Arabian Journal of Chemical and Environmental Research

Vol. 10 Issue 2 (2023) 92–105

Assessment of Petroleum Hydrocarbons in Terrestrial Snails (*Achatina achatina*) and Mud Fishes (*Clarias anguillaris*) from some parts of Ogbia LGA, Nigeria

A.A. Chokor[1]* and A.C. Ogonegbu[2]

[1]*Department of Chemistry, Faculty of Science. Federal University Otuoke, P.M.B. 126 Yenagoa, Bayelsa State, Nigeria.*
[2]*Department of Chemical Sciences, Dennis Osadebay University, Anwai Asaba, Delta State, Nigeria.*

Received 14 September 2023, Revised 13 December 2023, Accepted 17 December 2023

Cited as: *A.A. Chokor and A.C. Ogonegbu (2023) Assessment of Petroleum Hydrocarbons in Terrestrial Snails (Achatina achatina) and Mud Fishes (Clarias anguillaris) from some parts of Ogbia LGA, Nigeria, Arab. J. Chem. Environ. Res. 10(2) (2023) 92-105*

Abstract

Levels, source, health risk of Total Petroleum Hydrocarbons (TPHs) in Fish (*Clarias anguillaris*) and snail (*Achatina achatina*) tissues from three (3) communities in Ogbia LGA, Bayelsa, Niger Delta Area of Nigeria were assessed. Tissues samples were extracted with dichloromethane/hexane mixtures in soxhlet extractors followed by a silica gel clean-up and fractionation into aliphatic and aromatic fractions. The determinations of aliphatic and aromatic fractions of hydrocarbons were done with Gas Chromatography (GC) hyphenated to Flame Ionization Detector (GC-FID) and Mass Spectroscopy (MS) respectively. Levels of TPHs found in fish tissues ranged from 19.00 – 224.33mg/Kg; while a range of 172.59 – 281.68mg/Kg was found for the snail tissues. Source diagnosis revealed a mixed origin of the TPHs. Calculated hazard quotients (HQ) and Hazard indices (HI) were less than one (1) for the faunas except for samples of snails taken from Kolo axis which was slightly higher. This indicates that at a consumption rate of 20.8g/day, it is safe to consume these foods (fish and snail). However, due to possible biomagnifications of TPHs in human tissues, it is wise to curb all factors that will lead to further rise of TPHs in the environment.

Keywords: petrogenic, hazard index, risk assessment, bioavailability, human health.

*Corresponding author.
E-mail address: chokoraa@fuotuoke.edu.ng

ISSN : 2458-6544 © 2023 ;www.mocedes.org. All rights reserved.

1. Introduction

Ogbia Local Government Area (LGA) is one of the eight LGAs in Bayelsa State – an oil producing region characterized with oil production and oil related industrial activities. The indigenes of Ogbia are well known for their occupations of fishing, farming, and trade, with agriculture playing a very important role in their local economy. It is located in the fresh water mangrove swamp region with its characteristic mangroves and creeks serving as habitats for various species such as fishes and snails. However, oil related activities in the areas, accompanied by occasional spills have often led to the contaminations of this region. Besides, increase population with consequence increase in human activities such transportations, road constructions, discharge of agricultural and urban wastes, laundry processes, activities of various artisans etc; have added to the increase pollution load in this area. Hydrocarbons pollutants appears to be the most common pollutant of the oil industries; their presence in the environment is of great concern to public health as many of these compounds have been shown to be toxic to living organisms in both terrestrial and aquatic system. Some hydrocarbons have the tendency to bio-accumulate in living tissues and may become magnified along the food chain. Humans' health is endanger when they consume these products containing hydrocarbons that may be several orders of magnitude higher than in contaminated environment. Thus, those residing far away from these contaminated sites are not spared; as they could as well feed on the food products from these sites. Several authors have documented the negative impacts of petroleum hydrocarbons on the environment and human health.

Petroleum hydrocarbons releases into the environment will threaten public health and safety causing fire and explosion hazards, diminishing air, water, and soil quality, destroying recreational areas, compromising agriculture, destroying habitats and reducing fauna and flora capacity the environment (Chokor, 2022). Recovery may take several years once the soil and water are polluted by petroleum hydrocarbons (Ying *et al*, 2013). Subtle acute effects that may show up as a result of exposure of organisms and human to petroleum hydrocarbons include: impairment of feeding mechanisms, decrease in growth and developmental rates, and increased susceptibility to diseases and other histopathological disorders (Al-Shwafi 2008; Enuneku *et al*., 2015). Impaired physiology, reduced reproductive success, and shortened survival rate are possible chronic low-level exposure effects (Enuneku *et al*., 2015; Lee *et al*., 2015; Chokor, 2021). The disruption in the activities of various body organs, severe damage to the pancreas, kidney, liver, blood circulatory system, and ultimately death have been reported (Abha and Singh, 2012; Oyinbo *et al*., 2018). Also, associated with petroleum hydrocarbons contamination are human health complications such as: carcinogenicity, genotoxicity, deoxyribonucleic acid (DNA) damage, birth defects, childhood leukaemia, infertility and miscarriages in women, sterility, skin rashes

