Int. j. adv. multidisc. res. stud. 2025; 5(4):1673-1677

Received: 06-07-2025
Accepted: 16-08-2025

International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

Levels and Distribution of Benzene, Toluene, Ethylbenzene and Xylene (BTEX) in Fish, Water and Sediments from Etelebou: A Tributary of Taylor Creek in Bayelsa State, Nigeria

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Abstract
Benzene, Toluene, Ethylbenzene and Xylene (BTEX) are volatile organic compounds that are found in petroleum and petroleum products, e.g., gasoline, coal, and wood tars and are clear, colorless, highly flammable liquids at room temperature, sweet smell and evaporate quickly. The study was conducted in Etelebou, a tributary of Taylor Creek located in Bayelsa State, Nigeria. Etelebou is a significant watercourse that feeds into the larger Taylor Creek system, which plays a vital role in the local ecosystem and the livelihoods of surrounding communities. The coordinates lies between longitude E006^{0}20'38.0'' and E006^{0}20'57.2'' and latitude N05^0'02'12.8'' and N05^{0}02'57.6''. Samples of water, fish, and sediment were collected from different locations within the Etelebou tributary to evaluate the distribution of BTEX compounds. Water samples were collected using clean glass bottles, ensuring that no contaminants entered the samples during collection. Fish tissue samples were obtained by capturing fish from the tributary, followed by cleaning and homogenizing the muscle tissue for analysis. Sediment samples were collected using a sediment corer to obtain undisturbed samples from different depths of the streambed, which were then air-dried and sieved to a consistent particle size for analysis. All samples were analyzed following standard procedures. Physicochemical characteristics of temperature ranging from 28.75 ºC to 29.30 ºC, pH values ranged from 6.45 to 6.78, Alkalinity ranged from 87.50 mg/l to 216.67 mg/l, Acidity levels varied from 76.08 mg/l to 168.42 mg/l, Conductivity (µS/cm) ranging from 52.50 to 70.17, Total dissolved solids (TDS) levels ranged from 36.83 ± 3.77 mg/l, Dissolved oxygen (DO) concentrations ranged from 3.65 mg/l to 4.78 mg/l, Biochemical oxygen demand (BOD) values ranged from 1.42 mg/l to 3.60 mg/l. The levels of BTEX were found to be below detectable limits (ND) in fish, water and sediment samples.

Keywords: BTEX, Sediment, Freshwater, Environmental Monitoring

1. Introduction

Benzene, toluene, ethylbenzene, and xylenes, collectively termed BTEX, are a group of volatile organic compounds (VOCs) commonly found in crude oil and refined petroleum products. These compounds are colorless, flammable liquids that easily vaporize at room temperature and are characterized by a sweet odor. They are widely used as solvents and intermediates in the production of various industrial and household goods, including paints, adhesives, rubber, and pharmaceuticals [1, 2]. Human activities such as fossil fuel combustion, industrial processing, fuel storage, and vehicular emissions are major contributors to BTEX release into the environment. Additionally, natural phenomena like volcanic eruptions and forest fires can emit BTEX compounds into the atmosphere [3, 4].

BTEX compounds are recognized as hazardous environmental pollutants due to their toxicity, carcinogenic potential (notably benzene), and persistence in soil and water environments [5, 6]. Their relatively higher solubility in water compared to other hydrocarbons facilitates their movement from contaminated soils into groundwater systems. Despite being biodegradable under certain aerobic and anaerobic conditions, the breakdown of BTEX is often incomplete, resulting in intermediate by-products that may be more persistent or toxic than the parent compounds [7, 8]. This incomplete degradation is particularly concerning in soil and aquatic environments where co-contaminants may interfere with microbial metabolism, leading to the formation of bound residues or polymeric materials [9].

In aquatic ecosystems, BTEX contamination can originate from industrial discharges, petroleum spills, or proximity to oil and gas extraction sites. Once introduced, BTEX compounds can either volatilize into the atmosphere or dissolve into water bodies, where they can affect aquatic life. These substances are known to accumulate in the tissues of aquatic organisms, including fish, posing a risk to humans and wildlife through the food chain [10, 11]. The potential for bioaccumulation and biomagnification highlights the urgent need to monitor BTEX levels in water bodies, especially in regions where petroleum-related activities are prominent.

