

## Critical Evaluation of Crude Oil and Sediments from Selected Areas of the Niger Delta

Abolodje Onoriode Darlington<sup>1</sup>, Ibe KA<sup>2</sup>, Osisanya Olajuwon Wasiu<sup>3\*</sup>, and Saleh A Saleh<sup>4</sup>

<sup>1,2</sup>Department of Chemistry, Federal University of Petroleum Resources Effurun, Delta State, Nigeria

<sup>3</sup>Department of Physics, Federal University of Petroleum Resources Effurun, Delta State, Nigeria

<sup>4</sup>Department of Petroleum Engineering and Geosciences, Petroleum Training Institute, Effurun, Delta State, Nigeria

### ABSTRACT

Understanding the occurrence, composition, and distribution of aliphatic hydrocarbons (AHCs) is crucial for assessing anthropogenic contributions and identifying the sources of AHCs in the environment. Therefore, this study focused on analyzing the concentrations, distribution patterns, and compositional characteristics of AHCs present in crude oil and sediments from the Udu, Ethiope East, and Ughelli North Local Government Area. A total of nine crude oil samples and ten sediment samples were gathered from the research area. The concentrations of AHCs in these samples were quantified using gas chromatography with a Flame Ionization Detector (GC-FID) following extraction with a hexane/dichloromethane mixture and subsequent purification using a silica gel/alumina packed column. Analysis of the molecular indices indicated that the aliphatic hydrocarbons (AHCs) present in the sediments originated from marine biogenic, terrestrial biogenic, and petrogenic sources, whereas the hydrocarbons in the crude oil were derived exclusively from marine and terrestrial biogenic sources.

### \*Corresponding author

Osisanya Olajuwon Wasiu, Department of Physics, Federal University of Petroleum Resources Effurun, Delta State, Nigeria.

**Received:** September 15, 2025; **Accepted:** September 29, 2025; **Published:** September 30, 2025

**Keywords:** Aliphatic Hydrocarbons, Polycyclic Aromatic Hydrocarbons, Total Petroleum Hydrocarbons, Pristane/Phytane Ratio, Molecular Weight

### Introduction

The exploration and extraction of crude oil in Nigeria's Niger Delta have resulted in widespread environmental degradation, with sediments serving as major sinks for pollutants. Sediments in the region often contain elevated levels of Total Petroleum Hydrocarbons (TPHs) and Polycyclic Aromatic Hydrocarbons (PAHs), exceeding recognized environmental standards and adversely affecting ecosystems, particularly mangrove habitats [1,2]. These pollutants originate primarily from oil spills, leaks, and operational discharges, posing severe ecological and socio-economic risks that demand urgent remediation.

Sediments are of particular concern because they function both as repositories and secondary sources of contamination. According to, sediment-bound hydrocarbons and other toxicants can be released into overlying waters, where they impair aquatic organisms and degrade water quality. Consequently, sediments serve as sensitive indicators for monitoring pollutants in aquatic environments. In the Niger Delta, hydrocarbon-contaminated sediments manifest as polluted soils, tainted waters, and mangrove deposits, which collectively threaten environmental and human health [3]. The region's geology, characterized by dense sedimentary layers, not only facilitated the accumulation of petroleum deposits but also contributes to the persistence of contamination once spills occur.

Nigeria's oil exploration history dates back to 1908, when the German-owned Nigerian Bitumen Corporation drilled exploratory wells in Lagos State. Although operations were interrupted by the First World War, oil exploration expanded significantly after independence, and today Nigeria hosts numerous onshore and offshore wells [4]. Petroleum remains a cornerstone of modern society, serving as a critical energy source and raw material for plastics, paints, fertilizers, insecticides, and medicines. Crude oil itself exists in liquid, solid, and gaseous states, comprising a complex mixture of hydrocarbon molecules whose properties vary by composition [5]. Hydrocarbons, while essential as energy resources, are highly flammable and release carbon dioxide, water, and heat upon combustion. They originate from kerogen through catagenesis and metagenesis, processes that ultimately determine the quantity and type of hydrocarbons produced [6].

The Niger Delta has long been plagued by oil spills that have devastated communities and ecosystems. Historical records highlight several large-scale spills, including the 570,000-barrel Forcados terminal spill in 1979, which contaminated swamp forests and coastal waters, and the 1980 Funiwa No. 5 Well blowout, which destroyed over 836 acres of mangrove forest [7]. Subsequent spills in the 1980s and 1990s continued to damage aquatic life, soil fertility, and food production systems. For example, vegetables exposed to oil contamination have been found to lose up to 36% of their ascorbic acid content, while cassava may exhibit a 40% increase in crude protein levels due to altered soil chemistry.





**Figure 3.1:** Kokori



**Figure 3.2:** Eruemukowharien River



**Figure 3.3:** Ewvreni River



**Figure 3.4:** Utorogu River



**Figure 3.5:** Afiersere River

## Materials and Methods

### Materials/Reagents

The apparatus utilized in this study included the following items: Agilent 6890 Gas Chromatograph equipped with a Flame Ionization Detector (GC-FID), a weighing balance (S-Mettler FA210A model, USA), a rotary evaporator (Searchtech instrument RE52-2 model, USA), Teflon screw-cap vials, glass wool, a glass fractionating column, a 2mL glass pipette, a 100mL conical flask, a 100mL beaker, a 100mL measuring cylinder, and a Soxhlet extractor.