and irritation, and respiratory system disorders (Hurtig and Sabastian, 2002; Sudakin *et al*., 2011; Olawoyin *et al*., 2012; Ordinioha and Brisibe, 2013; Gudzenko *et al*., 2015; Ezekwe and Edoghotu, 2015; Kponee *et al*., 2015; Asghar *et al*, 2016, Briggs and Briggs, 2018; Ite *et al*., 2018). The impact of petroleum hydrocarbons on the ecosystem and human health in general is a function of time and period of exposures, concentrations and fractions of hydrocarbons present, persistence and bio-availabilities of specific hydrocarbon, the organisms' ability to accumulate and metabolize the various hydrocarbons, fate of the metabolized products, and the interference of specific hydrocarbons with normal metabolic processes (Chokor, 2024). Petroleum hydrocarbons include several hundreds of compounds – straight and branched chain alkanes, cycloalkanes and isoprenoids compounds, etc - that are difficult to measure individually. Thus, the term Total Petroleum Hydrocarbons (TPHs) is used as a collective parameter for their measurement and quantifications (Chokor, 2022). Their presence in the environment could be derived from petrogenic or natural inputs. Natural inputs include those from: terrestrial plant waxes, marine phytoplankton, volcanic eruptions, biomass combustion, and natural oil seeps (Tolosa *et al*., 2004). Though hydrocarbons are found naturally in the environment, large amount of it in a contaminated environment is derived from anthropogenic processes such as petroleum exploration, refining, usage, and related activities (Chokor, 2022). This work aims at determining the concentrations and source of Total Petroleum Hydrocarbons (TPHs) in snails (*Achatina achatina*) and mud fishes (*Clarias anguillaris)* from Ogbia LGA.; and to evaluate the health implications on consumers.

2. Materials and methods

2.1. Study area and samples collections

Ogbial LGA, Bayelsa was the source of samples used for this study. Land snails (*Achatina achatina*) and mudfish (*Clarias anguillaris*) samples were purchased from hunters and marketers who hunt or markets products from the creeks and forest of Ogbia. Samples of snails and mud-fishes were taken from three (3) communities viz: CT-1 (Kolo), CT-2 (Imiringi), and CT-3 (Otuokpoti; (Fig. 1). Samples of snails were taken whole with their shells, while the that of fishes were wrapped in aluminium foil, placed in polyethylene bags and housed in a cooler at 4^{o}C for onward transportation to the laboratory. In the laboratory, viscera of snails were removed after cracking the shells leaving only the edible portions. Edible portions of snails and fishes were thoroughly cleaned in tap water and then placed in a well labelled sample bottles and refrigerated at < 4^{o}C awaiting extractions.

2.2. Sample processing and extraction

Samples of edible portions of snails and fishes, were each cut into pieces and crushed with pestle in a mortal. 10 g of each sample (snails and mud-fishes from the different communities) were homogenized

with sodium sulphate anhydrous and spiked with surrogate standards (10 µg/mL of σ- terphenyl and 2-fluorobiphenyl) and wrapped in filter papers.

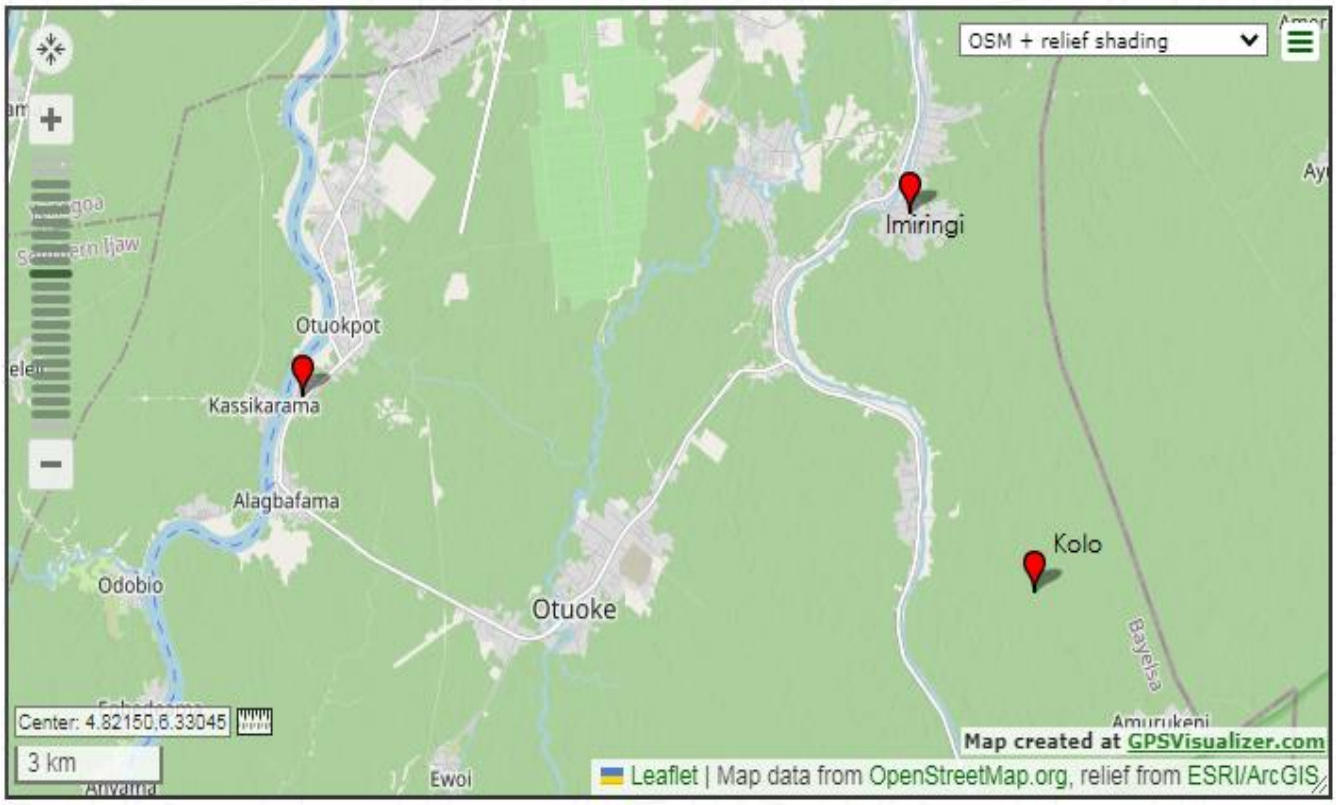

Fig. 1: Map showing part of Ogbia LGA communities where samples were taken.

