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Distribution, Source Appropriation, and Human Health Risk Assessment of Polycyclic Aromatic Hydrocarbons due to Consumption of *Callinectes amnicola* from Woji Creek in Sambreiro River

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Abstract

Crabs (*Callinectes amnicola*) and surface water sampled from the Sambreiro River, Rivers State of Nigeria, were analyzed for polycyclic aromatic hydrocarbons concentrations for four months (December (2019), January, February, and March (2020)). Excess cancer risk due to ingestion of the crabs was assessed for individuals of the age groups: 3 to < 6 years, 16 to < 21 years, 21 to < 50 years, and ≥ 50 years. Although concentrations in surface water (ΣPAH_{16} = 0.125±011 mg/L) were lower than in the previous study, results obtained revealed considerably higher concentrations of aromatic hydrocarbons in crab tissues (ΣPAH_{16}=10.659±2.399 mg/kg). Hepatopancreas (ΣPAH_{16}=6.590±0.266 mg/kg) accumulated the highest concentration of hydrocarbons followed by the gills (ΣPAH_{16}=2.349±0.029 mg/kg), then the muscles (ΣPAH_{16}=1.720±0.320 mg/kg). Source appropriation results revealed a combination of the petrogenic and pyrogenic contribution of hydrocarbons in the crab tissues. The trend for the toxicity equivalent quotient was hepatopancreas > muscles > gills; while the excess cancer risk exceeded for all age groups, suggesting that humans are at risk of cancer arising from the ingestion of crab species from this study location.

Introduction

Polycyclic aromatic hydrocarbons (PAHs) occur naturally as pollutants of soil, air, and water; they are constituents of organic compounds made up of two or more fused aromatic rings (Meador, 2008). They enter the environment naturally and through anthropogenic activities; the three major sources of PAHs are pyrogenic, petrogenic, and biological (Abdel-Shafy & Mansour, 2016). The release of industrial effluent mixed with municipal wastewater and the incomplete combustion of coal and oil have resulted in the accumulation of PAHs in the environment (Cai et al., 2007; Wu, 2020). In the aquatic environment, PAHs can accumulate in the macroinvertebrate (Girardin et al., 2020), which plays an important role in the aquatic food chain (Villamagna & Murphy, 2010). The most common route of PAHs accumulation is through ingestion (Wu, 2020); in addition to exposure through ingestion of biota accumulated with PAHs, the ingestion of microplastics can also serve as a means through which PAHs can enter higher aquatic organisms (Crawford & Quinn, 2017).

Order Decapoda (shrimps, crayfish, lobsters, and crabs) are crustaceans with carapace and compound eyes; they grow by molting and usually live at the bottom of the water column (William, 1996). The makeup of their respiratory system comprises of the gills located as brachial chambers along both thoraces and connected to the maxillipeds and pereiopods (Burggren & McMahon, 1983). The gills or crabs receive a stream of water by the beating actions of scaphognathites or gill bailers. The hemolymph (blood) fills the hemocoel (body

cavity) of a crab creating an open circulatory system in which the organs are directly fed with oxygen and nutrients (Cumberlidge et al., 2015). Mouth, esophagus, stomach hepatopancreatic glands, midgut, and intestine are the constituent of the digestive system of a crab (Vogt, 2013). *Callinectes amnicola* (Rochebrune, 1883) from the family Portunidae are common in the estuaries of tropical and subtropical regions; this species of crab is indigenous to the coast of Nigeria (Ezekiel & Bernard, 2014). This crab species serves as an important nutritional source of protein to coastal dwellers in Africa (Oduro et al., 2001).