Chronic exposure to BTEX compounds has been linked to a variety of adverse health effects in humans. These include neurological damage, hematological abnormalities, and increased risk of cancer, particularly leukemia associated with benzene exposure [1, 5]. In regions experiencing extensive oil exploration and agricultural chemical use, BTEX can enter the human body through inhalation, ingestion of contaminated water or food, and skin contact. The cumulative effects of these exposures present a significant public health concern, particularly in communities located near industrial sites, petrol stations, or oil spill zones. Given their widespread use and release into the environment, BTEX compounds warrant closer regulation and remediation strategies to minimize ecological and human health risks.

2. Materials and Methodology

2.1 Study Area

This study was carried out at Etelebou, a tributary of Taylor Creek in Bayelsa State, Nigeria. Etelebou plays a critical ecological role in the Niger Delta region, supporting aquatic biodiversity and serving as a resource for local communities engaged in agriculture, fishing, transportation, and other activities. The area is situated within a humid tropical climate zone characterized by high rainfall and year-round water availability. However, ongoing anthropogenic pressures—particularly oil exploration and farming—have raised concerns over environmental degradation and pollutant discharge into the water body.

Table 1: Geographic Coordinates and Common Activities at Sampling Stations

Station	Longitude	Latitude	Common Activities
1	E006°20′38.0″	N05°02′57.6″	Fishing, farming, bathing, lumbering, transportation
2	E006°20′47.0″	N05°02′29.3″	Farming, domestic chores, fishing
3	E006°20′57.2″	N05°02′12.8″	Artisanal dredging, fishing, farming
4	E006°20′46.1″	N05°00′44.0″	Oil exploration, fishing, construction, farming
5	E006°20′38.3″	N05°02′27.9″	Farming, fishing, lumbering, oil exploration

2.2 Sample Collection Procedure

Samples of water, sediment, and fish were obtained from five different points along the Etelebou tributary. These locations were strategically selected based on their closeness to major human activities such as agriculture, domestic wastewater discharge, dredging operations, and oil exploration or production sites. This selection was aimed at capturing a wide range of potential contamination sources and understanding their influence on the aquatic environment.

Water was collected using clean, sterile glass containers to prevent contamination. Immediately after collection, the containers were sealed tightly and kept in coolers to preserve the physical and chemical integrity of the samples until laboratory analysis.

Fish were captured using traditional fishing methods employed by local fishermen. After capture, the muscle tissue of each fish was carefully excised using clean instruments. These tissues were then washed thoroughly and homogenized to prepare them for subsequent chemical evaluation, particularly for the detection of potential pollutants.

Sediment samples were obtained with the aid of a sediment corer, which allowed for the careful extraction of material from multiple depths without disturbing the stratification. After collection, the sediments were air-dried under controlled conditions, finely ground, and sieved to obtain a uniform texture suitable for laboratory-based contaminant analysis.

2.3 Sampling Techniques

Sampling was carried out uniformly across all designated sites to maintain consistency and ensure that data from the various locations could be reliably compared. The collection procedures were carefully managed to minimize variability and preserve the integrity of each sample type [12].

Water samples were collected in pre-cleaned polyethylene bottles and immediately placed into chilled containers (at 4°C) after collection to inhibit microbial activity and prevent chemical alterations that could compromise analytical results. This preservation method ensured that the original composition of the water samples was maintained until laboratory analysis [12].

Fish tissues (*Clarias gariepinus*) were collected using cast nets and immediately placed in iceboxes to prevent tissue degradation. Dissection and tissue separation were done within 4 hours of capture to ensure biological and chemical integrity for accurate laboratory assessment [13].

Sediment samples were collected using a stainless-steel Ekman grab sampler designed to capture undisturbed surface sediments [14]. After retrieval, samples were transferred into airtight, clearly labeled glass containers to avoid contamination and maintain their original characteristics. All samples were handled and stored following recognized environmental quality assurance standards [12, 14].