The filter paper and its content were placed in thimbles followed by loading into the main chambers of the soxhlet extractors. 200mL of 1:1 dichloromethane (DCM)/*n*-hexane mixture were used for the 17 hrs extraction. Drying of extracts was performed by passing through columns of anhydrous sodium sulphate. Extracts were concentrated to volumes of 2mL with the aid of rotary evaporator (Iyang *et al*., 2018; Chokor and Achugwo, 2022).

2.3. Sample clean-up and separation

USEPA method 3630C was employed in the clean-up and separation of samples. Concentrated extracts were loaded onto prepared silica-gel columns (10mm id X 30cm) parked with 10g activated silica gel slurry lined at the top with anhydrous Na_2SO_4 (2cm thick). The samples were eluted first with 30mL of n-hexane to obtain the hydrocarbons fractions. Further elution with 30mL of DCM gave the aromatic fractions. The eluates were concentrated to approximately 2mL with rotary evaporator at 30 °C; and 1.5mL of it were transferred into chromatographic vials for storage at 4 °C prior to gas chromatographic determinations. Procedural blank was performed for the purpose of quality assurance (Maioli *et al*., 2011; Iyang *et al*., 2018; Chokor, 2024).

2.4. Gas chromatography analyses

Gas chromatography-flame ionization detector (GC-FID) system (Agilent 6890N) equipped with DB-5 capillary column with dimension of 30 m X 0.32 mm X 0.25 μm was used for the determination of aliphatic hydrocarbons (TAHs). Sample volume injected was 1 μL, carrier gas was helium at a flow rate of 1mL/min. Samples injection was in split less mode. The initial temperature of the column 50^{o}C for 5 minutes, latter increased 150^{o}C at rate of 10^{o}C /min. for 15 minutes; finally, the temperature was raised to 280^{o}C at rate of 16^{o}C/min and held for 5 minutes. The injector and detector temperatures were set at 200 and 300^{o}C respectively. The determinations of the of the sixteen-priority polycyclic aromatic hydrocarbons (Σ16PAHs) were carried out using same version of gas chromatography (Agilent 6890N) above but hyphenated to a mass spectrometer detector. The gas chromatographic column was initially held at temperature of 70^{o}C for 20 min. it was then increased at 25^{o}C min^{-1} to 150^{o}C; and latter to 200^{o}C at 3^{o}C min^{-1}, and finally to 300^{o}C at 2^{o}C min^{-1}. Injection volume was 1μL via a pulsed spit-less mode. The temperature of the injection port, ion source, quadrupole and transfer line were 250, 230, 150 and 280^{o}C respectively. The sums of all aliphatic and sum of 16-PAHs measured by the GC provide measure of total petroleum hydrocarbons (TPHs) concentrations.

2.5. Identification and quantification

Identifications of aliphatic hydrocarbons, and polycyclic aromatic hydrocarbons (PAHs) were performed by comparing their retentions time with those of respective standards. The response factors associated with the respective internal standards based on five-point calibration curve for the fractionated n-alkanes (nC8- nC40), and individual PAH were used for quantifications. The nC8- nC40 standard mixtures (internal standard), and standard solution of 1-chlorooctadecane (surrogate standard) were used for the quantifications of the aliphatic hydrocarbons. Deuterated PAH internal standard solutions (naphthalene-d8, acenaphthene-10, phenanthrene-d10, chrysene-d12, and perylene-d12) and surrogate standard solutions (2-fluorobiphenyl and σ-terphenyl-d14) were however employed for the quantifications of PAHs and its procedural recovery.

2.6. Assessment of health risks

Health risk analyses were performed using fractional approach; were TPHs were grouped into three defined carbon ranges viz: low (C5-C8), medium (C9- C18), and high (C19-C36) with their characteristic reference doses of 0.3, 0.1, and 3.0mgKg^{-1}Day^{-1} (PPRTV, 2009). Exposures to TPHs through the consumptions of fish and snails from these areas were then assessed using the indices of: Daily Dietary intake (DDI), Hazard quotient (HQ), and Hazard index (HI) (Tongo *et al*., 2017; Chokor, 2023).

$$DDI = [C \times CR]/Bw \quad (1)$$

$$HQ = DDI/RfD \quad (2)$$

$$HI = \sum_{i=1}^{n} HQ \quad (3)$$

where, DDI refers to the daily dietary intake ($mgKg^{-1}bwDay^{-1}$), C is the concentrations (mg/Kg) of individual or fractions TPHs; CR is the consumption rate (g/Day), Bw is the average body weight (60Kg) of an adult, and RfD represent the reference dose for the fractions of TPH. The 7.6Kg per capita consumption rate of fish in Nigeria, which is equivalent to 20.8g/day, was used for the calculations of DDIs. The reference dose values for fractions of TPHs were taken from the USEPA Provisional Peer Reviewed Toxicity Values for complex mixtures of Aliphatic and Aromatic hydrocarbons (PPRTV, 2009). HQ (Hazard Quotient) and HI (Hazard Index) values above one represents possible adverse effects whereas those below one indicates negligible health effects (Bandowe *et al*., 2014; Chokor, 2023).

