Seasonal Implications on the Microbiological and Physicochemical Characteristics of Sediments

*Unimke, A. A., Bassey, I. U., Mmuoegbulam, O. A. And Nseabasi, N. O
Department of Microbiology, Faculty of Biological Sciences, University of Calabar, PMB 1115, Calabar, Cross River State, Nigeria.
Department of Microbiology, College of Science, Federal University of Agriculture, Makurdi, Benue State, Nigeria.

Abstract: Analysis of seasonal implications on the microbiological and physicochemical characteristics of sediments was carried out on samples collected from Imo River estuary using standard analytical methods. The study was conducted during the wet and dry seasons. The results obtained showed that the sediment samples during the dry season had a significantly (P < 0.05) higher counts of total heterotrophic bacteria (THB) than the wet season (2.55 ± 2.34 × 10^7 cfug^-1 and 2.46 ± 2.20 × 10^7 cfug^-1) respectively. The total fungal (TF) densities observed were 1.42 ± 1.19 x 10^6 cfug^-1 and 1.60 ± 1.05 x 10^6 cfug^-1 during the wet and dry seasons respectively. However, there was a significant difference (P < 0.05) in the population of total heterotrophic and crude oil-utilizing microorganisms between crude oil-polluted and pristine samples. The results obtained also indicate that the sediment samples show a remarkable variation in physicochemical parameters during the wet and dry seasons. Sixteen microbial species with variable distribution and prevalence were isolated comprising of nine bacterial species and seven fungal species. This study has revealed valuable information about the periodic and seasonal changes in anthropogenic and environmental gradients that occur in the sediments of Imo River estuary, Nigeria.

Key words: Sediments, Microbiological, Physicochemical, Impacts, Seasonal

Introduction

Sediments are naturally occurring material that is broken down by processes of weathering and erosion, transported by the action of fluids such as wind, water, or ice, and/or by the force of gravity and is subsequently acting on the particle itself (Kormas et al., 2003). Sediments are most often transported by water (fluvial processes), wind (aeolian) and ice (glacial process). Beach sands and river channel deposits are examples of fluvial transport and deposition, though sediment also often settles out of slow-moving or standing water in lakes and oceans. Desert sand dunes and loess are examples of aeolian transport and deposition. Glacial moraine deposits and till are ice-transported sediments. It is a common practice to accept, as an operational definition, that sediment refers to particles greater than 0.45 µm. By this definition, dissolved matter includes particles finer than 0.45 µm, including colloids. Particulate matter is derived primarily from rock weathering processes, both physical and chemical, and may be further modified by soil-forming processes. Erosion subsequently transfers the sediments or soil particles from their point of origin into freshwater systems (Branch, 1999). During transport, the sediment is sorted into different size ranges and associated mineral fractions until it is deposited on the bottom of the receiving water body.

Two major natural sources of sediment to rivers and lakes can be considered: products of continental rock and soil erosion, and the autochthonous material which is formed within the water body and which usually results from the production of algae and the precipitation of a few minerals, mostly calcite (Chapman et al., 1992). Concentrations of autochthonous material are usually low in rivers not influenced by human activities. A third origin of autochthonous material is the debris of algal diatoms which are very rich in silica (Yoza et al., 2007). When allochthonous sediment sources to lakes (dust, river inputs and shoreline erosion) are limited, the sediments may be formed mostly by autochthonous material, i.e. diatomite, organic debris and lacustrine chalk.

Microorganisms in water and sediments attract other biota by providing resources (e.g. food, habitat, shelter), or, by signaling settlement sites with increased fitness expectations (i.e. high survival probabilities until reproduction) and, conversely to avoid others with low fitness potential. Consequently, the interactions of
microbial communities and settlement chemical cues became a focal point of research in the context of supply side ecology and marine invertebrate larval settlement (Thiyagarajan et al., 2006). Thus, microorganisms are key players in the marine ecosystem as they directly affect many aspects of sedimentary microenvironment. Over the last decade, the understanding of microbial diversity and dynamics in marine sediments has significantly increased due to the rapid development of culture independent molecular methods that allowed us to obtain more detailed information on the phylogeny and distribution of non-cultivable microorganisms (Ajao et al., 1990).

