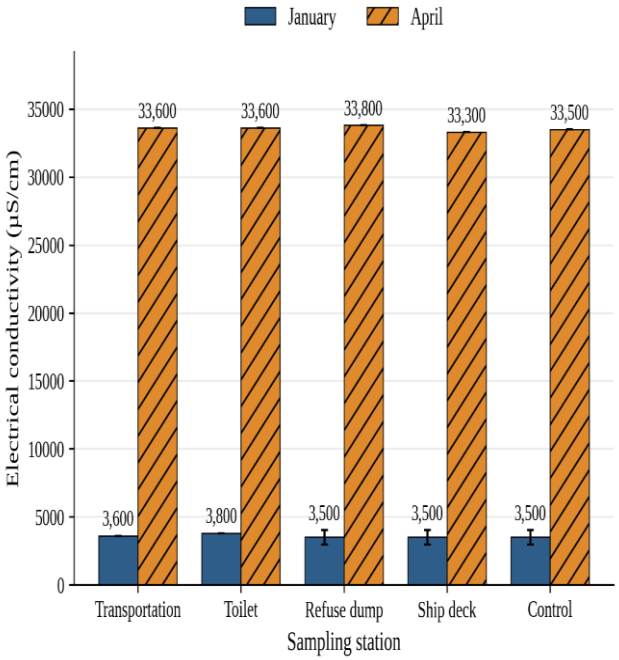


Figure 8: Electrical conductivity of the Stations.

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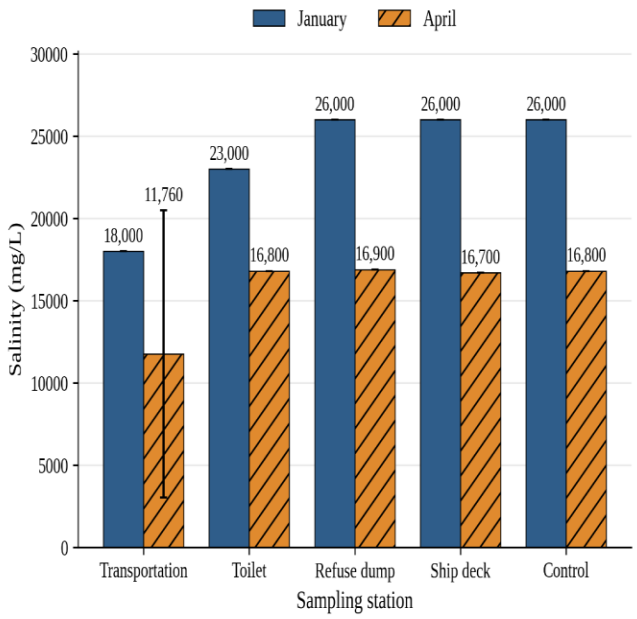


Fig. 9: Salinity values of the Stations.

Figure 10 revealed that turbidity increased substantially from January to April at all stations. April turbidity values ranged from 3.43 NTU at the Ship Deck station to 23.34 NTU at the Refuse Dump station. The Refuse Dump station recorded the highest turbidity, followed closely by the Toilet station.

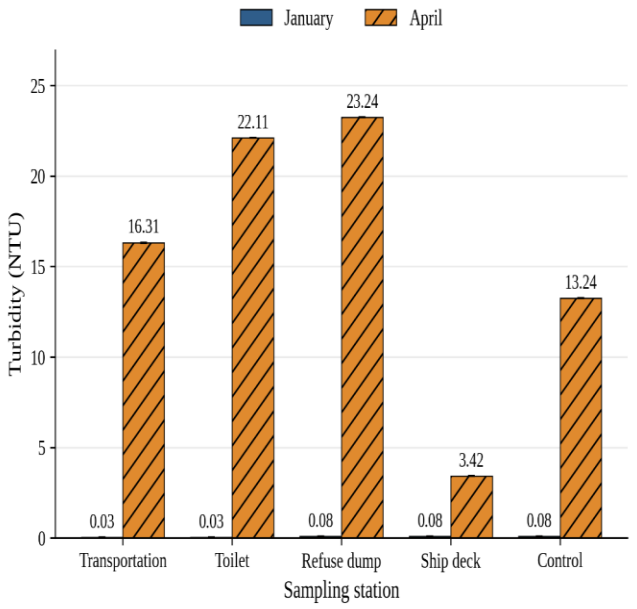


Fig. 10: Turbidity at each Station

Figure 11 revealed variations in Total Organic Carbon (TOC) January values ranged from 0.08% to 0.12%, while April values ranged from 0.07% to 0.16%. The highest TOC concentration was recorded at the Ship Deck station in April (0.16%), whereas the lowest value was observed at the Refuse Dump station in April (0.07%).

