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Assessment of Environmental Pollution and Its Effect on Polycyclic Aromatic Hydrocarbon Concentrations in River Water within Ogbia Local Government Area

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Abstract

This research evaluates the impact of environmental pollution on the concentration level of polycyclic aromatic hydrocarbons (PAHs) in the river water in Ogbia Local Government Area of Bayelsa State. Water samples were collected from three locations (Onuebum, Otuoke, and Kolo). Sixteen PAHs were analysed using Gas Chromatography–Mass Spectrometry (GC-MS). The concentrations obtained were compared with the World Health Organization (WHO) and USEPA permissible limits. The results revealed the presence of all the sixteen PAHs in the river water samples. The mean concentrations of the identified PAHs were 0.183 ppm, 0.178 ppm, and 0.209 ppm, respectively. Acenaphthene (0.56 ppm) was the predominant compound in Onuebum, Fluorene (0.42 ppm) was highest in Kolo, while Anthracene (0.37 ppm) recorded the highest concentration in Otuoke. Several carcinogenic PAHs, including Benzo[a]pyrene, Dibenz[a,h]anthracene, Benz[a]anthracene, Benzo[b]fluoranthene, Benzo[k]fluoranthene, Chrysene, and Indeno[1,2,3-cd]pyrene, exceeded the WHO/USEPA guideline values. This suggests that the contamination originated from both petrogenic sources, such as crude oil spills and petroleum products, and pyrogenic sources, including gas flaring, fuel combustion, and other anthropogenic activities. The study construed that the river water at the sampled communities in Ogbia are contaminated with PAHs at concentrations that may lead to environmental and human health risks. Therefore, regular environmental monitoring, strict enforcement of environmental regulations governing petroleum exploration and waste disposal, implementation of effective pollution control measures, and periodic assessment of water quality to protect aquatic ecosystems and safeguard human health should be implemented.

Keywords: Environmental Pollution, Polycyclic Aromatic Hydrocarbons, River Water

Introduction: Surface water resources are vital for human existence, economic growth, and ecological balance, especially in developing areas where access to treated water is often scarce (Priyan, 2021**)**. Rivers, streams, and creeks serve crucial functions such as supplying domestic water, supporting fisheries, enabling transportation, facilitating agriculture, and preserving cultural traditions (Colvin *et al.,* 2019). Environmental pollution poses a significant threat to aquatic ecosystems and public health worldwide, especially in regions with intensive industrial and petroleum-related activities (Berríos-Rolón *et al.*, 2025). Among various pollutants, Polycyclic Aromatic Hydrocarbons (PAHs) are a class of persistent organic compounds that are of particular concern due to their carcinogenic, mutagenic, and teratogenic potentials (Zhang *et al.,* 2025). PAHs are primarily generated from incomplete combustion of organic matter, petroleum spills, and industrial discharges, making them prevalent in regions with oil exploration and production activities (Haneen *et al.,* 2022). The Niger Delta region of Nigeria, notably the Ogbia Local Government Area, is a hub of oil exploration, transportation, and arctician refining activities. These operations have historically contributed to the contamination of water bodies with petroleum hydrocarbons, including PAHs (Bralewska & Rakowska, 2020 and Echendu *et al.,* 2022). Despite the environmental and health risks posed by PAHs, limited recent assessments have focused on their concentrations and sources in the region's river waters, which are vital for domestic use, fisheries, and agriculture (Echendu *et al.*, 2022). The persistent nature of PAHs and their tendency to bioaccumulate in aquatic organisms underscore the importance of understanding their concentration dynamics within contaminated water bodies (Ubuoh *et al.*, 2021; Chiedozie *et al.,* 2024).
Recent studies highlight that environmental pollution from oil exploration activities significantly influences PAH levels in water systems. For instance, research by Iwegbue *et al.,* (2022) demonstrated elevated PAH concentrations in water samples collected near oil spill sites, exceeding international safety thresholds and posing risks to human health and aquatic life. Moreover, anthropogenic sources such as gas flaring, illegal refining, and improper waste disposal exacerbate the contamination levels, leading to complex pollution patterns (Provencher *et al.,* 2020; Olugbojo *et al.,* 2026). These pollutants' lipophilic properties facilitate their accumulation in sediments and biota, further threatening ecological integrity and food safety in local communities (Sahoo *et al.,* 2020; Udofia *et al.,* 2021).

