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Cancer and Non-Cancer Risk Associated With PAHs Exposure from Consumption of Fish from Komadugu River Basin, Yobe State, Nigeria

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Abstract

The occurrence of antibiotics in the marine environment over a long time period can lead to development of Fish (*Clarias anguillaris, Tilapia zilli, Synodontis budgetti* and *Heterotis niloticus*) samples from Komadugu river basin of Yobe State, Nigeria were collected on seasonal basis (rainy, dry seasons and harmattan period) for the determination of the levels of seventeen (17) polycyclic aromatic hydrocarbon (PAHs). Risk assessment was conducted to evaluate the risk associated with consumption of fish from the study area. The concentrations of all the PAHs in tissues of fish samples were determined using GC/MS SHIMADZU (Agilent 7890A). The levels of the studied PAHs were observed to be higher in the tissues of *Heterotis niloticus* with a total value of 4.23E+01 mg/kg, while the lowest concentrations were observed in the tissues of *Clarias anguillaris* with a total value of 3.95E+01 mg/kg. In all the fish samples studied, the seasonal accumulation were observed to be in the order of rainy>dry>harmattan. In the present study, the highest average daily dose (ADD) value in the fish studied was observed in the liver of *Heterotis niloticus* with a value of 1.38E-06 mg/kg day^{-1}, while the lowest value was observed in the intestine of *Tilapia zilli* with a value of 9.93E-13 mg/kg day^{-1}. These values are less than the tolerable daily dose limit from the daily per capital fish consumption of 7.00E-02 kg for Nigeria. The hazard quotient (HQ) values obtained for all the fish samples studied were all below one (1), this shows that the fish consumption in the study area are found to be free of risk. The highest hazard index (HI) value for PAHs was found in the gills of *Tilapia zilli* with a value of 2.98E-06, whereas the lowest level was observed in the intestine of *Tilapia zilli* with a value of 5.16E-14. The (HI) values of all the PAHs in the tissues of fish samples were less than one (1), this is an indication that there is no risk from the intake of these fish from the study area. The cumulative probability distributions of calculated incremental life expectancy cancer risk (ILECR) for different tissues of *Clarias anguillaris*, *Tilapia zilli, Synodontis budgetti* and *Heterotis niloticus* showed that, more than one in one million of the population is prone to cancer risk upon consuming of the fish samples from the study area.

Keywords: PAHs; Average daily dose; Hazard quotient; Hazard index; ILECR

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Introduction

Coastal ecosystems are under threat because of climate change and anthropogenic pressure due to PAHs are part of the list of the 12 POPs and benzo(a)pyrene (BaP) is the most toxic of the PAHs. The objective of this convention is to control, reduce or eliminate discharges, emission and losses of POPs into the environment [1]. Owing to the different physicochemical properties of organic contaminants, PAHs tend to interact to different extent with water, soil/sediments and biota. Sediment-pore water interaction is one of the most dominant process controlling the distribution and behavior of PAHs in the river [2]. Dynamics of a river or dam ecosystems are complex with some pollutants adsorbed onto organic matter, while some undergo microbial degradation. Since POPs are capable of undergoing bioconcentration and biomagnifications, comprehensive risk assessment can only be performed by monitoring the presence and levels of these compounds in common freshwater fish. The levels and presence of pollutants in fish therefore have a direct bearing on human health risk. The concentration of pollutants in fish also presents the bioavailable fraction of the pollutants in water bodies. Measurements of the levels of PAHs in water, fish and sediments give almost a complete picture of the distribution of the chemical in the aquatic ecosystem. However, chemical analysis of PAHs in fish is more complex than in water and sediments.

The complexity of PAHs analysis in fish is due to their rapid metabolism by fish, which then lead to steady state tissue levels of these compounds and thus account for the failure to demonstrate appreciable levels of PAHs in the sample. It is also due to the accumulation and depuration of PAHs in fish which can be influenced by various factors including route and length of exposure, lipid content of tissues, environmental factors, age, sex and exposure to other xenobiotics [3]. Therefore, often water and sediment samples are assessed for PAHs or other organic pollutants. The adverse effect of PAHs on human health as a result of inhalation of dust particles have been described as the most detrimental to human health. This is because small particles are associated with the higher pollutants concentrations. Also soil ingestion has been recognized to be as an important exposure route as water and food to human [4].

Fishing is an important activity in the Komadugu river basin. Fishing seasons vary between villages but the flood plain as a whole has an annual pattern of fishing activity related to the rise and fall of the rains. The intensity of fishing activity is low during the rains (June-September), highest at the end of the rainy season and the beginning of the dry season (November-February). The activity gradually declines during the course of the dry season, According to Matthes, in order to maintain the economic fishing activity in the basin, the minimum water depth of about one meter is required in the riverbed and flood plains [5]. Livestock grazing in the basin takes place by sheep, goats and cattle and the water requirement for livestock was estimated to be about 36, 300,000 per liters per day [6].

The Komadugu river Basin in Yobe State covers an estimated area of about 47,153 km^2 and supports a human and livestock population of over 1.4 million and 1 million respectively [7,8]. The State shares border with the Niger Republic to the North, Jigawa and Bauchi States to the West, Borno State to the East and Gombe and Borno States to the South. The area of study, which is in the Northern part of the State is Sahelian in nature and is being threatened by desertification. The Komadugu-Yobe basin from which the State derived its name, supplies up a source of over 1.12 billion cubic meters of surface water per year. It is located between latitude 10ºN and 13ºN and longitude 9.45°E and 12.30°E [9]. The Komadugu-Yobe River originates from the Jos Pleateau and Kano ends up in the Lake Chad, the river was formed by the confluence of the Hadejia and Jam is rivers. The distance between the confluence upstream of Gashua near Karage and the outlet at Yau is about 280 km but the length along the Yobe River is about 660 km due to the extensive river meanders [9]. The curvature is of advantage because it provides a large increase in river, frontage and easier abstraction of irrigation water for a large area. The geological formation of the upstream part of the basin consists largely of impermeable basement complex rocks, which dips away to the east where it is covered by the permeable lakes sediments of the Chad formation. In some areas, the sediments are covered with oriented longitudinal dunes [10]. The three main rivers in the Hadejia-Jamaare-Yobe River System are the rivers Hadejia, Jarnaare and Komadugu-Yobe. The Hadejia River is formed by the confluence of the river Kano and Challawa at Tamburawa. It has a poorly defined channel and characterized by numerous oxbow lakes. The rivers pass through Hadejia and Madachi towns and enter a number of lakes and swamps. Downstream of Gashua, the River Yobe flows through major towns of Baimari, Geidam and Kanamma in Yobe state, Gashagar, Damasak and Yau in Borno state and discharge into the Lake Chad **(Figure 1)**.

Materials and Methods

Collection of fish samples

Fish samples were collected in accordance with method described by, four fish species (*Clarias anguillaris, Tilapia zilli, Synodontis budgetti* and *Heterotis niloticus)* were caught within the Komadugu river basin in Nguru and Gashua were commercial fishing activities take place through local fishermen of the area [11]. Fish samples of uniform size and weight were collected in order to avoid the possible error due to size differences. The fish were labeled with an identification number, identified by an expert in the Department of Fisheries, University of Maiduguri and later dissected to remove the flesh, liver, intestine and gills of each species of fish and transferred into an amber glass bottles and stored using ice box. The samples was transported to the Department of Chemistry research laboratory, University of Maiduguri and stored in a refrigerator at 4°C for further analysis.

Extraction of PAHs in fish samples

Preservation and processing: The original samples, until the commencement of the study, were preserved in refrigerator at -18°C ± 2°C. The samples were smashed and ground for homogeneity using a mortar and pestle. They were weighed and dried using anhydrous sodium sulphate prior to analysis.

Saponification: The homogenized samples were fortified with a surrogate standard solution and saponified with methanolic KOH. After repeated extraction in hexane, further cleanup was carried out with silica gel.

Extract and clean-up of fish samples for PAHs analysis: This clean-up step to remove more polar substances were performed

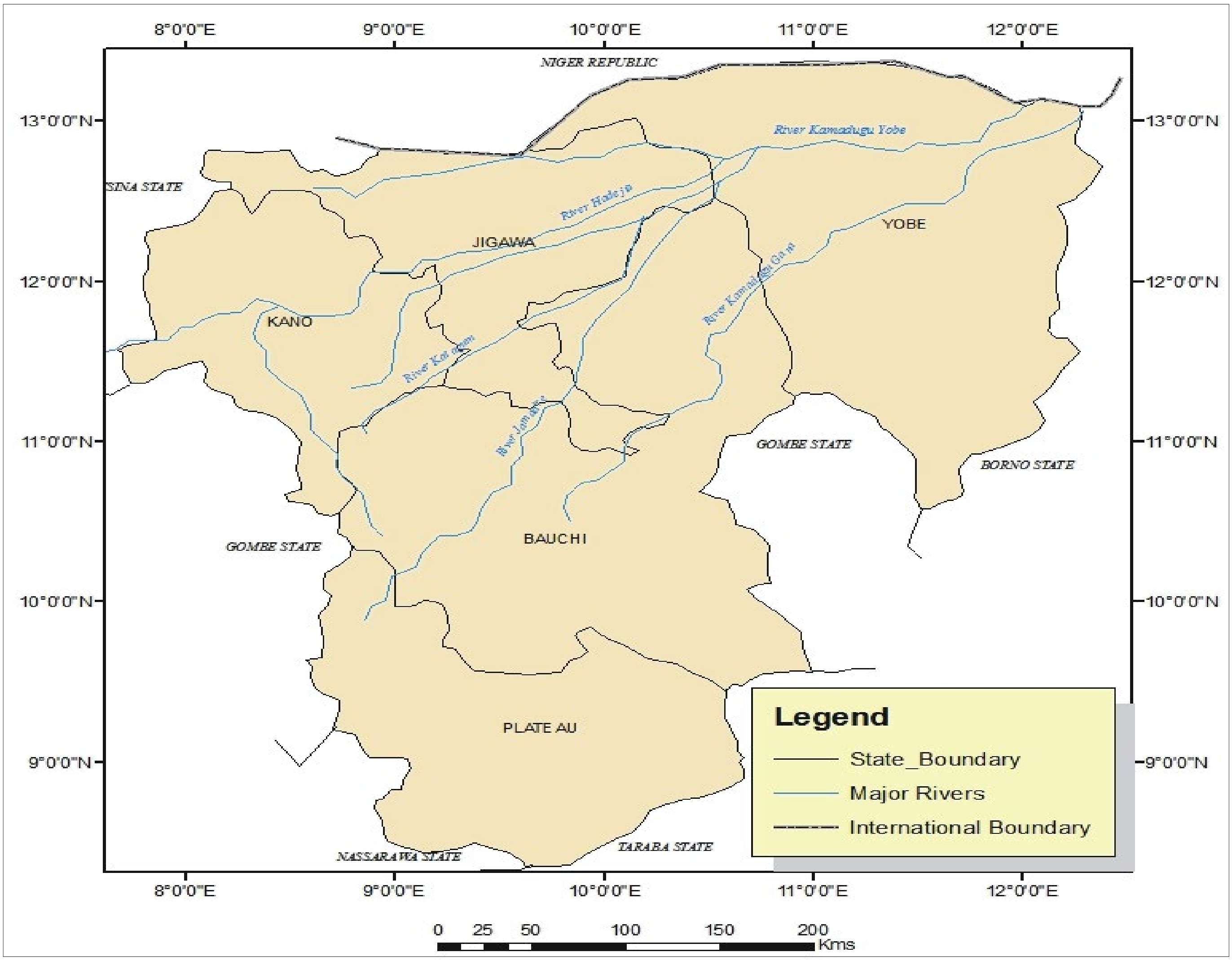

Figure 1 River system in Kano, Plateau and Yobe State Nigeria.

using activated florisil (Magnesium silicate) and anhydrous Na_2SO_4. The florisil were heated in an oven at 130ºC overnight (ca. 15 h) and transferred to a 250 ml size beaker and place in a desiccator. A 0.5 g anhydrous Na_2SO_4 was added to 1.0 g of activated florisil (60-100 mm mesh) on an 8 mls column which was plugged with glass wool. The packed column was filled with 5 ml *n*-hexane for conditioning. The stopcock on the set up was opened to allow the *n*-hexane run out until *n*-hexane just reached the top of the sodium sulfate into a receiving vessel whilst taping gently the top of the column till the florisil settle well in the column. The extract was transferred onto the column with a disposable Pasteur pipette from an evaporating flask. The crude extract was eluted on the column with the wide opening of the stopcock. Each evaporating flask was immediately rinsed twice with 1 ml portions of *n*-hexane and added to the column by the use of the Pasteur pipette. The eluate was collected into an evaporating flask and rotary evaporated to dryness. The dried elute was dissolve in 1 ml *n*-hexane for Gas Chromatographic analysis.

Instrumental analysis of PAHs using GSMS

The extract was thereafter analyzed using Agilent 7890A GC/MS previously calibrated with PAHs standards. The equipment turned out the concentration of the PAHs as the sample details were supplied for fish samples.

Dietary exposed to PAHs in fish

Estimation of human dietary PAHs exposure dosed mg kg^{-1} BW d^{-1}) occurring over a lifetime was determined. The daily BaP equivalent dose of mixture of carcinogenic PAH compound were calculated for carcinogenicity using the following equation.

$$ADD = \frac{TEQ \times IR \times CF}{Bw}$$

These exposure assumptions were made to be consistent with EPA guidance on assumption on reasonable maximum exposure [12]. Where IR is the ingestion or intake rate of carcinogenic PAHs based on average fish consumption rate set at 68.5 g day^{-1} per person from the annual per capital fish consumption of 25 kg for Nigeria CF is the conversion factor (0.000001 mg μg^{-1}) and BW represents body weight which is set at 70 kg [13].

Non-cancer hazard, carcinogenic risk calculation for fish samples

Risk associated with dietary exposure to non-carcinogenic PAHs was evaluated using hazard quotients approach. Hazard quotients represent a ratio of the exposure dose for each PAH divided by an oral chronic reference dose (RfD).

