



Research Article

Hazard Quotient and Hazard Indexes of Polycyclic Aromatic Hydrocarbon Levels in Fish Samples from Gubi Dam, Bauchi State, Nigeria

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ABSTRACT

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This study is aimed at determining the levels of sixteen (16) polycyclic aromatic hydrocarbons (PAHS) in fish samples from Gubi Dam, Bauchi State. *Tilapia dageti* (Coptodon fish), *Tilapia zilli* (Coptodon fish), *Alestes baremoze* (Pebble fish) and *Clarias gariepinus* (Catfish) fish species samples of uniform size were collected. Four tissues (Liver, flesh, intestine and gills) of the fish species were removed. Extraction and clean-up of the tissues were carried using standard methods. The levels of the PAHS in the tissues were determined using GC-MS. The results revealed that the highest concentration of PAHs was observed in *Tilapia dageti* (2.51E-01) while the lowest concentration was observed in *Clarias gariepinus* (4.97E-02). The estimated daily dose of PAHs in the different fish samples shows *Tilapia dageti* as having the highest daily dose of 1.3 IE-01 mg/kg was below the tolerable daily dose of fish per capital of 0.07 kg/day for Nigeria as set by FAO, 2008. The excess cancer risk values amongst the fish species relatively showed *Tilapia dageti* with high risk with a value of 1.08E-01 mg/kg day which are mostly observed in the liver, while *Clarias gariepinus* show the lower cancer risk with a value of 2.35E-16 mg/kg day¹ which are mostly recorded in the intestine. Both the hazard quotient and hazard indexes were observed to be less than 1. Therefore, there is no appreciable health risk for the development of non-cancer health effect via consumption of PAHs residues from all the four fish samples studied from Gubi Dam.

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INTRODUCTION

Polycyclic Aromatic Hydrocarbons (PAHs) are part of the list of the 12 Persistent Organic Pollutants (POPs) and benzo(a)pyrene (BaP) is the most toxic of the PAHs (Wilson, 2014). PAHs constitute a large class of organic compounds containing two or more fused aromatic rings. In the world, there are lake ecosystems under permanent chemical stress due to urbanization and the oil industry. PAHs are important environmental pollutants originating from a wide variety of natural and anthropogenic sources. PAHs are generally formed during incomplete combustion of organic matter containing carbon and hydrogen (Wilson, 2014). Hundreds of individual PAHs may be formed during incomplete combustion or pyrolysis of organic matter (FAO/WHO, 2005). The sources of PAH in food are mainly environmental pollution and food processing (drying, smoking) and cooking (roasting, grilling, and frying) (Zang *et al.*, 2010). One of the major routes of human exposure to PAHs in non-smoking people is food (Plaza-Bolanos *et al.*, 2010). These compounds occur as contaminants in different kinds of foodstuffs including dairy products, vegetables, fruits, oils, cereals, and smoked meats (Camargo and Toledo, 2002; Dobrinas *et al.*, 2008; Simko, 2002). Food items and products could be contaminated by soils, polluted air and water (WHO, 2005). Some aquatic food products, such as fish, can be exposed to PAHs present in water and sediments and the PAH content greatly depends on the ability of the aquatic organisms to metabolize them (Plaza-Bolanos *et al.*, 2010). On the other hand, PAHs are also found in foods as a result of certain industrial food processing methods such as smoke curing, broiling, roasting, and grilling over open fires or charcoal which permits the direct contact between food and combustion products (Silva *et al.*, 2011). PAHs have solubility in water but are readily soluble in organic solvent or organic acids. Thus environments, PAHs are generally found

adsorbed on particulates and on humic matter, or dissolved in any oily contamination that may be present in water, sediment soil. The solubility of PAHs in water is inversely proportional to the number of rings the PAHs molecule contains (EFSA, 2008).

A number of PAHs have been found to have carcinogenic and mutagenic effects while some of them may act as synergists (Wenzl *et al.*, 2006). PAHs and other pollutants have a detrimental effect on sea creatures which include the fishes consumed by humans. 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 (Wilson, 2014).

These compounds can reach the food chain by different ways as PAHs have been found in different food products, such as dairy products, vegetables, fruits, oils, coffee, tea, cereals and smoked meat, therefore the analysis of PAHs in food is a matter of concern (Plaza-Bolanos *et al.*, 2010). These contaminants in the environment are primarily evaluated by measuring the chemical concentration of PAHs. The results of chemical analyses are important for estimating water and sediment quality in the risk assessment to the flora and fauna of any contaminated sites. 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 (Wilson, 2014).

The objectives of the study are to determine the level of polycyclic aromatic hydrocarbons (PAHs) which include Naphthalene, 2-Methylnaphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, Anthracene, Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Dibenz(a,h)anthracene,

Benzo(g,h,i)perylene, and indinol (1,2,3-cd)pyrene in the tissues of fish (flesh, intestine, liver and gills) samples such as *Alestes bariemus*, *Clarias gariepinus*, *Tilapia zilli* and *Tilapia degati* and conduct risk assessment of PAHs in the fish samples.

Gubi Dam is greatly affected by the commercial, environment and industrial activities that take place within and around the city. The city is also a hub for long-haul and passenger vehicles that convey cargo and people to the northeast region of Nigeria. This population growth comes with a proportionate increase in wastes, oil-related spills, and increase in use of electricity and electrical components that are normal for a fast growing modern city. The pollutants, untreated sewage, industrial and domestic landfill waste and by-products of slash and burn activities from the city end up in Gubi Dam. Thus, the contamination of fish and the aquatic environment by pollutants such as PAHs is viewed with serious concern.