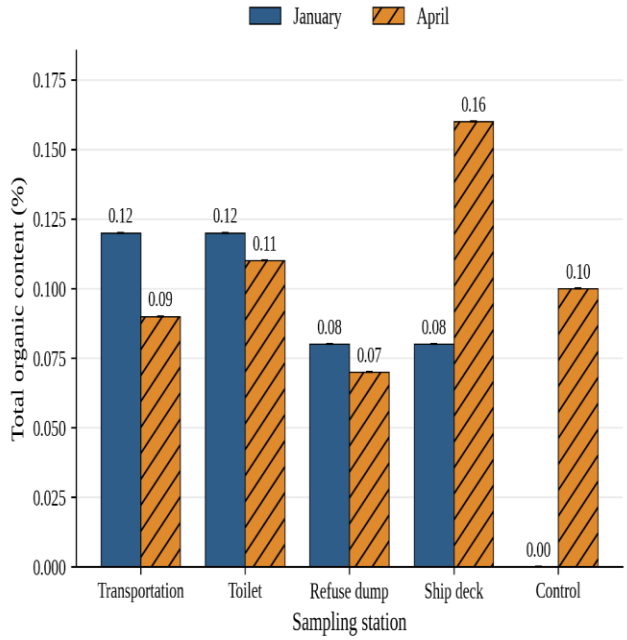


Fig. 11: Total Organic Carbon of the Stations

The result of the physicochemical Characteristics expressed as mean ± standard deviation (mean ± SD) for the months of January and April are as presented in Table 2.

The values showed clear differences between the January and April samplings. Mean temperature decreased from 30.63 to 29.03 °C, while mean pH increased from 6.518 to 6.849.

Mean TDS increased markedly from 6,480.1 to 18,458.0 mg/L and electrical conductivity from 3,580 to 33,560 µS/cm. Mean TSS increased from 0.0421 to 9.867 mg/L.

Mean alkalinity increased from 36.29 to 78.00 mg/L. Mean DO increased from 1.893 to 6.047 mg/L, while BOD increased from 0.8267 to 24.33 mg/L and COD from 1.452 to 37.80 mg/L.

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Table 2: Physicochemical parameters (mean ± SD) of the water samples in January and April

Parameter	January (mean ± SD)	April (mean ± SD)
Temperature (°C)	30.63 ± 0.10	29.03 ± 0.22
pH Unit	6.51 ± 0.08	6.85 ± 0.10
Total Dissolved Solids	6480.06 ± 0.13	18458.00 ± 99.91
Total Suspended Solids (mg/L)	0.04 ± 0.02	9.87 ± 4.96
Total solids (mg/L)	6480.06 ± 0.06	5472.00 ± 17.89
Electrical Conductivity (µS/cm)	3580 ± 130.38	33560 ± 181.66
Turbidity (NTU)	0.06 ± 0.03	15.66 ± 7.99
Salinity (mg/L)	23800 ± 3492.85	15792 ± 2255.07
Hardness (mg/L)	1050.85 ± 564.05	1,346.94 ± 47.03
Alkalinity (mg/L)	36.29 ± 0.00	78.00 ± 5.70
Dissolved oxygen (mg/L)	1.89 ± 0.01	6.05 ± 0.23
Biochemical oxygen demand(mg/L)	0.83 ± 0.10	24.32 ± 1.32
Chemical oxygen demand(mg/L)	1.45 ± 0.18	37.79 ± 2.74
Total organic content (%)	0.08 ± 0.05	0.11 ± 0.03

Heavy metals

Figure 12 llustrates the heavy metal concentrations across stations. The Ship Deck station recorded the highest concentrations of cadmium (0.113 mg/L), copper (0.088 mg/L), zinc (0.59 mg/L), and lead (0.326 mg/L). This metal profile differs from the hydrocarbon pattern, demonstrating that different stations were characterized by different contaminant signatures.