3. Results and discussion

3.1. Concentrations of TPHs in Faunas

The mean concentrations (mg/Kg) of TPHs in fish (*Clarias anguillaris*) and snails (*Achatina achatina*) from the different communities viz: Kolo (CT-1), imiringi (CT-2), and Otokputi (CT-3) were: CT-1 (229.33), CT-2 (19.00), and CT-3 (31.02) with a mean of 93.12 ± 118.11mg/Kg in fish samples; while that for the snails samples were: CT-1 (272.19), CT-2 (172.59), and CT-3 (281.68) with an average value of 242.15 ± 60.43mg/Kg. The values showed much variability in the fish samples compared to the snail samples. The values for both faunas were higher than the European Union (EU, 2005) recommended value of 2µg/Kg for foods. The values were also much higher than those reported in faunas by Ashraf and Mian (2010), Tolosa *et al* (2005), and Oparaji *et al* (2017) (Table 1). They were however much lower than those reported by Ogeleka *et al* (2016), Musa et al (2011), Ahmed *et al* (2014), and Akinola *et al* (2020) (Table 1).

3.2. Aliphatic profiles and source identifications.

The average distributions of the aliphatic hydrocarbons in faunas (fish and snails tissues) at the different sampled stations are shown in Table 2. The most visible hydrocarbons in tissues of fish samples were: C8, C9, C11, C17, C32, and C33. In the snail samples, it was hydrocarbons of the range C12 – C21 that was most dominant.

Table 1: Comparison of TPHs levels in faunas tissues in this study with those of others.

Region	Range and/ or mean* of TPHs (mg/Kg)	References
Odidi River, Delta State, Nigeria(fish & snails tissues)	(58334±32), (103380±98)	Ogeleka *et al*., 2016
Eqwa River, Delta State, Nigeria (fish & snails tissues)	(58314±35), (103180±99)	Ogeleka *et al*., 2016
Egyptian Mediterranean Sea water (8fishes tissues)	2100 – 4249 Winter 790 – 9186 Summer	Musa *et al*.,2011
Suez Gulf Coast (aquatic species)	987.43 – 2754.2	Ahmed *et al*., 2014
Coastal area of Ondo State, Nigeria (N. hastatus)	1995.99 – 3401.55	Akinola *et al*., 2020
Arabian Gulf (Scarus ghabon)	(7.4)	Ashraf and Mian, 2010
Al Marfa, UAE (Epinephelus coioides & Lethrinus nebulosus)	(2.07), (3.40)	Tolosa *et al*., 2005
Forcados Terminals Rivers in Delta & Rivers State, Nigeria	0.09 – 3.63 0.02 – 0.29	Oparaji *et al*., 2017
Ogbia LGA (fishes: edible portion)	19.00 – 229.33 (93.12)	This study
Ogbia LGA (snails: edible portion)	172.59 – 281.68 (242.15)	

* mean in Brackets

This was followed by those in the range of C29 – C33. The isoprenoid hydrocarbons – pristane and phytane – were also present in almost all samples – both fish and snails' samples. The Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG, 1997), classified TPHs into: Gasoline Range Organic (GRO) (C6-C10), Diesel Range Organic (DRO) (C10-C28), and Oil Range Organic (ORO) (>C28). Based on this classification, we can deduce that the tissues (of both fish and snails) were majorly contaminated by the Diesel Range Organic. The organisms could have directly adsorbed these hydrocarbons from the environment, or must have feed on other organisms or organic matter containing such hydrocarbons. Spilled oil, fumes and leakages from trucks and generators, leachates from automobiles and power engines servicing sites, as well as hydrocarbons in air washed down by the rains are possible sources of hydrocarbons in organisms' environment (Chokor, 2024). The USEPA committee on Provisional Peer Reviewed Toxicity Values for complex mixtures of aliphatic and aromatic hydrocarbons (PPRTV, 2009), grouped hydrocarbons on the basis of their chemical and toxicological properties into: low carbon range (LCR) (C5-C8), medium carbon range (MCR) (C9-C18), and high carbon range (HCR) (C19-C36). We can deduce based on this classification, that both C9 - C18, and C19 - C36 hydrocarbons fractions were quite abundant in the organisms tissues.

Table 2: Mean Aliphatic profiles of hydrocarbons in Faunas tissues at the different communities.