Fishing practice is attracting a lot of focus because it contributes significantly to the world proteins requirement. Fish is a high quality food; its content of protein matter is important. It is rich in vitamins and contains variable quantities of fat, and calcium for human health. The protein is first class and inexpensive and its composition and consumption is desirable (Moses, 1990). Nigeria is blessed with abundant natural water bodies with abundant fish resources. Nigerian freshwater bodies are the richest in West Africa in terms of fish abundance (Meye and Ikomi, 2008). The fish resources, apart from being a major source of high quality animal protein for man, provide several socio-economic values as sources of job opportunities and raw material for some industrial activities as well as recreational purposes (Yakub, 2012). Nigeria's populations live near water bodies such as lakes, lagoons, reservoirs, rivers, swamps and coastal lagoons. Many depend heavily on the resources of such water bodies for their main source of animal protein and family

income (Abubakar *et al.*, 2006). Ita (1993) reported 268 different species in 34 well known Nigerian freshwater rivers, lakes, reservoirs, which constitute about 12% of Nigeria's total surface area of about 98,185,000 hectares. However, according to Jamu and Ayinla (2003), the yields of most of these inland waters are generally on the decline due to environmental degradation such as water pollution and improper or poor management of fisheries resources. Environmental Protection Agency (EPA) recommended species richness and relative abundance as ecological risk assessment in aquatic ecosystem (EPA, 2007). Odo *et al.* (2009) reported an estimated fiftytwo (52) fish species belonging to seventeen (17) families from Anambra River, Nigeria. The fisheries and fish resources of Nigeria are not only of considerable economic importance but they are also making a significant contribution to national food security and as well providing a major source of employment in rural areas. The fish stock diversities are directly dependent on the quality and quantity of water resources in the country (Bolorunduro, 2003). Condition factor is a useful index for the monitoring of feeding intensity, age, and growth rates in fish (Oni *et al.*, 1983). Condition factor is strongly influenced by both biotic and abiotic environmental conditions and can be used as an index to assess the status of the aquatic ecosystem in which fish live (Afamdi, 2005). Condition factors of different tropical fish species were investigated and reported by Saliu (2001) and Lizama *et al.* (2002).

Gubi Dam was constructed to provide water to Bauchi metropolis. It was commissioned in 1980 with the knowledge that the water would have to be treated to make it fit for human use (Abdullahi *et al.*, 2014). Abdulkarim *et al.* (2005) identified eight (8) fish species in the dam – *Alestes bariemoze*, *Tilapia zilli*, *Clarias gariepinus* and *Tilapia degati*. Fishing activities at the dam are mainly traditional, characterized by the use of traditional fishing gears such as *Birgi*, *Mari*

(nets), *Kugiya* (lines), *Mali* and *Undurtu* (fishing traps).

Analytical methods for the identification and determination of organochlorine pesticides are widely available and are the result of an extensive environmental analytical method development and research on persistent organic pollutants over the past 30-40 years. Given the broad range of technical expertise for analysis of OCPs, the UNEP POPs workshop on global monitoring (UNEP, 2009) noted that no single, detailed, step-by-step analytical method can be specifically recommended. Laboratories are thus encouraged to use methods best-suited to their situation and take part in international interlaboratory comparisons to verify their work. This performance-based approach has also been adopted by the (USEPA, 2003) in an effort to introduce flexibility in conducting environmental monitoring. GC-MS is one of the analytical methods used for the identification and determination of organochlorine pesticide residues PCBs and PAHs in samples. The use of a mass spectrometer as the detector in gas chromatography was developed during the 1950s by Roland Goh Ike and Fred Me Lafferty (Muir and Sverko, 2006).

MATERIALS AND METHODS

Collection of Fish Samples

Fish samples *Alestes bariemus*, *Clarias gariepinus*, *Tilapia zilli* and *Tilapia degeti* were collected from Gubi Dam from fisher men in the early hours of the day, Fish samples of uniform size were collected in order to avoid the possible error due to size differences. Samples of fishes were transported to the laboratory, and identified by an expert in fishery Department and later dissected to remove the flesh, liver, intestine and gills of each species of fish. The tissues were placed in a well sterilized 200 g amber glass bottle and labelled with unique identification number and stored in an ice box at 10°C pending extraction and analysis.

Extraction of PAHs in Fish Samples

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. The homogenized dried 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.

Clean-up of Fish Extract for PAHs Analysis

This clean-up step to remove more polar substances was performed using activated florisil (Magnesium silicate) and anhydrous Na₂SO₄. The florisil was heated in an oven at 130°C overnight (ca. 15 h) and transferred to a 250 mL size beaker and place in a desiccator. A 0.5 g anhydrous Na₂SO₄ was added to 1.0 g of activated florisil (60-100 mm mesh) on an 8 mL 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 then 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 dissolved in 1 mL *n*-hexane for Gas Chromatographic analysis.

The extract was thereafter analyzed using Agilent 7890A GC/MS previously calibrated with PAHs standards.

RESULTS

Mean Concentration of Some Polycyclic Aromatic Hydrocarbon (PAHs) in Different Tissues of the Four Species of Fish Samples

Tables 1, 2, 3 and 4 shows the mean concentrations of some polycyclic aromatic hydrocarbons in the different tissues (gills, liver,

flesh and intestine) of the *Tilapia dageti*, *Tilapia zillii*, *Alestes baremoze* and *Clarias gariepinus* respectively from Gubi Dam, Bauchi State.