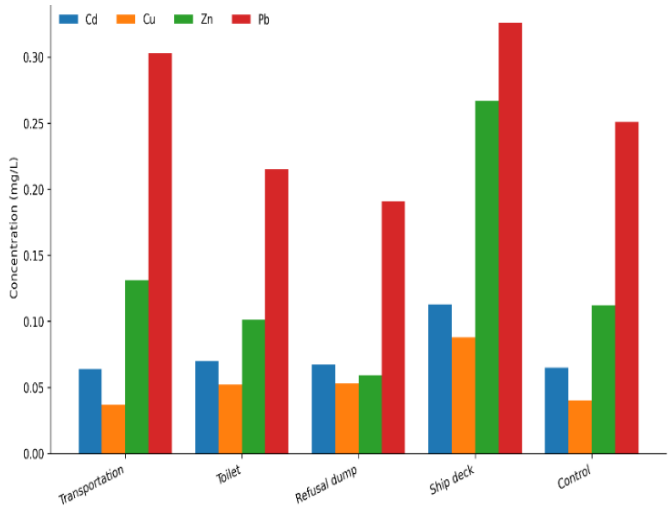


Fig. 12: Heavy Metal Concentrations of the stations

Petroleum hydrocarbons

Figure 13 revealed that Total Hydrocarbon Content (THC) increased across all stations from January to April. January values ranged from 24.00 to 25.00 mg/L, whereas April concentrations ranged from 25.54 mg/L at the Transportation station to 69.90 mg/L at the Refuse Dump station. The Refuse Dump station recorded the highest THC concentration, followed by the Toilet station (57.60 mg/L) and Ship Deck station (46.10 mg/L).

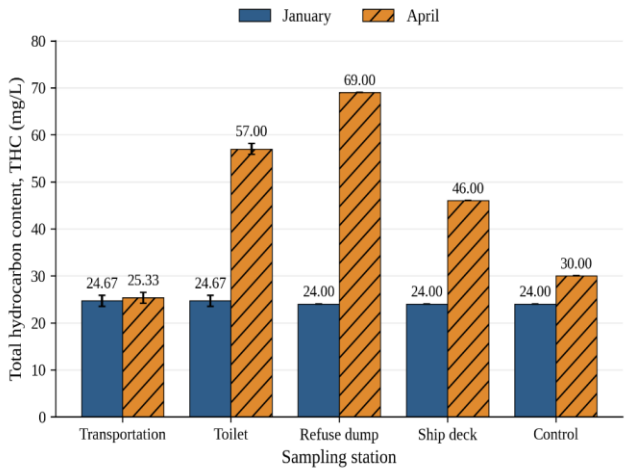


Fig. 13: Total Hydrocarbon Content (THC)

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Table 2 compares the approximate retention times (RT, in minutes) of the hydrocarbon peaks detected in the control water sample and in samples from the ship deck, toilet, refuse dump and transportation areas. A dash (–) means the compound was not detected in that sample at that retention time. The profile covers phytane and the n-alkane series from n-C19 to n-C38, eluting between about 12.0 and 21.6 minutes.

Table 2: Retention times of hydrocarbon peaks in the control and test water samples

Peak	Retention times (min) of hydrocarbon peaks in the control and test water samples				
	Control	Ship Deck	Toilet	Refuse Dump	Transportation
Phytane	~12.0	–	~12.0	–	–
n-C19	~12.4	–	–	~12.4	–
n-C20	~13.3	~13.3	~13.3	~13.3	~13.3
n-C21	~13.7	–	–	–	–
n-C22	~14.4	~14.4	~14.4	~14.4	~14.4
n-C23	~14.9	–	~14.9	~14.9	~14.9
n-C24	~15.4	~15.4	~15.4	~15.4	~15.4
n-C26	~16.4	~16.4	~16.4	~16.4	~16.4
n-C27	~16.8	–	–	~16.8	–
n-C29	~17.8	~17.8	~17.8	~17.8	~17.8
n-C30	~18.2	~18.2	~18.2	~18.2	~18.2
n-C31	–	–	–	~18.6	~18.6
n-C32	~19.3	~19.3	~19.3	~19.3	~19.3
n-C36	~21.0	–	~21.0	~21.0	–
n-C38	~21.6	–	~21.6	~21.6	–