Hazard quotient (HQ)=Average daily dose (ADD)/RfD

The total risk due to exposure to mixture of carcinogenic PAHs is the product of the dietary carcinogen exposure dose (mg kg^{-1} BW d^{-1}) and benzo(a)pyrene's slope factor value.

Risk (carcinogenic)=Average daily dose × slope factor

Results

Mean concentrations of some PAHs in different tissues of four species of fish samples during the rainy, dry seasons and harmattan period

The mean concentrations of some polycyclic aromatic hydrocarbon in the gills, liver, flesh and intestine of *Clarias anguillaris* for rainy, dry seasons and harmattan period from Komadugu river basin, Yobe State, Nigeria are as presented in **Table 1**. The concentration for naphthalene ranged from 2.00E-02 to 5.88E+00 mg/kg, 2.00E-02 to 5.52E+00 mg/kg 2-methylnaphthalene, 2.00E-02 to 6.00E-02 mg/kg acenaphthylene, 2.00E-02 to 4.30E-01 mg/kg acenaphthene, 3.00E-02 to 2.70E-01 mg/kg fluorine, 3.00E-02 to 4.00E-02 mg/kg phenanthrene, 2.00E-02 to 4.00E-02 mg/kg anthracene, 1.00E-02 to 4.00E-02 mg/kg fluoranthene, 2.00E-02 to 6.00E-02 mg/kg pyrene, 2.00E-02 to 6.00E-02 mg/kg benzo(a)anthracene, 3.00E-02 to 8.00E-02 mg/kg chrysene, 1.00E-02 to 2.00E-01 mg/kg benzo(b)fluoranthene, 2.000E-02 to 2.00E-01 mg/kg benzo(k)fluoranthene, 1.60E-01 to 2.10E-01 mg/kg benzo(a)pyrene, 2.00E-02 to 9.00E-01 mg/kg dibenz(a.h) anthracene, 2.00E-02 to 7.60E-01 mg/kg benzo(g,h,i)perylene and 2.00E-02 to 1.50E+00 mg/kg indinol(1,2,3-cd)pyrene. The highest total concentration of 1.49E+01 mg/kg was observed in the liver during the dry season, while intestine shows the lowest total value of 3.70E-01 mg/kg during the rainy season. **Table 2** shows the mean concentrations of some polycyclic aromatic hydrocarbon in the gills, liver, flesh and intestine of *Tilapia zillii* for rainy, dry seasons and harmattan period from Komadugu river basin, Yobe State, Nigeria. The concentration of naphthalene ranged from 2.00E-02 to 5.40E+00 mg/kg, 2.00E-02 to 5.00E+00 mg/kg 2-ethylnaphthalene, 2.00E-02 to 6.00E-02 mg/kg acenaphthylene, 2.00E-02 to 3.40E-01 mg/kg acenaphthene, 3.00E-02 to 4.00E-01 mg/kg fluorine, 2.00E-02 to 4.00E-02 mg/kg phenanthrene, 2.00E-02 to 5.00E-02 mg/kg anthracene, 1.00E-02 to 6.00E-02 mg/kg fluoranthenem, 2.00E-02 to 5.00E-02 mg/kg pyrene, 2.00E-02 to 7.00E-02 mg/kg benzo(a)anthracene, 3.00E-02 to 8.00E-02 mg/kg chrysene, 1.00E-02 to 4.00E-01 mg/kg benzo(b)fluoranthene, 3.00E-02 to 3.00E-01 mg/kg benzo(k) fluoranthene, 1.50E-02 to 2.00E-01 mg/kg benzo(a)pyrene, 2.00E-02 to 8.90E-01 mg/kg dibenz(a.h)anthracene, 2.00E-02 to 6.00E-01 mg/kg benzo(g,h,i)perylene and 2.00E-02 to 1.80E+00 mg/kg indinol(1,2,3-cd)pyrene. The highest total concentration of 1.46+01 mg/kg was observed in the liver during the dry season, while intestine shows the lowest value of 3.70E-01 mg/kg during the rainy season **(Tables 1 and 2)**.

Table 1 Mean concentrations (mg/kg) of some polycyclic aromatic hydrocarbon in different tissues of Clarias anguillaris from Komadugu River Basin, Yobe State, Nigeria during the rainy, dry seasons and harmattan period.

	Rainy Season				Harmattan Period				Dry Season			
PAHs	**Gills**	**Liver**	**Flesh**	**Intestine**	**Gills**	**Liver**	**Flesh**	**Intestine**	**Gills**	**Liver**	**Flesh**	**Intestine**
Nap	4.65E+00	2.00E-02	5.77E+00	2.00E-02	3.95E+00	5.62E+00	5.22E+00	1.50E-01	4.00E+00	5.88E+00	5.00E+00	3.20E-01
2Nap	2.80E+00	2.00E-01	4.02E+00	2.00E-02	3.80E+00	5.12E+00	4.00E+00	2.00E-02	4.00E+00	5.52E+00	3.80E+00	3.00E-02
Acy	4.00E-02	2.00E-02	6.00E-02	2.00E-02	3.00E-02	5.00E-02	4.10E-02	2.00E-02	3.30E-02	5.00E-02	4.00E-02	2.00E-02
Ace	2.60E-01	2.00E-02	4.30E-01	2.00E-02	2.10E-01	2.00E-02	2.10E-02	2.00E-02	3.00E-01	4.00E-02	2.30E-02	2.30E-02
Fluo	1.70E-01	3.00E-02	2.30E-01	3.00E-02	1.60E-01	3.50E-02	2.70E-01	3.30E-02	2.00E-01	4.00E-02	3.00E-01	3.70E-02
Phen	3.00E-02	3.00E-02	3.00E-02	3.00E-02	3.10E-02	4.00E-02	3.20E-02	3.10E-02	3.00E-02	3.00E-02	3.00E-02	3.00E-02
Anth	3.00E-02	2.00E-02	4.00E-02	2.00E-02	3.00E-02	3.00E-02	4.00E-02	2.90E-02	3.70E-02	3.80E-02	3.00E-02	2.90E-02
Fl	4.00E-02	1.00E-02	1.00E-02	1.00E-02	1.20E-02	1.50E-02	1.00E-02	1.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02
Py	2.00E-02	2.00E-02	6.00E-02	2.00E-02	2.00E-02	4.00E-02	3.00E-02	2.00E-02	3.00E-02	4.00E-02	3.00E-02	2.00E-02
BaA	6.00E-02	2.00E-02	5.00E-02	2.00E-02	4.00E-02	6.00E-02	3.00E-02	2.00E-02	4.50E-02	6.00E-02	4.00E-02	3.00E-02
Chry	7.00E-02	3.00E-02	7.00E-02	3.00E-02	7.00E-02	8.00E-02	7.00E-02	3.00E-02	6.00E-02	7.00E-02	5.00E-02	3.00E-02
BbF	2.00E-01	1.00E-02	1.70E-01	1.00E-02	2.00E-01	3.00E-02	1.70E-01	1.00E-02	2.00E-01	4.00E-02	3.00E-02	2.00E-02
BkF	2.00E-01	3.00E-02	1.90E-01	3.00E-02	2.00E-01	3.00E-02	1.80E-01	2.00E-02	2.00E-02	3.90E-02	2.00E-01	2.00E-02
BaP	2.00E-01	3.00E-02	1.70E-01	3.00E-02	2.10E-01	3.20E-02	1.80E-01	1.60E-02	3.70E-02	4.00E-02	2.00E-02	2.00E-02
DahA	8.70E-01	6.00E-02	7.90E-01	2.00E-02	6.00E-01	8.30E-01	7.90E-01	4.00E-01	7.00E-01	9.00E-01	8.00E-01	4.00E-01
BghiP	7.60E-01	1.20E-01	6.50E-01	2.00E-02	6.00E-01	1.50E-01	4.40E-01	2.00E-02	4.00E-01	6.00E-01	4.00E-01	2.80E-02
IP	1.10E+00	2.00E-02	1.09E+00	2.00E-02	1.10E+00	1.40E+00	1.09E+00	2.00E-01	1.30E+00	1.50E+00	1.30E+00	2.00E-02
Sum	**1.15E+01**	**6.90E-01**	**1.38E+01**	**3.70E-01**	**1.13E+01**	**1.36E+01**	**1.26E+01**	**1.05+00**	**1.14E+01**	**1.49E+01**	**1.21E+01**	**1.10E+00**

Nap: Naphthalene; 2Nap: 2-methyl Napthalene; Acy: Acenapthylene; Ace: Acenaphthene; Fluo: Fluorene; Phen: Phenanthrene; Anth: Anthracene; Fl: Fluoranthene; Py: Pyrene; BaA: Benz(a)anthracene; Chry: Chrysene; BbF: Benz(b)fluoranthene; BkF: Benz(k)fluoranthene; BaP: Benz(a)pyrene; DahA: Dibenz(a,h)anthracene; BghiP: Benzo(g,h,i)perylene; IP: Indinol(1,2,3-cd)pyrene

For that of *Synodontis budgetti* during the rainy, dry seasons and harmattan period, the concentration of naphthalene ranged from 3.00E-02 to 5.50E+00 mg/kg, 2.00E-02 to 5.06E+00 mg/kg 2-methylnaphthalene, 2.05E-02 to 7.00E-02 mg/kg acenaphthylene, 2.00E-02 to 5.20E-01 mg/kg acenaphthene, 2.00E-02 to 3.40E-01 mg/kg fluorine, 2.00E-02 to 4.50E-02 mg/kg phenanthrene, 1.00E-02 to 4.00E-02 mg/kg anthracene, 1.00E-02 to 5.00E-02 mg/kg fluoranthene, 2.00E-02 to 7.00E-02 mg/kg pyrene, 3.00E-02 to 7.00E-02 mg/kg benzo(a)anthracene, 3.50E-02 to 8.00E-02 mg/kg chrysene, 1.10E-02 to 3.00E-01 mg/kg benzo(b)fluoranthene, 2.00E-02 to 4.00E-01 mg/kg benzo(k)fluoranthene, 2.00E-02 to 4.00E-01 mg/kg benzo(a)pyrene, 3.00E-02 to 9.80E-01 mg/kg dibenz(a.h)anthracene, 3.00E-02 to 8.70E-01 mg/kg benzo(g,h,i)perylene and 3.00E-02 to 2.20E+00 mg/kg indinol(1,2,3-cd)pyrene in **Table 3**. The highest total concentration of 1.59+01 mg/kg was observed in the flesh during the rainy season, while intestine showed the lowest value of 5.20E-01 mg/kg during the same period. For that of *Heterotis niloticus* during rainy, dry seasons and harmattan period as presented in **Table 4**. The concentration of naphthalene ranged from 3.00E-02 to 5.30E+00 mg/kg, 2.50E-02 to 5.06E+00 mg/kg 2-methylnaphthalene, 2.00E-02 to 7.00E-02 mg/kg acenaphthylene, 2.00E-02 to 4.50E-01 mg/kg acenaphthene, 3.00E-02 to 8.00E-01 mg/kg fluorene, 2.00E-02 to 5.00E-02 mg/kg phenanthrene, 2.00E-02 to 4.00E-02 mg/kg anthracene, 1.00E-02 to 7.00E-02 mg/kg fluoranthene, 2.00E-02 to 5.50E-02 mg/kg pyrene, 2.00E-02 to 6.50E-02 mg/kg benzo(a)anthracene, 3.50E-02 to 8.00E-02 mg/kg chrysene, 1.10E-02 to 4.40E-01 mg/kg benzo(b)fluoranthene, 2.00E-02 to 3.30E-01 mg/kg benzo(k)fluoranthene, 1.55E-02 to 5.00E-01 mg/kg benzo(a)pyrene, 3.00E-02 to 8.60E-01 mg/kg dibenz(a.h)anthracene, 2.50E-02 to 7.00E-01 mg/kg benzo(g,h,i)perylene and 3.00E-02 to 1.51E+00 mg/kg indinol(1,2,3- cd)pyrene. The highest total concentration of 1.53+01 mg/kg was detected in the liver during the dry season, while intestine shows the lowest total value of 5.20E-01 mg/kg during the rainy season **(Tables 3 and 4)**.

Daily dose for PAHs in different tissues of fish samples for rainy, dry seasons and harmattan period

Table 5 shows the daily dose of PAHs in the gills, liver, flesh and intestine of *Clarias anguillaris* for rainy, dry seasons and harmattan period from Komadugu river basin, Yobe State Nigeria. The concentration of naphthalene ranged from 1.96E-11 to 5.75E-09 mg/kg day^{-1}, 1.96E-11 to 5.40E-09 mg/kg day^{-1} 2-methylnaphthalene, 1.96E-11 to 5.87E-11 mg/kg day^{-1} acenaphthylene, 1.96E-11 to 2.94E-10 mg/kg day^{-1} acenaphthene, 2.94E-11 to 2.94E-10 mg/kg day^{-1} fluorene, 2.94E-11 to 3.91E-11 mg/kg day^{-1} phenanthrene, 2.94E-11 to 3.91E-10 mg/kg day^{-1} anthracene, 9.79E-12 to 3.91E-11 mg/kg day^{-1} fluoranthene, 1.96E-11 to 5.58E-11 mg/kg day^{-1} pyrene, 1.96E-10 to 5.87E-09 mg/kg day^{-1} benzo(a)anthracene, 2.94E-11 to 4.89E-09 mg/kg day^{-1} chrysene, 2.94E-11 to 1.96E-08 mg/kg day^{-1} benzo(b)fluoranthene, 9.79E-10 to 1.96E-08 mg/kg day^{-1} benzo(k)fluoranthene, 2.94E-09 to 2.06E-07 mg/kg day^{-1} benzo(a)pyrene, 2.98E-08 to 8.81E-07 mg/kg day^{-1} dibenz(a.h)anthracene, 1.96E-10 to 7.76E-07 mg/kg day^{-1} benzo(g,h,i)perylene and 1.96E-10 to 1.47E-08 mg/kg day^{-1} indinol(1,2,3-cd)pyrene. The highest total daily dose of 1.12E-06 mg/kg day^{-1} was observed in the gills during the rainy season, while intestine shows the lowest total value of 5.56E-08 mg/kg day^{-1} during the same period. For the concentration of naphthalene for rainy, dry season and harmattan period in *Tilapia zilli* ranged from 3.72E-15 to 5.28E-08 mg/kg day^{-1}, 4.15E-15 to 4.89E-09 mg/kg day^{-1} 2-methylnaphthalene, 4.02E-17 to 5.87E-11 mg/kg day^{-1} acenaphthylene, 1.92E-17 to 3.33E-10 mg/kg day^{-1} acenaphthene, 2.87E-16 to 1.66E-09 mg/kg day^{-1} fluorene, 2.87E-17 to 3.91E-11 mg/kg day^{-1} phenanthrene, 2.87E-16 to 4.89E-10 mg/kg day^{-1} anthracene, 9.58E-18 to 5.87E-11 mg/kg day^{-1} fluoranthene, 2.87E-17 to 3.91E-10 mg/kg day^{-1} pyrene, 4.40E-15 to 4.11E-08 mg/kg day^{-1} benzo(a)anthracene, 4.79E-15 to 6.85E-09 mg/kg day^{-1} chrysene, 5.75E-17 to 3.91E-08 mg/kg day^{-1} benzo(b)fluoranthene, 1.72E-14 to 2.94E-08 mg/

Table 2 Mean concentrations (mg/kg) of some polycyclic aromatic hydrocarbon in different tissues of Tilapia zilli from Komadugu River Basin, Yobe State, Nigeria during the rainy, dry seasons and harmattan period.