### Reagents

The chemical reagents employed for the analysis of the samples were of analytical quality.

- i. Dichloromethane, DCM (99% reagent grade) from Fisher Scientific (Loughborough, UK).
- ii. Anhydrous Sodium Sulphate (BDH grade)
- iii. Silica gel (60-120 mesh)
- iv. Acetone (Analar grade)
- v. n-Hexane (HPLC grade)

### Sample Extraction

The extraction of n-alkanes from sediment was performed utilizing a Soxhlet extractor. A solvent mixture comprising hexane and dichloromethane in a 1:1 ratio was prepared. Ten grams of finely ground sediment, which had been sieved through a 0.4µm mesh, were measured and placed into extractable thimbles. To eliminate any residual moisture, 5 grams of anhydrous sodium sulfate were added to each sample. Two hundred milliliters of the prepared solvent mix was transferred into the round-bottom flask connected to the Soxhlet extractor, allowing it to reflux sufficiently for a complete extraction. Following this process, the extract was concentrated to 3 mL using a Rotary Evaporator before being transferred into a Teflon screw-cap vial and labeled clearly.

### Preparation of Packed Fractionating Column

The glass column was filled with glass wool, while 10g of silica gel with a mesh size of 60-120 was activated overnight at 105°C. This activated silica gel was then dissolved in Dichloromethane (DCM) to form a slurry, which was subsequently packed into the column. Prior to the extraction process, the fractionating glass column was conditioned with 10mL of DCM, following

the addition of 5g of anhydrous sodium sulfate to facilitate water absorption. The extracts underwent desasphalting by being precipitated in a 1:30 dichloromethane-petroleum ether solution (boiling point 40-60°C) for 20 minutes at a speed of 3000 rpm, as detailed by [10]. The desphalted extracts underwent separation into three categories: saturated compounds, aromatic compounds, and heterocompounds (which include resins or NSO). This process utilized liquid chromatography alongside silica gel (70/230 mesh, pre-activated for 6 hours at 400° C), enhanced with neutral alumina that had been activated for 2 hours at 700° C. The fraction containing saturated aliphatic hydrocarbons was eluted using 50 mL of n-hexane, while both the monoaromatic and polycyclic aromatic hydrocarbons were separated with 50 mL of dichloromethane. Subsequently, the heterocyclic fractions (Resin or NSO) were removed by employing a 50 mL mixture of methanol and dichloromethane in a 1:2 ratio. Following this, the solvents were evaporated using a nitrogen stream.

### Sample Analysis using Gas Chromatography (Gc)

An Agilent 6890 chromatograph, equipped with a 30 m x 0.25 mm x 0.25 µm film thickness (DB-5MS) capillary column and a flame ionization detector (FID), was employed for the gas chromatography (GC) analysis of complete oil samples. The operational temperature of the oven was programmed to rise from 60°C to 295°C at a rate of 3°C/min, utilizing helium as the carrier gas at a flow rate of 300 mL/s. Initial and final temperature holds were set for five minutes and twenty minutes, respectively. The detection of peak positions was achieved through electronic integration, retention time measurements, and comparisons with standards at 300°C. Additionally, the identification of specific compounds was facilitated by analyzing mass spectra against established standards and GC retention times [10].

## Results and Discussion

### Sources of Ahcs in the Crude Oil and Sediment Samples

Identifying the origins of AHCs across various environmental matrices can be challenging, owing to the intricate and diverse sources stemming from the post-deposition and environmental alterations of parent chemicals. Nevertheless, compositional evaluation stands out as an essential technique for source signature analysis. The results of source apportionment from this study are presented in Table 1.

**Table 1: Total Aliphatic Hydrocarbons Present in Troeschpeter@aol.comhe Sediments Examined in This Study Have been Compared with those Reported in Existing Literature.**

Location (Country)	Concentration (mg/Kg)	References
(Udu, Ughelli North and Ethiope East) Niger Delta (Nigeria)	10.8-470	This Study
Egboko, Ife and Ubeji creeks (Nigeria)	0.03–287	Egubbe <i>et al.</i> (2015)
Forcados River (Nigeria)	0.02–0.60	Iwegbue <i>et al.</i> (2016)
Escravos Estuary (Nigeria)	95-3430	Iwegbue <i>et al.</i> (2021)
Qua Iboe Estuary (Nigeria)	5.0–232	Essien <i>et al.</i> (2012)
Qua-Iboe River (Nigeria)	270–830	Iyang <i>et al.</i> (2018)
Coastal areas of the Bonny River (Nigeria)	1.65–12.7	Ekpo <i>et al.</i> (2012)
Jiaozhou Bay, Qingdao (China)	0.50-8.20	Wang <i>et al.</i> (2006b)
Arabian Gulf (Bahrain)	0.67-4.30	Tolosa <i>et al.</i> (2005)
Black Sea (Turkey, Russia and Ukraine)	0.10-3.40	Readman <i>et al.</i> (2002)
Nuequen River (Argentina)	0.41-125	Monza <i>et al.</i> (2013)
Prai Strait (Penang, Malaysia)	421-3135	Sakari <i>et al.</i> (2008)
South China Sea off Kuching division (Sarawak)	35.6-1466	Yusoff <i>et al.</i> (2012)
Fraser River basin (Canada)	1.60-20.6	Yunkerand Macdonald (2003)