Table 1: Mean Concentrations of Some Polycyclic Aromatic Hydrocarbon (PAHs) in Different Tissues of *Tilapia dageti* from Gubi Dam, Bauchi State, Nigeria

PAHs	No. of Rings	Concentrations (mg/kg)				
		MACs	Liver	Flesh	Intestine	Gills
Naphthalene	2	1	2.21E-05	1.17E-02	1.70E-02	8.64E-02
2-methylnaphthalene	2	1	3.36E-04	7.90E-05	5.93E-04	3.76E-03
Acenaphthylene	3	3	4.31E-05	9.12E-06	3.54E-04	3.21E-03
Acenaphthene	3	3	5.60E-06	8.07E-05	2.54E-04	2.87E-04
Fluorene	3	3	4.63E-05	2.47E-05	1.52E-04	4.22E-03
Phenanthrene	3	3	5.23E-04	8.13E-04	1.13E-02	5.10E-04
Anthracene	3	3	4.68E-04	3.00E-04	2.52E-04	2.38E-04
Fluoranthene	4	3	6.16E-03	3.96E-03	1.97E-01	1.92E-02
Pyrene	4	3	7.65E-03	1.61E-03	1.46E-02	1.39E-02
Benzo(a)anthracene	4	0.15	6.89E-05	1.95E-03	1.78E-04	8.10E-03
Chrysene	4	-	7.38E-06	3.90E-04	2.24E-04	5.42E-04
Benz(b)fluoranthene	5	0.3	1.87E-04	2.44E-04	7.33E-03	1.97E-03
Benz(k)fluoranthene	5	-	1.47E-04	4.05E-05	1.23E-04	1.94E-03
Benzo(a)pyrene	5	0.3	2.03E-05	1.05E-04	2.46E-04	5.84E-05
Dibenz(a,h)anthracene	5	0.3	3.82E-05	1.88E-05	5.54E-05	9.15E-05
Indinol(1,2,3-cd)pyrene	6	-	1.90E-04	1.17E-04	8.90E-04	2.27E-04
TOTAL			1.59E-02	2.14E-02	2.51E-01	1.45E-01

MACs= Maximum Allowable Concentrations (ATSDR, 2006)

Table 2: Mean Concentrations of Some Polycyclic Aromatic Hydrocarbon (PAHs) in Different Tissues of *Tilapia zillii* from Gubi Dam, Bauchi State, Nigeria

PAHs	No. of Rings	Concentrations (mg/kg)				
		MACs	Liver	Flesh	Intestine	Gills
Naphthalene	2	1	7.28E-02	2.14E-04	1.46E-02	7.73E-02
2-methylnaphthalene	2	1	5.34E-03	3.62E-05	2.84E-04	5.47E-03
Acenaphthylene	3	3	5.31E-04	2.43E-04	2.43E-03	4.51E-03
Acenaphthene	3	3	3.75E-04	9.46E-05	8.04E-04	6.30E-04
Fluorene	3	3	8.23E-04	1.25E-04	4.32E-03	2.61E-02
Phenanthrene	3	3	2.12E-04	1.65E-05	1.94E-03	5.11E-02
Anthracene	3	3	7.52E-04	1.37E-04	1.94E-03	6.30E-03
Fluoranthene	4	3	2.82E-02	5.31E-03	5.52E-02	9.61E-03
Pyrene	4	3	9.27E-03	1.88E-05	1.64E-02	5.19E-03
Benzo(a)anthracene	4	0.15	1.97E-04	4.67E-05	8.72E-04	2.96E-03
Chrysene	4	-	6.19E-05	2.41E-05	1.51E-04	2.32E-03
Benzo(b)fluoranthene	5	0.3	3.89E-04	9.09E-04	5.71E-03	2.26E-04
Benzo(k)fluoranthene	5	-	4.16E-05	4.10E-04	1.48E-05	4.54E-04
Benzo(a)pyrene	5	0.3	5.19E-06	6.25E-05	4.65E-04	1.21E-05
Dibenzo(a,h)anthracene	5	0.3	8.89E-05	8.10E-05	2.23E-05	4.56E-05
Indinol(1,2,3-cd)pyrene	6	-	6.35E-05	2.07E-04	4.15E-04	1.73E-03
TOTAL			1.19E-01	7.94E-03	1.06E-01	1.94E-01

MACs= Maximum Allowable Concentrations (ATSDR, 2006)

Table 3: Mean Concentrations of Some Polycyclic Aromatic Hydrocarbon (PAHs) in Different Tissues of *Alestes baremoze* from Gubi Dam, Bauchi State, Nigeria

Concentrations (mg/kg)						
PAHs	No. of Rings	MACs	Liver	Flesh	Intestine	Gills
Naphthalene	2	1	3.57E-02	2.02E-02	3.51E-03	4.54E-02
2-methylnaphthalene	2	1	1.09E-04	3.02E-03	8.22E-05	1.24E-03
Acenaphthylene	3	3	2.93E-03	2.31E-02	3.22E-02	4.75E-04
Acenaphthene	3	3	3.71E-03	4.33E-04	1.46E-04	1.83E-03
Fluorene	3	3	1.73E-04	5.21E-05	3.18E-04	2.90E-03
Phenanthrene	3	3	2.84E-03	2.14E-05	2.52E-04	2.13E-03
Anthracene	3	3	4.21E-04	3.22E-04	3.20E-04	2.61E-03
Fluoranthene	4	3	1.49E-02	4.00E-03	1.44E-02	6.81E-03
Pyrene	4	3	2.42E-03	7.70E-03	1.26E-02	6.44E-03
Benzo(a)anthracene	4	0.15	6.49E-05	6.77E-03	1.82E-03	6.11E-03
Chrysene	4		3.19E-06	5.33E-05	5.47E-04	2.57E-03
Benzo(b)fluoranthene	5	0.3	7.72E-04	1.89E-03	9.19E-06	1.78E-02
Benzo(k)fluoranthene	5		8.79E-05	3.66E-06	7.09E-06	2.63E-03
Benzo(a)pyrene	5	0.3	4.87E-05	9.82E-05	7.08E-06	9.49E-04
Dibenz(a,h)anthracene	5	0.3	1.32E-05	1.71E-05	4.21E-06	6.65E-05
Indinol(1,2,3-cd)pyrene	6		1.30E-04	2.43E-05	3.07E-05	8.60E-05
TOTAL			6.43E-02	6.77E-02	6.63E-02	1.00E-01