	Rainy Season				Harmattan Period				Dry Season			
PAHs	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine
Nap	5.40E+00	4.17E+00	5.16E+00	2.00E-02	3.65E+00	4.89E+00	3.88E+00	1.70E-01	4.06E+00	5.00E+00	4.40E+00	2.00E-02
2Nap	3.65E+00	3.30E+00	3.63E+00	2.00E-02	3.90E+00	5.00E+00	4.33E+00	3.00E-02	4.00E+00	5.00E+00	4.33E+00	2.00E-02
Acy	6.00E-02	4.00E-02	5.00E-02	2.00E-02	4.00E-02	5.00E-02	4.20E-02	2.10E-02	4.70E-02	6.00E-02	4.90E-02	2.00E-02
Ace	3.40E-01	3.00E-01	3.40E-01	2.00E-02	2.20E-01	2.30E-02	2.00E-02	2.00E-02	3.00E-01	4.00E-02	3.00E-02	3.00E-02
Fluo	1.90E-01	1.70E-01	2.00E-01	3.00E-02	1.50E-01	4.00E-02	3.00E-01	3.00E-02	2.00E-01	4.00E-01	3.00E-01	3.00E-02
Phen	3.00E-02	3.00E-02	2.00E-02	3.00E-02	2.80E-02	3.90E-02	3.00E-02	3.00E-02	3.00E-02	4.00E-02	3.50E-02	3.00E-02
Anth	2.00E-02	2.00E-02	3.00E-02	2.00E-02	3.00E-02	4.00E-02	3.00E-02	2.50E-02	4.00E-02	5.00E-02	3.00E-02	2.50E-02
Fl	5.00E-02	4.00E-02	6.00E-02	1.00E-02	1.30E-02	1.40E-02	1.00E-02	1.00E-02	2.00E-02	3.00E-02	2.00E-02	1.00E-02
Py	4.00E-02	4.00E-02	4.00E-02	2.00E-02	3.00E-02	3.70E-02	3.00E-02	2.00E-02	4.00E-02	5.00E-02	3.00E-02	2.00E-02
BaA	4.00E-02	3.00E-02	2.00E-02	2.00E-02	3.00E-02	7.00E-02	5.00E-02	2.00E-02	3.30E-02	6.00E-02	5.00E-02	3.00E-02
Chry	5.00E-02	3.00E-02	3.00E-02	3.00E-02	6.00E-02	8.00E-02	6.00E-02	4.00E-02	5.20E-02	7.60E-02	5.00E-02	3.00E-02
BbF	1.20E-01	9.00E-02	1.00E-01	1.00E-02	2.00E-01	3.30E-02	1.80E-01	1.20E-02	3.00E-01	4.00E-01	2.00E-01	2.00E-02
BkF	1.50E-01	9.00E-02	8.00E-02	3.00E-02	2.00E-01	3.00E-02	1.90E-01	2.20E-02	2.30E-01	3.00E-01	2.00E-01	2.00E-02

Nap: Naphthalene; 2Nap: 2-methyl Napthalene; Acy: Acenapthylene; Ace: Acenaphthene; Fluo: Fluorene; Phen: Phenanthrene; Anth: Anthracene; Fl: Fluoranthene; Py: Pyrene; BaA: Benz(a)anthracene; Chry: Chrysene; BbF: Benz(b)fluoranthene; BkF: Benz(k)fluoranthene; BaP: Benz(a)pyrene; DahA: Dibenz(a,h)anthracene; BghiP: Benzo(g,h,i)perylene; IP: Indinol(1,2,3-cd)pyrene

Table 3 Mean concentrations (mg/kg) of some polycyclic aromatic hydrocarbon in different tissues of Synodontis budgetti from Komadugu River Basin, Yobe State, Nigeria during the rainy, dry seasons and harmattan period.

	Rainy Season				Harmattan Period				Dry Season			
PAHs	**Gills**	**Liver**	**Flesh**	**Intestine**	**Gills**	**Liver**	**Flesh**	**Intestine**	**Gills**	**Liver**	**Flesh**	**Intestine**
Nap	4.23E+00	3.00E-02	5.06E+00	3.00E-02	3.80E+00	5.26E+00	4.55E+00	1.60E-01	4.00E+00	5.50E+00	4.70E+00	2.00E-01
2Nap	3.01E+00	3.00E-01	5.01E+00	3.00E-02	3.85E+00	5.06E+00	4.17E+00	2.50E-02	3.90E+00	5.00E+00	4.20E+00	2.00E-02
Acy	5.00E-02	3.00E-02	7.00E-02	3.00E-02	3.50E-02	5.00E-02	4.15E-02	2.05E-02	4.00E-02	5.50E-02	4.50E-02	2.50E-02
Ace	3.60E-01	3.00E-02	5.20E-01	3.00E-02	2.15E-01	2.15E-02	2.05E-02	2.00E-02	3.00E-01	4.00E-02	2.50E-02	2.00E-02
Fluo	2.80E-01	4.00E-02	3.40E-01	4.00E-02	1.55E-01	3.75E-02	2.85E-01	3.15E-02	2.00E-01	4.00E-02	3.00E-02	2.00E-02
Phen	4.00E-02	4.00E-02	4.00E-02	4.00E-02	2.95E-02	3.95E-02	3.10E-02	3.05E-02	3.50E-02	4.50E-02	3.00E-02	2.00E-02
Anth	2.00E-02	1.00E-02	3.00E-02	1.00E-02	3.00E-02	3.50E-02	3.50E-02	2.70E-02	3.00E-02	4.00E-02	3.50E-02	2.80E-02
Fl	5.00E-02	2.00E-02	2.00E-02	2.00E-02	1.25E-02	1.45E-02	1.00E-02	1.00E-02	3.00E-02	5.00E-02	3.00E-02	2.00E-02
Py	3.00E-02	3.00E-02	7.00E-02	3.00E-02	2.50E-02	3.85E-02	3.00E-02	2.00E-02	3.00E-02	4.50E-02	3.30E-02	3.00E-02
BaA	7.00E-02	3.00E-02	6.00E-02	3.00E-02	3.50E-02	6.50E-02	4.00E-02	2.00E-02	3.80E-02	7.00E-02	3.50E-02	2.60E-02
Chry	8.00E-02	4.00E-02	8.00E-02	4.00E-02	6.50E-02	8.00E-02	6.50E-02	3.50E-02	7.00E-02	8.00E-02	6.50E-02	3.50E-02
BbF	3.00E-01	2.00E-02	2.70E-01	2.00E-02	2.00E-01	3.15E-02	1.75E-01	1.10E-02	3.00E-01	4.00E-02	3.00E-02	3.00E-02
BkF	3.00E-01	4.00E-02	2.90E-01	4.00E-02	2.00E-01	3.00E-02	1.85E-01	2.10E-02	3.00E-01	4.00E-01	3.00E-01	2.00E-02
BaP	3.00E-01	4.00E-02	2.70E-01	4.00E-02	2.05E-01	3.20E-02	1.75E-01	1.55E-02	3.00E-01	4.00E-01	2.30E-01	2.00E-02
DahA	9.80E-01	7.00E-02	9.00E-01	3.00E-02	5.50E-01	8.60E-01	7.95E-01	4.50E-01	6.00E-01	9.00E-01	8.00E-01	5.00E-01
BghiP	8.70E-01	2.30E-01	7.60E-01	3.00E-02	5.00E-01	1.60E-01	4.50E-01	2.50E-02	5.00E-01	6.00E-01	4.50E-01	2.50E-02
IP	2.20E+00	3.00E-02	2.10E+00	3.00E-02	1.20E+00	1.51E+00	1.10E+00	2.00E-01	1.40E+00	1.70E+00	1.40E+00	3.00E-01
Sum	**1.32E+01**	**1.03E+00**	**1.59E+01**	**5.20E-01**	**1.11E+01**	**1.33E+01**	**1.22E+01**	**1.12E+00**	**1.21E+01**	**1.50E+01**	**1.24E+01**	**1.34E+00**

Nap: Naphthalene; 2Nap: 2-methyl Napthalene; Acy: Acenapthylene; Ace: Acenaphthene; Fluo: Fluorene; Phen: Phenanthrene; Anth: Anthracene; Fl: Fluoranthene; Py: Pyrene; BaA: Benz(a)anthracene; Chry: Chrysene; BbF: Benz(b)fluoranthene; BkF: Benz(k)fluoranthene; BaP: Benz(a)pyrene; DahA: Dibenz(a,h)anthracene; BghiP: Benzo(g,h,i)perylene; IP: Indinol(1,2,3-cd)pyrene

Table 4 Mean concentrations (mg/kg) of some polycyclic aromatic hydrocarbon in different tissues of *Heterotis niloticus* from Komadugu River Basin, Yobe State, Nigeria during the rainy, dry seasons and harmattan period.

	Rainy Season				Harmattan Period				Dry Season			
PAHs	**Gills**	**Liver**	**Flesh**	**Intestine**	**Gills**	**Liver**	**Flesh**	**Intestine**	**Gills**	**Liver**	**Flesh**	**Intestine**
Nap	5.30E+00	4.07E+00	5.06E+00	3.00E-02	3.80E+00	5.26E+00	4.55E+00	1.60E-01	4.30E+00	5.00E+00	4.40E+00	3.00E-01
2Nap	2.95E+00	3.20E+00	4.00E+00	3.00E-02	3.85E+00	5.06E+00	4.17E+00	2.50E-02	4.00E+00	4.70E+00	4.00E+00	3.00E-02
Acy	7.00E-02	5.00E-02	6.00E-02	3.00E-02	3.50E-02	5.00E-02	4.15E-02	2.05E-02	5.00E-02	4.00E-02	3.90E-02	2.00E-02
Ace	4.50E-01	4.00E-01	3.50E-01	3.00E-02	2.15E-01	2.15E-02	2.05E-02	2.00E-02	3.00E-01	2.00E-01	2.00E-02	2.00E-02
Fluo	2.00E-01	2.00E-01	2.00E-01	4.00E-02	1.55E-01	3.75E-02	2.85E-01	3.15E-02	3.00E-01	8.00E-01	5.00E-01	3.00E-02
Phen	3.00E-02	3.00E-02	2.00E-02	3.00E-02	2.95E-02	3.95E-02	3.10E-02	3.05E-02	4.00E-02	5.00E-02	3.00E-02	2.80E-02
Anth	2.00E-02	2.00E-02	3.00E-02	2.00E-02	3.00E-02	3.50E-02	3.50E-02	2.70E-02	3.00E-02	4.00E-02	3.60E-02	2.80E-02
Fl	6.00E-02	5.00E-02	7.00E-02	2.00E-02	1.25E-02	1.45E-02	1.00E-02	1.00E-02	3.00E-02	5.00E-02	4.00E-02	2.00E-02
Py	5.00E-02	5.00E-02	5.00E-02	3.00E-02	2.50E-02	3.85E-02	3.00E-02	2.00E-02	4.00E-02	5.50E-02	3.90E-02	3.00E-02
BaA	5.00E-02	4.00E-02	3.00E-02	3.00E-02	3.50E-02	6.50E-02	4.00E-02	2.00E-02	4.00E-02	5.00E-02	3.80E-02	3.00E-02
Chry	6.00E-02	4.00E-02	4.00E-02	4.00E-02	6.50E-02	8.00E-02	6.50E-02	3.50E-02	6.00E-02	7.00E-02	5.00E-02	4.00E-02
BbF	2.30E-01	2.00E-01	2.00E-01	2.00E-02	2.00E-01	3.15E-02	1.75E-01	1.10E-02	3.00E-01	4.40E-01	3.30E-01	2.00E-02
BkF	2.40E-01	1.20E-01	9.00E-02	4.00E-02	2.00E-01	3.00E-02	1.85E-01	2.10E-02	3.00E-01	3.30E-01	3.00E-01	2.00E-02
BaP	2.10E-01	1.00E-01	1.20E-01	4.00E-02	2.05E-01	3.20E-02	1.75E-01	1.55E-02	3.00E-01	5.00E-01	4.30E-01	2.00E-02
DahA	8.00E-01	6.30E-01	5.00E-01	3.00E-02	5.50E-01	8.60E-01	7.95E-01	4.50E-01	6.00E-01	8.00E-01	7.00E-01	5.00E-01
BghiP	5.20E-01	5.10E-01	4.30E-01	3.00E-02	5.00E-01	1.60E-01	4.50E-01	2.50E-02	6.00E-01	7.00E-01	5.50E-01	3.00E-02
IP	1.02E+00	7.00E-01	6.40E-01	3.00E-02	1.20E+00	1.51E+00	1.10E+00	2.00E-01	1.40E+00	1.50E+00	1.33E+00	3.00E-01
Sum	**1.23E+01**	**1.04E+01**	**1.19E+01**	**5.20E-01**	**1.11E+01**	**1.33E+01**	**1.22E+01**	**1.12E+00**	**1.27E+01**	**1.53E+01**	**1.28E+01**	**1.47E+00**

Nap: Naphthalene; 2Nap: 2-methyl Napthalene; Acy: Acenapthylene; Ace: Acenaphthene; Fluo: Fluorene; Phen: Phenanthrene; Anth: Anthracene; Fl: Fluoranthene; Py: Pyrene; BaA: Benz(a)anthracene; Chry: Chrysene; BbF: Benz(b)fluoranthene; BkF: Benz(k)fluoranthene; BaP: Benz(a)pyrene; DahA: Dibenz(a,h)anthracene; BghiP: Benzo(g,h,i)perylene; IP: Indinol(1,2,3-cd)pyrene

kg day^{-1} benzo(k)fluoranthene, 1.82E-14 to 3.82E-02 mg/kg day^{-1} benzo(a)pyrene, 1.63E-13 to 6.85E-07 mg/kg day^{-1} dibenz(a.h) anthracene, 7.66E-13 to 8.71E-07 mg/kg day^{-1} benzo(g,h,i) perylene and 1.06E-14 to 1.76E-08 mg/kg day^{-1} indinol(1,2,3-cd) pyrene) in **Table 6**. The highest total daily dose of 1.01E-06 mg/kg day^{-1} was observed in the flesh during the harmattan period, while intestine shows the lowest total value of 9.93E-13 mg/kg day^{-1} during the same period **(Tables 5 and 6)**.