Samples Conc. (mg/Kg)	Fish			Snails		
	CT-1	CT-2	CT-3	CT-1	CT-2	CT-3
C8	79.47	0.90	10.58	7.91	1.29	3.65
C9	62.54	8.04	8.33	4.54	1.05	13.60
C10	3.34	0.06	0.49	4.02	1.30	0.50
C11	7.52	1.00	1.02	1.07	0.60	2.64
C12	3.74	1.50	0.50	11.55	11.59	15.90
C13	2.68	0.16	0.35	13.82	14.19	19.41
C14	1.63	0.08	0.55	6.13	16.48	17.46
C15	3.03	0.36	0.42	17.47	16.97	22.92
C16	1.52	0.20	0.25	9.14	12.57	17.84
C17	6.62	1.87	0.91	3.52	9.85	15.04
Pr	1.72	0.18	0.23	21.87	26.11	37.34
C18	0.09	2.58	0.24	11.56	8.15	12.51
Ph	0.02	0.01	Bd	23.25	12.16	19.93
C19	0.32	0.14	0.04	7.96	6.40	10.61
C20	0.45	0.25	0.07	6.01	4.88	12.00
C21	0.54	0.24	0.09	4.24	1.67	10.87
C22	0.24	0.03	0.03	2.37	1.65	4.66
C23	0.23	0.12	0.03	4.09	1.62	1.42
C24	4.11	0.17	0.56	6.25	0.95	2.35
C25	3.88	0.20	Bd	6.48	2.33	5.93
C26	0.37	0.02	0.06	8.32	0.32	1.87
C27	0.29	Bd	0.04	4.76	1.17	4.39
C28	1.00	0.01	0.12	11.45	1.99	1.39
C29	1.97	0.02	0.24	12.88	2.67	8.58
C30	2.69	0.06	0.35	9.13	3.37	0.81
C31	1.44	0.04	0.38	10.61	2.02	2.68
C32	6.85	0.25	0.97	17.87	1.19	1.53
C33	13.23	0.05	1.74	7.32	2.39	5.33
C34	4.69	Bd	0.53	7.37	1.88	1.04
C35	4.83	0.03	0.63	2.32	1.56	2.52
C36	0.92	Bd	0.10	0.89	0.01	0.70
C37	3.56	0.01	0.34	1.69	0.01	0.25
C38	1.60	Bd	0.15	0.56	0.01	0.10
C39	0.87	Bd	0.13	Bd	0.07	0.03
C40	0.70	Bd	0.03	Bd	Bd	Bd
TAH	228.69	18.59	30.51	268.41	170.49	277.80
∑PAHs	0.64	0.41	0.51	3.78	2.10	3.88
TPHs	229.33	19.00	31.02	272.19	172.59	281.68

*TAH: Total Aliphatic Hydrocarbons, ∑PAHs: Sum of sixteen polycyclic aromatic hydrocarbons, TPH: Total Petroleum Hydrocarbons, Bd: Below detection

Table 3: Source diagnostic indices calculated for faunas tissues at the different communities

	Fish Samples			Snails Samples		
Diagnostic indices	CT-1	CT-2	CT-3	CT-1	CT-2	CT-3
E/O	0.078	0.149	0.248	0.689	0.442	0.605
CPI	1.3597	0.791	1.182	0.7848	1.2789	3.7197
∑LMW/∑HMW	0.289	4.427	0.376	0.492	2.331	1.720
Pr/Ph	101.4	34.68	73.97	0.94	2.15	1.87

Table 3 shows the diagnostic indices for sampled tissues from the different Communities. The Even to odd numbered alkane ratio (E/O) for all samples (both fish and snails) were less than one; elucidating strong element of biogenic contributions. The evidence of biogenic contributions was supported by the high pristane/ phytane (Pr/Ph) ratios in the fish samples. In the snails, Pr/Ph ratios were relatively smaller ranging between 0.94 – 2.17; however, except for Kolo Community (CT-1) (0.94), the other communities had values that were slightly higher than one indicting biogenic origin. These biogenic hydrocarbons in the tissues could have come from direct adsorption from the environment, dietary uptake through the food chain, as well as synthesis of these hydrocarbons by the organisms themselves. According to Chokor (2022), the predominance of odd numbered alkanes (nC15, nC17, nC19) over even numbered alkanes (nC16, nC18, nC20), as reflected in the even to odd numbered alkanes ratio (E/O) less than unity (1) connote biogenic inputs. The reverse is true for anthropogenic inputs (Sakari *et al*., 2012; Adeniji *et al*., 2017). The Pr/Ph ratios have been use as a diagnostic tool; abundance of pristane over phytane is a clear signal of biogenic inputs whereas, dominance of phytane over pristane indicates the presence of petroleum (Abdullah *et al*., 2015; Chokor, 2022).

However, when the ratios of even to odd number alkanes were calculated using Carbon preference index (CPI), evidence of petrogenic contributions to contaminations become more obvious. The CPI values for the fish samples range from 0.79 – 1.359, evidencing of petrogenic and degraded petroleum. The snail samples showed mean CPI values of: CT-1 (0.78), CT-2 (1.278), and CT-3 (3.979). Except for Otuokpoti (CT-3) which implicated biogenic source, the other stations also demonstrated evidence of degraded petroleum and petrogenic source. The CPI measures the ratio of odd to even numbered hydrocarbons using a different formula as expressed in Eq. 4; and has been useful in indexing the predominance of natural hydrocarbons over anthropogenic ones or otherwise.

$$CPI_{25\text{-}33} = 0.5 \text{ X } [(C25 – C33)/ (C24 – C32)] + [(C25 – C33)/(C26 – C34)] \quad \text{(Eq. 4)}$$

Ratio of this index in the neighbourhood of one (1) implicates crude oil sources; while values below unity represent degraded crude oils. Value of CPI higher than one (1), especially in the range of 3 – 10 typified biogenic inputs. These inputs may come from marine algae, or terrestrial vascular plants (Jeaneau *et al*., 2006; Maioli *et al*., 2011; Onyema *et al*., 2013; Iheonye *et al*., 2019; Chokor and

Achugwo, 2022). Evidence from the sums of low molecular weight to high molecular weight hydrocarbons (∑LMW/∑HMW) ratios (Table 3), also gave credence to both petrogenic and biogenic sources. Hydrocarbon source can be characterized by ∑LMW/∑HMW ratio. Ratios lower than unity (1) implicate biogenic sources (inputs from higher plants, marine animals and sedimentary bacterial), whereas those higher than one represents petrogenic source (Farid *et al*., 2014; Kanzari *et al*., 2014; Chokor, 2022). The values obtained in this study ranged from 0.289 – 4.427, and 0.492 – 2.33 in fish and snail respectively indicating mixed origin of TPHs in the samples.