Given the ongoing industrial activities and the potential health implications, there is an urgent need for systematic assessment of PAH pollution levels and their correlation with environmental pollution sources within Ogbia. Such studies can inform targeted pollution control measures, regulatory enforcement, and community awareness programs (Zhou *et al.,* 2023). Environmental pollution has become a pressing concern in many regions, including Ogbia Local Government Area, where increasing human activities such as industrialization, oil exploration, and urban development threaten the quality of natural water bodies. Among the various pollutants, Polycyclic Aromatic Hydrocarbons (PAHs) are of particular concern due to their toxic, carcinogenic, and persistent nature, which pose significant risks to aquatic ecosystems and public health. Despite the recognized hazards associated with PAHs, there is limited comprehensive data on their concentrations and distribution in the river waters within Ogbia. This knowledge gap hampers effective assessment of pollution levels and the development of targeted mitigation strategies. Therefore, it is crucial to evaluate the extent of environmental pollution and its effect on PAH concentrations in river water within this area to inform sustainable environmental management and safeguard community health. This study seeks to assess the level of environmental pollution and its impact on PAH concentrations in the river waters of Ogbia Local Government Area. Its specific objectives include identifying the types of polycyclic aromatic hydrocarbons (PAHs) present in the river water within the area, measuring the concentration levels of selected PAHs in the collected water samples, and analyzing the spatial distribution of PAH concentrations across various sampling sites within the study region. The findings will offer essential data to support sustainable management of environmental pollution and the safeguarding of public health.

Study Area: This study was carried out in Ogbia Local Government Area, located in Bayelsa State within the Niger Delta region of Nigeria. The area is characterized by numerous rivers, creeks, and wetlands, with water bodies serving as major sources of domestic use, fishing, transportation, and agriculture. Ogbia is also known for oil exploration and petroleum-related activities, which may contribute to hydrocarbon contamination of aquatic environments.

Sample Collection : River water samples were collected from Onuebum, Otuoke and Kolo in Ogbia Local Government area. The sampling bottles were thoroughly rinsed with the river water at the sampling site. The bottles were submerge underwater facing upstream to avoid surface contaminants. The bottles were filled completely, leaving minimal headspace to prevent volatilization. The bottles were immediately caped after collection. The samples were kept cool in a cooler with ice packs during transportation to the laboratory. The samples were transported to the laboratory within 24 hours after collection.

Sample Preservation and Preparation: Water samples were filtered using Whatman glass fiber filter paper to remove suspended particles. The filtrate was stored in clean amber bottles and acidified to pH < 2 using hydrochloric acid to minimize microbial degradation before extraction.

Extraction of PAHs from Water Samples: Liquid-liquid extraction method was employed.

A measured volume (500 ml) of water sample was transferred into a separatory funnel and extracted three times with 25 ml portions of dichloromethane/n-hexane solvent mixture (1:1 v/v). The extracts were combined and dried over anhydrous sodium sulfate.

The concentrated extract was reduced to about 2 ml using rotary evaporator and further concentrated under gentle nitrogen stream prior to instrumental analysis.

Instrumental Analysis of PAHs: Quantitative determination of PAHs was carried out using Gas Chromatography-Mass Spectrometry equipped with capillary column.

The target PAHs analyzed included: Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benz[a]anthracene, Chrysene, Benzo[b]fluoranthene, Benzo[k]fluoranthene, Benzo[a]pyrene, Indeno[1,2,3-cd]pyrene, Dibenz[a,h]anthracene, Benzo[ghi]perylene

Identification of compounds was based on retention time and comparison with certified PAH standards.

Data Analysis: Data obtained were expressed in parts per million (ppm) and analyzed using descriptive statistics.