For the concentration of naphthalene for rainy, dry seasons and harmattan period in *Synodontis budgetti* ranged from

2.94E-11 to 5.38E-09 mg/kg day^{-1}, 1.96E-11 to 4.95E-09 mg/kg day^{-1} 2-methylnaphthalene, 2.01E-11 to 6.85E-11 mg/kg day^{-1} acenaphthylene, 1.96E-11 to 5.09E-10 mg/kg day^{-1} acenaphthene, 1.96E-11 to 3.91E-11 mg/kg day^{-1} fluorene, 1.96E-11 to 4.40E-11 mg/kg day^{-1} phenanthrene, 9.76E-11 to 3.91E-10 mg/kg day^{-1} anthracene, 4.89E-11 to 9.79E-12 mg/kg day^{-1} fluoranthene, 1.46E-14 to 4.40E-11 mg/kg day^{-1} pyrene, 2.45E-10 to 8.51E-09 mg/kg day^{-1} benzo(a)anthracene, 3.43E-11 to 6.85E-09 mg/kg day^{-1} chrysene, 3.43E-11 to 2.94E-08 mg/kg day^{-1} benzo(b)fluoranthene, 1.96E-09 to 3.91E-08 mg/kg

Table 5 Daily dose (mg/kg day^{-1}) for polycyclic aromatic hydrocarbon in different tissues of *Clarias anguillaris* from Komadugu River Basin of Yobe State, Nigeria during the rainy, dry seasons and harmattan period.

	Rainy Season				Harmattan Period				Dry Season			
PAHs	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine
Nap	4.45E-09	1.96E-11	5.68E-09	1.96E-11	3.87E-09	5.50E-09	5.11E-09	1.47E-10	3.91E-09	5.75E-09	4.89E-09	3.13E-10
2Nap	2.74E-09	1.96E-11	3.93E-09	1.96E-11	3.72E-09	5.01E-09	3.91E-09	1.96E-11	3.91E-09	5.40E-09	3.72E-09	2.94E-11
Acy	3.91E-11	1.96E-11	5.87E-11	1.96E-11	2.94E-11	4.89E-11	4.01E-11	1.96E-11	3.23E-11	4.89E-11	3.91E-11	1.96E-11
Ace	2.54E-10	1.96E-11	4.21E-10	1.96E-11	2.06E-10	1.96E-11	2.06E-11	1.96E-11	2.94E-10	3.91E-11	2.25E-11	2.25E-11
Fluo	1.66E-10	2.94E-11	2.25E-10	2.94E-11	1.57E-10	3.43E-11	2.64E-10	3.23E-11	1.96E-10	3.91E-11	2.94E-10	3.62E-11
Phen	2.94E-11	2.94E-11	2.94E-11	2.94E-11	3.03E-11	3.91E-11	3.13E-11	3.03E-11	2.94E-11	2.94E-11	2.94E-11	2.94E-11
Anth	2.94E-11	1.96E-10	3.91E-10	1.96E-10	2.94E-10	2.94E-10	3.91E-10	2.84E-10	3.62E-10	3.72E-10	2.94E-10	2.84E-10
Fl	3.91E-11	9.79E-12	9.79E-12	9.79E-12	1.17E-11	1.47E-11	9.79E-12	9.79E-12	1.96E-11	1.96E-11	1.96E-11	1.96E-11
Py	1.96E-11	1.96E-11	5.58E-11	1.96E-11	1.96E-11	3.91E-11	2.94E-11	1.96E-11	2.94E-11	3.91E-11	2.94E-11	1.96E-11
BaA	5.87E-09	1.17E-09	6.36E-09	1.96E-10	3.91E-09	5.87E-09	2.94E-09	1.96E-09	4.40E-09	5.87E-09	3.91E-09	2.94E-09
Chry	6.85E-11	1.96E-09	4.89E-09	1.96E-09	6.85E-11	7.83E-11	6.85E-11	2.94E-11	5.87E-11	6.85E-11	4.89E-11	2.94E-11
BbF	1.96E-08	2.94E-11	6.65E-11	2.94E-11	1.96E-08	2.94E-09	1.66E-08	9.79E-10	1.96E-08	3.91E-09	2.94E-09	1.96E-09
BkF	1.96E-08	9.79E-10	1.66E-08	9.79E-10	1.96E-08	2.94E-09	1.76E-08	1.96E-09	1.96E-09	3.82E-09	1.96E-08	1.96E-09
BaP	1.96E-07	2.94E-09	1.86E-08	2.94E-09	2.06E-07	3.13E-08	1.76E-07	1.57E-08	3.62E-08	3.91E-08	1.96E-08	1.96E-08
DahA	8.51E-07	2.94E-08	1.66E-07	2.93E-08	5.87E-07	8.12E-07	7.73E-07	3.91E-07	6.85E-07	8.81E-07	7.83E-07	3.91E-07
BghiP	7.44E-09	5.87E-08	7.76E-07	1.96E-08	5.87E-09	1.47E-09	4.31E-09	1.96E-10	3.91E-09	5.87E-09	3.91E-09	2.74E-10
IP	1.08E-08	1.96E-10	1.07E-08	1.96E-10	1.08E-08	1.37E-08	1.07E-08	1.96E-09	1.27E-08	1.47E-08	1.27E-08	1.96E-10
TDD	**1.12E-06**	**9.57E-08**	**1.01E-06**	**5.56E-08**	**8.61E-07**	**8.81E-07**	**1.01E-06**	**4.14E-07**	**7.73E-07**	**9.66E-07**	**8.55E-07**	**4.19E-07**

Nap: Naphthalene; 2Nap: 2-methyl Napthalene; Acy: Acenapthylene; Ace: Acenaphthene; Fluo: Fluorene; Phen: Phenanthrene; Anth: Anthracene; Fl: Fluoranthene; Py: Pyrene; BaA: Benz(a)anthracene; Chry: Chrysene; BbF: Benz(b)fluoranthene; BkF: Benz(k)fluoranthene; BaP: Benz(a)pyrene; DahA: Dibenz(a,h)anthracene; BghiP: Benzo(g,h,i)perylene; IP: Indinol(1,2,3-cd)pyrene

Table 6 Daily dose (mg/kg day^{-1}) for polycyclic aromatic hydrocarbon in different tissues of *Tilapia zilli* from Komadugu River Basin of Yobe State, Nigeria during the rainy, dry seasons and harmattan period.

	Rainy Season				Harmattan Period				Dry Season			
PAHs	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine
Nap	5.28E-08	4.09E-09	5.05E-09	1.96E-11	3.57E-09	4.79E-09	3.80E-09	3.72E-15	3.97E-09	4.89E-09	4.31E-09	1.96E-11
2Nap	3.62E-09	3.23E-09	3.52E-09	1.96E-11	3.82E-09	4.89E-09	4.24E-09	4.15E-15	3.91E-09	4.89E-09	4.24E-09	1.96E-11
Acy	5.87E-11	3.91E-11	4.89E-11	1.96E-11	3.91E-11	4.89E-11	4.11E-11	4.02E-17	4.60E-11	5.87E-11	4.80E-11	1.96E-11
Ace	3.33E-10	2.94E-10	3.33E-10	1.96E-11	2.15E-10	2.25E-11	1.96E-11	1.92E-17	2.94E-10	3.91E-11	2.94E-11	2.94E-11
Fluo	1.86E-10	1.66E-09	1.96E-10	2.94E-11	1.47E-10	3.91E-11	2.94E-10	2.87E-16	1.96E-10	3.91E-10	2.94E-10	2.94E-11
Phen	2.94E-11	2.94E-11	1.96E-11	2.94E-11	2.74E-11	3.82E-11	2.94E-11	2.87E-17	2.94E-11	3.91E-11	3.43E-11	2.94E-11
Anth	1.96E-10	1.96E-10	2.94E-10	1.96E-10	2.94E-10	3.91E-10	2.94E-10	2.87E-16	3.91E-10	4.89E-10	2.94E-10	2.45E-10
Fl	4.89E-11	3.91E-11	5.87E-11	9.79E-12	1.27E-11	1.37E-11	9.79E-12	9.58E-18	1.96E-11	2.94E-11	1.96E-11	9.79E-12
Py	3.91E-10	3.91E-10	3.91E-10	1.96E-11	2.94E-11	3.62E-11	2.94E-11	2.87E-17	3.91E-11	4.89E-11	2.94E-11	1.96E-11
BaA	5.19E-09	4.11E-08	3.33E-09	1.96E-10	3.91E-09	1.66E-09	4.50E-09	4.40E-15	3.23E-09	5.87E-09	4.89E-09	2.94E-09
Chry	3.91E-09	2.94E-09	1.96E-09	1.96E-09	2.94E-09	6.85E-09	4.89E-09	4.79E-15	5.09E-11	7.44E-11	4.89E-11	2.94E-11
BbF	4.89E-11	2.94E-11	2.94E-11	2.94E-11	5.87E-11	7.83E-11	5.87E-11	5.75E-17	2.94E-08	3.91E-08	1.96E-08	1.96E-09
BkF	1.17E-08	8.81E-09	9.76E-09	9.79E-10	1.96E-08	3.23E-09	1.76E-08	1.72E-14	2.25E-08	2.94E-08	1.96E-08	1.96E-09
BaP	1.47E-08	8.81E-09	7.83E-09	2.94E-09	1.96E-08	2.94E-09	1.86E-08	1.82E-14	1.96E-07	3.82E-08	1.96E-08	1.96E-08
DahA	1.17E-07	8.81E-08	9.79E-08	2.93E-08	1.96E-07	3.13E-08	1.66E-07	1.63E-13	5.87E-07	6.85E-07	5.38E-07	3.23E-07
BghiP	6.85E-07	5.28E-07	4.01E-07	1.96E-08	4.89E-07	8.71E-07	7.83E-07	7.66E-13	4.89E-09	5.87E-09	3.91E-09	2.94E-10
IP	9.79E-09	6.75E-09	6.06E-09	1.96E-10	1.27E-08	1.59E-08	1.09E-08	1.06E-14	1.17E-08	1.76E-08	1.32E-08	4.31E-09
TDD	**9.05E-07**	**6.95E-07**	**5.38E-07**	**5.56E-08**	**7.52E-07**	**9.43E-07**	**1.01E-06**	**9.93E-13**	**8.64E-07**	**8.32E-07**	**6.28E-07**	**3.55E-07**

Nap: Naphthalene; 2Nap: 2-methyl Napthalene; Acy: Acenapthylene; Ace: Acenaphthene; Fluo: Fluorene; Phen: Phenanthrene; Anth: Anthracene; Fl: Fluoranthene; Py: Pyrene; BaA: Benz(a)anthracene; Chry: Chrysene; BbF: Benz(b)fluoranthene; BkF: Benz(k)fluoranthene; BaP: Benz(a)pyrene; DahA: Dibenz(a,h)anthracene; BghiP: Benzo(g,h,i)perylene; IP: Indinol(1,2,3-cd)pyrene

day^{-1} benzo(k)fluoranthene, 2.94E-09 to 3.91E-07 mg/kg day^{-1} benzo(a)pyrene, 1.52E-08 to 8.81E-07 mg/kg day^{-1} dibenz(a.h) anthracene, 2.45E-10 to 9.59E-07 mg/kg day^{-1} benzo(g,h,i) perylene and 2.94E-10 to 2.15E-08 mg/kg day^{-1} indinol(1,2,3-cd)pyrene IN **Table 7**. The highest total daily dose of 1.36E-06 mg/kg day^{-1} was observed the in the liver during the dry season, while intestine shows the lowest total value of 7.83E-08 mg/kg day^{-1} during the rainy season. For that of *Heterotis niloticus*, the concentration of naphthalene for rainy, dry seasons and harmattan period ranged from 2.94E-11 to 5.19E-09 mg/kg day^{-1}, 2.20E-11 to 4.60E-09 mg/kg day^{-1} 2-methylnaphthalenem, 1.96E-11 to 6.85E-11 mg/kg day^{-1} acenaphthylene, 1.96E-11 to 4.40E-10 mg/kg day^{-1} acenaphthene, 2.94E-11 to 4.89E-10 mg/kg day^{-1} fluorene, 1.96E-11 to 4.89E-11 mg/kg day^{-1} phenanthrene, 1.96E-10 to 3.91E-10 mg/kg day^{-1} anthracene, 9.79E-12 to 6.85E-11 mg/kg day^{-1} fluoranthene, 1.96E-11 to 5.38E-11 mg/kg day^{-1} pyrene, 2.20E-10 to 5.38E-09 mg/kg day^{-1} benzo(a)anthracene, 3.91E-11 to 4.89E-09 mg/kg day^{-1} chrysene, 3.18E-11 to 4.31E-08 mg/kg day^{-1} benzo(b)fluoranthene, 1.96E-09 to 3.23E-08 mg/kg day^{-1} benzo(k)fluoranthene, 2.01E-09 to 4.89E-07 mg/kg day^{-1} benzo(a) pyrene, 1.55E-08 to 7.83E-07 mg/kg day^{-1}dibenz(a.h)anthracene, 2.94E-10 to 7.83E-07 mg/kg day^{-1} benzo(g,h,i)perylene and 2.94E-10 to 1.47E-08 mg/kg day^{-1} indinol(1,2,3-cd)pyrene in **Table 8**. The highest total daily dose of 1.38E-06 mg/kg day^{-1} was observed in the liver during the dry season, while intestine shows the lowest total value of 7.85E-08 mg/kg day^{-1} during the rainy season **(Tables 7 and 8)**.