3.3. Health risk assessment

The values for calculated daily dietary intake (DDI), hazard quotient (HQ), and hazard Index (HI) (∑HQ) for the faunas samples from the different stations are as shown in Table 4. The health risks were assessed using fractional approach were TPHs were grouped into three different fractions viz: C_5- C_8, C_9-C_{18}, and C_{19}-C_{36}. The determination method used in this study did not allow for complete determination of the first group (C_5-C_8). However, the C_8 values determined were used. The estimated DDI for the petroleum hydrocarbons fractions ranges from 0.000312 – 0.0276, and 0.000448 – 0.274 $mgKg^{-1}bwDay^{-1}$ in fish and snail respectively. The sums of the DDIs for all fractions in fish were: 0.0771, 0.00645, and 0.00706 $mgKg^{-1}bwDay^{-1}$ in communities CT-1, CT-2, and CT-3 respectively. In the snails' samples values in $mgKg^{-1}bwDay^{-1}$ were: CT-1 (0.296), CT-2 (0.059), and CT-3 (0.0963). The hazard quotients for the fractions were of the range: 0.0001897 – 0.328, and 0.00148 – 0.913 in fish and snails respectively. The sum of the hazard quotient (hazard index) for the fish samples from the various communities were: CT-1 (0.425), CT-2 (0.057), and CT-3 (0.048). While, that for snail samples were: 1.357, 0.461, and 0.690 for communities CT-1, CT-2, and CT-3 respectively. Hazard quotients and index values smaller than one (<1) suggest that these fractions individually and collectively are incapable of causing harm to the human health and environment. However, values larger than one (>1) implicate the possibility of causing harm either individually or collectively (Chokor, 2023).

Table 4: Calculated DDI, HQ, and HI for faunas samples from the communities

Indices	Fish samples			Snails samples		
	CT-1	CT-2	CT-3	CT-1	CT-2	CT-3
DDI_{C5-C8}	0.0276	0.000312	0.000367	0.274	0.000448	0.00127
HQ_{C5-C8}	0.092	0.00104	0.00122	0.913	0.00149	0.00423
DDI_{C9-C18}	0.0328	0.00557	0.00461	0.0443	0.0455	0.0677
HQ_{C9-C18}	0.328	0.0557	0.0461	0.433	0.455	0.677
$DDI_{C19-C36}$	0.0167	0.000569	0.00208	0.00462	0.0132	0.0273
$HQ_{C19-C36}$	0.00557	0.0001897	0.000693	0.00154	0.0044	0.0091
∑DDI	0.0771	0.00645	0.00706	0.296	0.059	0.0963
∑HQ	0.425	0.057	0.048	1.357	0.461	0.690

The calculated HI values at a consumption rate of 20.8gday-1 were all less than one except in snail samples from CT-1 (Kolo). The deduction to be drawn from this study is that levels of TPHs in fish and snails sampled from these area are save for consumption at the specified consumption rate (20.8 gday-1) except those snails from Kolo axis whose hazard index were slightly higher than one.

Conclusion

Examination of fauna tissues for TPHs revealed mean values of 93.11 ± 118.11 and 242.15 ± 60.48mg/Kg for fish and snail respectively. Health risk assessment using Dietary Daily Intake (DDI), Hazard Quotient (HQ), and Hazard Index (HI) indicated that tissues concentrations were within safe limit except for the snail samples taken from Kolo axis that were slightly higher than the safe limit. Effort to keep TPHs levels in soils and water environment as low as possible is recommended in order prevent unnecessary accumulations in the food chain.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

Abdallah, R.I., Khalil, N.M., Roushdie, M.I. (2015) Monitoring of Pollution in Egyptian Red Sea. *Egyptian Journal of Petroleum* 24, 59-70

Abha, S., Singh, C.S. (2012) Hydrocarbon pollution: effects on living organisms' remediation of contaminated environments, and effects of heavy metals co-contamination on bioremediation. In: Introduction to Enhanced Oil Recovery (EOR) Processes and Bioremediation of Oil-Contaminated Sites, pp. 186–206.

Adeniji, A., Okoh, O., Okoh, A. (2017) Petroleum hydrocarbon fingerprints of water and sediment samples of Buffalo River Estuary in the Eastern Cape Province, South Africa. *Journal of Analytical Methods in Chemistry* 2017, 1-10.

Ahmed, O.E., Ali, N.A., Mahmoud, S.A., Doheim, M.M. (2014) Environmental Assessment of Contamination by Petroleum Hydrocarbons in the Aquatic Species of Suez Gulf, International *Journal of Modern Organic Chemistry*, 3(1), 1-17

Akinola, J.O., Olawusi-Peters, O.O., Apkambang, V.O.E., (2020) Human health risk assessment of TPHs in brackish water prawn (Nematopalaemon hastatus, AURIVILLUS, 1898) *Heliyon* 6 (2020) e03234

Al-Shwafi, N. A. A. (2008) Total petroleum hydrocarbon carcinogens in commercial fish in the red sea and Gulf of Aden-Yemen. *Marine Science* 19, 15–28.