Sao Sebastiao (Brazil)	0.03-4.77	Medeiros and Bicego (2004)
Kaohsiung harbor (Taiwan)	0.46-22.6	Lee <i>et al.</i> (2005)
Sfax coastal zone (Tunisia)	2.18-430	Zaghden <i>et al.</i> (2007)
Khmiss coast (Tunisia)	9.69-36.08	Zrafi <i>et al.</i> (2013)
Itajai-Acu estuary (Brazil)	0.50-69.7	Frena <i>et al.</i> (2017)
Shatt Al-Arab, River (Iraq)	0.08-42.58	Farid (2017)
Guanabara Bay	7.66-57.22	Wagener <i>et al.</i> (2012)
Marmugoaharbor (India)	1.60-10.7	Harji <i>et al.</i> (2008)
Gulf of Fos (France)	7.80-180	Mille <i>et al.</i> (2007)
Yellow River (China)	22.1-81.15	Wang <i>et al.</i> (2011)

The API gravity of crude oils generally ranges from 10 to 50, with the majority of crude oils situated between 20 and 45. Based on API gravity, conventional crude oils are typically categorized as light (API > 30), medium (30 > API > 22), and heavy (API < 22). According to Table 2, B1, B2, and C2 are classified as light crude oils, whereas A is classified as medium, and C1, D1, D2, E1, and E2 are deemed slightly heavy. The specific gravity for the samples varied from 0.8576 in sample B2 to 0.9485 in sample E2, and the API gravity exhibited a range from 33.50 in sample B2 to 17.68 in sample E2.

**Table 2: Molecular Indices for Source Apportionment of AHCs in the Crude Oil and Sediments**

		MH	LMW/HMW	CPI	C31/C19	Pr/Ph	n-C17/Pr	C18/Ph	n-C29/n-C17	TAR	NAR	Paq	ACL
Crude Oil	A	C16	2.42	1.06	0.68	1.53	1.12	1.86	0.74	0.89	0.05	0.58	28.2
	B1	C16	3.27	1.09	0.29	1.69	0.94	1.59	0.48	0.54	0.07	0.57	28.3
	B2	C18	2.14	1.27	1.04	1.49	1.19	2.03	0.81	0.88	0.12	0.40	28.8
	C1	C31	0.48	1.56	3.39	1.83	0.18	0.69	8.02	2.71	0.24	0.01	30.3
	C2	C8	0.86	1.30	3.07	1.58	0.32	0.58	3.98	1.78	0.18	0.26	29.5
	D1	C31	1.41	1.12	1.71	1.66	1.10	2.33	1.19	1.34	0.05	0.34	29.1
	D2	C32	0.31	0.78	12.76	0.82	0.95	1.53	2.85	2.12	-0.17	0.12	30.7
	E1	Pr	1.66	0.92	0.54	3.18	0.59	1.76	1.16	0.72	0.00	0.41	28.8
E2	C32	1.06	0.37	0.68	1.37	1.27	2.74	0.89	1.21	-0.28	0.48	28.0	
Sediment	AA1	C36	3.39	2.62	0.00	0.78	1.28	1.67	0.00	1.00	0.22	1.00	25.7
	AA2	C36	2.36	1.24	0.00	1.92	0.46	0.97	0.00	0.86	-0.03	1.00	26.0
	BB1	C38	11.19	2.44	0.00	1.05	0.73	1.73	0.00	1.10	0.21	1.00	25.7
	BB2	C38	3.07	0.44	0.00	0.79	1.31	1.85	0.00	1.00	-0.20	1.00	27.0
	CC1	C24	0.00	0.59	0.00	1.81	0.49	0.99	0.00	0.36	-0.11	1.00	25.0
	CC2	C38	12.18	2.50	0.00	1.08	0.75	1.86	0.00	1.10	0.16	1.00	25.7
	DD1	C37	1.91	1.29	0.00	0.86	1.27	2.24	1.57	0.97	0.09	0.73	26.5
	DD2	C37	1.95	1.40	0.00	0.80	1.27	2.29	1.57	0.98	0.10	0.76	26.4
EE1	C25	1.01	1.42	21.03	1.28	0.46	0.58	2.68	2.00	0.09	0.60	28.4	
EE2	C34	0.18	1.60	18.70	2.53	0.44	2.49	2.94	11.47	0.09	0.41	30.7	

**HM**= Major hydrocarbon, **LMW/HMW**=Low Molecular Weight/High Molecular Weight Ratio, **CPI**=Carbon Preference Index, **Pr/Ph**- Pristane/Phytane Ratio, **TAR**=Terrigenous/aquatic n-alkane ratio, **NAR** =Natural n-alkane ratio, **Paq**= n-Alkane proxy, **ACL**= Average carbon chain length

### Major Hydrocarbon (MH)

Major hydrocarbons (MH) refer to the AHCs with the highest carbon numbers, which play a crucial role in the overall concentration of AHCs [11]. This index can serve as a means to verify the hydrocarbon load's direction, as it exhibits variability across different sites. In the crude oil and sediment samples analyzed during this study, the predominant hydrocarbons (MH) were those with even carbon numbers, including C8, C16, C18, C32, C34, C36, and C38, with the exceptions being samples C1, D1, and E1 for crude oil, along with DD1 and DD2 for sediments.