2.4 Analytical Procedures for Water Quality Assessment

Water samples were analyzed for key physicochemical parameters using standard methods for the examination of water and wastewater as recommended by the American Public Health Association [12]. The pH was measured in situ using a pre-calibrated HANNA digital pH meter (Model HI991003) following APHA Method 4500-H^+ B. Electrical Conductivity (EC) was determined using a calibrated conductivity meter according to APHA Method 2510 B. Total Dissolved Solids (TDS) were estimated using a TDS meter, following standard protocols outlined in APHA [12]. Dissolved Oxygen (DO) was measured on-site using a DO meter, based on APHA Method 4500-O G. Biochemical Oxygen Demand (BOD) was determined using the standard five-day BOD test (BOD_5) at 20°C in accordance with APHA Method 5210 B. Temperature was recorded directly at the sampling site using a handheld temperature probe to reflect field conditions. Alkalinity was measured by titration with standard hydrochloric acid using phenolphthalein and methyl orange indicators in line with APHA Method 2320 B. Acidity was determined by titration with sodium hydroxide using methyl orange as an indicator, following APHA Method 2310 B.

2.5 Analytical Procedures for Sediment Quality

Sediment samples were analyzed for selected physicochemical properties following USEPA [14] and APHA [12] guidelines. Soil Organic Matter (SOM) was determined using the Walkley-Black wet oxidation method as described by Nelson and Sommers [15]. This involved digestion with potassium dichromate and concentrated sulfuric acid, with unreacted dichromate titrated using ferrous ammonium sulfate, and the amount of organic carbon present was calculated using the formula:

$$\text{Organic Carbon} = \frac{(Vsample - Vblank) \times M \times 0.3}{Wt}$$

Where:

- Vsample = volume (mL) of ferrous ammonium sulfate used for sample titration
- Vblank = volume (mL) of ferrous ammonium sulfate used for blank titration
- M = molarity of the ferrous ammonium sulfate solution (0.5 M)
- Wt = weight (g) of the soil sample
- 0.3 is a constant representing the amount of carbon equivalent to 1 mL of 1 M dichromate.

The sediment pH was analyzed by mixing air-dried sediment with distilled water in a 1:1 ratio (weight/volume). After allowing the mixture to equilibrate, the pH was measured using a calibrated pH meter [12].

Electrical Conductivity (EC) was measured to assess the soluble salt content of the sediment. This was done by filtering the sediment-water mixture and then using a conductivity meter on the filtrate [14].

The temperature of the sediment suspensions was monitored using a thermometer during preparation and measurement to ensure consistency in readings. All procedures adhered to recognized environmental laboratory standards to ensure the integrity and reliability of the data collected.

2.6 Analytical Method for BTEX Compounds in Water, Fish, and Sediment

Extraction and analysis of BTEX (benzene, toluene, ethylbenzene, xylene) compounds followed USEPA Method 8015B [16] and APHA Method 6232 B [12]. Water samples were stored in amber glass bottles with minimal headspace and chilled to 4°C until extraction. Fish tissues were dissected and homogenized. Sediment samples were air-dried, ground, and sieved. Two grams of homogenized fish or sediment were extracted with 20 mL of hexane. After shaking and filtration, the extract was concentrated to 2 mL. Clean-up involved passing 1 mL of extract through a silica gel column pre-conditioned with hexane and further eluted with 8–10 mL hexane. A 1 µL aliquot of the final extract was injected into a Gas Chromatograph (GC-FID) with a flame ionization detector. BTEX identification was based on retention time matching with standards, and quantification was based on peak area integration. Quality assurance included use of blanks, duplicates, spiked samples, and external calibration standards. Detection and quantification limits were established following USEPA protocols [6].

2.7 Statistical Analysis

Statistical analyses were performed using SPSS version 25. Descriptive statistics (Mean ± standard error) summarized measured variables. One-way Analysis of Variance (ANOVA) was conducted at a 95% confidence level to determine significant differences across sampling stations. When differences were significant, the Waller-Duncan post hoc test was employed to determine pairwise group differences. Pearson correlation analysis was applied to evaluate the relationships between physicochemical parameters in water and sediment samples (Zar, 1999).