Carcinogenic risk assessment of PAHs in different tissues of fish samples during the rainy, dry seasons and harmattan period

Table 9 shows the carcinogenic risk assessment of PAHs in the gills, liver, flesh and intestine of *Clarias anguillaris* for rainy, dry season and harmattan period from Komadugu river basin, Yobe State, Nigeria. The concentration of benzo(a)anthracene ranged from 1.49E-09 to 4.29E-09 mg/kg day^{-1}, 2.14E-13 to 5.00E-13 mg/kg day^{-1} chrysene, 7.14E-10 to 1.43E-08 mg/kg day^{-1} benzo(b)fluoranthene, 1.43E-10 to 1.36E-08 mg/kg day^{-1} benzo(k)fluoranthene, 1.14E-07 to 1.50E-06 mg/kg day^{-1} benzo(a) pyrene, 1.43E-07 to 6.43E-06 mg/kg day^{-1} dibenz(a.h)anthracene and 1.43E-11 to 1.07E-08 mg/kg day^{-1} indinol(1,2,3-cd)pyrene. Gills showed the highest value of 7.67E-06 mg/kg day^{-1} during the rainy season, while intestine shows the lowest value of 3.61E-07 mg/kg day^{-1} during the same period. **Table 10** present the carcinogenic risk assessment PAHs in the gills, liver, flesh and intestine of *Tilapia zillii* for rainy, dry season and harmattan period from Komadugu river basin, Yobe State Nigeria. The concentration of benzo(a)anthracene ranged from 1.49E-09 to 5.00E-09 mg/kg day^{-1}, 2.14E-13 to 5.72E-13 mg/kg day^{-1} chrysene, 1.26E-14 to 2.85E-08 mg/kg day^{-1} benzo(b)fluoranthene, 1.33E-15 to 1.07E-08 mg/kg day^{-1} benzo(k)fluoranthene, 1.92E-12 to 1.43E-06 mg/kg day^{-1} benzo(a)pyrene, 5.59E-12 to 5.00E-06 mg/kg day^{-1} dibenz(a.h)anthracene and 7.74E-15 to 1.28E-08 mg/kg day^{-1} indinol(1,2,3-cd)pyrene. The highest total value was observed in the liver with a value of 6.96E-06 mg/kg day^{-1} during the harmattan period, while intestine shows the lowest total value of 6.81E-12 mg/kg day^{-1} during the same period. For that of *Synodontis budgetti* from Komadugu river basin, Yobe State Nigeria **(Tables 9 and 10)**.

The concentration of benzo(a)anthracene for rainy, dry seasons and harmattan period ranged from 1.85E-09 to 5.01E-09 mg/kg day^{-1}, 2.50E-13 to 5.72E-13 mg/kg day^{-1} chrysene, 7.88E-10 to

Table 7 Daily dose (mg/kg day^{-1}) for polycyclic aromatic hydrocarbon in different tissues of *Synodontis budgetti* from Komadugu River Basin of Yobe State, Nigeria during the rainy, dry seasons and harmattan period.

	Rainy Season				Harmattan Period				Dry Season			
PAHs	**Gills**	**Liver**	**Flesh**	**Intestine**	**Gills**	**Liver**	**Flesh**	**Intestine**	**Gills**	**Liver**	**Flesh**	**Intestine**
Nap	4.14E-09	2.94E-11	4.99E-09	2.94E-11	3.72E-09	5.15E-09	4.45E-09	1.57E-10	3.91E-09	5.38E-09	4.60E-09	1.96E-10
2Nap	2.96E-09	2.94E-10	4.90E-09	2.94E-11	3.77E-09	4.95E-09	4.08E-09	2.45E-11	3.82E-09	4.89E-09	4.11E-09	1.96E-11
Acy	4.89E-11	2.94E-11	6.85E-11	2.94E-11	3.43E-11	4.89E-11	4.06E-11	2.01E-11	3.91E-11	5.38E-11	4.40E-11	2.45E-11
Ace	3.52E-10	2.94E-11	5.09E-10	2.94E-11	2.10E-10	2.10E-11	2.01E-11	1.96E-11	2.94E-10	3.91E-11	2.45E-11	1.96E-11
Fluo	2.74E-10	3.91E-11	3.33E-10	3.91E-11	1.52E-10	3.67E-11	2.79E-10	3.08E-11	1.96E-10	3.91E-11	2.94E-11	1.96E-11
Phen	3.91E-11	3.91E-11	3.91E-11	3.91E-11	2.89E-11	3.87E-11	3.03E-11	2.98E-11	3.43E-11	4.40E-11	2.94E-11	1.96E-11
Anth	1.96E-10	9.76E-11	2.94E-10	9.76E-11	2.94E-10	3.43E-10	3.43E-10	2.64E-10	2.94E-10	3.91E-10	3.43E-10	2.74E-10
Fl	4.89E-11	1.96E-11	1.96E-11	1.96E-11	1.22E-11	1.42E-11	9.79E-12	9.79E-12	2.94E-11	4.89E-11	2.94E-11	1.96E-11
Py	2.94E-11	2.94E-11	1.46E-14	2.94E-11	2.45E-11	3.77E-11	2.94E-11	1.96E-11	2.94E-11	4.40E-11	3.23E-11	2.94E-11
BaA	8.51E-09	2.25E-09	7.43E-09	2.94E-10	4.89E-09	1.57E-09	4.40E-09	2.45E-10	3.72E-09	6.85E-09	3.43E-09	2.54E-09
Chry	6.85E-09	2.94E-09	5.87E-09	2.94E-09	3.43E-09	6.36E-09	3.91E-09	1.96E-09	6.85E-11	7.83E-11	6.36E-11	3.43E-11
BbF	7.83E-11	3.91E-11	7.83E-11	3.91E-11	6.36E-11	7.83E-11	6.36E-11	3.43E-11	2.94E-08	3.91E-09	2.94E-09	2.94E-09
BkF	2.94E-08	1.96E-09	2.64E-08	1.96E-09	1.96E-08	3.08E-09	1.71E-08	1.08E-09	2.94E-08	3.91E-08	2.94E-08	1.96E-09
BaP	2.94E-08	3.91E-09	2.84E-08	3.91E-09	1.96E-08	2.94E-09	1.81E-08	2.06E-09	2.94E-07	3.91E-07	2.25E-07	1.96E-08
DahA	2.94E-07	3.91E-08	2.64E-07	3.91E-08	2.01E-07	3.13E-08	1.71E-07	1.52E-08	5.87E-07	8.81E-07	7.83E-07	4.89E-07
BghiP	9.59E-07	6.85E-08	8.80E-07	2.94E-08	5.38E-07	8.42E-07	7.78E-07	4.40E-07	4.89E-09	5.87E-09	4.40E-09	2.45E-10
IP	2.15E-08	2.94E-10	2.06E-08	2.94E-10	1.17E-08	1.48E-08	1.08E-08	1.96E-09	1.37E-08	1.66E-08	1.37E-08	2.94E-09
TDD	**1.36E-06**	**1.20E-07**	**1.24E-06**	**7.83E-08**	**8.07E-07**	**9.13E-07**	**1.01E-06**	**4.63E-07**	**9.71E-07**	**1.36E-06**	**1.07E-06**	**5.20E-07**

Nap: Naphthalene; 2Nap: 2-methyl Napthalene; Acy: Acenapthylene; Ace: Acenaphthene; Fluo: Fluorene; Phen: Phenanthrene; Anth: Anthracene; Fl: Fluoranthene; Py: Pyrene; BaA: Benz(a)anthracene; Chry: Chrysene; BbF: Benz(b)fluoranthene; BkF: Benz(k)fluoranthene; BaP: Benz(a)pyrene; DahA: Dibenz(a,h)anthracene; BghiP: Benzo(g,h,i)perylene; IP: Indinol(1,2,3-cd)pyrene

2.15E-08 mg/kg day^{-1} benzo(b)fluoranthene, 1.43E-10 to 2.14E-08 mg/kg day^{-1} benzo(k)fluoranthene, 1.11E-07 to 2.15E-06 mg/kg day^{-1} benzo(a)pyrene, 2.14E-07 to 7.00E-06 mg/kg day^{-1} dibenz(a.h)anthracene and 2.14E-11 to 1.21E-08 mg/kg day^{-1} indinol(1,2,3-cd)pyrene **Table 11**. Liver shows the highest value of 9.30E-06 mg/kg day^{-1} during the dry seasons, while intestine shows the lowest value of 5.06E-07 mg/kg day^{-1} during the rainy season. **Table 12** shows the carcinogenic risk assessment of PAHs in the gills, liver, flesh and intestine of *Heterotis niloticus* for rainy, dry season and harmattan period from Komadugu river basin, Yobe State Nigeria. The concentration of benzo(a)anthracene ranged from 2.14E-09 to 3.57E-09 mg/kg day^{-1}, 2.32E-13 to 5.18E-13 mg/kg day^{-1} chrysene, 7.52E-10 to 3.15E-08 mg/kg day^{-1} benzo(b)fluoranthene, 1.43E-10 to 5.57E-09 mg/kg day^{-1} benzo(k) fluoranthene, 1.13E-07 to 3.57E-06 mg/kg day^{-1} benzo(a)pyrene, 2.14E-07 to 5.72E-06 mg/kg day^{-1} dibenz(a.h)anthracene and 2.14E-11 to 1.07E-08 mg/kg day^{-1} indinol(1,2,3-cd)pyrene. Liver shows the highest total value of 9.34E-06 mg/kg day^{-1} during the dry season, while intestine shows the lowest value of 5.06E-07 mg/kg day^{-1} during the rainy season **(Tables 11 and 12)**.

Hazard quotient and hazard index of non-carcinogenic PAHs in different tissues of fish samples during the rainy, dry seasons and harmattan period

The hazard quotient and hazard index of non-carcinogenic PAHs in the gills, liver, flesh and intestine of *Clarias anguillaris* for rainy, dry seasons and harmattan period from Komadugu river basin, Yobe State Nigeria are as presented in **Table 13**. The concentration

Table 8 Daily dose (mg/kg day^{-1}) for polycyclic aromatic hydrocarbon in different tissues of *Heterotis niloticus* from Komadugu River Basin of Yobe State, Nigeria during the rainy, dry seasons and harmattan period.

	Rainy Season				Harmattan Period				Dry Season			
PAHs	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine
Nap	5.19E-09	3.98E-09	4.95E-09	2.94E-11	3.80E-09	4.61E-09	4.79E-09	1.52E-10	4.21E-09	4.89E-09	4.31E-09	2.94E-10
2Nap	2.89E-09	3.13E-09	3.91E-09	2.94E-11	3.75E-09	4.39E-09	3.99E-09	2.20E-11	3.91E-09	4.60E-09	3.91E-09	2.94E-11
Acy	6.85E-11	4.89E-11	5.87E-11	2.94E-11	3.18E-11	4.16E-11	4.04E-11	1.99E-11	4.89E-11	3.91E-11	3.82E-11	1.96E-11
Ace	4.40E-10	3.91E-10	3.43E-10	2.94E-11	2.08E-10	1.15E-10	2.04E-11	1.96E-11	2.94E-10	1.96E-10	1.96E-11	1.96E-11
Fluo	1.96E-10	1.96E-10	1.96E-10	3.91E-11	1.55E-10	9.30E-11	2.72E-10	3.16E-11	2.94E-10	7.83E-10	4.89E-10	2.94E-11
Phen	2.94E-11	2.94E-11	1.96E-11	2.94E-11	2.97E-11	3.41E-11	3.08E-11	3.01E-11	3.91E-11	4.89E-11	2.94E-11	2.74E-11
Anth	1.96E-10	1.96E-10	2.94E-10	1.96E-10	2.94E-10	2.94E-10	3.67E-10	2.74E-10	2.94E-10	3.91E-10	3.52E-10	2.74E-10
Fl	5.87E-11	4.89E-11	6.85E-11	1.96E-11	1.20E-11	1.35E-11	9.79E-12	9.79E-12	2.94E-11	4.89E-11	3.91E-11	1.96E-11
Py	4.89E-11	4.89E-11	4.89E-11	2.94E-11	2.20E-11	3.18E-11	2.94E-11	1.96E-11	3.91E-11	5.38E-11	3.82E-11	2.94E-11
BaA	5.09E-09	4.99E-09	4.21E-09	2.94E-10	5.38E-09	3.18E-09	4.35E-09	2.20E-10	3.91E-09	4.89E-09	3.72E-09	2.94E-09
Chry	4.89E-09	3.91E-09	2.94E-09	2.94E-09	3.67E-09	4.65E-09	3.43E-09	1.96E-09	5.87E-11	6.85E-11	4.89E-11	3.91E-11
BbF	5.87E-11	3.91E-11	3.91E-11	3.91E-11	6.61E-11	7.09E-11	6.61E-11	3.18E-11	2.94E-08	4.31E-08	3.23E-08	1.96E-09
BkF	2.35E-08	1.96E-08	1.96E-08	1.96E-09	1.96E-08	1.13E-08	1.69E-08	1.03E-09	2.94E-08	3.23E-08	2.94E-08	1.96E-09
BaP	2.35E-08	1.17E-08	8.81E-09	3.91E-09	1.96E-08	1.13E-08	1.79E-08	2.01E-09	2.94E-07	4.89E-07	4.21E-07	1.96E-08
DahA	2.06E-07	9.74E-08	1.17E-07	3.91E-08	2.04E-07	1.16E-07	1.74E-07	1.55E-08	5.87E-07	7.83E-07	6.85E-07	4.89E-07
BghiP	7.83E-07	6.17E-07	4.89E-07	2.94E-08	5.63E-07	6.75E-07	7.76E-07	4.16E-07	5.87E-09	6.85E-09	5.38E-09	2.94E-10
IP	9.98E-09	6.85E-09	6.26E-09	2.94E-10	1.13E-08	1.27E-08	1.08E-08	1.96E-09	1.37E-08	1.47E-08	1.30E-08	2.94E-09
TDD	**1.07E-06**	**7.70E-07**	**6.58E-07**	**7.85E-08**	**8.35E-07**	**8.44E-07**	**1.01E-06**	**4.39E-07**	**9.72E-07**	**1.38E-06**	**1.20E-06**	**5.19E-07**