### Low Molecular Weight/ High Molecular Weight (LMW/HMW AHCs ratio)

The estimation of the LMW/HMW aliphatic hydrocarbons ratio was conducted to ascertain the origins of these hydrocarbons and to differentiate between terrestrial and macrophyte sources. This ratio is determined by calculating the quotient of low-molecular-weight aliphatic hydrocarbons against high-molecular-weight aliphatic hydrocarbons. Specifically, LMW-AHCs comprise n-alkanes with carbon chain lengths from C16 to C26, while HMW-AHCs encompass n-alkanes that range from C27 to C36. As noted by Fagbote and Olanipekun, high molecular weight n-alkanes are associated with terrestrial vascular plants, in contrast to low molecular weight n-alkanes, which are linked to marine biogenic sources [12]. n-Alkanes indicative of higher plants, marine organisms, and sedimentary bacteria exhibit an LMW/HMW alkane ratio of 1. In contrast, n-alkanes derived from petroleum and plankton show an LMW/HMW alkane ratio that is approximately equal to 1. Fresh oil contamination is characterized by an LMW/HMW ratio exceeding 2 [13,14]. In this research, the LMW/HMW ratios for crude oil varied from 0.31 to 3.27, while sediment ratios ranged from 0.18 to 12.18 see Table 2. The findings revealed that n-alkanes found in crude oil samples from sites C1, C2, and D2, along with those in sediment from site EE2, are linked to higher plants, marine life, and sedimentary microorganisms. This reinforces the idea that aliphatic hydrocarbons originate from a combination of petroleum and terrestrial biogenic sources, while also acknowledging significant input from marine biogenic sources (Fig. 4).

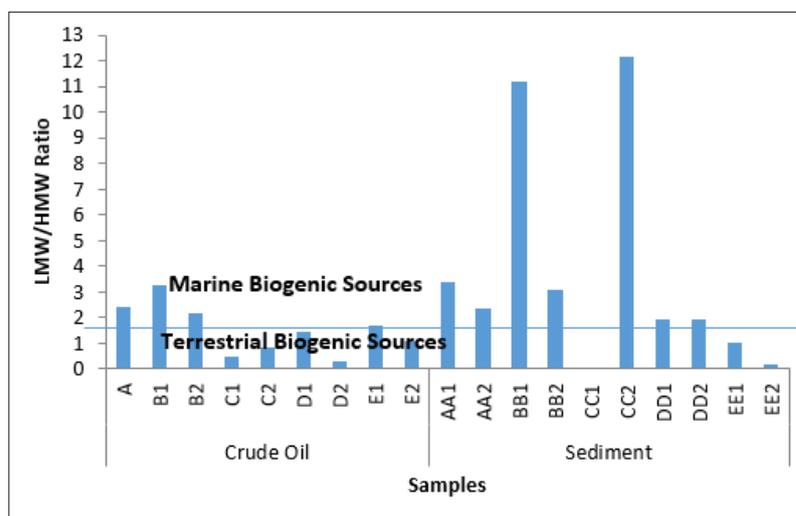


Figure 4: Plot of LMW/HMW n-alkanes in the Crude Oil Against Sediment Samples

### Carbon Preference Index (CPI)

CPI values play a significant role in distinguishing between anthropogenic and biogenic inputs of aliphatic hydrocarbons present in the environment as shown in equation 1. A CPI value exceeding 1 indicates a contribution from odd-numbered aliphatic hydrocarbons that are of biogenic nature. As noted by Colombo et al., CPI values ranging from 3 to 6 typically reflect the influence of vascular plants in the environment [11]. In samples exhibiting high maturity, where there is a substantial presence of both even and odd aliphatic hydrocarbons, it is common to find that even-numbered hydrocarbons have CPI values below 1, indicating a petroleum origin. The assessment of CPI was based on the n-C25 to n-C33 range. Notably, the CPI ratios were found to be above 1 for all samples except for D2, E1, and E2 from crude oil, as well as BB2 and CC1 from sediments as shown in Table 2, and Fig 5. This indicates that the aliphatic hydrocarbons originate from biogenic sources, specifically terrestrial higher plant waxes, as well as from petroleum.

$$CPI = 0.5 \times \left[ \frac{C_{25} + C_{27} + C_{29} + C_{31} + C_{33}}{C_{24} + C_{26} + C_{28} + C_{30} + C_{32}} \right] + \left[ \frac{C_{25} + C_{27} + C_{29} + C_{31} + C_{33}}{C_{26} + C_{28} + C_{30} + C_{32} + C_{34}} \right] \quad (1)$$

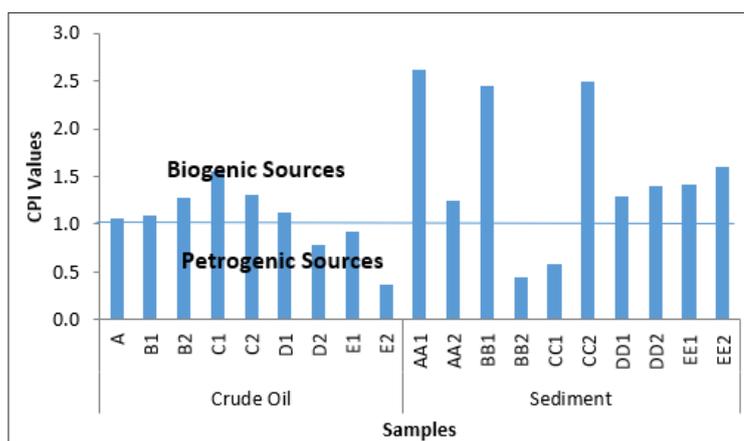


Figure 5: CPI Values of Aliphatic Hydrocarbons in the Crude Oil and Sediment Samples

### n-C31/n-C19 ratio

A carbon chain length of C31 serves as an indicator of terrestrial biogenic hydrocarbons, whereas C19 is associated with marine biogenic sources (Yusoff et al., 2012) [15]. The ratio of n-C31/n-C19 is a marker of the predominance of hydrocarbon input from the land or sea, the value of n-C31/n-C19 < 0.4 and > 0.4 shows the predominance of marine biogenic sources and land-derived hydrocarbons respectively [15]. The ratios of n-C31 to n-C19 in both the crude oil and sediment samples EE1 and EE2 exceeded 0.4 as shown in Table 2. This indicates that the hydrocarbons were mainly delivered to the research locations through human activities and are largely derived from terrestrial sources. This observation aligns with the conclusions drawn by [16].