Materials and methods

Study Site
The study site for this research work was Imo River estuary, Nigeria. Pristine samples were collected from Great Qua River, Calabar. Imo River estuary lies between latitude 04°34’52”N and longitude 007°32’59”E, with an elevation of 11 m above sea level.

Materials
Materials used for the collection of samples for microbiological and biochemical analysis were: Maps/plot plan, survey stakes, flags, stainless steel, teflon-lined lids, ziploc plastic bags, logbook, sample jar labels, field data sheets, cooler(s), ice, decontamination supplies/equipment, and nylon rope. The equipment used were: Compass (GPS), measuring tape, survey stakes, buoys and anchors, camera and film, spade and shovel spatula, scoop, trowel, extension rods.

Methods

Sample collection
Using a decontaminated shovel and a scoop, the desired thickness and volume of sediment from the sampling area was removed and transferred into an appropriate homogenization container. Surface water was decanted from the homogenization container prior to sealing and transfer; care was taken to retain the fine sediment fraction during this procedure.

Pre-treatment of the sample
After collection, the sediment samples were transferred into pre-cleaned aluminum boxes and aluminum paper for organic analysis and deep-frozen. The samples were refrigerated at about 4°C during the transport to the laboratory (Radojevic and Bashkin, 1999; APHA, 1985, 1998).

Microbiological analysis
Sediment samples for microbial analysis were collected aseptically, labeled and stored in ice-packed plastic coolers and transported to the laboratory where analysis within 24 hours of collection was done. Microbiological analysis was completed within 48 hours of sampling. Prior to analysis, the sediment samples were homogenized. Ten (10) g of each sample was weighed out, added...
to 90 ml of sterile deionized water and vigorously shaken for 1 minute using a vortex shaker to dislodge the microbiota. Treated samples were allowed to settle for 10 minutes prior to withdrawal of supernatant for serial dilution. Ten-fold serial dilution was carried out for enumeration of densities of the different microbial groups.

**Estimation of microbial densities**

Several methods and media were used for the enumeration of the various microbial groups. The densities of the following microbial groups were determined:

- (a) Total heterotrophic bacteria (THB)
- (b) Total fungi (TF)
- (c) Crude-oil utilizing bacteria (CUB)
- (d) Crude-oil utilizing fungi (CUF)

**Culture media**

The analytical media employed in the course of this research include: Nutrient agar (NA), Sabouroud dextrose agar (SDA), mineral salt medium (MSM), thiosulfate citrate-bile salts-sucrose agar (TCBS), Salmonella-Shigella agar (SSA) and agar-agar. The media were prepared according to recommendations by the manufacturers (Difco; Biotech).

**Estimation of densities of heterotrophic microorganisms**

The counts of total heterotrophic bacteria were determined by the pour plate techniques (Chikere et al., 2009) using nutrient agar (NA). The NA medium was amended with nystatin (50μgml⁻¹) to prevent the growth of fungal contaminants. The total fungal count was determined by pour plate technique using Sabouroud dextrose agar (SDA) supplemented with streptomycin (50μgml⁻¹) to inhibit the growth of bacteria (Martini et al., 1980; Barnett and Hunter, 1972). Inoculated NA plates were incubated at 28°C for 24 hours, while the SDA plates were incubated at room temperature for 3 days before enumeration of microbial colonies.

**Isolation, purification and maintenance of pure microbial isolates**

Distinct and representative colonies from the culture plates were selected for characterization. Bacterial colonies were repeatedly transferred to freshly prepared nutrient agar plates by the streak-plate method and allowed to grow for 24 hours before stocking. Similarly, distinct fungal colonies were subcultured repeatedly on freshly prepared Sabouroud dextrose agar plates for 72 hours before stocking. Pure isolates of the microorganisms were maintained on agar slants as stock, and were preserved in the refrigerator for further use.