Figure 1. Sambreiro River in Port Harcourt, Rivers State (Nigeria) and five sample stations (St1 – St5)

Table 1. Percentage recovery analysis of PAH compound

Compound	Sample without spike	Sample with spike	% Recovery
Naphthalene	0.799	2.299	100.0
Acenaphthylene	0.456	1.956	100.0
Acenaphthene	0.402	1.902	100.0
Fluorene	2.192	3.692	100.0
Phenanthrene	0.198	1.698	100.0
Anthracene	0.146	1.646	100.0
Fluoranthene	0.401	1.901	100.0
Pyrene	0.457	1.957	100.0
Benz [a] anthracene	0.243	1.743	100.0
Chrysene	0.408	1.908	100.0
Benzo [b] Fluoranthene	0.119	1.619	100.0
Benzo [k] Fluoranthene	0.060	1.560	100.0
Benzo (g, h, i) perylene	0.847	2.347	100.0
Benzo [a] pyrene		1.500	100.0
Dibenz (a, h) anthrancene		1.500	100.0
Indeno (1, 2, 3, -cd) pyrene			

Studies have also shown that PAHs can accumulate in the muscles, gills, and hepatopancreas of crabs exposed to aquatic systems contaminated by PAHs (Fernando et al., 2019; Mothershead & Hale, 1992). An initial study carried out by Ihunwo et al. (2019) identified high concentrations of PAHs in surface water and sediment sampled from Woji creek. Therefore, this study was designed to assess the concentrations of PAHs in surface water and crab tissues (hepatopancreas, gills, and muscles) collected from Woji Creek in the Niger Delta Region of Nigeria.

Materials and Method

Study Area

The terminal of the North Atlantic Ocean in the Niger Delta is at the Sambreiro River, where Woji creek (study area) is a significant tributary. Woji creek serves as a source of seafood, and a major route for ocean liners to convey goods and services in and out of Port Harcourt; and as such has facilitated the transportation of petroleum products, manufacture and maintenance of petroleum carrying vessels, and hosts a lot of companies that are involved in stevedore business (Dibofori- Orji et al., 2019; Ibezim-Ezeani & Ihunwo, 2020). More so, the creek harbors wrecked boats, films from diesel boats, boats and barges, boatyards, floating films of oil on the water surface, industrial and municipal effluents, etc.; coupled with the activities of bunkers who spill oil along this creek causing environmental pollution and impacting negatively on the aquatic and terrestrial lives. The five stations selected along the 1.3 km stretch of Woji Creek was identified and the study area located as follows: St1 - 4°48'52.8"N 7°02'46.7"E, St2 - 4°48'46.4"N 7°03'14.6"E, St3 - 4°48'25.8"N 7°03'36.4"E, St4 - 4°48'11.3"N 7°03'55.5"E, and St5 - 4°47'47.8"N 7°04'07.5"E (Figure 1).

Sample Collection, Extraction, and Analysis

Crab nets were placed at each station; with the aid of a boat, crabs were captured at each sample station. Adult crabs were selected irrespective of sex. From each station, five crabs were collected; the crabs collected were put into well-labeled plastic zip-lock bags and put into a cooler with ice. Water samples from each station were collected using well-labeled borosilicate glass jars; three samples were collected across each station. Sampling was done weekly for four months (December (2019), January, February, and March (2020)).

In the laboratory, all crab samples were washed with distilled water to remove possible external sources of PAHs. Using a scalpel, scissors, and forceps, the crabs were opened; the hepatopancreas, gills, and muscles were collected and put into sterile vials. Two grams of each sample tissue was homogenized using a blender; the homogenized sample was added into a 10 ml of extraction solvent, dichloromethane (DCM), and shaken (thoroughly mixed). The shaken mixture was kept to separate the organic layer from the aqueous layer. The aqueous layer was carefully filtered using filter paper. The methodology employed is summarized in Method 8270E: Semi-volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS) (U.S. EPA, 2014). Analysis of the PAHs concentration was determined by the means of the Agilent 7890B Gas Chromatograph (GC-MS) produced by Agilent Technologies, Inc. in Santa Clara, Colifonia United States.