MACs= Maximum Allowable Concentrations (ATSDR, 2006)

Table 4: Mean Concentrations of Some Polycyclic Aromatic Hydrocarbon (PAHs) in Different Tissues of *Clarias gariepinus* from Gubi Dam, Bauchi State, Nigeria

Concentrations (mg/kg)						
PAHs	No of Rings	MACs	Liver	Flesh	Intestine	Gills
Naphthalene	2	1	1.90E-02	2.30E-02	6.35E-04	6.52E-02
2-methylnaphthalene	2	1	2.33E-02	1.01E-04	1.16E-03	2.07E-04
Acenaphthylene	3	3	2.76E-04	5.76E-05	6.60E-04	2.56E-04
Acenaphthene	3	3	4.73E-05	1.75E-04	1.58E-02	2.46E-04
Fluorene	3	3	1.93E-04	3.23E-03	8.94E-04	2.45E-03
Phenanthrene	3	3	2.43E-04	8.94E-05	1.63E-05	8.10E-03
Anthracene	3	3	2.32E-04	6.68E-04	2.54E-05	1.82E-03
Fluoranthene	4	3	1.51E-03	5.89E-03	1.11E-02	2.80E-02
Pyrene	4	3	3.48E-05	1.29E-03	3.94E-03	8.81E-03
Benzo(a)anthracene	4	0.15	4.75E-04	1.00E-05	1.82E-03	9.43E-04
Chrysene	4	-	4.93E-05	3.30E-06	3.87E-04	1.12E-04
Benzo(b)fluoranthene	5	0.3	7.07E-06	4.33E-05	2.25E-04	2.51E-05
Benzo(k)fluoranthene	5	-	6.46E-06	9.66E-06	3.67E-04	1.58E-05
Benzo(a)pyrene	5	0.3	3.23E-05	3.60E-05	2.60E-04	3.37E-05
Dibenz(a,h)anthracene	5	0.3	2.86E-05	1.44E-04	7.31E-04	2.08E-05
Indinol(1,2,3-cd)pyrene	6	-	1.86E-04	2.13E-05	1.17E-02	3.65E-05
TOTAL			4.56E-02	3.48E-02	4.97E-02	1.16E-01

MACs= Maximum Allowable Concentrations (ATSDR, 2006)

Calculated Benzo(A)pyrene Equivalent Polycyclic Aromatic Hydrocarbon in Different Tissues of Fish Samples

Table 5: Calculated Benzo(a)pyrene Equivalent Concentrations of Polycyclic Aromatic Hydrocarbon (PAHs) in Different Tissues of *Tilapia dageti* from Gubi Dam, Bauchi State, Nigeria

PAHs	Concentrations (mg/kg)				
	USEPA TEF	Liver	Flesh	Intestine	Gills
Naphthalene	0.001	2.21E-08	1.17E-05	1.17E-05	8.64E-05
2-methyl Naphthalene	0.001	3.36E-07	7.90E-08	5.93E-08	3.76E-06
Acenaphthylene	0.001	4.31E-03	9.12E-09	3.54E-07	3.21E-06
Acenaphthene	0.001	5.60E-09	8.07E-08	2.54E-07	2.87E-07
Fluorene	0.001	4.63E-08	2.47E-08	1.52E-07	4.22E-06
Phenanthrene	0.001	5.23E-07	8.13E-07	1.13E-05	5.10E-07
Anthracene	0.01	4.68E-06	3.00E-06	2.52E-06	2.38E-06
Fluoranthene	0.001	6.16E-06	3.96E-06	1.97E-04	1.92E-05
Pyrene	0.001	7.65E-06	1.61E-06	1.46E-05	1.39E-05
Benzo(a)anthracene	0.1	6.89E-06	1.95E-04	1.78E-05	8.10E-04
Chrysene	0.001	7.38E-09	3.90E-07	2.24E-07	5.42E-07
Benzo(b)fluoranthene	0.1	1.87E-05	2.44E-05	7.33E-04	1.97E-04
Benzo(k) Fluoranthene	0.1	1.47E-05	4.05E-06	1.23E-05	1.94E-04
Benzo(a)pyrene	1	2.03E-05	1.05E-05	2.46E-04	5.84E-05
Dibenz(a,h)anthracene	1	3.82E-05	1.88E-05	5.54E-05	9.15E-05
Indinol(1,2,3-cd)pyrene	0.01	1.90E-06	1.17E-06	5.90E-06	2.27E-06
ΣBaPTEQ		4.43E-03	2.76E-04	1.31E-03	1.49E-03