### Pristane/Phytane Ratio

While phytol and other isoprenoidyl compounds are not critical elements of most terrestrial biota, they do undergo diagenetic changes to transform into phytone and pristane hydrocarbons. These compounds are indeed found in living organisms as well as in petroleum. It is suggested that pristane and phytane are naturally occurring hydrocarbons formed during post-depositional processes, which may involve the catalytic hydrogenation of phytadiene or oxidation reactions of the phytol side chain. Their presence in zooplankton and various marine organisms, along with their occurrence in crude oils, supports this theory [17]. Furthermore, the ratio of Pristane to Phytane typically tends to be greater in biogenic samples than in oil. In sediments that lack hydrocarbon input, the Pr/Ph ratio typically falls within the range of 3 to 5, whereas a Pr/Ph value of ≤ 1 is indicative of petroleum contamination [18]. The observed Pr/Ph ratio range in the sediments, which spans from 0.78 to 2.53 see Table 2, suggests a combination of biogenic and petrogenic sources. Furthermore, the Pr/Ph ratio for the crude oil varied from 0.82 to 3.18, signifying the presence of biogenic input (Fig. 6).

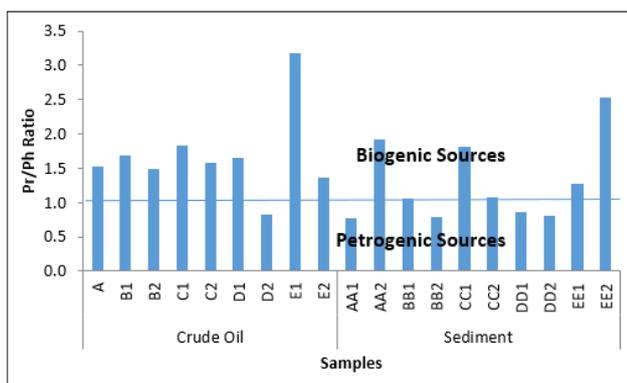


Figure 6: Pr/Ph Ratio of Aliphatic Hydrocarbons in the Crude Oil and Sediment Samples

### n-Alkane/isoprenoid ratio

Due to their lower susceptibility to biodegradation, n-alkanes act as significant indicators that can provide essential insights into the origins, fate, and relative importance of both aquatic and terrestrial organic materials. Consequently, the ratios of n-C17/Pr and n-C18/Ph prove to be valuable instruments for assessing the source and degree of degradation in petroleum. As microorganisms tend to preferentially utilize n-alkanes over isoprenoids for energy during the biodegradation process, a ratio below 1 typically signifies biodegraded petroleum, whereas more recent inputs are likely to result in values exceeding 1. The ratios of n-C17/Pr and n-C18/Ph for crude oil varied from 0.32 to 1.27 and 0.58 to 2.74 respectively see Table 2., while for sediment, they ranged from 0.44 to 1.31

and 0.58 to 2.49 respectively. These n-C17/Pr and n-C18/Ph ratios observed in both crude oil and sediment imply the presence of a combination of extensively degraded hydrocarbons alongside more recent inputs.

### n-C29/n-C17 ratio

The ratio of n-C29 to n-C17 offers valuable insights into the relative contributions of allochthonous and autochthonous hydrocarbons in environmental samples, given that n-C29 is linked to terrestrial plants, whereas n-C17 is related to marine life. In the analyzed samples, the n-C29/n-C17 ratios varied from 0.48 to 8.02 for crude oil and from 1.57 to 2.94 for sediment as shown in Table 2.. Notably, values exceeding 1 were observed in 55% of the crude oil samples and 40% of the sediment samples, indicating a dominance of allochthonous hydrocarbons. Conversely, 45% of the crude oil exhibited n-C29/n-C17 ratios below 1, which implies a predominance of autochthonous contributions.

### Terrigenous/Aquatic n-alkane Ratio (TAR)

The proportion of terrigenous to aquatic n-alkanes was employed to determine the relative contributions of these two sources to the origins of AHCs, as illustrated in equation 2. The TAR values for crude oil ranged from 0.54 to 2.71, while for sediment, they varied from 0.36 to 11.47, as detailed in Table 2. This elevated TAR ratio may be explained by the tendency of shorter-chain n-alkanes to degrade more readily than their longer-chain counterparts. Nevertheless, the TAR values obtained in this study align with those previously reported for sediments from the Red Sea [19].