Table 2. PAH ratios for source appropriation

PAH ratio	Value range	Source	Reference
ΣLMW/ΣHMW	<1	Pyrogenic	(W. Zhang et al., 2008)
	>1	Petrogenic	
F/ (F + Pyr)	<0.5	Petrol emissions	(Ravindra et al., 2008)
	>0.5	Diesel emissions	
Ant/ (Ant + Phe)	<0.1	Petrogenic	(Pies et al., 2008)
	>0.1	Pyrogenic	
Flu/ (Flu + Pyr)	<0.4	Petrogenic	(De La Torre-Roche et al., 2009)
	0.4–0.5	Fossil fuel combustion	
	>0.5	Grass, wood, coal combustion	
BaAn/ (BaAn + Chy)	0.2–0.35	Coal combustion	(Akyüz & Çabuk, 2010)
	>0.35	Vehicular emissions	
	<0.2	Petrogenic	(Yunker et al., 2002)
	>0.35	Combustion	
IP/(IP + Bghi)	<0.2	Petrogenic	(Yunker et al., 2002)
	0.2–0.5	Petroleum combustion	
	>0.5	Grass, wood, and coal combustion	

(Tobiszewski & Namieśnik, 2012)

Quality Control and Quality Assurance

Surface water sample bottles used were washed with laboratory-grade detergent produced by Sigma-Aldrich and clean water, then rinsed thrice with Milli-Q. Further rinsing was done using Methanol, then Capillary GC pesticide residue grade methylene chloride and allowed to dry before use. By ensuring that the calibration range consists of no less than three linear concentration points, the calibration of the system was verified. Blank or zero analyte samples were run, and the assessment of bias was performed by analyzing in duplicate. Detection limits for hydrocarbon analyses were 0.00001 mg/L. The standard used was the AccuStandard (Catalog No: DRH-006S) with purity ranging from 96 to 100% for all components. Results of % recovery are presented in Table 1.

Data Analysis

Analysis of variance (ANOVA) was performed to assess statistically significant differences in PAH compounds in water samples and crab samples. PAH ratios (Table 2) were used to assess the possible sources of the PAHs sin water and crab tissues.

Human Health Risk Assessment

The toxic equivalent of benzo[a]pyrene (TEQ BaP) was used to assess the carcinogenic potential of PAHs in crab with equation 1:

$$TEQ\ (BaP) = \sum C_i \times TEF \qquad (1)$$

Where C_i is the concentration of individual PAH and TEF is the toxicity equivalent factor of individual PAH in the different crab tissues (USEPA, 1992).

Excess cancer risk (ECR) due to lifetime consumption of these crabs were estimated with equation 2:

$$ECR = \frac{\sum Q \times TEQ\ (BaP) \times IR \times ED}{BW \times AT} \qquad (2)$$

Where Q is the potential cancer factor of BaP (7.3 mg/kg/day), ED is the life time expectancy (70 years for adults), BW is body weight (3 to < 6 years=18.6 kg, 16 to < 21 years=71.6 kg, 21 to 50 years=80 kg, ≥ 50 years=80 kg), AT is the average life span for cancer (25,500 days), IR is ingestion rate for shellfish (3 to < 6 years=1 g/day 16 to < 21 years=0.61 g/day 21 to 50 years=0.65 g/day ≥ 50 years=0.41 g/day) (USEPA, 2018).