The concentrations of the sixteen PAHs in the river water samples from Kolo, Otuoke, and Onuebum were summarized using totals and mean values.

Results: The data presented in Table 1 below illustrate the concentrations of polycyclic aromatic hydrocarbons (PAHs) in water samples from Onuebum Community. The sample from Onuebum exhibited the highest total PAH level at 3.35 ppm among the three locations, indicating the most severe hydrocarbon pollution. Notably, among low molecular weight PAHs, Acenaphthene (0.56 ppm) surpassed the WHO/USEPA permissible limit of 0.30 ppm. Phenanthrene (0.10 ppm) was exactly at the permissible limit, while Anthracene (0.21 ppm) exceeded the recommended threshold of 0.20 ppm. Fluoranthene (0.12 ppm) also surpassed the permissible limit of 0.10 ppm. In the high molecular weight PAHs category, several compounds exceeded international guidelines: Benz[a]anthracene (0.21 ppm) surpassed the permissible limit of 0.05 ppm; Chrysene (0.14 ppm) exceeded the guideline value; Benzo[b]fluoranthene (0.16 ppm) and Benzo[k]fluoranthene (0.18 ppm) both exceeded the 0.05 ppm limit; Benzo[a]pyrene (0.25 ppm) vastly surpassed the WHO/USEPA guideline of 0.0007 ppm; Indeno[1,2,3-cd]pyrene (0.13 ppm) and Dibenz[a,h]anthracene (0.36 ppm) exceeded their respective limits of 0.05 ppm and 0.005 ppm; Benzo[ghi]perylene (0.17 ppm) also exceeded the permissible threshold. The widespread presence of carcinogenic PAHs above established international standards indicates a significant level of hydrocarbon contamination in the aquatic environment of Onuebum.

Table 2 details the PAH concentrations in water samples from Otuoke Community. The total PAH concentration here was 2.84 ppm, reflecting considerable hydrocarbon pollution. Among low molecular weight PAHs, Phenanthrene (0.15 ppm), Anthracene (0.37 ppm), and Fluoranthene (0.16 ppm) all exceeded their respective permissible limits of 0.10 ppm, 0.20 ppm, and 0.10 ppm. Other compounds such as Naphthalene (0.04 ppm), Acenaphthylene (0.08 ppm), Acenaphthene (0.14 ppm), Fluorene (0.21 ppm), and Pyrene (0.13 ppm) remained within permissible limits. In the high molecular weight PAHs, several compounds exceeded international standards: Benz[a]anthracene (0.20 ppm), Chrysene (0.16 ppm), Benzo[b]fluoranthene (0.09 ppm), Benzo[k]fluoranthene (0.17 ppm), Benzo[a]pyrene (0.24 ppm), Indeno[1,2,3-cd]pyrene (0.31 ppm), Dibenz[a,h]anthracene (0.17 ppm), and Benzo[ghi]perylene (0.22 ppm), all surpassing their respective guideline values. Similarly, Table 3 shows PAH levels in water from Kolo Community, with a total concentration of 2.92 ppm, indicating high hydrocarbon contamination. Among the low molecular weight PAHs, Phenanthrene (0.15 ppm) and Anthracene (0.24 ppm) exceeded permissible limits, while other compounds such as Naphthalene (0.03 ppm), Acenaphthylene (0.06 ppm), Acenaphthene (0.13 ppm), Fluorene (0.42 ppm), and Pyrene (0.08 ppm) remained within acceptable limits. In the high molecular weight PAHs, several compounds exceeded international guidelines: Benz[a]anthracene (0.16 ppm), Chrysene (0.35 ppm), Benzo[b]fluoranthene (0.16 ppm), Benzo[k]fluoranthene (0.20 ppm), Benzo[a]pyrene (0.15 ppm), Indeno[1,2,3-cd]pyrene (0.33 ppm), Dibenz[a,h]anthracene (0.24 ppm), and Benzo[ghi]perylene (0.12 ppm). Chromatograms of water samples from Onuebum, Otuoke, and Kolo (Figures 1–3) reveal characteristic peaks corresponding to various PAH compounds. These patterns confirm the presence of hydrocarbon contaminants in the aquatic systems, with peaks at different retention times indicating contributions from multiple pollution sources. The chromatographic profiles demonstrate a mixture of low- and high-molecular-weight PAHs, suggesting contamination from petroleum-related products and combustion processes. These qualitative findings align with the quantitative chemical analyses, confirming significant hydrocarbon pollution in these communities.