Table 5 show the calculated benzo(a)pyrene equivalent of some polycyclic aromatic hydrocarbon in different tissues (gills, liver, flesh and intestine) of *Tilapia dageti* from Gubi Dam, Bauchi State, Nigeria. The calculated BaP concentration of naphthalene ranged from 2.21E-08 to 8.64E-05 mg/kg; 2-methylnaphthylene; 7.09E-08 to 3.76E-06 mg/kg; 9.12E-09 to 4.31E-03 mg/kg acenaphthylene; 5.06E-09 to 2.87E-07 mg/kg acenaphthene; 2.47E-08 to 4.22E-06 mg/kg fluorene; 5.01E-07 to 1.13E-05 mg/kg phenanthrene; 2.38E-06 to 4.68E-06 mg/kg anthracene; 3.96E-06 to 1.97E-04 mg/kg fluoranthene; 1.61E-06 to 1.46E-05 mg/kg benzo(a)pyrene; 6.89E-06 to 8.01E-04 mg/kg benzo(a)anthracene; 7.38E-09 to 5.42E-07 mg/kg chrysene; 1.87E-05 to 7.33E-04 mg/kg benzo(b)fluoranthene; 4.05E-06 to 1.94E-04 mg/kg benzo(k)fluoranthene; 1.05E-05 to 2.46E-04 mg/kg benzo(a)pyrene; 1.88E-05 to 9.15E-05 mg/kg dibenz(a,h)anthracene and 1.09E-06 to 5.09E-06 mg/kg indinol(1,2,3-cd)pyrene. The highest total BaP equivalent concentration of 4.36E-04 mg/kg was recorded in the liver, while the lowest total BaP equivalent concentration of 1.31E-03 mg/kg was recorded in the gills.

Table 6 shows the calculated benzo(a)pyrene equivalent concentrations of some polycyclic aromatic hydrocarbons in different tissues of *Tilapia zillii* from Gubi Dam, Bauchi State. The concentration of naphthalene ranged from 2.14E-07 to 7.73E-05 mg/kg; 2-methylnaphthylene; 3.62E-08 to 5.47E-06 mg/kg; 2.43E-07 to 4.51E-05 mg/kg acenaphthylene; 9.46E-08 to 8.04E-07 mg/kg acenaphthene; 1.25E-07 to 2.61E-05 mg/kg fluorene; 1.65E-08 to 5.11E-06 mg/kg phenanthrene; 1.37E-06 to 6.03E-05 mg/kg anthracene; 5.31E-06 to 5.52E-05 mg/kg fluoranthene; 1.88E-08 to 1.64E-05 mg/kg pyrene; 4.67E-06 to 2.96E-04 mg/kg benzo(a)anthracene; 2.41E-08 to 2.32E-06 mg/kg chrysene; 2.26E-05 to 5.71E-04 mg/kg benzo(b)fluoranthene; 1.48E-06 to 4.52E-05 mg/kg benzo(k)fluoranthene; 5.19E-06 to 4.65E-04 mg/kg benzo(a)pyrene; 2.23E-05 to 8.89E-05 mg/kg dibenzo(a,h)anthracene and 4.15E-07 to 1.73E-05 mg/kg indinol(1,2,3-cd)pyrene. The highest total BaP equivalent concentration of 6.38E-04 mg/kg was recorded in the gills, while the lowest total BaP equivalent concentration of 1.26E-03 mg/kg was recorded in the intestine.

Table 6: Calculated Benzo(a)pyrene Equivalent Concentrations of Polycyclic Hydrocarbon (PAHs) in Different Tissues of *Tilapia zillii* from Gubi Dam, Bauchi State, Nigeria

PAHs	Concentrations (mg/kg)				
	USEPA TEF	Liver	Flesh	Intestine	Gills
Naphthalene	0.001	7.28E-05	2.14E-07	1.46E-05	7.73E-05
2-methylnaphthalene	0.001	5.34E-06	3.62E-08	2.84E-07	5.47E-06
Acenaphthylene	0.001	5.31E-07	2.43E-07	2.43E-06	4.51E-05
Acenaphthene	0.001	3.75E-07	9.46E-08	8.04E-07	6.30E-07
Fluorene	0.001	8.32E-07	1.25E-07	4.32E-06	2.61E-05
Phenanthrene	0.001	2.12E-07	1.65E-08	1.94E-06	5.11E-06
Anthracene	0.01	7.52E-06	1.37E-06	1.94E-05	6.30E-05
Fluoranthene	0.001	2.82E-05	5.31E-06	5.52E-05	9.61E-06
Pyrene	0.001	9.27E-06	1.88E-08	1.64E-05	5.19E-06
Benzo(a)anthracene	0.1	1.97E-05	4.67E-06	8.72E-05	2.96E-04
Chrysene	0.001	6.19E-08	2.41E-08	1.51E-07	2.32E-06
Benzo(b)fluoranthene	0.1	3.89E-05	9.09E-05	5.71E-04	2.26E-05
Benzo(k)fluoranthene	0.1	4.16E-06	4.10E-05	1.48E-06	4.52E-06
Benzo(a)pyrene	1	5.19E-06	6.25E-05	4.65E-04	1.21E-05
Dibenz(a,h)anthracene	1	8.89E-05	8.10E-05	2.23E-05	4.56E-05
Indinol(1,2,3-cd)pyrene	0.01	6.35E-07	2.07E-06	4.15E-07	1.73E-05
Σ BaPTEQ		2.83E-04	2.90E-04	1.26E-03	6.38E-04