**Enumeration of crude oil-utilizing microorganisms**

The counts of crude oil-utilizing bacteria and fungi were enumerated by pour plate techniques (Mills et al., 1978; Obire et al., 2008) using vapour phase transfer technique on mineral salt medium (MSM).

**Characterization and identification of bacterial isolates**

Various indices were employed to characterize and identify the isolates. These were colonial appearance on solid media, changes in the surrounding medium, pigment production, Gram reaction, microscopic appearance, sugar fermentation and other biochemical characteristics. The test results for bacteria were evaluated using characteristics presented in Bergey’s Manual of Determinative Bacteriology (Holt et al., 1994).

**Characterization and identification of fungal isolates**

Representative colonies of fungal isolates were characterized and identified based on their cultural and morphological features as described by Barnett and Hunter (1987). The characterization was enhanced through staining techniques-using cotton blue in lactophenol.

**Physicochemical analysis**

Many physicochemical parameters (fast changing parameters) were determined in situ.

**Determination of temperature**

Temperature was measured in situ, using a thermometer and thermistor by means of a thermocouple electrode calibrated in 0.2°C units from 0°C to 100°C.

**Determination of chloride**

The chloride content was determined titrimetrically by the silver-nitrate method (APHA, 1985, 1998).

**Determination of electrical conductivity (EC)**

Electrical conductivity was measured in the extract obtained from sediment: water suspension using a conductivity bridge (APHA, 1985, 1998).

**Determination of organic matter**

An acid method using potassium permanganate at 100°C in a water bath for 30 minutes was employed to measure organic matter (APHA, 1998; Radiojevic and Bashkin, 1999).

**Exchangeable cations**

The bases were extracted with neutral NH₄OAO₄. Calcium and magnesium were determined in the extract by EDTA titration and potassium and sodium by the use of flame photometer (Udo et al., 2009).

**Particle size distribution**

The particle size distribution of the sediment samples was determined by the hydrometer method as described by Gee and Bauder (1986) and AOAC (1990). The determination of particle size larger than 63μm was
done by sieving and particle sizes smaller than 63µ were determined using hydrometer with Calgon (sodium hexametaphosphate) as the displacing agent. The hydrometer was calibrated so that the corrected reading gives the grams of sediment materials in suspension. The sand settled to the bottom of the cylinder within 40 seconds. Therefore, the 40 seconds hydrometer reading gave the amount of silt and clay in suspension. The weight of sand in the sample was obtained by subtracting the corrected hydrometer reading from the total weight of the sample.

\[
\% \text{silt} = \frac{\text{Wt of silt}}{\text{Wt of sample}} \times 100
\]

The percent silt in the sample was obtained by difference as follows:

\[
\% \text{silt} = 100\% - (\% \text{sand} + \% \text{clay})
\]

**Determination of pH**

The pH of sediment samples was determined in water 1:2 sediment: water ratio using pH meter with glass electrode (APHA, 1998; Radojevic and Bashkin, 1999).

**Result**

**Total heterotrophic bacteria (THB)**

It was observed in this study that seasonal changes influenced microbial growth as significantly (P < 0.05) higher microbial population levels were observed during the dry season. The result shows that dry season produced significantly higher (P < 0.05) THB with a mean density of 2.55 ± 2.34 × 10^7 cfug^{-1} than the wet season with a mean density of 2.46 ± 2.20 × 10^7 cfug^{-1}. While the counts observed in Imo River estuary were significantly (P < 0.05) higher than the counts observed in Great Qua River (pristine location).