Discussion of Findings: This study's findings demonstrate the pervasive presence of all sixteen-priority polycyclic aromatic hydrocarbons (PAHs) in water samples from Kolo, Otuoke, and Onuebum communities within Ogbia Local Government Area, Bayelsa State. The detection across all sampling sites underscores widespread hydrocarbon contamination, aligning with recent research indicating the significant impact of anthropogenic activities such as petroleum exploration, crude oil transportation, gas flaring, and industrial discharges in the Niger Delta (Anyanwu *et al.,* 2023; Ola *et al.,* 2024). These activities continue to be major contributors to PAH pollution in the region, consistent with findings by Faboya *et al.,* (2023) and Chiedozie *et al.,* (2024), who documented elevated PAH levels linked to oil extraction and combustion processes. Spatial variation in PAH concentrations was evident, with Onuebum recording the highest total PAH concentration (3.15 ppm), followed by Kolo (2.92 ppm), and Otuoke (2.84 ppm). The elevated levels in Onuebum suggest more intense pollution sources, which may include artisanal refining, oil spills, and atmospheric deposition from gas flaring—activities documented to significantly influence PAH levels in the Niger Delta (Akpan & Umoh, 2020; Iwegbue *et al.,* 2022). Notably, high concentrations of Acenaphthene (0.56 ppm), Dibenz[a,h]anthracene (0.36 ppm), and Benzo[a]pyrene (0.25 ppm) indicate substantial hydrocarbon inputs, potentially arising from petroleum leakage, refining activities, and combustion emissions, consistent with previous assessments of industrial pollution impacts (Udofia *et al.,* 2021). Similarly, Kolo exhibited elevated concentrations of pyrogenic PAHs such as Fluorene (0.42 ppm), Chrysene (0.35 ppm), and Indeno[1,2,3-cd]pyrene (0.33 ppm), indicative of combustion-related pollution sources like gas flaring, vehicular emissions, and biomass burning (Agbozu *et al.,* 2020; Aigberua *et al.,* 2020). Otuoke, despite having the lowest total PAH levels, still registered high concentrations of carcinogenic PAHs, including Anthracene (0.37 ppm) and Benzo[a]pyrene (0.24 ppm), which pose significant environmental and health risks. Comparison with WHO and USEPA guideline values reveals that several PAHs, notably Benzo[a]pyrene and Dibenz[a,h]anthracene, exceeded permissible limits by orders of magnitude—Benzo[a]pyrene levels ranged from 0.15 to 0.25 ppm against the guideline of 0.0007 ppm, and Dibenz[a,h]anthracene ranged from 0.17 to 0.36 ppm compared to 0.005 ppm (WHO/USEPA). The widespread exceedance of regulatory standards highlights serious deterioration of water quality and ongoing pollution, consistent with reports by Udofia *et al.,* (2021) and Adamu *et al.* (2026) on the persistent threat of hydrocarbon pollutants in the region.