Asghar, H.N., Rafique, H.M., Zahir, Z.A., Khan, M.Y., Akhtar, M.J., Naveed, M., Saleem, M., (2016) Petroleum hydrocarbons-contaminated soils: remediation approaches, Soil science: agricultural and environmental prospective. Springer, pp. 105-129.

Ashraf, W. and Mian, A. (2010) Total Petroleum Hydrocarbon (TPH) Burden in Fish Tissues from the Arabian Gulf, *Toxicological and Environmental Chemistry* 92(1), 61 – 66

Bandowe, B.A.M., Bigalke, M., Boamah, L., Nyarko, E., Saalia, F.K., Wilcke, W. (2014) Polycyclic aromatic compounds (PAHs and oxygenated PAHs) and trace metals in fish species from Ghana (West Africa): Bioaccumulation and health risk assessment, *Environ. Int.*, 65, 135–146.

Briggs, I. L., Briggs, B.C. (2018) Petroleum industry activities and human health A2-Ndimele, Prince E," The political ecology of oil and gas activities in the Nigerian aquatic ecosystem, Ndimele, P.E. ed., Academic Press, pp. 143-147.

Chokor, A.A. (2021) Total petroleum and aliphatic hydrocarbons profile of the River Niger surface water at Okpu and Iyiowa-Odekpe regions in South-Eastern, Nigeria. *Chemistry International*, 7(3), 188 – 196.

Chokor, A.A. (2022) Distribution and Source Fingerprinting of Total Petroleum Hydrocarbons in Sediments of the River Niger at Okpu and Iyiowa-Odekpe Axes in South-Eastern, Nigeria, *World News of Natural Sciences*, 42, 151 – 168.

Chokor, A.A. (2023) Impact Assessment of some Toxic Phenols and Heavy Metals in Farmlands' Soils of Obio-Akpor LGA, Rivers State, Nigeria, *J. Mater. Environ. Sci*., 14(12), 1517-1528

Chokor, A.A. (2024) Levels, Profiles, and Sources of Total Petroleum Hydrocarbons (TPHs) in Sediments of the Aba River at Ogbor-Hill Region, South-Eastern, Nigeria, *World Scientific News*,187, 31-46

Chokor, A.A. and Achugwo, C.N. (2022). Distribution, Source Identification and Eco-toxicological Risks of PAHs in Sediments of Aba River at Ogbor-Hill Region, Nigeria, *Chemistry International*, 8(2), 47 – 57.

EC (2005) European Commission, Commission Regulation (EC) No 208/ 2005, *Off. J. Eur. Union L* 34, 3– 5.

Enuneku, A.A., Ainerua M., Erhunmwunse, N.O., Osakue O.E. (2015) Total petroleum hydrocarbons in organs of commercially available fish; *Trachurus Trecae* (Cadenat, 1949) from Oliha Market, Benin City, Nigeria. *Ife Journal of Science* 17, 383–393.

Ezekwe, C.I., Edoghotu, M.I. (2015) Water quality and environmental health indicators in the Andoni River estuary, Eastern Niger Delta of Nigeria. *Environmental Earth Sciences* 74, 6123-6136.

Farid, N.A., Mahmoud, S.A., Ahmed, O.E. (2014) Assessment of Contamination by Petroleum Hydrocarbons in Sediments along Discharge Basin of Suez Oil Refinery Company, Southwest of the Suez Gulf. *Egyptian Journal of Chemistry* 57, 75-96.

Gudzenko, N., Hatch, M., Bazyka, D., Dyagil, I., Reiss, R.F., Brenner, A., Chumak, V., Babkina, N., Zablotska, L.B., Mabuchi, K. (2015) Non-radiation risk factors for leukaemia: A case-control study among chornobyl clean-up workers in Ukraine. *Environmental Research* 142 (Supplement C), 72-76.

Hurtig, A. K., San Sebastian, M. (2002) Geographical differences in cancer incidence in the Amazon basin of Ecuador in relation to residence near oil fields. *International Journal of Epidemiology* 31, 1021-1027.

Iheonye, C., Osuji, L.C., Onyema, M.O. (2019) Petroleum contamination of Sombreiro River in Akuku-Toru Local Government Area Rivers State, Nigeria, Revealed by Chemical fingerprinting of aliphatic hydrocarbons. *J. Appl. Sci. Environ. Manage*. 23(4), 805-809

Ite, A.E., Harry, T.A., Obadimu, C.O., Asuaiko, E.R., Inim, I.J. (2018) Petroleum hydrocarbons contamination of surface water and groundwater in the Niger Delta region of Nigeria. *Journal of Environment Pollution and Human Health* 6(2), 51-61. doi: 10.12691/jephh-6-2-2.

Iyang, S.E. Aliyu, A.B. Oyewale, A.O. (2018) Total petroleum Hydrocarbons content in Surface Water and Sediment of Qua-Iboe River, Ibeno, Akwa-Ibom State, Nigeria, *J. Appl. Sci. Environ. Manage.*, 22(12), 1953-1959

Jeanneau, L., Faure, P., Montarges-Pelletier, E., Ramelli, M. (2006) Impact of a highly contaminated river on a more important hydrologic system: changes in organic markers. *Sci. Total Environ*. 372, 183-192

Kanzari, F., Syakti, A.D., Asia, L., Malleret, L., Piram, A., Mille, G., Doumenq, P. (2014) Distributions and sources of persistent organic pollutants (aliphatic hydrocarbons, PAHs, PCBs and pesticides) in surface sediments, of an industrialized urban river (Huveaune), France. *Science of the Total Environment*, 478, 141-151

Kponee, K. Z., Chiger, A., Kakulu, I. I., Vorhees, D., Heiger-Bernays, W. (2015) Petroleum contaminated water and health symptoms: a cross-sectional pilot study in a rural Nigerian community. *Environmental Health* 14, 86.