**Crude oil-utilizing bacteria (CUB)**

The densities of crude oil utilizing microorganisms were significantly (P < 0.05) low compared to total heterotrophic counts. The results showed that there was a significant difference (P < 0.05) in population of crude oil utilizers with respect to season (Table 3). The mean densities of crude oil utilizing bacteria observed were 1.52 ± 2.03 x 10^6 cfug^{-1} and 1.63 ± 1.34 x 10^5 cfug^{-1} during the wet and dry seasons respectively. In Great Qua River (pristine site), lower densities of crude oil utilizing microorganisms were observed. The mean density observed was 1.49 ± 1.90 x 10^5 cfug^{-1}.

**Total fungi (TF)**

The total fungal (TF) counts revealed that the mean densities observed were 1.42 ± 1.19 x 10^6 cfug^{-1} and 1.60 ± 1.05 x 10^6 cfug^{-1} during the wet and dry seasons respectively. The result shows that samples produced significantly (P < 0.05) higher counts of total fungi during the dry season than the wet season. The mean density of TF observed in sediments of Imo River estuary was significantly (P < 0.05) higher than pristine location (Great Qua River).

**Crude oil-utilizing fungi (CUF)**

The mean density of crude oil-utilizing fungi (CUF) was related to the patterns observed for total fungi (TF). The mean densities were 9.9 x 10^4 ± 0.94 cfug^{-1} and 1.15 ±0.98 x 10^5 cfug^{-1} during the wet and dry seasons. In Great Qua River, the mean density of crude oil-utilizing fungi was 1.11 ± 0.43 x 10^2 cfug^{-1}. Significantly (P < 0.05) higher density of crude oil-utilizing fungi (CUF) was observed during the dry season.

**Organic matter**

The result of the investigation revealed that there was a significant (P < 0.05) difference in organic matter levels in the sediments of both Imo River estuary and Great Qua River. It was observed that the sediments of Great Qua River during the wet season had a significantly (P < 0.05) higher mean percentage of organic matter (5.26 ± 0.2%) than the sediments in Imo River estuary during the wet season (3.80 ± 0.04%). The result further revealed that the sediments in Great Qua River during the dry season with a mean of 3.24 ± 0.09% had the lowest percentage of organic matter content.

**Total Nitrogen**

The concentrations of total nitrogen in both the study site and the pristine site were quite low and similar. The result obtained revealed that there was no significant difference (P > 0.05) in the mean levels of total nitrogen in both locations during the wet and dry seasons. The levels observed in Imo River estuary were 0.12± 0.01% and 0.11± 0.02% during the wet and dry seasons respectively. Similarly, the levels obtained for the wet and dry seasons in the pristine site were 0.13± 0.01% and 0.11± 0.02% respectively.
### TABLE 1. Impact of Source of Sample and Sampling Points on Microbial Populations of the Sediment

<table>
<thead>
<tr>
<th></th>
<th>THB</th>
<th>CUB</th>
<th>TF</th>
<th>CUF</th>
</tr>
</thead>
</table>
| P     | 2.36±0.17
×10^6 | 1.49±1.90
×10^6 | 1.34±1.63
×10^7 | 1.11±0.43
×10^4 |
| SP1   | 2.63±0.10
×10^7 | 1.51±0.18
×10^6 | 1.44±0.54
×10^6 | 1.08±0.50
×10^5 |
| SP2   | 2.43±0.94
×10^7 | 1.62±0.17
×10^6 | 1.52±0.23
×10^6 | 9.1±0.26
×10^5 |
| SP3   | 2.58±1.32
×10^7 | 1.73±0.23
×10^6 | 1.55±0.91
×10^6 | 1.08±0.32
×10^5 |
| SP4   | 2.50±11.04
×10^7 | 1.53±0.95
×10^6 | 1.46±0.60
×10^6 | 1.21±0.12
×10^5 |
| SP5   | 2.52±0.95
×10^7 | 1.58±1.60
×10^6 | 1.74±1.08
×10^6 | 1.04±0.20
×10^5 |

Means with the same superscript along the horizontal array represent no significant difference (P>0.05).