The distribution pattern of low molecular weight (LMW) and high molecular weight (HMW) PAHs provides insights into pollution sources. LMW PAHs such as Naphthalene, Acenaphthylene, and Phenanthrene are typically associated with petrogenic sources like oil spills and petroleum leakage (Hasan *et al.,* 2024), whereas HMW PAHs—including Chrysene, Benzo[a]pyrene, and Indeno[1,2,3-cd]pyrene—are linked to pyrogenic sources such as incomplete combustion of fossil fuels and biomass (Haneen *et al.,* 2022; Zhang *et al.,* 2023). The concurrent presence of both classes indicates that both petrogenic and pyrogenic activities contribute significantly to hydrocarbon contamination in these water bodies, corroborating findings from recent studies in the Niger Delta (Faboya *et al.,* 2023; Iwegbue *et al.,* 2022). The detection of carcinogenic PAHs, such as Benzo[a]pyrene, Dibenz[a,h]anthracene, and Chrysene, raises critical environmental and public health concerns, given their mutagenic, teratogenic, and carcinogenic potentials. Chronic exposure through contaminated water and aquatic food sources may lead to bioaccumulation and biomagnification, threatening human health—an issue highlighted in recent reviews by Montano *et al.,* (2025) and Udofia *et al.,* (2021). Given that many local communities depend on surface water for domestic and nutritional needs, ongoing contamination poses a significant risk, emphasizing the need for comprehensive monitoring and stricter pollution control measures (Iwegbue *et al.,* 2022; Adamu *et al.,* 2026). Overall, these findings reinforce the critical need for sustained environmental surveillance, enforcement of pollution regulations, and sustainable management of petroleum activities to mitigate the health and ecological risks associated with PAH pollution in the Niger Delta (Ola *et al.,* 2024; Zhang *et al.,* 2025). Addressing these challenges is essential for safeguarding both aquatic ecosystems and community health in the region.

Conclusion: This study evaluated the concentration patterns and potential sources of polycyclic aromatic hydrocarbons (PAHs) in water samples collected from Kolo, Otuoke, and Onuebum within Ogbia Local Government Area. The results confirmed the presence of all sixteen priority PAHs across the three sites, indicating widespread hydrocarbon pollution in the aquatic environment. Findings revealed that Onuebum exhibited the highest total PAH concentrations, followed by Kolo, with Otuoke showing the lowest levels. Although the differences among locations were modest, the consistently elevated PAH levels in Onuebum suggest a stronger contamination pressure, likely driven by localized human activities such as petroleum discharges, combustion processes, and runoff from settlements. Molecular weight distribution analysis indicated a mixed origin of PAHs in the area. The predominance of low molecular weight PAHs in Onuebum points to recent petrogenic (oil-related) inputs, whereas higher proportions of high molecular weight PAHs in Kolo and Otuoke suggest pyrogenic sources such as fossil fuel combustion, gas flaring, and bush burning. The detection of carcinogenic PAHs like Benzo[a]pyrene and Dibenz[a,h]anthracene across all sites raises significant concerns regarding ecological and human health risks. Therefore, continuous monitoring of PAHs in water, sediments, and aquatic organisms is recommended to track pollution trends and identify emerging hotspots within the study area. Regulatory agencies should enhance surveillance of oil exploration activities, illegal refining, and fuel handling practices to minimize hydrocarbon input into the environment. Efforts to reduce gas flaring, bush burning, and uncontrolled combustion should be intensified through stricter enforcement of environmental regulations and promotion of cleaner energy sources. Additionally, communities relying on these water bodies should undergo periodic health risk assessments, especially concerning the consumption of contaminated fish and aquatic resources. Finally, priority should be given to remediating heavily contaminated water bodies using appropriate technologies such as bioremediation and phytoremediation to mitigate pollution impacts.

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Table 1: Concentrations of Polycyclic Aromatic Hydrocarbons (PAHs) in river water Samples from Onuebum Community

Compound	R.T.	QIon	Response	Conc	Units		Dev(Min)
Target Compounds							Qvalue
1) Naphthalene	2.262	128	54	0.06	ppm		100
2) Acenaphthylene	3.532	152	66	0.17	ppm	#	1
3) Acenaphthene	3.555	153	132	0.56	ppm	#	60
4) Fluorene	4.057	166	57	0.20	ppm	#	15
5) Phenanthrene	5.043	178	83	0.10	ppm	#	60
6) Anthracene	5.130	178	80	0.21	ppm	#	60
7) Fluoranthene	6.964	202	60	0.12	ppm	#	10
8) Pyrene	7.437	202	66	0.13	ppm	#	59
9) Benz[a]anthracene	8.972	228	57	0.21	ppm	#	1
10) Chrysene	8.972	228	57	0.14	ppm	#	1
11) Benzo[b]fluoranthene	10.062	252	93	0.16	ppm	#	1
12) Benzo[k]fluoranthene	10.062	252	93	0.18	ppm	#	1
13) Benzo[a]pyrene	10.414	252	131	0.25	ppm	#	1
14) Indeno[1,2,3-cd]pyrene	11.758	276	90	0.13	ppm	#	1
15) Dibenz[a,h]anthracene	11.787	278	210	0.36	ppm	#	1
16) Benzo[ghi]perylene	12.127	276	96	0.17	ppm	#	1