Nap: Naphthalene; 2Nap: 2-methyl Napthalene; Acy: Acenapthylene; Ace: Acenaphthene; Fluo: Fluorene; Phen: Phenanthrene; Anth: Anthracene; Fl: Fluoranthene; Py: Pyrene; BaA: Benz(a)anthracene; Chry: Chrysene; BbF: Benz(b)fluoranthene; BkF: Benz(k)fluoranthene; BaP: Benz(a)pyrene; DahA: Dibenz(a,h)anthracene; BghiP: Benzo(g,h,i)perylene; IP: Indinol(1,2,3-cd)pyrene

Table 9 Carcinogenic risk assessment (mg/kg day^{-1}) of some polycyclic aromatic hydrocarbon in different tissues of *Clarias anguillaris* from Komadugu River Basin of Yobe State, Nigeria during the harmattan period (LOQ).

	Rainy Season				Harmattan Period				Dry Season			
PAHs	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine
BaA	4.29E-09	1.43E-09	3.57E-09	1.49E-09	2.86E-09	4.29E-09	2.14E-09	1.43E-09	3.21E-09	4.29E-09	2.85E-09	2.15E-09
Chry	5.00E-13	2.14E-13	5.01E-13	2.14E-13	5.00E-13	5.71E-13	5.00E-13	2.14E-13	4.29E-13	5.00E-13	3.57E-13	2.15E-13
BbF	1.43E-08	7.14E-10	1.21E-08	7.14E-10	1.43E-08	2.14E-09	1.21E-08	7.14E-10	1.43E-08	2.85E-09	2.15E-09	1.43E-09
BkF	1.43E-09	2.14E-09	1.36E-08	2.14E-09	1.43E-09	2.14E-10	1.29E-09	1.43E-10	1.43E-10	2.79E-10	1.43E-09	1.43E-10
BaP	1.43E-09	2.14E-07	1.21E-06	2.14E-07	1.50E-06	2.29E-07	1.29E-06	1.14E-07	2.64E-07	2.85E-07	1.43E-07	1.43E-07
DahA	6.21E-06	4.29E-07	5.67E-06	1.43E-07	4.29E-06	5.93E-06	5.64E-06	2.86E-06	5.00E-06	6.43E-06	5.72E-06	2.85E-06
IP	7.86E-09	1.43E-11	7.79E-10	1.43E-11	7.86E-09	1.00E-08	7.79E-09	1.43E-09	9.27E-09	1.07E-08	9.27E-09	1.43E-10
∑ILECR	**7.67E-06**	**4.29E-07**	**6.91E-06**	**3.61E-07**	**5.82E-06**	**6.18E-06**	**6.95E-06**	**2.98E-06**	**5.29E-06**	**6.73E-06**	**5.88E-06**	**3.00E-06**

BaA: Benz(a)anthracene; Chry: Chrysene; BbF: Benz(b)fluoranthene; BkF: Benz(k)fluoranthene; BaP: Benz(a)pyrene; DahA: Dibenz(a,h)anthracene; IP: Indinol(1,2,3-cd)pyrene of naphthalene ranged from 7.35E-10 to 2.88E-07 mg/kg day^{-1}, 9.80E-11 to 2.70E-08 mg/kg day^{-1} 2-methylnaphthalene, 9.80E-11 to 2.45E-10 mg/kg day^{-1} acenaphthylene, 3.27E-11 to 9.90E-10 mg/kg day^{-1} acenaphthene, 8.08E-11 to 7.35E-10 mg/kg day^{-1} fluorene, 7.35E-11 to 9.78E-11 mg/kg day^{-1} phenanthrene, 9.47E-11 to 1.30E-10 mg/kg day^{-1} anthracene, 2.45E-11 to 4.90E-11 mg/kg day^{-1} fluoranthene, 6.53E-11 to 1.30E-10 mg/kg day^{-1} pyrene and 4.90E-10 to 1.47E-08 mg/kg day^{-1} benzo(g,h,i)perylene. The highest value of hazard index (HI) was observed in the flesh with a value of 7.13E-08 mg/kg day^{-1} during the dry season, while intestine shows the lowest value of 1.79E-09 mg/kg day^{-1} during the harmattan period. The hazard quotient and hazard index of non-carcinogenic polycyclic aromatic hydrocarbon in the gills, liver, flesh and intestine of *Tilapia zilli* for rainy, dry seasons and harmattan period from Komadugu river basin, Yobe State Nigeria are as presented in **Table 14**. The concentration of naphthalene ranged from 1.86E-14 to 2.64E-06 mg/kg day^{-1}, 2.08E-14 to 1.76E-07 mg/kg day^{-1} 2-methylnaphthalene, 2.01E-16 to 2.45E-09 mg/kg day^{-1} acenaphthylene, 3.20E-17 to 5.55E-09mg/kg day^{-1} acenaphthene, 7.18E-16 to 4.16E-08 mg/kg day^{-1} fluorene, 7.18E-17 to 7.34E-10 mg/kg day^{-1} phenanthrene, 9.57E-17 to 9.79E-10 mg/kg day^{-1} anthracene, 2.40E-17 to 1.47E-09 mg/kg day^{-1} fluoranthene, 9..57E-17 to 1.30E-08 mg/kg day^{-1} pyrene and 1.10E-14 to 1.03E-06 mg/kg day^{-1} benzo(g,h,i)perylene. The

Table 10 Carcinogenic risk assessment (mg/kg day^{-1}) of some polycyclic aromatic hydrocarbon in different tissues of *Tilapia zilli* from Komadugu River Basin of Yobe State, Nigeria during the rainy, dry seasons and harmattan period.

	Rainy Season				Harmattan Period				Dry Season			
PAHs	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine
BaA	2.86E-09	2.14E-09	1.43E-09	1.43E-09	2.15E-09	5.00E-09	3.57E-09	3.50E-15	2.36E-09	4.29E-09	3.57E-09	2.15E-09
Chry	3.57E-13	2.14E-13	2.14E-13	2.14E-13	4.29E-13	5.72E-13	4.29E-13	4.20E-19	3.72E-13	5.43E-13	3.57E-13	2.15E-13
BbF	8.57E-09	6.43E-09	7.14E-13	7.14E-10	1.43E-08	2.36E-09	1.28E-08	1.26E-14	2.15E-08	2.85E-08	1.43E-08	1.43E-09
BkF	1.07E-08	6.43E-09	5.71E-09	2.14E-09	1.43E-09	2.15E-10	1.36E-09	1.33E-15	1.64E-09	2.15E-09	1.43E-09	1.43E-10
BaP	8.57E-07	6.43E-07	7.14E-07	2.14E-09	1.43E-06	2.28E-07	1.21E-06	1.19E-12	1.43E-06	2.79E-07	1.43E-07	1.43E-07
DahA	5.01E-06	3.85E-06	2.93E-06	1.43E-07	3.57E-06	6.36E-06	5.72E-06	5.59E-12	4.29E-06	5.00E-06	3.93E-06	2.36E-06
IP	7.14E-10	4.93E-10	4.43E-10	1.43E-11	9.27E-09	1.16E-08	7.96E-09	7.74E-15	8.54E-09	1.28E-08	9.64E-09	3.15E-09
∑ILECR	**5.89E-06**	**3.85E-06**	**3.65E-06**	**1.49E-07**	**5.03E-06**	**6.61E-06**	**6.96E-06**	**6.81E-07**	**5.75E-06**	**5.33E-06**	**4.10E-06**	**2.51E-06**

BaA: Benz(a)anthracene; Chry: Chrysene; BbF: Benz(b)fluoranthene; BkF: Benz(k)fluoranthene; BaP: Benz(a)pyrene; DahA: Dibenz(a,h)anthracene; IP: Indinol(1,2,3-cd)pyrene

Table 11 Carcinogenic risk assessment of some polycyclic aromatic hydrocarbon (mg/kg day^{-1}) in different tissues of *Synodontis budgetti* from Komadugu River Basin of Yobe State, Nigeria during the rainy, dry seasons and harmattan period.

	Rainy Season				Harmattan Period				Dry Season			
PAHs	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine
BaA	5.01E-09	2.14E-09	4.29E-09	2.14E-09	2.50E-09	4.64E-09	2.85E-09	1.43E-09	2.72E-09	5.00E-09	2.50E-09	1.85E-09
Chry	5.72E-13	2.86E-13	5.71E-13	2.86E-13	4.64E-13	5.72E-13	4.64E-13	2.50E-13	5.00E-13	5.72E-13	4.64E-13	2.50E-13
BbF	2.14E-08	1.43E-09	1.93E-08	1.43E-09	1.43E-08	2.25E-09	1.25E-08	7.88E-10	2.15E-08	2.85E-09	2.15E-09	2.15E-09
BkF	2.14E-08	2.86E-09	2.07E-08	2.86E-09	1.43E-09	2.15E-10	1.32E-09	1.50E-10	2.15E-09	2.85E-09	2.15E-09	1.43E-10
BaP	2.14E-06	2.86E-07	1.93E-06	2.86E-07	1.47E-06	2.28E-07	1.25E-06	1.11E-07	2.15E-06	2.85E-06	1.64E-06	1.43E-07
DahA	7.00E-06	5.00E-07	6.43E-06	2.14E-07	3.93E-06	6.15E-06	5.68E-06	3.21E-06	4.29E-06	6.43E-06	5.72E-06	3.57E-06
IP	1.57E-09	2.14E-11	1.50E-09	2.14E-11	8.54E-09	1.08E-08	7.88E-09	1.43E-09	1.00E-08	1.21E-08	1.00E-08	2.15E-09
∑ILECR	**9.19E-06**	**7.92E-07**	**5.71E-06**	**5.06E-07**	**5.43E-06**	**6.40E-06**	**6.95E-06**	**3.32E-07**	**6.48E-06**	**9.30E-06**	**7.38E-06**	**3.72E-06**

BaA: Benz(a)anthracene; Chry: Chrysene; BbF: Benz(b)fluoranthene; BkF: Benz(k)fluoranthene; BaP: Benz(a)pyrene; DahA: Dibenz(a,h)anthracene; IP: Indinol(1,2,3-cd)pyrene

Table 12 Carcinogenic risk assessment (mg/kg day^{-1}) of some polycyclic aromatic hydrocarbon in different tissues of *Heterotis niloticus* from Komadugu River Basin of Yobe State, Nigeria during the rainy, dry seasons and harmattan period.

	Rainy Season				Harmattan Period				Dry Season			
PAHs	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine
BaA	3.57E-09	2.86E-09	2.14E-09	2.14E-09	2.68E-09	3.39E-09	2.50E-09	1.43E-09	2.85E-09	3.57E-09	2.72E-09	2.15E-09
Chry	4.29E-13	2.86E-13	2.86E-13	2.86E-13	4.83E-13	5.18E-13	4.83E-13	2.32E-13	4.29E-13	5.00E-13	3.57E-13	2.85E-13
BbF	1.17E-08	1.43E-08	1.43E-08	1.43E-09	1.43E-08	8.25E-09	1.23E-08	7.52E-10	2.15E-08	3.15E-08	2.36E-08	1.43E-09
BkF	1.71E-08	8.57E-09	6.43E-09	2.86E-09	1.43E-09	8.25E-10	1.31E-09	1.47E-10	2.15E-09	2.36E-09	2.15E-09	1.43E-10
BaP	1.50E-06	7.14E-07	8.57E-07	2.86E-07	1.49E-06	8.47E-07	1.27E-06	1.13E-07	2.15E-06	3.57E-06	3.07E-06	1.43E-07
DahA	5.72E-06	4.50E-06	3.57E-06	2.14E-07	4.11E-06	4.93E-06	5.66E-06	3.04E-06	4.29E-06	5.72E-06	5.00E-06	3.57E-06
IP	7.29E-10	5.00E-10	4.57E-10	2.14E-11	8.25E-09	9.27E-09	7.88E-09	1.43E-09	1.00E-08	1.07E-08	9.49E-09	2.15E-09
∑ILECR	**7.25E-06**	**5.24E-06**	**4.45E-06**	**5.06E-07**	**5.63E-06**	**5.80E-06**	**6.95E-06**	**3.16E-06**	**6.48E-06**	**9.34E-06**	**8.11E-06**	**3.72E-06**

BaA: Benz(a)anthracene; Chry: Chrysene; BbF: Benz(b)fluoranthene; BkF: Benz(k)fluoranthene; BaP: Benz(a)pyrene; DahA: Dibenz(a,h)anthracene; IP: Indinol(1,2,3-cd)pyrene

Table 13 Hazard quotient and hazard index (mg/kg day^{-1}) of non-carcinogenic polycyclic aromatic hydrocarbon via consumption of *Clarias anguillaris* from Komadugu River Basin of Yobe State, Nigeria during the rainy, dry seasons and harmattan period.