$$TAR = \frac{C27+C29+C31}{C15+C17+C19} \quad (2)$$

### Natural n-alkane (NAR) Ratio

Aly Salem, note that an NAR value approaching 1 implies a higher presence of terrestrial or marine vegetation, such as posidonia, as referenced in equation 3 [19]. The findings of this study revealed NAR values fluctuating between -0.17 and 0.18 for crude oil, and from -0.03 to 0.22 for sediments, as illustrated in Table 2. These results highlight a diverse range of terrestrial and marine contributions. The ratio presented below was employed to assess the NAR.

$$NAR = \sum n - \text{alkanes } (C19 - C32) - [2 \times \frac{\sum n - \text{alkanes } (C20 - C32)}{\sum n - \text{alkanes } (C19 - C32)}] \quad (3)$$

### n-Alkane Proxy (P<sub>aq</sub>)

Taq values ranging from 0.01 to 0.23 see Table 2, are indicative of terrestrial plant waxes, whereas values between 0.48 and 0.94, derived from equation 3, are linked to submerged or floating macrophyte species [20]. As shown in Table 2, the Paq ratios for crude oil and sediment fluctuated from 0.01 to 0.58 and 0.41 to 1.0, respectively. This data suggests that aliphatic hydrocarbons result from a blend of terrestrial plant waxes and submerged or floating macrophytes.

$$P_{aq} = \frac{C23+C25}{C23+C25+C29+C31} \quad (4)$$

### Average Carbon Chain Length (ACL)

This information is valuable for identifying environmental alterations that impact a specific ecosystem. The consistent value of ACL illustrates the infrequency of changes within an

environment, with ACL being calculated through Equation 4. The measured ACL ratios for sediments and crude oil ranged from 25.0 to 30.7, as shown in Table 2. For sediments and crude oil, the ACL revealed variances of 2.7 and 5.7 units, respectively. Due to substantial human activities and inputs that disturb the balance of ACL with petroleum hydrocarbons and their derivatives, the sediment may have experienced a significant range of transformations [13]. This was evaluated using the subsequent ratio.

$$ACL = \frac{25 (C_{25}) + 27 (C_{27}) + 29 (C_{29}) + 31 (C_{31}) + 33 (C_{33})}{C_{25} + C_{27} + C_{29} + 31 + C_{33}} \quad (5)$$

### Relationship between AHCs in Crude Oil and Sediments

Fig. 7 illustrates the regression relationship between the amounts of aliphatic hydrocarbons (AHCs) found in crude oils and sediments. According to the regression analysis, there is minimal to no correlation between the AHC levels in crude oil and those present in sediment. This lack of a significant relationship may be attributed to the influence of multiple sources and the continual input of fresh aliphatic hydrocarbons.

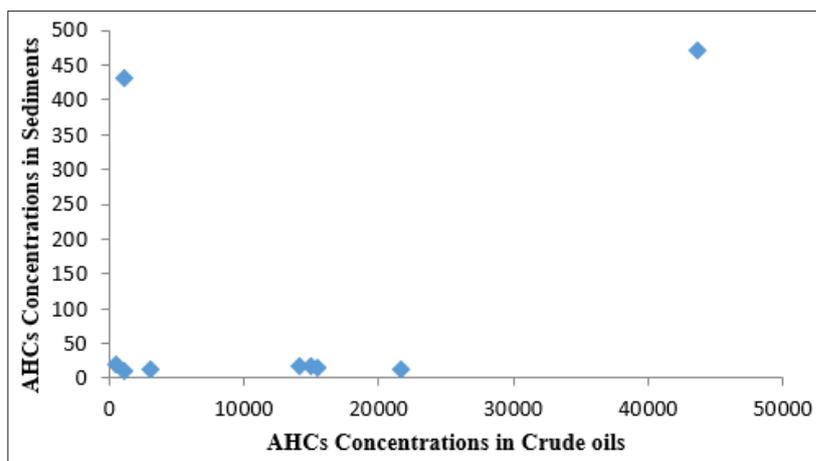


Figure7: Plot of AHCs Concentrations in Crude Oil Against AHCs in Sediment

Table 3: Results for Specific Gravity and APIO for Crude Oil Samples

Sample Code	A	B1	B2	C1	C2	D1	D2	E1	E2
Specific Gravity	0.8895	0.8596	0.8576	0.9436	0.8785	0.9373	0.9437	0.9423	0.9485
APIO	27.58	33.11	33.50	18.46	29.57	19.47	18.44	18.66	17.68

The API of crude oils varies typically between 10 and 50, with most crude oils falling in the range of 20 – 45. Using API gravity, the conventional crude oils can be generally considered as light (0API >30), medium (30 >0API > 22) and heavy (0API <22). From table 4.7 B1, B2 and C2 are light crude oil, while A is medium and C1, D1, D2, E1, and E2 are slightly heavy. The Specific gravity ranged from 0.8576 in sample B2 to 0.9485 in sample E2, while the APIO gravity ranged from 33.50 to 17.68 also in sample B2 and E2 respectively.

The API gravity of crude oils generally ranges from 10 to 50, with the majority of crude oils typically categorized between 20 and 45. According to API gravity classifications, conventional crude oils can be classified as light (°API > 30), medium (30 > °API > 22), or heavy (°API < 22). As indicated in Table 3 samples B1, B2, and C2 are classified as light crude oils, whereas sample A is categorized as medium, and samples C1, D1, D2, E1, and E2 are regarded as slightly heavy. The specific gravity values varied from 0.8576 in sample B2 to 0.9485 in sample E2, while the API gravity measurements ranged from 33.50 for sample B2 to 17.68 for sample E2.