The control sample showed the widest range of peaks, with 14 of the 15 listed compounds detected and only n-C31 absent. Among the test samples, the refuse dump had the most peaks (13), followed by the toilet (11), transportation (9) and the ship deck (7). This suggests that the refuse dump profile most closely resembles the control in the number and distribution of peaks, while the ship deck showed the narrowest range of detectable hydrocarbons

The control water sample, recorded with a flame ionisation detector (FID) using the calibrated TPH method. Detector response (pA) is plotted against retention time (min) over about 0 to 23 minutes. After the solvent front at about 1 minute, the baseline settles at roughly 13 to 15 pA.

Phytane and the n-alkanes n-C19 to n-C38 are labelled across the 12-to-22-minute window. The most intense responses come from n-C30 (~18.2 min), phytane (~12.0 min) and the peaks near 13.3 and 14.4 minutes (n-C20 and n-C22). This is the most heavily populated chromatogram of the set, and it serves as the reference profile against which the station samples are compared.

The Ship Deck (Station 1) sample has the simplest profile of the five, with only seven labelled peaks: n-C20, n-C22, n-C24, n-C26, n-C29, n-C30 and n-C32. n-C30 (~18.2 min) dominates the trace, while the other alkanes appear as small, discrete peaks just above the baseline. The lighter and heavier compounds seen in the control, including phytane, n-C19, n-C21, n-C36 and n-C38, were not detected. This indicates a narrower range of hydrocarbons at this station.

The Toilet (Station 2) sample in which eleven peaks are labelled; these are phytane, n-C20, n-C22, n-C23, n-C24, n-C26, n-C29, n-C30, n-C32, n-C36 and n-C38. n-C30 is again the tallest peak, and the remaining alkanes are small and fairly evenly spaced along the baseline. The presence of phytane and the heavy n-C36 and n-C38 compounds gives this profile a wider carbon-number range than Station 1. It is the closest of the stations to the control in the lighter and heavier regions of the chromatogram.

The Refuse Dump (Station 3) sample, which has thirteen labelled peaks: n-C19, n-C20, n-C22, n-C23, n-C24, n-C26, n-C27, n-C29, n-C30, n-C31, n-C32, n-C36 and n-C38. Two features stand out.

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The first is a very intense, sharp n-C19 peak at about 12.4 minutes that exceeds the upper limit of the plotted scale. The second is the strong n-C30 peak at about 18.2 minutes. n-C31 and n-C27 also appear here, and these are among the compounds that distinguish this station from the others. Of the test samples, this chromatogram contains the largest number of identified hydrocarbons and the greatest variety in carbon-chain length.

The Transportation (Station 4) sample, in which nine peaks are labelled: n-C20, n-C22, n-C23, n-C24, n-C26, n-C29, n-C30, n-C31 and n-C32. As at the other stations, n-C30 is the dominant peak, and the other alkanes appear as small peaks on a gradually rising baseline. n-C31 (~18.6 min) is present here as in the refuse dump sample, but the heavier n-C36 and n-C38 compounds were not detected. The profile is therefore intermediate in complexity, with more peaks than the Ship Deck but fewer than the Toilet and Refuse Dump samples.

The morphological and Biochemical characteristics of the bacteria isolates from the sampled stations revealed that the following bacterial isolates *Escherichia coli, Salmonella* spp, *Pseudomonas* spp, *Micrococcus* spp, *Aeromonas* spp, *Bacillus* spp, *Shigella* spp, *Staphylococcus* spp *and Klebsiella* spp. While *Penicillium* sp, *Aspergillus flavus, Candida, Aspergillus fumigatus, Aspergillus niger, Rhizopus* sp and *Mucor* sp.

The NCBI database was used for sequence analysis of the obtained 16S rRNA sequences from the chosen isolates. The bacterial isolates displayed a strong resemblance to *Escherichia coli strain CEE10 Salmonella enterica subsp. enterica serovar Paratyphi B strain F11 Pseudomonas fluorescens strain PM5153 Salmonella enterica subsp. enterica serovar Paratyphi B strain F12 Pseudomonas aeruginosa strain BAQVP6 Aeromonas caviae strain A8. enterica serovar Paratyphi B strain F12.* The amplified are displayed in Plate 1 16S rRNA gene bands on agarose gel after electrolysis.