	Rainy Season				Harmattan Period				Dry Season			
PAHs	**Gills**	**Liver**	**Flesh**	**Intestine**	**Gills**	**Liver**	**Flesh**	**Intestine**	**Gills**	**Liver**	**Flesh**	**Intestine**
Nap	2.28E-08	2.88E-08	2.45E-08	1.57E-09	1.94E-08	2.75E-08	2.56E-08	7.35E-10	1.96E-08	2.88E-08	2.45E-08	1.57E-09
2Nap	1.37E-08	2.70E-08	1.86E-08	1.47E-10	1.86E-08	2.51E-08	1.96E-08	9.80E-11	1.96E-08	2.70E-08	1.86E-08	1.47E-10
Acy	1.96E-10	2.45E-10	1.96E-10	9.80E-11	1.47E-10	2.45E-10	2.01E-10	9.80E-11	1.62E-10	2.45E-10	1.96E-10	9.80E-11
Ace	4.24E-10	6.52E-11	3.75E-11	3.75E-11	3.43E-10	3.27E-11	3.43E-11	3.27E-11	4.90E-10	6.52E-11	3.75E-11	3.75E-11
Fluo	4.16E-10	9.78E-11	7.35E-10	9.05E-11	3.93E-10	8.58E-11	6.60E-10	8.08E-11	4.90E-10	9.78E-11	7.35E-10	9.05E-11
Phen	7.34E-11	7.35E-11	7.35E-11	7.35E-11	7.58E-11	9.78E-11	7.83E-11	7.58E-11	7.35E-11	7.35E-11	7.35E-11	7.35E-11
Anth	9.79E-11	1.24E-10	9.80E-11	9.47E-11	9.80E-11	9.80E-11	1.30E-10	9.47E-11	1.21E-10	1.24E-10	9.80E-11	9.47E-11
Fl	9.79E-11	4.90E-11	4.90E-11	4.90E-11	2.93E-11	3.68E-11	2.45E-11	2.45E-11	4.90E-11	4.90E-11	4.90E-11	4.90E-11
Py	6.52E-11	1.30E-10	9.80E-11	6.53E-11	6.53E-11	1.30E-10	9.80E-11	6.53E-11	9.80E-11	1.30E-10	9.80E-11	6.53E-11
BghiP	1.86E-08	1.47E-08	9.78E-09	6.85E-10	1.47E-08	3.68E-09	1.08E-08	4.90E-10	9.78E-09	1.47E-08	9.78E-09	6.85E-10
HI	**5.64E-08**	**7.12E-08**	**5.41E-08**	**2.91E-09**	**5.39E-08**	**5.70E-08**	**5.72E-08**	**1.79E-09**	**5.05E-08**	**7.13E-08**	**5.42E-08**	**2.91E-09**

Nap: Naphthalene; 2Nap: 2-methyl Napthalene; Acy: Acenapthylene; Ace: Acenaphthene; Fluo: Fluorene; Phen: Phenanthrene; Anth: Anthracene; Fl: Fluoranthene; Py: Pyrene; BghiP: Benzo(g,h,i)perylene

Table 14 Hazard quotient and hazard index (mg/kg day^{-1}) of non-carcinogenic polycyclic aromatic hydrocarbon via consumption of *Tilapia zillii* from Komadugu River Basin of Yobe State, Nigeria during the rainy, dry seasons and harmattan period.

	Rainy Season				Harmattan Period				Dry Season			
PAHs	**Gills**	**Liver**	**Flesh**	**Intestine**	**Gills**	**Liver**	**Flesh**	**Intestine**	**Gills**	**Liver**	**Flesh**	**Intestine**
Nap	2.64E-06	2.04E-07	2.52E-07	9.79E-10	1.79E-08	2.40E-08	1.90E-08	1.86E-14	1.99E-08	2.45E-08	2.16E-08	9.80E-11
2Nap	1.81E-07	1.61E-07	1.76E-07	9.79E-10	1.91E-08	2.45E-08	2.12E-08	2.08E-14	1.96E-08	2.45E-08	2.12E-08	9.80E-11
Acy	2.94E-09	1.96E-09	2.45E-09	9.79E-10	1.96E-10	2.45E-10	2.06E-10	2.01E-16	2.30E-10	2.94E-10	2.40E-10	9.80E-11
Ace	5.55E-09	4.89E-09	5.55E-09	1.17E-12	3.58E-10	3.75E-11	3.27E-11	3.20E-17	4.90E-10	6.52E-11	4.90E-11	4.90E-11
Fluo	4.65E-09	4.16E-08	4.89E-09	7.34E-10	3.68E-10	9.78E-11	7.35E-10	7.18E-16	4.90E-10	9.78E-10	7.35E-10	7.35E-11
Phen	7.34E-10	7.34E-10	4.89E-10	7.34E-10	6.85E-11	9.55E-11	7.35E-11	7.18E-17	7.35E-11	9.78E-11	8.58E-11	7.35E-11
Anth	6.52E-10	6.52E-10	9.79E-10	6.52E-10	9.80E-11	1.30E-10	9.80E-11	9.57E-17	1.30E-10	1.63E-10	9.80E-11	8.17E-11
Fl	1.22E-09	9.79E-10	1.47E-09	2.45E-10	3.18E-11	3.43E-11	2.45E-11	2.40E-17	4.90E-11	7.35E-11	4.90E-11	2.45E-11
Py	1.30E-08	1.30E-08	1.30E-08	6.52E-10	9.80E-11	1.21E-10	9.80E-11	9.57E-17	1.30E-10	1.63E-10	9.80E-11	6.53E-11
BghiP	1.30E-07	1.03E-06	8.32E-08	4.89E-09	9.78E-09	4.15E-09	1.13E-08	1.10E-14	1.22E-08	1.47E-08	9.78E-09	7.35E-10
HI	**2.98E-06**	**1.46E-06**	**5.40E-07**	**1.08E-08**	**4.80E-08**	**5.34E-08**	**5.28E-08**	**5.16E-14**	**5.33E-08**	**6.55E-08**	**5.39E-08**	**1.40E-09**

Nap: Naphthalene; 2Nap: 2-methyl Napthalene; Acy: Acenapthylene; Ace: Acenaphthene; Fluo: Fluorene; Phen: Phenanthrene; Anth: Anthracene; Fl: Fluoranthene; Py: Pyrene; BghiP: Benzo(g,h,i)perylene

highest value of hazard index (HI) was observed in the gills with a value of 2.98E-06 mg/kg day^{-1} during the rainy season, while intestine shows the lowest value of 5.16E-14 mg/kg day^{-1} during the harmattan period **(Tables 13 and 14)**.

For that of *Synodotis budgetti*, the concentration of naphthalene for rainy, dry seasons and harmattan period ranged from 7.85E-10 to 2.07E-07 mg/kg day^{-1}, 9.80E-11 to 1.47E-07 mg/kg day^{-1} 2-methylnaphthalene, 1.01E-10 to 3.43E-09 mg/kg day^{-1} acenaphthylene, 3.27E-11 to 8.48E-09 mg/kg day^{-1} acenaphthene, 4.90E-11 to 8.32E-09 mg/kg day^{-1} fluorene, 4.90E-11 to 9.79E-10 mg/kg day^{-1} phenanthrene, 8.80E-11 to 9.79E-10 mg/kg day^{-1} anthracene, 2.45E-11 to 4.89E-10 mg/kg day^{-1} fluoranthene, 4.87E-13 to 9.79E-10 mg/kg day^{-1} pyrene and 6.13E-10 to 2.13E-07 mg/kg day^{-1} benzo(g,h,i)perylene in **Table 15**. The highest value of hazard index (HI) was observed in the flesh with a value of 7.04E-07 mg/kg day^{-1} during the rainy season, while intestine shows the lowest value of 1.98E-09 mg/kg day^{-1} during the harmattan period **(Table 15)**.

The hazard quotient and hazard index of non-carcinogenic PAHs in the gills, liver, flesh and intestine of *Synodotis budgetti* for rainy, dry seasons and harmattan period from Komadugu river basin, Yobe State Nigeria are as presented in **Table 16**. The concentration of naphthalene ranged from 7.60E-10 to 2.60E-07 mg/kg day^{-1}, 1.10E-10 to 1.57E-07 mg/kg day^{-1} 2-methylnaphthalene, 9.80E-11 to 3.43E-09 mg/kg day^{-1} acenaphthylene, 3.27E-11 to 7.34E-09 mg/kg day^{-1} acenaphthene, 7.35E-11 to 4.89E-09 mg/kg day^{-1} fluorene, 6.85E-11 to 7.34E-10 mg/kg day^{-1} phenanthrene, 9.13E-11 to 9.79E-10 mg/kg day^{-1} anthracene, 2.45E-11 to 6.52E-09 mg/kg day^{-1} fluoranthene, 7.33E-11 to 1.63E-09 mg/kg day^{-1} pyrene and 5.50E-10 to 1.27E-07 mg/kg day^{-1} benzo(g,h,i)perylene. Flesh shows the highest value of hazard index (HI) with a value of 5.67E-07 mg/kg day^{-1} during the rainy season, while intestine shows the lowest value of 1.89E-09 mg/kg day^{-1} during the harmattan period **(Table 16).**

Discussion

The 17 PAHs were detected in all the four fish samples examined. Exposure pathways of polycyclic aromatic hydrocarbons (PAHs) in fish include bioconcentration from water across their gills and skin and ingestion of PAH-contaminated particulate matter along with food, as PAHs readily adsorb onto particulate organic matter especially sediments [14-17]. PAHs are lipophilic and so they accumulate in the fatty tissues of fish following their uptake [18]. Generally, the levels of the studied PAHs in the fish samples were significantly higher in the liver and gills of all the fishes studied than other organs, such high levels is due to the fact that fresh water fishes gills might be expected to be the primary rout for the uptake of water pollutants, while the liver served as a storage organs for vast variety of nutrient. High accumulation of these PAHs in the gills and liver can also be as a result of detoxicating mechanisms and may originate from PAHs deposited in the sediments and food in the aquatic environment. However, the liver is the preferred organs for PAHs accumulation as could be observed in the present study. Accumulation of PAHs in different species is the function of their respective membrane permeability and enzyme system and because of the fact that PAHs accumulate in different organs of fish as observed in the present study.

Heterotis niloticus and *Tilapia zilli* showed the highest levels of PAHs with total values of 1.15E+02 mg/kg and 1.11E+02 mg/kg as compared to *Clarias anguillaris* and *Synodontis budgetti* with total values of 1.03E+02 mg/kg and 1.09E+02 mg/kg respectively. *Heterotis niloticus* and *Tilapia zilli* feed on detritus and most species have unusually muscular stomach and pharynx that help in digestion [19,20]. The observed differences in PAH bioaccumulation in both species may also be attributed to differences in feeding preferences and general behavior, as well as the mode of feeding in these species [21,22]. These may be the reasons why some of this fish species have a significant higher concentration of PAHs as compared to other species of fish. Total PAHs concentrations in all the fish species were significantly higher in the rainy season and harmattan period when compared to dry season. The variation in concentrations of the studied PAHs in the rainy season and harmattan period when compared to dry season might be attributed to the polluted inflowing river, runoff and atmospheric deposit coupled with the discharged of industrial effluent from the Kano and Jos axis into the river which flows to the study area.

PAHs are classified into two broad groups based on their physical and biological properties including high molecular weight (HMW)

Table 15 Hazard quotient and hazard index (mg/kg day^{-1}) of non-carcinogenic polycyclic aromatic hydrocarbon via consumption of *Synodetis budgetti* from Komadugu River Basin of Yobe State, Nigeria during the rainy, dry seasons and harmattan period.

	Rainy Season				Harmattan Period				Dry Season			
PAHs	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine
Nap	2.07E-07	1.47E-09	2.50E-07	1.47E-09	1.86E-08	2.58E-08	2.23E-08	7.85E-10	1.96E-08	2.69E-08	2.30E-08	9.80E-10
2Nap	1.47E-07	1.47E-08	2.45E-07	1.47E-09	1.89E-08	2.48E-08	2.04E-08	1.23E-10	1.91E-08	2.45E-08	2.06E-08	9.80E-11
Acy	2.45E-09	1.47E-09	3.43E-09	1.47E-09	1.72E-10	2.45E-10	2.03E-10	1.01E-10	1.96E-10	2.69E-10	2.20E-10	1.23E-10
Ace	5.87E-09	4.89E-10	8.48E-09	4.89E-10	3.50E-10	3.50E-11	3.35E-11	3.27E-11	4.90E-10	6.52E-11	4.08E-11	3.27E-11
Fluo	6.85E-09	9.79E-10	8.32E-09	9.79E-10	3.80E-10	9.18E-11	6.98E-10	7.70E-11	4.90E-10	9.78E-11	7.35E-11	4.90E-11
Phen	9.79E-10	9.79E-10	9.79E-10	9.79E-10	7.23E-11	9.68E-11	7.58E-11	7.45E-11	8.58E-11	1.10E-10	7.35E-11	4.90E-11
Anth	6.52E-10	3.26E-10	9.79E-10	3.26E-10	9.80E-11	1.14E-10	1.14E-10	8.80E-11	9.80E-11	1.30E-10	1.14E-10	9.13E-11
Fl	1.22E-09	4.89E-10	4.89E-10	4.89E-10	3.05E-11	3.55E-11	2.45E-11	2.45E-11	7.35E-11	1.22E-10	7.35E-11	4.90E-11
Py	9.79E-10	9.79E-10	4.87E-13	9.79E-10	8.17E-11	1.26E-10	9.80E-11	6.53E-11	9.80E-11	1.47E-10	1.08E-10	9.80E-11
BghiP	2.13E-07	5.63E-08	1.86E-07	7.34E-09	1.22E-08	3.93E-09	1.10E-08	6.13E-10	1.22E-08	1.47E-08	1.10E-08	6.13E-10
HI	**5.86E-07**	**7.82E-08**	**7.04E-07**	**1.60E-08**	**5.09E-08**	**5.53E-08**	**5.49E-08**	**1.98E-09**	**5.24E-08**	**6.70E-08**	**5.53E-08**	**2.18E-09**

Nap: Naphthalene; 2Nap: 2-methyl Napthalene; Acy: Acenapthylene; Ace: Acenaphthene; Fluo: Fluorene; Phen: Phenanthrene; Anth: Anthracene; Fl: Fluoranthene; Py: Pyrene; BghiP: Benzo(g,h,i)perylene

Table 16 Hazard quotient and hazard index (mg/kg day^{-1}) of non-carcinogenic polycyclic aromatic hydrocarbon via Consumption of *Heterotuis niloticus* from Komadugu River Basin of Yobe State, Nigeria during the rainy, dry seasons and harmattan period.