**KEY:** THB = total heterotrophic bacteria, THF = total heterotrophic fungi, CUB = crude oil utilizing bacteria, CUF = crude oil utilizing fungi, cfu = colony forming unit, P = pristine, SP_n = sampling point number. LSD:
- THB = 2.53
- CUB = 1.48
- THF = 2.64
- CUF = 1.28

### TABLE 2. Impact of Season and Source of Sample on the Microbial Population of the Samples

<table>
<thead>
<tr>
<th></th>
<th>Wet season</th>
<th>Dry season</th>
<th>LSD</th>
</tr>
</thead>
</table>
| THB   | 2.46±2.20
×10^7 | 2.55±2.34
×10^7 | 1.46 |
| CUB   | 1.52±2.03
×10^6 | 1.63±1.34
×10^6 | 8.5  |
| THF   | 1.42±1.19
×10^7 | 1.60±1.05
×10^6 | 1.52 |
| CUF   | 9.9±0.94
×10^5 | 1.15±0.98
×10^5 | 1.05 |

Means with the same superscript along the horizontal array represent no significant difference (P>0.05).

**KEY:** SW = surface water, SSW = sub-surface water, SED = sediment, THB = total heterotrophic bacteria, THF = total heterotrophic fungi, CUB = crude oil utilizing bacteria, CUF = crude oil utilizing fungi, cfu = colony forming unit.

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**Fig. 1:** Impact of season and sampling points on crude oil utilizing microorganisms

KEY: CUB – Crude oil utilizing bacteria, CUF – Crude oil utilizing fungi
P – Pristine, SP_n – Sampling point number

**Available phosphorus (av. P)**
The levels of available phosphorus in sediments of Imo River estuary were significantly (P < 0.05) higher than the levels in Great Qua River. In Imo River estuary, the mean concentrations of available phosphorus observed were 3.30 ± 0.09 mg kg⁻¹ and 3.21 ± 0.10 mg kg⁻¹ for the wet and dry seasons respectively, while in Great Qua River, the concentrations observed were 1.39 ± 0.20 mg kg⁻¹ and 1.20 ± 0.11 mg kg⁻¹ during the wet and dry seasons respectively. The result shows that there was no significant difference (P > 0.05) in available phosphorus in Imo River estuary throughout the study. The mean levels of available phosphorus in Imo River estuary were significantly (P < 0.05) higher than the mean levels observed in the pristine site throughout the study, whereas the mean levels obtained during the wet season in Great Qua River were significantly (P < 0.05) higher than the mean levels obtained during the dry season.

**Exchangeable bases (Calcium, Magnesium, Phosphorus and Sodium)**

The concentrations of exchangeable bases (calcium, magnesium, phosphorus and sodium) in Imo River estuary and Great Qua River during the wet and dry seasons are shown in Table 3. The mean concentrations during the wet season in Imo River estuary were 6.70 ± 0.12 cmol kg⁻¹ Ca, 2.60 ± 0.04 cmol kg⁻¹ Mg, 0.48 ± 0.02 cmol kg⁻¹ K, and 0.33 ± 0.06 cmol kg⁻¹ Na. During the dry season, the mean concentrations were 6.88 ± 0.09 cmol kg⁻¹ Ca, 2.91 ± 0.05 cmol kg⁻¹ Mg, 0.56 ± 0.04 cmol kg⁻¹ K, and 1.22 ± 0.08 cmol kg⁻¹ Na. Similarly, the mean concentrations of exchangeable bases obtained in Great Qua River were 6.11 ± 0.08 cmol kg⁻¹ Ca, 2.20 ± 0.04 cmol kg⁻¹ Mg, 0.26 ± 0.03 cmol kg⁻¹ K and 0.77 ± 0.06 cmol kg⁻¹ Na during the wet season and 6.29 ± 0.10 cmol kg⁻¹ Ca, 2.47 ± 0.06 cmol kg⁻¹ Mg, 0.92 ± 0.06 cmol kg⁻¹ K and 0.57 ± 0.04 cmol kg⁻¹ Na during the dry season (Table 3).