### Conclusion

This research conducted a geochemical analysis of crude oil and

bottom sediments from water bodies in the Udu, Ethiope East, and Ughelli North Local Government Areas within the Niger Delta Basin. Findings from the study identified the concentration levels, compositional characteristics, and origins of aliphatic hydrocarbons (AHCs) present in both crude oil and bottom sediments in the region. The investigation determined the average concentrations of aliphatic hydrocarbons to be 102.74±2.85 mg/Kg in crude oil and 12859.11±7884.68 mg/Kg in bottom water sediments, respectively. The investigation indicated that the aliphatic hydrocarbons (AHCs) present in the sediments originated from petrogenic, terrestrial, and marine biogenic sources, in contrast to crude oil, which was sourced from both marine and terrestrial biogenic origins. Consequently, the study illustrated that the concentrations of aliphatic hydrocarbons from these diverse sources .

### Recommendations

In light of the results obtained from this research, it is advisable to implement the following recommendations:

1. An environmental clean-up and remediation process should be initiated in the study area.
2. Additional investigations should be conducted regarding the presence and distribution of other organic contaminants, including monoaromatic hydrocarbons (BTEX), polycyclic aromatic

hydrocarbons (PAHs), and polychlorinated biphenyls, among sediments, water, and biota within the study region [21-40].

1. Esi EO, Orisekpabor OP, Eyankware M O (2025) Integration of geophysical and radiological assessment of solid waste disposal impact on groundwater and human health in southern Nigeria, *Geosystems and Geoenvironment* <https://doi.org/10.1016/j.geogeo.2025.100425>.
2. Eyankware M O, Obasi PN (2021) A holistic review of heavy metals in water and soil in Ebonyi SE, Nigeria; with emphasis on its effects on human, aquatic organisms and plants. *World News of Natural Science* 38: 1-19.
3. Eyankware M O, Akakuru O C, Igwe E O, Olajuwon W O, Ukor K P (2024) Pollution Indices, Potential Ecological Risks and Spatial distribution of Heavy Metals in soils around Delta State, Nigeria. *Water, air, & soil Pollution*. <https://doi.org/10.1007/s11270-024-07209-yI>.
4. Akinshola O D (2006) Origin and occurrence of crude oil in the Niger Delta, Nigeria. *Journal of American Science* 4: 56-67.
5. Carey F A (2021) Hydrocarbons *Encyclopedia Britannica*, retrieved from <http://www.britannica.com/hydrocarbon>. Accessed 14 May 2021.
6. Wang G, Huang L, Zhao X, Niu H, Dai Z (2006a) Aliphatic and polycyclic aromatic hydrocarbon of atmospheric aerosols in five locations of Nanjing urban area, China. *Atmospheric Research* 81: 4583-4591.
7. Tuttle M Charpentier, R Brownfield M (2015) The Niger Delta Petroleum System: Niger Delta Province, Nigeria, Cameroon, and Equatorial Guinea, Africa. United States Geologic Survey. United States Geologic Survey. Retrieved 6 March 2015.
8. Best O. and Seiyefa B. (2023) The human health implications of crude oil spills in the Niger delta, Nigeria: An interpretation of published studies. *Nigerian Medical Journal* 54: 10-16.
9. Muhammed I, Olcay Kaplan I (2019) Introductory chapter: sources, health impact and environmental effect of hydrocarbon, *Hydrocarbon pollution and its effect on the environment* 68: 283-286.
10. Ekpo BO, Fubara EP, Ekpa OD, Marynowski HL (2012) Determination of hydrocarbon sources using n-alkane and PAH distribution indices in sediments from coastal areas of Bonny river in Niger Delta, Nigeria. *ARPN Journal of Earth Science* 1: 9-20.
11. Colombo J C, Pelletier C, Brochu A, Khalil M, Catoggio J A (1989) Determination of hydrocarbon sources using n-alkane and polyaromatic hydrocarbons distribution indexes. Case study: Rio de La Plata estuary, Argentina. *Environmental Science and Technology* 23: 888-894.
12. Fagbote E O, Olanipekun E O (2013) Characterization and sources of aliphatic hydrocarbons of the sediment of River Oluwa Bitumen deposit area, Western Nigeria. *Journal of Scientific Research and Reports* 2: 228-248.
13. Iwegbue CMA, Bebenimibo E, Obi G, Tesi GO, Olisah C, et al. (2021) Distribution and sources of n-Alkanes and polycyclic aromatic hydrocarbons in sediments around oil production facilities in the Escravos River Basin, Niger Delta, Nigeria. *Archives of Environmental Contamination and Toxicology*, <https://doi.org/10.1007/s00244-021-00810-w>
14. Gao X, Chen S, Xie X, Long A, Ma F (2007) Non-aromatic hydrocarbons in surface sediments near the Pearl River estuary in the South China Sea. *Environmental Pollution*. 148: 40-47.
15. Yusoff HB, Assim ZB, Mohamad SB (2012) Aliphatic hydrocarbons in surface sediments from south China Sea off Kuching Division, Sarawak. *Malays. Journal. Analytical. Science* 16: 1-11.
16. Commendatore M G, Esteves J L (2004) Natural and anthropogenic hydrocarbons in sediments from the Chubut River (Patagonia, Argentina). *Marine Pollution Bulletin* 48: 910-918.
17. Gomez-Belinchon J.I, Llop R, Grimalt JO, Albaig'es R (1988) The decoupling of hydrocarbons and fatty acids in the dissolved and particulate water phases of a deltaic environment. *Marine Chemistry* 25: 325-348.
18. Rontani J F, Volkman J K (2003) Phytol degradation product as biogeochemical tracers in aquatic environments. *Organic Geochemistry* 34: 1-35.
19. Aly Salem DMS, Morsy FAEM, El Nerm A, El-Kaily A, Khaled A (2014) The monitoring and risk assessment of aliphatic and aromatic hydrocarbons in sediments of the Red Sea, Egypt. *Egyptian Journal Aquatic Research* 40: 333-348.
20. Ficken K J, Li B, Swain D L, Eglinton G (2000) An n-alkane proxy for the sedimentary input of submerged/floating freshwater aquatic macrophytes. *Organic Geochemistry*. 31: 745-749.
21. Atunbi O A (2011) Effect of Warri refinery effluents on water quality from the Iffie River, Delta State, Nigeria, *American Review of Political Economy* 5: 45-56.
22. Eguvbe PM, Iwegbue CMA, Egboh SHO, Ogala JE (2015) Aliphatic hydrocarbon distribution in sediment cores of selected creeks in Delta State, Nigeria. *Environ. Foren.* 16: 275-295.
23. El Nerm AA, Moneer A Khaled, A El Sikaily (2013) Levels, distribution and risk assessment of organochlorines in surficial sediments of the red sea coast, Egypt. *Environmental Monitoring and Assessment* 185: 4835.
24. Emoyan OO, Ikechukwu CI, Tesi GO (2020) Occurrence and sources of aliphatic hydrocarbons in anthropogenic impacted soils from petroleum tank-farms in the Niger Delta, Nigeria. *Ovidius University Annals of Chemistry* 31: 132-144.
25. Essien JP, Ebong GA, Asuquo JE, Olajire AA (2012) Hydrocarbons contamination and microbial degradation in mangrove sediment of the Niger Delta, Nigeria. *Chem. Ecol* 28: 421-434.
26. Ivwurie W (2004) Source apportionment and use of hydrolysis to elucidate sources of biodegraded hydrocarbons. *Journal of Science and Multidisciplinary Research*, 8(1), 13-8
27. Iwegbue CMA, Aganbi E, Obi G, Osakwe SA, Eguvbe PM, Ogala JE, et al. (2016) Aliphatic hydrocarbon profiles in sediments of the Forcados River, Niger Delta, Nigeria. *Environmental Forensic* 17: 144-155.
28. Iyang SE, Aliyu AB, Oyewale AO (2018) Total petroleum hydrocarbons in surface water and sediments of Qua-Iboe River, Ibeno, Akwa-Ibom State, Nigeria. *Journal of Applied Science. Environmental Management* 22: 1953-1959.
29. Medeiros PM, Bicego MC (2004) Investigation of natural and anthropogenic hydrocarbon inputs in sediments using geochemical markers. II. São Sebastião, SP—Brazil. *Marine Pollution Bulletin* 49: 892-899.
30. Monza LB, Loewy RM, Savini MC, Pechen De D'Angelo AM (2013) Sources and distribution of aliphatic and polyaromatic hydrocarbons in sediments from the Neuquen River, Argentine Patagonia. *Journal Environmental Science Health A Toxic Hazard Subst Environ Eng* 48: 370-379.
31. Nigerian Tribune, March, 9th, (2022).
32. Odesa G E, Ozulu G U, Eyankware M O, Mba-Otike M N, Okudibie E J (2024) A holistic review three-decade oil