Table 7 show the Calculated benz(a)pyrene equivalent concentrations of some polycyclic aromatic hydrocarbon in different tissues of *Alestes baremoze* from Gubi Dam, Bauchi State, Nigeria. The concentration of naphthalene ranged from 3.51E-06 to 4.54E-05 mg/kg ; 8.22E-08 to 3.02E-06 mg/kg 2-methylnaphthylene; 2.31E-09 to 3.22E-05 mg/kg acenaphthylene; 1.46E-07 to 3.71E-06 mg/kg acenaphthene; 5.21E-08 to 2.09E-06 mg/kg fluorene; 2.14E-08 to 2.84E-06 mg/kg phenanthrene; 3.22E-07 to 2.61E-05 mg/kg anthracene; 4.00E-06 to 1.49E-05 mg/kg fluoranthene; 2.42E-06 to 1.26E-05 mg/kg pyrene; 6.49E-06 to 6.77E-04 mg/kg benzo(a)anthracene; 3.11E-09 to 2.57E-06 mg/kg chrysene; 9.19E-07 to 1.78E-03 mg/kg

benzo(b)fluoranthene; 3.66E-07 to 2.63E-04 mg/kg benzo(k)fluoranthene; 7.08E-06 to 9.49E-04 mg/kg benzo(a)pyrene; 4.21E-06 to 6.65E-05 mg/kg dibenz(a,h)anthracene and 2.43E-07 to 1.03E-06 mg/kg indinol(1,2,3-cd)pyrene. The highest total BaP equivalent concentration of 3.76E-05 mg/kg was observed in the gills, while the lowest total BaP equivalent of 2.57E-04 mg/kg was observed in the liver.

Table 8 present calculated benzo(a)pyrene equivalent concentration of some polycyclic aromatic hydrocarbon in different tissues of *Clarias gariepinus* from Gubi Dam, Bauchi State. The concentration of naphthalene ranged from 6.35E-07 to 6.52E-05 mg/kg; 1.01E-07 to 2.33E-05 mg/kg 2-methylnaphthylene; 5.76E-08

to 6.06E-07 mg/kg acenaphthylene; 4.73E-08 to 1.58E-05 mg/kg acenaphthene; 1.93E-07 to 3.23E-06 mg/kg fluorene; 1.63E-08 to 8.01E-06 mg/kg phenanthrene; 2.54E-07 to 2.32E-06 mg/kg anthracene; 1.51E-06 to 2.08E-04 mg/kg fluoranthene; 3.48E-08 to 8.81E-06 mg/kg pyrene; 1.00E-06 to 1.82E-04 mg/kg benzo(a)anthracene; 3.03E-09 to 3.87E-07 mg/kg chrysene; 7.07E-07 to 2.25E-05 mg/kg

benzo(b)fluoranthene; 1.58E-08 to 3.67E-05 mg/kg benzo(k)fluoranthene; 3.23E-05 to 3.06E-08 mg/kg benzo(a)pyrene; 2.28E-05 to 7.31E-07 mg/kg dibenz(a,h)pyrene and 2.13E-07 to 1.86E-06 mg/kg indinol(1,2,3-cd)pyrene. The highest and the lowest total BaP equivalent concentrations of 1.27E-04mg/kg and 1.98E-04 were both recorded in the gills

Table 7: Calculated Benzo(a)pyrene Equivalent Concentration of Some Polycyclic Aromatic Hydrocarbons (PAHs) in Different Tissues of *Alestes baremoze* from Gubi Dam, Bauchi State, Nigeria

PAHs	Concentrations (mg/kg)				
	USEPA TEF	Liver	Flesh	Intestine	Gills
Naphthalene	0.001	3.57E-05	2.02E-05	3.51E-06	4.54E-05
2-methylnaphthalene	0.001	1.09E-07	3.02E-06	8.22E-08	1.24E-06
Acenaphthylene	0.001	2.93E-06	2.31E-09	3.22E-05	4.75E-07
Acenaphthene	0.001	3.71E-06	4.33E-07	1.46E-07	1.83E-06
Flourene	0.001	1.73E-07	5.21E-08	3.18E-07	2.90E-06
Phenanthrene	0.001	2.84E-06	2.14E-08	2.52E-07	2.13E-06
Anthracene	0.01	4.21E-06	3.22E-07	3.20E-06	2.61E-05
Fluoranthene	0.001	4.21E-06	4.00E-06	1.44E-05	6.81E-06
Pyrene	0.001	1.49E-05	7.70E-06	1.26E-05	6.44E-06
Benz(a)anthracene	0.1	2.42E-06	6.77E-04	1.82E-04	6.11E-04
Chrysene	0.001	6.49E-06	5.33E-08	5.47E-07	2.57E-06
Benzo(b)fluoranthene	0.1	3.11E-09	1.89E-04	9.19E-07	1.78E-03
Benzo(k) Fluoranthene	0.1	7.72E-05	3.66E-07	7.09E-07	2.63E-04
Benzo(a)pyrene	1	8.79E-05	9.82E-05	7.08E-06	9.49E-04
Dibenz(a,h)anthracene	1	1.32E-05	1.71E-05	4.21E-06	6.65E-05
Indinol(1,2,3-cd)pyrene	0.01	1.30E-06	2.43E-07	3.07E-07	8.60E-07
∑BaPTEQ		2.57E-04	1.02E-03	2.62E-04	3.76E-03

Table 8: Calculated Benz(a)pyrene Equivalent Concentration of Some Polycyclic Aromatic Hydrocarbon (PAHs) in Different Tissues of *Clarias gariepinus* from Gubi Dam, Bauchi State, Nigeria.