**Effective cation exchange capacity (ECEC)**

The mean concentration of effective cation exchange capacity in Imo River estuary was 12.61 ± 0.08 cmol kg⁻¹ during the wet season and 14.27 ± 0.04 cmol kg⁻¹ during the dry season (Table 3), while in Great Qua River, the mean concentration levels were 12.37 ± 0.26 cmol kg⁻¹ and 13.32 ± 0.34 cmol kg⁻¹ during the wet and dry seasons respectively (Table 3).

**Base saturation**

The results of the investigation revealed that the mean percentage levels of base saturation were 80.17 ± 0.29% and 81.07 ± 0.48% for the sediments of Imo River estuary during the wet and dry seasons respectively and 75.51 ± 0.30% and 76.95 ± 0.42% for the sediments of Great Qua River during the wet and dry seasons respectively, indicating similar patterns in both sites (Table 3).

**Particle size analysis**

Variable percentages of particle sizes were obtained from the sediments of both locations. The results show that the sediments in Imo River estuary were predominantly sandy while there was a close range between sand and silt in the sediments of Great Qua River. The percentages of particle size in sediments in Imo River estuary were 64.0 ± 0.61% sand, 28.2 ± 0.15% silt, and 7.80 ± 0.03% clay during the wet season and 62.2 ± 0.38% sand, 22.4 ± 0.21% silt and 15.4 ± 0.06% clay during the dry season, while the mean values for sediments in Great Qua River were 40.60 ± 0.28% sand, 37.00 ± 0.43% silt and 22.40 ± 0.09% clay during the wet season and 39.72 ± 0.18% sand, 36.00 ± 0.08% silt and 24.28 ± 0.20% clay were obtained during the dry season (Table 3).

However, the mean level observed in Imo River estuary during the dry season was significantly (P < 0.05) higher than the mean level observed during the wet season. The textural class of both locations was sandy-loam.

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**FIG. 1:** Fluctuations in temperature (°C) levels in sediments of Great Qua River (pristine) and Imo River estuary during the wet and dry seasons.
TABLE 3. Impact of Sample Sites and Season on the Physicochemical Properties of the Sediments

<table>
<thead>
<tr>
<th></th>
<th>Great Qua River (pristine)</th>
<th>Imo River estuary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wet season</td>
<td>Dry season</td>
</tr>
<tr>
<td>pH</td>
<td>6.3±0.02</td>
<td>6.45±0.01</td>
</tr>
<tr>
<td>EC (µScm⁻¹)</td>
<td>0.41±0.04</td>
<td>0.61±0.03</td>
</tr>
<tr>
<td>Organic matter (%)</td>
<td>5.26±0.21</td>
<td>3.24±0.09</td>
</tr>
<tr>
<td>Total N (%)</td>
<td>0.13±0.01</td>
<td>0.11±0.02</td>
</tr>
<tr>
<td>Av. P (mgkg⁻¹)</td>
<td>1.39±0.20</td>
<td>1.2±0.11</td>
</tr>
<tr>
<td>Ex. B (cmolkg⁻¹)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ca</td>
<td>6.11±0.08</td>
<td>6.29±0.10</td>
</tr>
<tr>
<td>mg</td>
<td>2.23±0.04</td>
<td>2.47±0.06</td>
</tr>
<tr>
<td>K</td>
<td>0.26±0.03</td>
<td>0.92±0.06</td>
</tr>
<tr>
<td>Na</td>
<td>0.77±0.06</td>
<td>0.57±0.04</td>
</tr>
<tr>
<td>EA (cmolkg⁻¹)</td>
<td>3.03±0.07</td>
<td>3.07±0.02</td>
</tr>
<tr>
<td>ECEC (cmolkg⁻¹)</td>
<td>12.37±0.26</td>
<td>13.32±0.34</td>
</tr>
<tr>
<td>B. saturation (%)</td>
<td>75.51±0.30</td>
<td>76.95±0.42</td>
</tr>
<tr>
<td>Particle size (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>40.6±0.28</td>
<td>39.72±0.18</td>
</tr>
<tr>
<td>Salt</td>
<td>37±0.43</td>
<td>36±0.08</td>
</tr>
<tr>
<td>Clay</td>
<td>22.4±0.09</td>
<td>24.28±0.20</td>
</tr>
</tbody>
</table>