Results and Discussion

Distribution of PAH and Source Appropriation

Accumulation of PAHs in the tissues analyzed were in the trend hepatopancreas > gills > muscles (Table 3). Hepatopancreas accumulated the highest concentration of PAHs, and 14 PAH compounds were detected in this tissue. Mean concentrations of PAH ranged from 1.612 ± 0.012 mg/kg (Np) to 0.024 ± 0.001 mg/kg (F); mean Σ PAH_{16} in hepatopancreas was 6.590 ± 0.266 mg/kg. ANOVA revealed statistically significant difference in PAH concentrations in all hepatopancreas tissues. Twelve PAH compounds were detected in gill tissues; concentrations ranged from 0.855 ± 0.040 mg/kg (Phen) to 0.017 ± 0.001 mg/kg (Py). Σ PAH_{16} concentration in the gill tissues was 2.349 ± 0.029 mg/kg; ANOVA also revealed statistically significant difference in gill tissues of crabs analyzed. Also, ANOVA revealed statistically significant difference in the 13 PAH compounds identified in the muscles of crabs analyzed. Np has the highest concentration in the muscles (0.517 ± 0.011 mg/kg), while BaAn (0.022 ± 0.011 mg/kg) and Flu (0.022 ± 0.005 mg/kg) has the lowest concentrations of PAH in muscles. PAH concentrations in surface water were generally lower than those in the crabs. Four PAHs were detected in the surface water (Np - 0.038 ± 0.001 mg/L, Phen - 0.047 ± 0.002 mg/L, Ant - 0.017 ± 0.003 mg/L, Flu - 0.002 ± 0.002 mg/L, BaAn - 0.016 ± 0.004 mg/L and Chy - 0.005 ± 0.001 mg/L; with Σ PAH_{16} as 0.125 ± 011 mg/L).

LMW PAHs (2, 3, and 4 rings) have a higher proportion of the PAHs in the crab tissues and surface water compared to the HMW PAHs (5 and 6 rings). % LMW PAHs were: hepatopancreas – 58.6%, gills – 82.0%, muscles – 75.7% and surface water – 100%; while % HMW PAHs were: hepatopancreas – 41.4%, gills – 18.0%, muscles – 33.5% and surface water – 0%.

In a study carried out in 2018, Ihunwo et al. (2019) recorded 10 PAHs in the surface water (Acl, Ace, F, Ant, Flu, BaAn, Chy, B [b] Fl, B [k] Fl and BaP) with higher concentrations of PAHs ranging from 0.375 ± 0.033 - 3.161 ± 0.122 mg/L. Surface water sampled from the estuaries of Qua Iboe river recorded 17 PAHs with higher concentrations ranging from 9.443 ± 0.551 - 17.670 ± 3.836 mg/L (Okpashi et al., 2017). Table 4 shows the concentration of PAHs in crabs from different locations. Although the concetration of $\sum_{15}$PAHs in seawater from the nearshore (462 ± 244 ng L^{-1}) was higher than that from offshore (80.5 ± 72.1 ng L^{-1}) collected from Zhongsha Islands from the South China sea, the concentrations were lower than those sampled in the present study (R. Zhang et al., 2021). Similarly, PAH concentration in surface water sampled from Wuhai and Lingwu sections of the Yellow River varied from 27.5 ng/L to 234 ng/L and from 135 ng/L to 265 ng/L respectively (Liu et al., 2020), which were lower than those measured in the present study.

ΣLMW/ΣHMW ratio for crab tissues was > 1 indication a petrogenic source of PAHs accumulated in the crab (W. Zhang et al., 2008). Similarly, ratio of Ant/ (Ant + Phen) was above 0.1, confirming pyrogenic source of PAHs (Pies et al., 2008). However, according to the ratios Flu/ (Flu + Py) and BaAn/ (BaAn + Chy), there is also a combustion source input of PAHs (Akyüz & Çabuk, 2010; De La Torre-Roche et al., 2009; Yunker et al.,

Table 3. Concentrations of PAH in crabs and water, and PAH source apportionment ratios.