Table 2: Concentrations of Polycyclic Aromatic Hydrocarbons (PAHs) in water Samples Collected from Otuoke, Community in Ogbia LGA, Bayelsa State

Compound	R.T.	QIon	Response	Conc	Units		Dev(Min)
Target Compounds							Qvalue
1) Naphthalene	2.320	128	56	0.04	ppm		100
2) Acenaphthylene	3.480	152	68	0.08	ppm	#	1
3) Acenaphthene	3.537	153	165	0.14	ppm	#	42
4) Fluorene	4.097	166	60	0.21	ppm	#	1
5) Phenanthrene	4.956	178	64	0.15	ppm	#	1
6) Anthracene	4.956	178	64	0.37	ppm	#	1
7) Fluoranthene	6.849	202	78	0.16	ppm	#	60
8) Pyrene	7.275	202	65	0.13	ppm	#	17
9) Benz[a]anthracene	8.937	228	65	0.20	ppm	#	1
10) Chrysene	8.937	228	65	0.16	ppm	#	1
11) Benzo[b]fluoranthene	10.056	252	66	0.09	ppm	#	1
12) Benzo[k]fluoranthene	10.056	252	66	0.17	ppm	#	1
13) Benzo[a]pyrene	10.408	252	129	0.24	ppm	#	1
14) Indeno[1,2,3-cd]pyrene	11.723	276	210	0.31	ppm	#	1
15) Dibenz[a,h]anthracene	11.775	278	116	0.17	ppm	#	1
16) Benzo[ghi]perylene	12.133	276	122	0.22	ppm	#	1

Table 3: Concentrations of Polycyclic Aromatic Hydrocarbons (PAHs) in water Samples Collected from Kolo Community in Ogbia L.G.A. Bayelsa State.

Compound	R.T.	QIon	Response	Conc	Units		Dev(Min)
Target Compounds							Qvalue
1) Naphthalene	2.383	128	59	0.03	ppm		100
2) Acenaphthylene	3.422	152	84	0.06	ppm	#	1
3) Acenaphthene	3.635	153	87	0.13	ppm	#	58
4) Fluorene	4.131	166	100	0.42	ppm	#	45
5) Phenanthrene	5.072	178	55	0.15	ppm	#	60
6) Anthracene	5.106	178	76	0.24	ppm	#	60
7) Fluoranthene	6.929	202	62	0.10	ppm	#	60
8) Pyrene	7.114	202	59	0.08	ppm	#	6
9) Benz[a]anthracene	8.948	228	66	0.16	ppm	#	1
10) Chrysene	8.948	228	66	0.35	ppm	#	1
11) Benzo[b]fluoranthene	10.079	252	79	0.16	ppm	#	1
12) Benzo[k]fluoranthene	10.079	252	79	0.20	ppm	#	1
13) Benzo[a]pyrene	10.425	252	204	0.15	ppm	#	1
14) Indeno[1,2,3-cd]pyrene	11.712	276	192	0.33	ppm	#	1
15) Dibenz[a,h]anthracene	11.746	278	119	0.24	ppm	#	1
16) Benzo[ghi]perylene	12.110	276	59	0.12	ppm	#	1