3. Result and Discussion

3.1 Result

3.1.1 Levels and distribution of BTEX and selected water quality characteristics from Etelebou.

Table 3.1 below presents the physicochemical properties and BTEX levels in water samples from five stations along Etelebou, a tributary of Taylor Creek in Bayelsa State. Parameters such as pH, conductivity, TDS, DO, BOD, temperature, alkalinity, and acidity varied slightly across sites, but all BTEX compounds-benzene, toluene, ethylbenzene, and xylenes-were not detected in any of the samples, indicating no measurable contamination by these pollutants at the time of sampling.

Table 2: Levels and Distribution of BTEX In Water from Etelebou

Sampling Stations	SW1	SW2	SW3	SW4	SW5
Ph	6.78±0.26^a	6.74±0.21^a	6.73±0.21^a	6.47±0.26^a	6.45±0.66^a
Conductivity (µS/cm)	53.33±1.61^a	57.83±4.35^a	55.00±2.58^a	70.17±16.30^a	52.50±7.10^a
TDS (mg/l)	36.83±3.77^a	41.83±6.54^a	40.00±5.46^a	70.17±5.34^a	38.00±3.02^a
DO (mg/l)	3.83±0.72^a	4.22±0.59^a	3.73±0.24^a	3.65±0.69^a	4.78±1.24^a
BOD (mg/l)	1.42±0.36^a	2.28±0.67^{ab}	2.20±0.61^{ab}	1.72±0.46^{ab}	3.60±0.80^b
Temp (°C)	29.30±0.64^a	29.18±0.66^a	28.75±0.63^a	28.75±0.63^a	28.93±0.55^a
Alkalinity (mg/l)	96.50±14.63^a	155.00±29.72^a	216.67±106.78^a	87.50±10.70^a	114.58±12.25^a
Acidity (mg/l)	87.92±19.82^a	104.17±28.44^a	168.42±83.82^a	79.17±4.17^a	76.08±12.16^a
Benzene (mg/l)	ND	ND	ND	ND	ND
Toluene (mg/l)	ND	ND	ND	ND	ND
Ethylbenzene (mg/l)	ND	ND	ND	ND	ND
Xylenes (mg/l)	ND	ND	ND	ND	ND

Data are presented as mean ± standard error (n=3); The same letters along the column indicate no significant difference (p>0.05). ND=not detected.

Table 3: Physiochemical Parameters and Levels and Distribution Of (BTEX) in Sediment from Etelebou

Physicochemical parameters/Sampling Station	**SS1**	**SS2**	**SS3**	**SS4**	**SS5**
pH (±SD)	6.51 ± 0.48[a]	6.79 ± 0.31[a]	6.35 ± 0.50[a]	6.16 ± 0.49[a]	6.02 ± 0.49[a]
Conductivity (µS/cm ±SD)	73.67 ± 27.52[a]	62.00 ± 12.97[a]	66.00 ± 20.67[a]	54.67 ± 12.77[a]	67.50 ± 11.52[a]
Organic Carbon (%) ±SD	2.71 ± 0.96[a]	1.80 ± 0.93[a]	2.49 ± 0.75[a]	1.10 ± 0.19[a]	1.84 ± 0.64[a]
Sediment Organic Matter (%) ±SD	1.65 ± 0.57[ab]	1.13 ± 0.46[a]	0.50 ± 0.10[a]	2.13 ± 0.44[ab]	3.48 ± 1.12[b]
Temperature (°C ±SD)	27.68 ± 0.37[a]	27.87 ± 0.34[a]	27.80 ± 0.37[a]	27.80 ± 0.37[a]	27.78 ± 0.38[a]
Benzene (mg/kg)	ND	ND	ND	ND	ND
Toluene (mg/kg)	ND	ND	ND	ND	ND
Ethylbenzene (mg/kg)	ND	ND	ND	ND	ND
Xylenes (mg/kg)	ND	ND	ND	ND	ND

Data are presented as mean ± standard error (n=3); The same letters along the column indicate no significant difference (p>0.05). ND=not detected

Table 4: Levels and Distribution of (BTEX) in Fish from Etelebou

Sampling Stations	**Benzene (mg/kg)**	**Toluene (mg/kg)**	**Ethylbenzene (mg/kg)**	**Xylenes (mg/kg)**
SS1	ND	ND	ND	ND
SS2	ND	ND	ND	ND
SS3	ND	ND	ND	ND
SS4	ND	ND	ND	ND
SS5	ND	ND	ND	ND