PAHs	Hepatopancreas (mg/kg)	Gills (mg/kg)	Muscles (mg/kg)	Total crabs (mg/kg)	Water (mg/L)
Np	1.612 ± 0.012*	0.504 ± 0.003*	0.517 ± 0.011**	2.634 ± 0.130**	0.038 ± 0.001**
Acy	<dl	<dl	<dl	<dl	<dl
Ace	<dl	<dl	<dl	<dl	<dl
F	0.024 ± 0.001*	<dl	<dl	0.024 ± 0.003*	<dl
Phen	1.124 ± 0.022*	0.855 ± 0.040*	0.448 ± 0.018**	2.427 ± 0.201**	0.047 ± 0.002**
Ant	0.443 ± 0.031*	0.325 ± 0.031*	0.190 ± 0.006*	0.958 ± 0.011*	0.017 ± 0.003**
Flu	0.054 ± 0.033*	0.037 ± 0.009*	0.022 ± 0.005*	0.113 ± 0.005*	0.002 ± 0.002**
Py	0.037 ± 0.006*	0.017 ± 0.001*	0.023 ± 0.003*	0.077 ± 0.010**	<dl
BaAn	0.353 ± 0.009*	0.135 ± 0.031**	0.022 ± 0.011**	0.510 ± 0.011**	0.016 ± 0.004**
Chy	0.214 ± 0.022**	0.054 ± 0.008*	0.080 ± 0.004*	0.349 ± 0.091**	0.005 ± 0.001**
B [b] Fl	0.045 ± 0.007*	<dl	0.030 ± 0.001*	0.075 ± 0.008*	<dl
B [k] Fl	0.065 ± 0.009*	0.029 ± 0.006*	0.030 ± 0.004*	0.124 ± 0.101*	<dl
BaP	0.674 ± 0.011**	0.083 ± 0.011*	0.100 ± 0.065**	0.857 ± 0.092**	<dl
Bghi	1.307 ± 0.009*	0.173 ± 0.003*	0.054 ± 0.003*	1.533 ± 0.002*	<dl
D [a,h] an	0.160 ± 0.107 *	0.089 ± 0.005*	0.146 ± 0.033**	0.395 ± 0.033**	<dl
IP	0.477 ± 0.033*	0.048 ± 0.002*	0.058 ± 0.002*	0.584 ± 0.006*	<dl
Σ PAH_{16}	6.590 ± 0.266 *	2.349 ± 0.029	1.720 ± 0.320	10.659 ± 2.399 *	0.125 ± 011**
2 rings %	24.5	21.5	30.1	24.7	30.5
3 rings %	24.1	50.2	37.1	32.0	50.9
4 rings %	10.0	10.3	8.6	9.8	18.6
5 rings %	11.9	4.8	9.3	9.9	-
6 rings %	29.5	13.2	15.0	23.6	-
Σ LMW PAHs	3.9	1.9	1.3	7.1	0.125
Σ HMW PAHs	2.7	0.4	0.4	3.6	-
% LMW PAHs	58.6	82.0	75.7	66.5	100.0
% HMW PAHs	41.4	18.0	24.3	33.5	-
ΣLMW/ΣHMW	1.4	4.6	3.1	2.0	-
F/ (F + Pyr)	0.4	-	-	0.2	-
Ant/ (Ant + Phen)	0.3	0.3	0.3	0.3	0.3
Flu/ (Flu + Pyr)	0.6	0.7	0.5	0.6	1.0
BaAn/ (BaAn + Chy)	0.6	0.7	0.2	0.6	0.8
IP/ (IP + Bghi)	0.3	0.2	0.5	0.3	-

*- statistically significant difference: P<0.05, **- statistically significant difference: P<0.001
<dl- below detectable limit

Table 4. Concentration (mg/kg) of PAHs in crabs from different locations.

Country, region	Sample location	Crab species	[PAHs]	Reference
Lagos, Nigeria	Ibasa area of Lagos Lagoon	*Callinectes amnicola*	2.40	(Akinsanya et al., 2018)
Lagos, Nigeria	Unilag lagoon front	*Callinectes amnicola*	264.61	(Rose et al. 2012)
	Mouth of Ogun River	*Callinectes amnicola*	170.02	
Lagos, Nigeria	Atlas Cove	*Callinectes amnicola*	60.3*	(Olayinka, 2019)
China	Bering and Chukchi Sea shelf	*Hyas Sp.*	72.88	(Ma et al., 2020)

*- concentration in µg/kg

2002). Hence, there is a combination of petrogenic and combustion source of PAHs, this is confirmed by IP/ (IP + Bghi) ratio which showed values between 0.2 – 0.5, indicating petroleum combustion (Yunker et al., 2002). This is in line with an earlier study carried out by Ihunwo et al. (2019) (Ihunwo et al., 2019). Therefore, over these years, although the concentration of PAHs earlier detected in the surface water has reduced, the crabs growing in this water, however, have accumulated the compounds in their tissues.