PAHs	Concentrations (mg/kg)				
	USEPA TEF	Liver	Flesh	Intestine	Gills
Naphthalene	0.001	1.90E-05	2.30E-06	6.35E-07	6.52E-05
2-methylnaphthalene	0.001	2.33E-05	1.01E-07	1.16E-06	2.07E-07
Acenaphthylene	0.001	2.76E-07	5.76E-08	6.60E-07	2.56E-07
Acenaphthene	0.001	4.73E-08	1.75E-07	1.58E-05	2.46E-07
Fluorene	0.001	1.93E-07	3.23E-06	8.94E-07	2.45E-06
Phenanthrene	0.001	2.43E-07	8.94E-08	1.63E-08	8.10E-06
Anthracene	0.01	2.32E-06	6.68E-06	2.54E-07	1.82E-05
Fluoranthene	0.001	1.51E-06	5.89E-06	1.11E-05	2.80E-05
Pyrene	0.001	3.48E-08	1.29E-06	3.94E-06	8.81E-06
Benz(a)anthracene	0.1	4.75E-05	1.00E-06	1.82E-04	9.43E-06
Chrysene	0.001	4.93E-08	3.30E-09	3.87E-07	1.12E-07
Benzo(b)fluoranthene	0.1	7.07E-07	4.33E-06	2.25E-05	2.51E-06
Benzo(k)fluoranthene	0.1	6.46E-07	9.66E-07	3.67E-05	1.58E-08
Benzo(a)pyrene	1	3.23E-05	3.60E-04	2.60E-04	3.37E-05
Dibenz(a,h)anthracene	1	2.86E-05	1.44E-04	7.31E-04	2.08E-05
Indinol(1,2,3-cd)pyrene	0.01	1.86E-06	2.13E-07	2.13E-07	3.65E-07
∑BaPTEQ		1.59E-04	5.30E-04	1.27E-03	1.98E-04

Average Daily Dose (ADD) of Some Polycyclic Aromatic Hydrocarbon in Fish Samples

Table 9 Present the average daily dose of some polycyclic aromatic hydrocarbon in different tissues (gills, liver, flesh and intestine) of *Tillapia dageti* from Gubi Dam, Bauchi State, Nigeria. The average daily dose of naphthalene ranged from 2.16E-13 to 8.45E-10 mg/kg ; 5.80E-12 to 7.73E-10 mg/kg acenaphthylene; 3.55E-14 to 7.89E-13 mg/kg acenaphthene; 2.41E-13 to 4.12E-11 mg/kg fluorene; 4.99E-12 to 1.10E-10 mg/kg phenanthrene; 3.32E-13 to 4.57E-11 mg/kg anthracene; 3.87E-11 to 1.87E-10 mg/kg fluoranthene; 7.48E-11 to 1.42E-10 mg/kg

pyrene; 6.74E-11 to 7.92E-09 mg/kg benzo(a)anthracene; 3.13E-14 to 5.30E-12 mg/kg chrysene; 1.89E-10 to 7.17E-09 mg/kg benzo(b)fluoranthene; 3.96E-11 to 1.89E-09 mg/kg benzo(k)fluoranthene; 1.46E-12 to 5.71E-10 mg/kg benzo(a)pyrene; 1.83E-10 to 8.95E-10 mg/kg dibenz(a,h)anthracene; 1.14E-11 to 5.77E-11 mg/kg benzo(1,2,3-cd)pyrene. The highest total daily dose of 4.33E-08 mg/kg was observed in the liver, while the lowest total daily dose was recorded in the intestine.

Table 10 Show the average daily dose of some polycyclic aromatic hydrocarbon in different tissues (gills, liver, flesh and intestine) of *Tilapia*

zillii from Gubi Dam, Bauchi State. The ADD of naphthalene ranged from 2.09E-12 to 7.56E-10 mg/kg; 3.54E-13 to 5.35E-11 mg/kg 2-methyl naphthalene; 2.37E-12 to 4.41E-10 mg/kg acenaphthylene; 8.80E-14 to 7.86E-12 mg/kg acenaphthene; 1.22E-12 to 2.55E-10 mg/kg

fluorene; 1.61E-13 to 1.89E-11 mg/kg phenanthrene; 8.80E-12 to 1.89E-10 mg/kg anthracene; 5.19E-11 to 5.40E-10 mg/kg fluoranthene; 1.83E-13 to 1.60E-10 mg/kg pyrene; 4.56E-11 to 2.89E-09 mg/kg

Table 9: Average Daily Dose (mg/kg day⁻¹) of some Polycyclic Aromatic Hydrocarbon (PAHs) in Different Tissues of *Tilapia dageti* from Gubi Dam, Bauchi State

PAHs	Concentrations (mg/kg day ⁻¹)			
	Liver	Flesh	Intestine	Gills
Naphthalene	2.16E-13	1.14E-10	1.66E-10	8.45E-10
2-methylnaphthalene	3.28E-12	7.73E-10	5.80E-12	3.67E-11
Acenaphthylene	4.21E-08	8.92E-14	3.46E-12	3.14E-11
Acenaphthene	5.48E-14	7.89E-13	3.5E-14	4.01E-14
Fluorene	4.53E-13	2.41E-13	1.48E-12	4.12E-11
Phenanthrene	5.11E-12	7.95E-12	1.10E-10	4.99E-12
Anthracene	4.57E-11	2.93E-11	3.52E-13	3.22E-13
Fluoranthene	6.02E-11	3.87E-11	1.92E-09	1.87E-10
Pyrene	7.48E-11	1.57E-11	1.42E-10	1.36E-10
Benzo(a)anthracene	6.74E-11	1.90E-09	1.74E-10	7.92E-09
Chrysene	7.22E-14	3.81E-12	3.13E-14	5.30E-12
Benzo(b)fluoranthene	1.82E-10	2.38E-10	7.17E-09	1.92E-09
Benzo(k)fluoranthene	1.43E-10	3.96E-11	1.20E-10	1.89E-09
Benzo(a)pyrene	1.98E-10	1.46E-12	2.40E-10	5.71E-10
Dibenz(a,h)anthracene	3.73E-10	1.83E-10	5.42E-10	8.95E-10
Indinol(1,2,3-cd)pyrene	1.85E-11	1.14E-11	5.77E-11	2.22E-11
TDD	4.33E-08	3.36E-09	1.07E-08	1.45E-08