Means with the same superscript along the horizontal array represent no significant difference (P>0.05).

Discussion

In this research, the result showed that the season of study contributed greatly to the microbial proliferation. Significantly (P < 0.05) higher counts were observed during the dry season. This conformed to a similar study carried out by Unimke et al., (2014). The increase in microbial density of heterotrophic microorganisms during the dry season can be linked with the slight increase in the temperature of the ecosystem during the research period. The slightly lower population of heterotrophic microorganisms during the wet season may be due to changes in biological oxygen demand (BOD), dissolved oxygen (DO) levels, temperature and salinity. Microbial loads were significantly high (P < 0.05), but varied with sampling points (SP). Similar patterns were observed in the study site and the pristine site. It was noted that the inflow of both seawater and freshwater provide high levels of nutrients in both the water column and sediment. Estuaries are therefore among the most productive natural habitats in the world. The low microbial populations observed in Great Qua River may be due to low levels of nutrients and productivity in the river environment.

The significantly (P < 0.05) high density of total heterotrophic bacteria (THB) is in agreement with the report of Youssef et al., 2010, Bassey et al., 2015). In Great Qua River (pristine site), low densities of heterotrophic bacteria were observed. The densities of crude oil-utilizing microorganisms were low compared to total heterotrophic counts. The results showed that there was a significant difference (P < 0.05) in crude oil utilizers with respect to season and sampling points. The results further showed that dry season had a significantly (P < 0.05) higher counts of total heterotrophic bacteria (THB) than the wet season. However, there was a significant difference (P < 0.05) in the population of total heterotrophic and crude oil-utilizing microorganisms between crude oil-polluted and pristine samples with crude oil-utilizing bacteria (CUB) producing significantly (P < 0.05) higher counts than crude oil-utilizing fungi (CUF) during both seasons as shown in Figure 1. There was significant difference in matching of both CUB and CUF for wet and dry seasons (P < 0.05).

Nine (9) bacterial species and six (6) fungal species were isolated, characterized and identified. The bacterial species were Flavobacterium sp, Vibrio sp, Pseudomonas sp, Salmonella sp, Klebsiella sp, Escherichia coli, Staphylococcus aureus, Enterococcus sp and Bacillus sp. The fungal species isolated were Paecilomyces sp, Cladosporium sp, Penicillium sp, Aspergillus sp, Saccharomyces sp and Fusarium sp. In the pristine site, the predominant bacterial species were Staphylococcus aureus, Enterococcus sp, Escherichia coli and Bacillus sp, while the fungal species encountered were Penicillium sp, Aspergillus sp and Cladosporium sp.
This investigation revealed that there was a significant (P < 0.05) difference in organic matter levels in the sediments of Imo River estuary and Great Qua River. Most water bodies contain organic matter which can be measured as total organic carbon (TOC). The results revealed that the sediment materials are derived from mineral source, since the levels are less than 12% w/w of sediments (levels above 12% suggest that the sediment materials are from decayed organic sources).

The concentrations of exchangeable bases (Ca, Mg, K and Na) in sediments in both locations display significant differences (P < 0.05) with season and location. The presence of these bases in sediments indicates that they are important sources of micronutrients. The micronutrients analyzed (Ca, Mg, K and Na) are abundant natural elements and are important in ensuring optimal primary and secondary productivity of the marine and brackish ecosystem. The textural class of both locations was sandy-loam.

References