- spillage across the Niger Delta Region, with emphasis on its impact on soil and water. *World News of Science* 190: 119-139.
33. Odesa GE, Okanigbuan PN, Eyankware MO, Ngozi-Chika CS, Efetobo O (2025) Health risk assessment of water resources within the lignite series of Obomkpa and environs, southern Nigeria. *Journal of Contaminant Hydrology*. <https://doi.org/10.1016/j.jconhyd.2025.104665>.
  34. Readman J W, Fillmann G, Tolosa I, Bartocci J, Villeneuve J P, et al. (2002) Petroleum and PAH contamination of the Black Sea. *Marine Pollution Bulletin* 44: 48-62.
  35. Sakari M, Zakaria MP, Lajis NH, Mohamed CAR, Bahry PS, et al. (2008) Characterization, distribution, sources and origins of aliphatic hydrocarbons from surface sediment of Prai Strait, Penang, Malaysia: A widespread anthropogenic input. *Environment-Asia* 2: 1–14.
  36. United Nations Environment Programme (UNEP) 1992.
  37. Wang C, Wang W, He S, Du J, Sun Z (2011) Sources and distribution of aliphatic and polycyclic aromatic hydrocarbons in Yellow River Delta Nature Reserve, China. *Applied Geochemistry* 26: 1330-1336
  38. Wang XC, Sun S, Ma HQ, Liu Y (2006b) Sources and distribution of aliphatic and polyaromatic hydrocarbons in sediments of Jiaozhou Bay, Qingdao, China. *Marine Pollution Bulletin* 52: 129-138.
  39. Wigger GS, Torkelson BE (1997) A technique for estimating the age of regular/ mid-grade gasolines released to the subsurface since the early 1970's. *Environment Forensics* 3: 145-162.
  40. Yunker MB, Macdonald RW (2003) Alkane and PAH depositional history, sources and fluxes in sediments from the Fraser River basin and strait of Georgia, Canada. *Org Geochem* 34: 1429-1454.