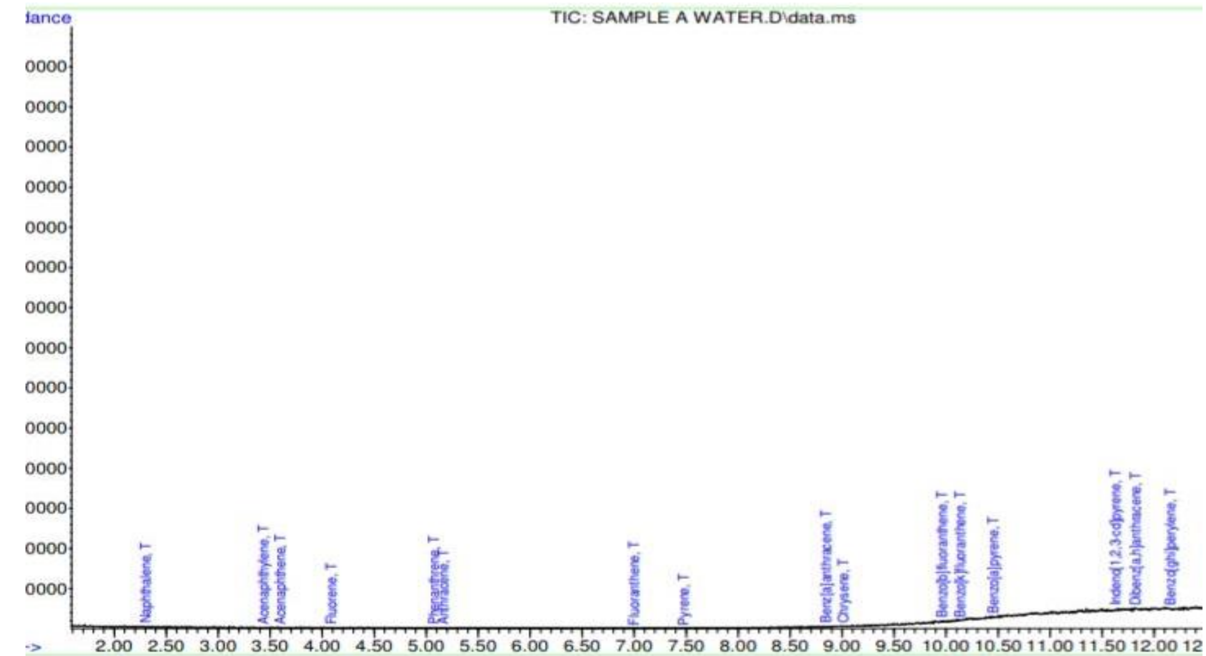

Figure1: Total Ion Chromatogram (TIC) of PAHs Detected in water Sample from Onuebum Community.