	Rainy Season				Harmattan Period				Dry Season			
PAHs	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine	Gills	Liver	Flesh	Intestine
Nap	2.60E-07	1.99E-07	2.48E-07	1.47E-09	1.90E-08	2.31E-08	2.40E-08	7.60E-10	2.11E-08	2.45E-08	2.16E-08	1.47E-09
2Nap	1.44E-07	1.57E-07	1.96E-07	1.47E-09	1.88E-08	2.20E-08	2.00E-08	1.10E-10	1.96E-08	2.30E-08	1.96E-08	1.47E-10
Acy	3.43E-09	2.45E-09	2.94E-09	1.47E-09	1.59E-10	2.08E-10	2.02E-10	9.95E-11	2.45E-10	1.96E-10	1.91E-10	9.80E-11
Ace	7.34E-09	6.53E-09	5.71E-09	4.89E-10	3.47E-10	1.92E-10	3.40E-11	3.27E-11	4.90E-10	3.27E-10	3.27E-11	3.27E-11
Fluo	4.89E-09	4.89E-09	4.89E-09	9.79E-10	3.88E-10	2.33E-10	6.80E-10	7.90E-11	7.35E-10	1.96E-09	1.22E-09	7.35E-11
Phen	7.34E-10	7.34E-10	4.89E-10	7.34E-10	7.43E-11	8.53E-11	7.70E-11	7.53E-11	9.78E-11	1.22E-10	7.35E-11	6.85E-11
Anth	6.52E-10	6.52E-10	9.79E-10	6.52E-10	9.80E-11	9.80E-11	1.22E-10	9.13E-11	9.80E-11	1.30E-10	1.17E-10	9.13E-11
Fl	1.47E-09	1.22E-09	1.71E-09	6.52E-09	3.00E-11	3.38E-11	2.45E-11	2.45E-11	7.35E-11	1.22E-10	9.78E-11	4.90E-11
Py	1.63E-09	1.63E-09	1.63E-09	9.79E-10	7.33E-11	1.06E-10	9.80E-11	6.53E-11	1.30E-10	1.79E-10	1.27E-10	9.80E-11
BghiP	1.27E-07	1.25E-07	1.05E-07	7.40E-09	1.35E-08	7.95E-09	1.09E-08	5.50E-10	1.47E-08	1.71E-08	1.35E-08	7.35E-10
HI	**5.51E-07**	**4.99E-07**	**5.67E-07**	**2.22E-08**	**5.25E-08**	**5.40E-08**	**5.61E-08**	**1.89E-09**	**5.73E-08**	**6.76E-08**	**5.66E-08**	**2.86E-09**

Nap: Naphthalene; 2Nap: 2-methyl Napthalene; Acy: Acenapthylene; Ace: Acenaphthene; Fluo: Fluorene; Phen: Phenanthrene; Anth: Anthracene; Fl: Fluoranthene; Py: Pyrene; BghiP: Benzo(g,h,i)perylene and low molecular weight (LMW) PAHs. The HMW PAHs consist of 4-6 aromatic rings and are less readily bio-degraded by indigenous microorganisms, hence can persist in the aqueous environment by bio-accumulating in aquatic organisms like fish and mussels and are more carcinogenic [23]. The LMW PAHs consists of 2-3 aromatic rings and although less carcinogenic also pose toxic effect to many aquatic organisms [24]. The PAHs composition of water and sediments can give some information about their sources and how they were derived. Larger concentration of LMW PAHs (e.g. acenaphthene, fluorene) most often occur in sample matrices contaminated with naturally occurring PAHs (petrogenic and biogenic origins) and also as a result of resent discharged into the environment, while the PAHs from combustion processes (pyrolytic origin) often contain elevated concentrations of HMW (e.g. phenanthrene, fluoranthene, pyrene) and fewer LMW PAHs [25]. In the present study, low molecular weight PAHs (LMW-PAHs) was generally predominant compared to high molecular weight PAHs (HMW-PAHs). Naphthalene (2 ringed) is the most dominant PAHs in all the tissues of fish samples studied. The high concentrations of LMW when compared to HMW PAHs might be due to the resent discharged into the environment, also high molecular weight compounds (4-6 ringed) get lost as a result of photo-oxidation and maybe attached to the underlying sediments [26,27]. The occurrence of PAHs in fish is an indication of PAH contamination in rivers. Possible sources of PAHs in Nigeria waters include oil slicks, accidental discharges of oil from ships and fishing boats, burning of garbage on land, dumping of domestic wastes on the rivers and smoke emissions from industries and automobile exhaust. Exposure pathways of PAHs to fish include bioconcentration from water across their gills and skin and ingestion of PAH-contaminated particulate matter along with food, as PAHs readily adsorb onto particulate organic matter [14-17]. PAHs are lipophilic and so they accumulate in the fatty tissues of fish following their uptake [18].

For *Clarias anguillaris* during the rainy, dry seasons and hammatan periods, the gills accumulated significantly higher concentrations of total PAHs with a value of 3.42E+01 mg/kg, while intestine shows the lowest value of 1.47E+00 mg/kg among the studied fish samples at $P<0.05$. For *Tilapia zilli* during the rainy, dry seasons and hammatan periods, the liver accumulated significantly higher concentrations of total PAHs with a value of 3.78E+01 mg/kg, while intestine shows the lowest value of 2.70E+00 mg/kg among the studied tissues of fish samples $P<0.05$. For *Synodontis budgetti* during the rainy, dry seasons and hammatan periods, the flesh accumulated significantly higher concentrations of total PAHs with a value of 4.05+01 mg/kg, while intestine shows the lowest value of 2.98E+00 mg/kg among the studied tissues of fish samples $P<0.05$. For *Heterotis niloticus* during the rainy, dry seasons and hammatan periods, the liver accumulated significantly higher concentrations of total PAHs with a value of 3.90+01 mg/kg, while intestine shows the lowest value of 3.11E+00 mg/kg among the studied tissues of fish samples $P<0.05$. Hence, the levels of the studied PAHs in the fish samples were significantly higher in the liver and gills of all the tissues of fishes studied than other organs, such high levels is due to the fact that gills might be expected to be the primary rout for the uptake of water pollutants during respiration, while the liver served as a storage organs for vast variety of nutrient. High accumulation of these PAHs in the gills and liver can also be as a result of detoxicating mechanisms and may originate from PAHs deposited in the sediments and food in the aquatic environment. However, the liver is the preferred organs for PAHs accumulation as could be observed in the present study. Accumulation of PAHs in different species is the function of their respective membrane permeability and enzyme system and because of the fact that PAHs accumulate in different organs of fish as observed in the present study **(Tables 1-4)**.

Heterotis niloticus shows the highest total levels of PAHs accumulation with a value of 1.15E+02 mg/kg, while *Clarias anguillaris* shows the lowest total concentration with a value of 1.03E+02 mg/kg. The variation in the levels of PAHs in the fish samples is possibly due to local physical mixing, which can result in resuspension of bottom sediments and might be redistribution of PAHs into the water column, thereby, exposing fishes to PAHs irrespective of where these fishes may be found [28]. The observed differences in PAH bioaccumulation in *Clarias anguillaris, Tilapia zilli, Synodontis budgetti* and *Heterotis niloticus* may also be attributed to differences in feeding preferences and general behavior, as well as the mode of feeding in these species [21,22]. All the fishes samples studied were observed to be below the average BaP concentrations set by European Union (EU) limit of 2 µg/kg wet weight for fish, which is recommended to be safe for human consumption.

Estimation of average daily dose (ADD)

In Komadugu river basin, the estimated average daily dose (ADD) of polycyclic aromatic hydrocarbons (PAHs) through the consumption of fish in the study area was less than tolerable daily dose limit from the daily per capital fish consumption of 0.07 kg/day for Nigeria set by the FAO [13]. In the present study, the highest ADD value in the fish studied were observed in the liver of *Heterotis niloticus* with a value of 1.38E-06 mg/kg day^{-1}, while the lowest value was observed in the intestine of *Tilapia zilli* with a value of 9.93E-13 mg/kg day^{-1}.

Estimation of hazard quotient (HQ)

The hazard quotient (HQ) values were calculated on the basis of the reference dose (RfD) for PAHs as proposed by USEPA [29]. From the results of the study, the HQ values of all the fish samples studied were all below one (1). When HQ exceed one (1), there is concern for health effect [30]. This shows that the fish consumption in the study area found to be free of risk. With the lower HQ values observed in all the tissues of fish samples, all the PAHs were least responsible for causing risk to the consumers as the value of HQ was below 1 for all the tissues of fish from Komadugu river basin, Yobe State, Nigeria **(Tables 13-16)**.

Estimation of hazard index (HI)

An index of risk called hazard index (HI) for residents of ingesting these PAHs by consuming fish from the study area were calculated by summation of HQ of all PAHs for each fish tissues. In the present study the highest (HI) of PAHs was found in the gills of *Tilapia zilli* with a value of 2.98E-06, whereas the lowest level was observed in the intestine of *Tilapia zilli* with a value of 5.16E-14. HI values of all the PAHs for all tissues of fish samples were less than one (1) by USEPA and IRIS, indicated that there was no risk from the intake of these fish from the study area **(Tables 13-16)** [31].

Incremental Life Expectancy by Ingestion of PAHs in Fish

The cumulative probability distributions of calculated incremental life expectancy cancer risk (ILECR) for different tissues of *Clarias anguillaris*, *Tilapia zilli, Synodontis budgetti* and *Heterotis niloticus* from Komadugu river basin are presented in **Tables 9 to 12**. ILECR values in different tissues of *Clarias anguillaris, Tilapia zilli, Synodontis budgetti* and *Heterotis niloticus* were in the range of 3.61E-07 to 7.67E-06 mg/kg day^{-1}, 6.81E-07 to 6.69E-06 mg/kg day^{-1}, 3.32E-07 to 9.30E-06 mg/kg day^{-1} and 5.06E-07 to 9.34E-06 mg/kg day^{-1}, respectively, some of the values were observed to be higher than the acceptable risk level (1.00E-06). As for the major edible parts, ILECR mean values in flesh were 1.97E-05 mg/kg day^{-1} for *Clarias anguillaris,* 1.47E-05 mg/kg day^{-1} for *Tilapia zilli*, 2.00E-05 mg/kg day^{-1} for *Synodontis budgetti* and 1.95E-05 mg/kg day^{-1} for *Heterotis niloticus* respectively. In addition, higher ILECR was also found in liver of *Clarias anguillaris* with the value of 1.33E-05 mg/kg day^{-1}, 1.58E-05 mg/kg day^{-1} for *Tilapia zilli*, 1.65E-05 mg/kg day^{-1} for *Synodontis budgetti* and 2.04E-05 mg/kg day^{-1} for *Heterotis niloticus* in comparing to other major tissues (flesh, intestine and gills) of fish [32].

The total ILECR PAHs cumulative probability in all the tissues (gills, liver, flesh and intestine) of fish samples studied from Komadugu river basin were in the order of *Heterotis niloticus*>*Synodontis budgetti*>*Clarias anguillaris*>*Tilapia zilli*. *Heterotis niloticus* with a value of 2.77E-05 mg/kg day^{-1} revealed that 3 out of 100,000 are likely to suffer cancer-related illness in their lifetime due to consumption of *Heterotis niloticus*. For *Synodontis budgetti* with a total ILECR value of 2.69E-05 mg/kg day^{-1} means 3 out of 100,000 that are likely to suffer cancer-related illness in their lifetime due to consumption of *Synodontis budgetti* exposure, 2 out of 100,000 that are likely to suffer cancer-related illness in their lifetime due to *Clarias anguillaris* exposure with a total ILECR value of 2.09E-05 mg/kg day^{-1} and 2 out of 100,000 that are likely to suffer cancer-related illness in their lifetime due to consumption of *Tilapia zilli* with a total ILECR value of 1.77E-05 mg/kg day^{-1}.

Conclusion

The levels of the studied PAHs were observed to be higher in the tissues of *Heterotis niloticus*, while the lowest concentrations were observed in the tissues of *Clarias anguillaris.* In the present study, the highest average daily dose (ADD) value in the fish studied was observed in the liver of *Heterotis niloticus* with a value of 1.38E-06 mg/kg day^{-1}, while the lowest value was observed in the intestine of *Tilapia zilli* with a value of 9.93E-13 mg/kg day^{-1}. These values are less than the tolerable daily dose limit from the daily per capital fish consumption of 0.07 kg for Nigeria. The hazard quotient (HQ) values obtained for all the fish samples studied were all below one (1), this shows that the fish consumption in the study area found to be free of risk. The highest hazard index (HI) value for PAHs was found in the gills of Tilapia zilli with a value of 2.98E-06, whereas the lowest level was observed in the intestine of Tilapia zilli with a value of 5.16E-14. The (HI) values of all the PAHs in the tissues of fish samples were less than one (1); this is an indication that there is no risk from the intake of these fish from the study area. The cumulative probability distributions of calculated incremental life expectancy cancer risk (ILECR) for different tissues of *Clarias anguillaris*, *Tilapia zilli, Synodontis budgetti* and *Heterotis niloticus* shows that more than one in one million of the population are prone to cancer upon consumption of fish from Komadugu river basin.

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