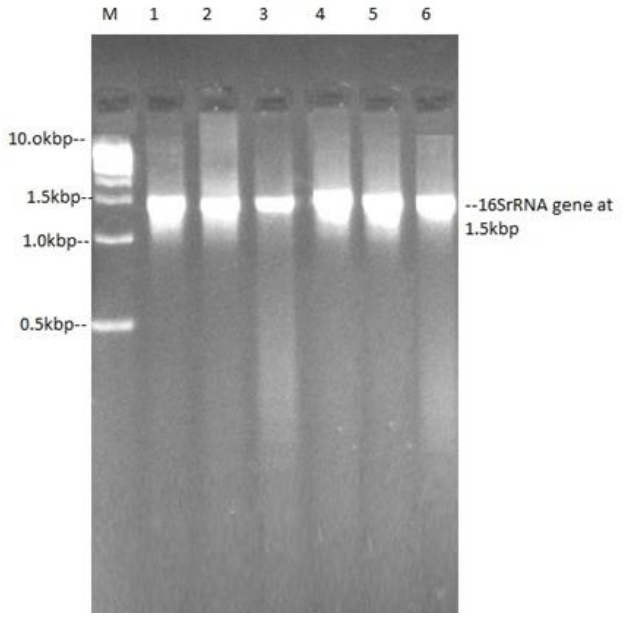


Plate 1: Gel image showing the amplification of the 16SrRNA gene of bacteria Isolates at 1500bp. (Lane M is a 1Kbp DNA Ladder used for the estimation of amplicon size. Lane 1 = 1, Lane 2 = E2, Lane 3 = HUB 1, Lane 4 = M4, Lane 5 = SS2, Lane 6 = T1).

Discussion

These findings corroborate those of Wokem and Lawson-Jack (2014), who reported microbial contamination of domestic water sources in Abonnema and attributed it to poor sanitation and environmental pollution. Findings also support Ocheli et al. (2020), who identified sewage discharge, waste disposal, and runoff as major contributors to microbial contamination of water resources in the Niger Delta. Microbial pollution remains a persistent challenge within aquatic ecosystems in the region.

The detection of hydrocarbon-utilising microorganisms further suggests adaptation of the microbial community to petroleum-contaminated conditions. Similar observations have been reported by Chettri et al., (2021), who demonstrated the hydrocarbon-degrading capacity of species of *Pseudomonas* and *Bacillus*. Their occurrence in the present study therefore supports the likelihood of continued hydrocarbon influence within the aquatic environment. The presence of total and faecal coliforms throughout the study area provides evidence of faecal contamination and indicates compromised sanitary conditions within the aquatic environment.