ND=not detected

3.2 Discussion

The assessment of water, sediment, and fish samples from the Etelebou tributary of Taylor Creek in Bayelsa State revealed an absence of detectable BTEX compounds—benzene, toluene, ethylbenzene, and xylenes—across all sampled stations. This suggests no recent or ongoing contamination by petroleum-derived aromatic hydrocarbons in the studied area at the time of sampling. The physicochemical parameters of the water remained relatively stable among the sites, with pH values ranging between 6.45 and 6.78, slightly acidic but still within tolerable limits for freshwater ecosystems. These findings are consistent with previous reports on similar Niger Delta freshwater systems where mildly acidic conditions are common due to surrounding vegetation and organic acid deposition [18, 19].

Conductivity and TDS values remained low, indicating limited ionic presence and low mineralization in the water. DO values ranged from 3.65 to 4.78 mg/L, which are marginally sufficient for aquatic life, although slightly below the optimum threshold (>5 mg/L) for sensitive species. BOD values were moderate, suggesting limited organic pollution. These findings are aligned with those reported by Igbinosa and Okoh [20], who observed similar water quality in non-impacted freshwater bodies.

The sediment samples displayed comparable trends. pH ranged from 6.02 to 6.79, again reflecting weak acidity typical of tropical wetland sediments. Organic carbon and sediment organic matter content showed variability but did not suggest any significant enrichment that would indicate hydrocarbon input. Most importantly, BTEX compounds were undetected in all sediment samples, reinforcing the notion of limited hydrocarbon contamination in this part of the Taylor Creek catchment. This contrasts with findings in more industrialized or heavily impacted areas of the Niger Delta, where elevated levels of BTEX in sediments have been recorded due to persistent oil discharges [21, 22].

Fish tissue analysis further confirmed the absence of BTEX contamination. None of the sampled stations showed detectable levels of any BTEX compound in fish, suggesting low bioaccumulation risk from the surrounding aquatic environment. This is particularly significant, as BTEX compounds are known to bioaccumulate in aquatic organisms exposed to petroleum pollution [23]. The absence of BTEX in fish tissues supports the conclusion that the water and sediment environments are presently not impacted by petroleum hydrocarbon contamination.

When compared to previous studies conducted in heavily industrialized or oil spill-prone zones in the Niger Delta, the results from Etelebou suggest a more pristine condition. For instance, Ite *et al.* [18] reported elevated BTEX concentrations in surface water and biota near oil-producing facilities, unlike the current findings. Therefore, this study not only provides a baseline for the Etelebou tributary but also highlights spatial variation in hydrocarbon pollution within the broader Niger Delta region.

In conclusion, the absence of BTEX compounds across all environmental matrices analyzed in this study indicates that the Etelebou tributary, at the time of sampling, was free from measurable petroleum hydrocarbon pollution. This presents a valuable reference point for future monitoring and underscores the importance of continued surveillance in oil-producing regions where environmental conditions can change rapidly due to industrial activities.

4. Conclusion

This study assessed the presence of BTEX compounds in water, sediment, and fish samples collected from the Etelebou tributary of Taylor Creek in Bayelsa State and revealed an encouraging absence of detectable levels across all matrices. The physicochemical parameters of the water and sediment remained within acceptable limits for freshwater ecosystems, indicating minimal anthropogenic disturbance. Dissolved oxygen and biological oxygen demand levels suggested a relatively balanced aquatic environment, further supported by the absence of hydrocarbon contamination in fish tissues.

The consistent non-detection of BTEX in all sampled stations implies that the Etelebou tributary is not currently experiencing significant hydrocarbon pollution, setting it apart from other regions in the Niger Delta that are heavily impacted by petroleum activities. This highlights the importance of localized environmental assessments and underscores the spatial variability of contamination even within oil-producing regions.

The findings serve as a valuable baseline for future environmental monitoring and stress the need for proactive conservation efforts to preserve the ecological integrity of less-impacted freshwater systems. Continued surveillance and environmental stewardship are recommended to safeguard such ecosystems from potential future contamination associated with industrial expansion or oil-related activities.

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