Due to the presence of highly polar hydrocarbon metabolites, including dihydroxy-compounds and their conjugates in the hepatopancreas of crabs, it is the site for PAHs metabolism (Lee et al., 1976). This accounts for the higher concentrations of PAHs detected in the hepatopancreas compared to the muscles and gills. This is supported by studies carried out by Nudi et al. (2007) (Adriana Haddad Nudi et al., 2007), Nudi et al. (2010) (Adriana H Nudi et al., 2010), and Yu et al. (2018) (Yu et al., 2018). The most common and water-soluble PAHs in the environment is Naphthalene. Np is also the simplest PAHs and through the process of crystallization and distillation, it is produced from coal tar (Phale et al., 2019). In *Scylla serrata*, results have revealed a decreasing trend in the hemolymph-related parameters induced by Np (Kannappan et al., 2005).

Human Health Risk Assessment due to Crab Consumption

TEQ (BaP) values were 8.07E-01 – hepatopancreas, 1.20E-01 – gills and 1.33E-01 – muscles; BaP contributed the highest toxicity equivalence (hepatopancreas - 6.74E-01, gills - 8.29E-02, muscles - 9.98E-02) (Table 5).

ECR due to ingestion by all age groups exceeded 1 X 10^{-6}, an indication of cancer risk due to the ingestion of crabs sampled from this study location (USEPA, 2018). TEQ (BaP) of *Callinectes amnicola* sampled from Atlas Cove, Nigeria (6.08E-02) was lower than those estimated for crabs in the present study (Olayinka, 2019). ECR of PAH in *Portunus trituberculatus* (4.58 X 10^{-6}) and *Charybdis japonica* (1.93 X 10^{-6}) sampled from Haizhou Bay fishing ground, and *Portunus trituberculatus* (2.97 X 10^{-6}) sampled from Lusi fishery fishing ground, both in South Yellow Sea, China, also indicated cancer risk (C. Zhang et al., 2020).

Benzo [a] pyrene is an IARC Group 1 human genotoxic carcinogen; in vivo experiments revealed tumorigenic potential in animals. The ability to induce tightly interconnected genotoxic and nongenotoxic epigenetic alterations is a key associate with the carcinogenic ability of BaP (Pogribny, 2019). The occurrence of cycloalkanes are detected naturally in crude oil and a variety of fuels and solvents derived from crude oil; the most common compounds encountered are based on cyclopentane and cyclohexane (Stauffer et al., 2008). BaP is converted in the liver to an epoxy diol (7,8-Dihydroxy-9,10-epoxy-7,8,9,10-tetrahydrobenzo [a] pyrene (Carey, 2003). Study has also shown that BaP can cross the human placenta in pregnant women and bind to fetal hemoglobin (Gray, 2014). Unlike BaP, Np is not metabolized in the liver into a diol epoxide, however, due to their relative abundance, they are considered as biomarkers of exposure (Ifegwu & Anyakora, 2016). In a 44-year-old man chronically exposed to Np powder occupationally, adverse effects such as the development of cataracts and retinal hemorrhage have been reported (Robles, 2005). There is also a relationship between exposure to Np and degeneration of the ciliary body and choroid; and pyrithione causes edema and degeneration of the choroid (Leandro & Richard, 2018).