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Their occurrence across multiple stations suggests that contamination is not restricted to a single location but may result from several pollution pathways, including sewage discharge, runoff, and inappropriate waste disposal practices. This observation agrees with the findings of Wokem and Lawson-Jack (2014), who reported faecal contamination in water sources within Abonnema community. The recovery of enteric bacteria such as *Escherichia coli*, *Salmonella* spp., and *Shigella* spp. strengthens the evidence of sewage-related contamination and highlights the potential public-health significance of the observed microbial pollution. Their occurrence suggests possible exposure to waterborne pathogens, particularly for individuals who frequently interact with the water body. The physicochemical characteristics demonstrate the combined influence of natural estuarine processes and anthropogenic activities on water quality. Variations in conductivity, dissolved solids, oxygen-related parameters, and other indicators reflect changing environmental conditions within the study area and suggest the presence of organic and inorganic pollutant inputs. These findings broadly align with those reported by Ocheli et al. (2020), who observed that runoff, waste disposal, sewage inputs, and industrial activities contributed to physicochemical deterioration of water resources in the Niger Delta. Similarly, Jonah et al., (2025) demonstrated that anthropogenic activities and seasonal runoff significantly influenced water quality in the Qua Iboe River. The agreement among these studies indicates that human activities remain major drivers of water-quality changes across Niger Delta aquatic systems. However, the influence of intensive waterfront activities observed in the present study suggests that local pollution sources may exert additional pressure on water quality at Abonnema Wharf. Such conditions may disrupt nutrient cycling, alter ecological balance, and affect the overall productivity of the aquatic ecosystem. The detection of cadmium, copper, zinc, lead, and mercury confirms the occurrence of heavy metal contamination within the study area. The distribution pattern observed across the sampling stations suggests that transportation activities, petroleum handling, waste disposal, and other waterfront operations may contribute to metal inputs into the aquatic environment. These findings reinforce the observations of Ahmed et al., (2024), who identified anthropogenic activities as major contributors to heavy metal contamination in Niger Delta aquatic systems. The similarity in contamination patterns supports the growing body of evidence that heavy metals remain important environmental pollutants in the region. The environmental significance of these findings lies in the persistence and bioaccumulative nature of heavy metals. Their continued presence may affect aquatic organisms, contaminate food chains, and increase the likelihood of long-term ecological and human-health risks. Heavy metals do not undergo biological degradation; instead, they persist in water, adsorb onto suspended sediments, and bioaccumulate in benthic fauna such as crabs, shrimps, and fish (Diete-Spiff & Kpee, 2022). Chronic exposure to lead and cadmium through the consumption of contaminated seafood or direct contact poses long-term neurotoxic, renal, and carcinogenic risks to human populations (Umeoguaju et al., 2022). The occurrence of petroleum hydrocarbons across the study area reflects the influence of petroleum-related activities that characterize the Niger Delta environment. Their distribution suggests contributions from fuel handling, boat operations, petroleum transportation, waste disposal, and other waterfront activities. The findings support those of Diete-Spiff, Kpee, and Nwineewii (2022), who reported petroleum-associated contamination within aquatic environments of Rivers State and linked the observed pollution to anthropogenic activities. The isolation of *Escherichia*, *Salmonella*, *Shigella*, *Klebsiella*, *Aeromonas*, *Pseudomonas*, *Bacillus*, and other microbial genera reflects the diverse microbial composition of the study area. The occurrence of several organisms associated with faecal pollution and environmental contamination indicates that the microbial community is strongly influenced by anthropogenic activities. These findings closely mirror those reported by Wokem and Lawson-Jack (2014), who isolated similar bacterial genera from water sources in Abonnema community. The persistence of comparable microbial populations over time suggests that many of the contamination pressures previously identified in the area remain active. Similarly, the fungal genera recovered in this study are commonly associated with organic-rich and polluted environments, further supporting the influence of waste inputs and environmental disturbance on water quality. Collectively, the microbial profile confirms the degraded microbiological condition of the surface water and underscores the need for continuous monitoring and pollution-control measures.

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Conclusion

This study demonstrates that the surface waters of Abonnema Wharf suffer from severe microbiological contamination, faecal pollution, heavy metal accumulation, and petroleum hydrocarbon degradation driven by intensive anthropogenic activities. High loads of total heterotrophic bacteria, coliforms, and enteric pathogens (*Escherichia coli*, *Salmonella*, *Shigella*, and *Pseudomonas* species) across the transportation, toilet, refuse dump, and ship deck stations highlight significant public health risks for riparian users. Furthermore, physicochemical parameters including sharp increases in TDS, electrical conductivity, BOD, and COD from January to April 2026 coupled with elevated concentrations of lead, cadmium, zinc, and total petroleum hydrocarbons (TPH), confirm profound environmental degradation. The occurrence of several pathogenic and pollution-associated microorganisms highlights the microbiological deterioration of the water body and emphasizes the need for continuous monitoring and effective pollution-control measures.

Recommendations

1. Sanitation Infrastructure: Construct modern onshore public toilet facilities and sewage containment systems to eliminate over-water pier latrines.
2. Shoreline Waste Management: Establish systematic waste collection systems along the waterfront to prevent open refuse dumping into the estuarine channel.
3. Maritime Regulations: Enforce regulations governing vessel maintenance, bilge water discharge, and fuel handling at the Abonnema Wharf jetty.
4. Environmental Monitoring: Implement routine monitoring of microbiological indicators, heavy metals, and petroleum hydrocarbons to track pollution trends and evaluate remediation efforts.
5. Community Health Awareness: Conduct public education campaigns regarding personal hygiene, sanitation, and the health risks of using untreated surface water.

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