Lee, K., Boufadel, M., Chen, B., Foght, J., Hodson, P., Swanson, S., Venosa, A. (2015) Expert panel report on the behaviour and environmental impacts of crude oil released into aqueous environments. *Royal Society of Canada, Ottawa*, ON. ISBN: 978-1-928140-02-3.

Maioli, O.L.G., Rodrigues, K.C., Knoppers, B.A., Azevedo, D.A. (2011) Distribution and sources of aliphatic and polycyclic aromatic hydrocarbons in suspended particulate matter in water from two Brazilian estuarine systems. *Continental Shelf Research* 31, 1116–1127.

Mousa, A.M., Farid, N.A., Ahmed, O.E. (2011) Contamination of fish by oil pollution along the Egyptian Mediterranean Sea water, *The 14th International Conference on petroleum Mineral Resources, Egyptian Petroleum Research institute*, 2011, March 27-29.

Ogeleka, D. F., Edjere, O., Nwudu, A., Okieimen, F.E. (2016) Ecological effects of oil spill on pelagic and bottom dwelling organisms in the riverine areas of Odidi and Egwa in Warri, Delta State. *Journal of Ecology and the Natural Environment*, 8(12), 201-211

Olawoyin, R., Larry Grayson, R., Okareh, O.T. (2012) Eco-toxicological and epidemiological assessment of human exposure to polycyclic aromatic hydrocarbons in the Niger Delta, Nigeria. *Toxicology and Environmental Health Sciences*, 4, 173-185.

Onyema, M.O. Osuji, L.C. Ofodile, S.E. (2013) Geochemical fingerprinting of an oil-impacted site, Niger Delta: source and weathering profile of aliphatic hydrocarbons. *Researcher* 5, 16-21.

Oparaji, E.H., Nweze, E.J., Agbo, K.U., Arinzechukwu, E.O., Anosike, J.C., et al., (2017) Estimations of polycyclic aliphatic hydrocarbon and total petroleum hydrocarbon in aquatic faunas found in forcardos terminal river in Port harcourt, rivers state. *J. Environ. Anal. Toxicol*. 7 (6), 519-523.

Ordinioha, B., Brisibe, S. (2013) The human health implications of crude oil spills in the Niger delta, Nigeria: An interpretation of published studies. *Nigerian Medical Journal*, 54 (1), 10-16

Oyibo, J.N., Wegwu, M.O., Uwakwe, A.A., Osuoh, J.O., et al. (2018) Analysis of total petroleum hydrocarbons, polycyclic aromatic hydrocarbons and risk assessment of heavy metals in some selected fin fishes at Forcados Terminal, Delta State, Nigeria. *Environmental Nanotechnology, Monitoring and Management* 9: 128–135.

PPRTV (2009) USEPA Provisional Peer Reviewed Toxicity Values for Complex Mixtures of Aliphatic and Aromatic Hydrocarbons, *US Environmental Protection Agency, Superfund Health Risk Technical Support Centre, National Centre for Environmental Assessment*, Office of Research and Development: Washington, DC, USA., EPA/690/R-09/012F, 2009.

Sakari, M., Zakaria, M.P., Lajis, N.H., Mohamed, C.A.R., Abdullah, M.H. (2012) Reconstruction of aliphatic hydrocarbon history and sources from sedimentary record of the Johor Strait, Malaysia. *Coast. Mar. Sci.* 35, 142-152

Sudakin, D.L., Stone, D.L., Power, L. (2011) Naphthalene Mothballs: Emerging and Recurring Issues and their Relevance to Environmental Health. Current Topics in Toxicology 7, 13-19.

Tolosa, I., De Mora, S., Sheikholeslami, M.R., Villeneuve, J., Bartocci, J., Cattini., C. (2004) Aliphatic and aromatic hydrocarbons in coastal Caspian Sea sediments. *Marine Pollution Bulletin*, 48, 44-60

Tolosa, I., de Mora, S.J., Fowler, S.W., Villeneuve J.P., Bartocci, J., Cattini C. (2005) Aliphatic and aromatic hydrocarbons in marine biota and coastal sediments from the Gulf and the Gulf of Oman' , *Mar. Pollut. Bull*. 50, 1619-1633

Tongo, J.I., Ogbeide, O., Ezemonye, L. (2017) Human health risk assessment of polycyclic aromatic hydrocarbons (PAHs) in smoked fish species from markets in Southern Nigeria, *Toxicology Reports*, 4, 55 – 61.

TPHCWG (1997) Selection of Representative TPH Fractions Based on Fate and Transport Considerations, *Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG) Series*, (John B. Gustafson, Ph.D.; Joan Griffith Tell, Ph.D. and Doug Orem). (1997) vol. 3, (http://www.aehs.com/)

Ying W., Jiang F., Qianxin L., Xianguo L., Xiaoyu W., Guopin W. (2013) Effects of Crude Oil Contamination on Soil Physical and Chemical Properties in Momoge Wetland of China. *Chin. Geogra. Sci.*, 23(6), 708–715.