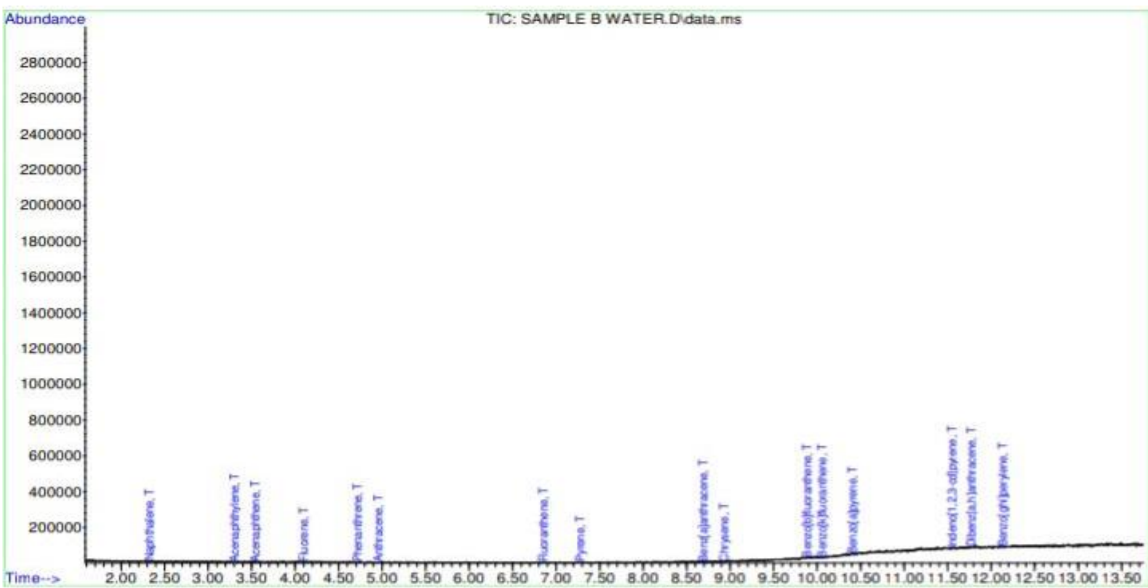

Figure 2: Total Ion Chromatogram (TIC) of PAHs Detected in Water Sample from Otuoke Community

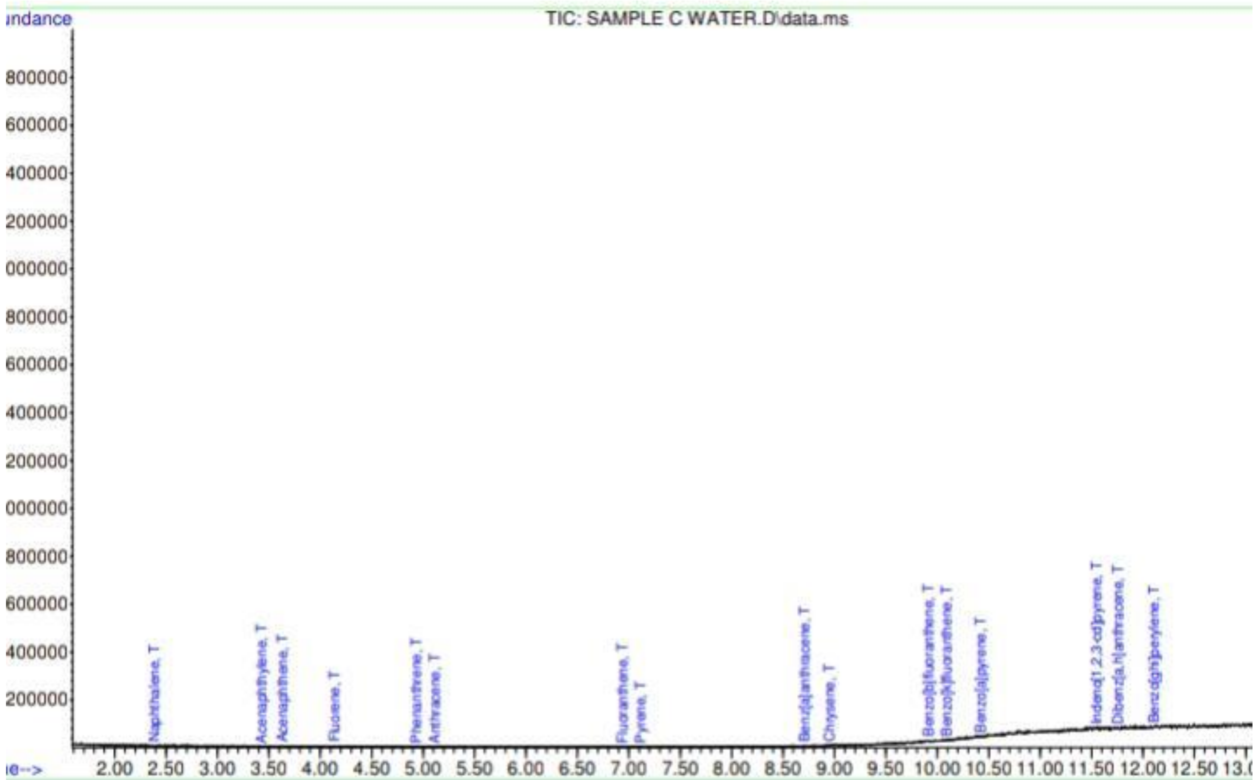

Figure 3: Total Ion Chromatogram (TIC) of PAHs Detected in Water Sample from Kolo Community