Table 5. Toxicity equivalent quotient (mg/kg) and excess cancer risk due to ingestion of crabs

PAHs	TEF (BaP)[a]	Hepatopancreas	Gills	Muscles	Total crab
Np	0.001	1.61E-03	5.04E-04	5.17E-04	2.63E-03
Acy	0.001	-	-	-	-
Ace	0.001	-	-	-	-
F	0.001	2.45E-05	-	-	2.45E-05
Phen	0.001	1.12E-03	8.55E-04	4.48E-04	2.43E-03
Ant	0.01	4.43E-03	3.25E-03	1.90E-03	9.58E-03
Flu	0.001	5.43E-05	3.65E-05	2.19E-05	1.13E-04
Py	0.001	3.70E-05	1.66E-05	2.31E-05	7.67E-05
BaAn	0.1	3.53E-02	1.35E-02	2.24E-03	5.10E-02
Chy	0.01	2.14E-03	5.42E-04	8.00E-04	3.49E-03
B [b] Fl	0.1	4.49E-03	-	3.04E-03	7.54E-03
B [k] Fl	0.1	6.48E-03	2.94E-03	2.97E-03	1.24E-02
BaP	1	6.74E-01	8.29E-02	9.98E-02	8.57E-01
Bghi	0.01	1.31E-02	1.73E-03	5.36E-04	1.53E-02
D [a,h] an	0.1	1.60E-02	8.92E-03	1.46E-02	3.95E-02
IP	0.1	4.77E-02	4.84E-03	5.80E-03	5.84E-02
TEQ (BaP)		8.07E-01	1.20E-01	1.33E-01	1.06E+00
$ECR_{(ingestion)}$ 3 to < 6 years		8.69E-04	1.29E-04	1.43E-04	1.14E-03
$ECR_{(ingestion)}$ 16 to < 21 years		1.38E-04	2.05E-05	2.27E-05	1.81E-04
$ECR_{(ingestion)}$ 21 to < 50 years		1.27E-04	1.89E-05	2.10E-05	1.67E-04
$ECR_{(ingestion)}$ ≥ 50 years		8.28E-05	1.23E-05	1.36E-05	1.09E-04

Conclusion

This study was designed as a biological monitoring investigation of PAH following initial studies which revealed high concentrations of PAH in the surface water and sediment. In the present study, PAH concentrations in the crab tissues analyzed were higher than those in the surface water. In the PAHs tested, the LMW PAHs (2-3 rings) accounted for 66.5%, while HMW PAHs (4-6 rings) accounted for 33.5% of the total PAHs accumulated in the crabs. Source apportionment based on the ratios of compounds of PAHs suggested that the PAHs in the location of survey emanated from the combination of petrogenic and pyrogenic inputs; this is in line with earlier studies on source appropriation of PAHs in the creek. The ECR due to ingestion of crabs sampled from the studied location within the tested indicated carcinogenic risk arising from the consumption of crab species since the values exceeded 1 X 10^{-6}. This is the first study in this location that assessed PAH accumulation in crab tissues and the potential human health risk. Therefore, the findings of this study are pivotal to the health of the people in this region; it will also serve as a scientific record in time. The study also reveals that, although hydrocarbons in an aquatic system may reduce in surface water concentration due to water flow, it can persist in biological tissues for a longer period. Therefore, it is important to include biological monitoring in environmental assessment, especially in environments that have experienced considerable pollution events.

Ethical statement

All research studes submtted papers has been conducted n an ethcal and responsible manner, and is in full complance wth all relevant codes of expermentaton and legslatons.

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Author's Contributions

Owhonda C. Ihunwo: Conceptualization, Methodology, Software, Data curation, Writing- Original draft preparation.
Owhonda C. Ihunwo and Millicent U. Ibezim-Ezeani: Visualization, Investigation.
Millicent U. Ibezim-Ezeani: Supervision
Owhonda C. Ihunwo, Millicent U. Ibezim-Ezeani: Software, Validation

Conflict of Interest

The authors declare no conflict of interest

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