Table 10: Average Daily Dose (mg/kg day⁻¹) of some Polycyclic Aromatic Hydrocarbon (PAHs) in Different Tissues of *Tilapia zillii* from Gubi Dam, Bauchi State, Nigeria

PAHs	Concentrations (mg/kg day ⁻¹)			
	Liver	Flesh	Intestine	Gills
Naphthalene	1.01E-11	2.09E-12	1.42E-10	7.56E-10
2-methylnaphthalene	5.22E-11	3.54E-13	2.77E-12	5.35E-11
Acenaphthylene	5.19E-12	2.37E-12	2.37E-11	4.41E-10
Acenaphthene	3.66E-12	9.25E-13	7.86E-12	8.80E-14
Fluorene	8.14E-12	1.22E-12	4.22E-11	2.5E-10
Phenanthrene	2.07E-12	1.61E-13	1.89E-11	7.14E-13
Anthracene	7.35E-11	1.34E-11	1.89E-10	8.80E-12
Fluoranthene	2.75E-10	5.19E-11	5.40E-10	9.40E-11
Pyrene	9.07E-11	1.83E-13	1.60E-10	5.07E-11
Benzo(a)anthracene	1.92E-10	4.56E-11	8.53E-10	2.89E-09
Chrysene	6.05E-13	2.35E-13	1.47E-12	2.27E-11
Benzo(b)fluoranthene	3.80E-10	8.89E-10	5.58E-09	2.21E-10
Benzo(k)fluoranthene	4.07E-11	4.01E-10	1.44E-11	4.42E-10
Benzo(a)pyrene	5.07E-11	6.11E-10	4.5E-09	1.18EE-10
Dibenz(a,h)anthracene	8.69E-10	7.92E-10	2.18E-10	4.46E-10
Indinol(1,2,3-cd)pyrene	6.21E-12	2.02E-11	4.06E-12	1.69E-10
TDD	2.06E-09	2.83E-09	1.23E-08	5.85E-09

benzo(a)anthracene; 2.35E-13 to 2.27E-11 mg/kg chrysene; 2.21E-10 to 5.58E-09 mg/kg benzo(b)fluoranthene; 1.44E-11 to 4.42E-10 mg/kg benzo(k)fluoranthene; 5.07E-11 to 4.55E-09 mg/kg benzo(a)pyrene; 2.18E-10 to 8.69E-10 mg/kg benzo(a,h)anthracene and 4.06E-12 to 1.69E-10 mg/kg indinol(1,2,3-cd)pyrene. The highest total daily dose of 1.23E-08 mg/kg was observed in the intestine, while the lowest total daily dose of 1.12E-09 mg/kg was recorded in the liver.

Table 11 present the average daily dose of some polycyclic aromatic hydrocarbon in different tissues of *Alestes baremoze* from Gubi Dam, Bauchi State. The ADD of naphthalene ranged from 3.43E-11 to 4.44E-10 mg/kg; 8.04E-13 to 2.95E-10 mg/kg 2-methylnaphthalene; 3.22E-16 to 2.86E-11 mg/kg acenaphthylene; 8.18E-13 to 1.79E-11 mg/kg acenaphthene; 5.09E-13 to 2.83E-11 mg/kg fluorene; 3.52E-14 to 2.77E-11 mg/kg phenanthrene; 4.50E-14 to 2.55E-10 mg/kg anthracene; 3.91E-11 to 1.45E-10 mg/kg fluoranthene; 9.00E-13 to 2.36E-11 mg/kg benzo(a)anthracene; 2.54E-11 to 6.62E-09 mg/kg pyrene; 3.12E-14 to 2.51E-11 mg/kg chrysene; 8.99E-12 to 1.72E-08 mg/kg benzo(b)fluoranthene; 3.58E-12 to 2.57E-09 mg/kg benzo(k)fluoranthene; 6.92E-11 to 9.28E-09 mg/kg benzo(a)pyrene; 9.29E-12 to 1.69E-10 mg/kg dibenz(a,h)anthracene and 2.37E-12 to 1.27E-11 mg/kg indinol(1,2,3-cd)pyrene. The

highest total daily dose of 2.04E-08 mg/kg was observed in the gills, while the lowest total daily dose of 3.77E-10 mg/kg was recorded in the intestine.

Table 12 shows the average daily dose of some polycyclic aromatic hydrocarbon in different tissues (gills, liver, flesh and intestine) of *Clarias gariepinus* from Gubi Dam, Bauchi State. The ADD of naphthalene ranged from 6.21E-12 to 6.38E-10 mg/kg; 9.88E-13 to 2.28E-10 mg/kg 2-methylnaphthalene; 5.63E-13 to 6.45E-12 mg/kg acenaphthylene; 2.44E-14 to 1.54E-10 mg/kg acenaphthene; 4.89E-13 to 3.16E-11 mg/kg fluorene; 1.59E-13 to 7.92E-11 mg/kg phenanthrene; 2.48E-12 to 6.53E-11 mg/kg anthracene; 3.91E-12 to 1.08E-10 mg/kg

Table 11: Average Daily Dose (mg/kg day⁻¹) of Some Polycyclic Aromatic Hydrocarbon (PAHs) in Different Tissues *Alestes baremoze* from Gubi Dam, Bauchi State, Nigeria

Concentrations (mg/kg day ⁻¹)				
PAHs	Liver	Flesh	Intestine	Gills
Naphthalene	3.49E-10	1.97E-10	3.43E-11	4.44E-10
2-methylnaphthalene	1.06E-12	2.95E-10	8.04E-13	1.21E-11
Acenaphthylene	2.86E-11	3.22E-16	4.50E-12	4.64E-12
Acenaphthene	5.18E-13	4.23E-12	1.42E-12	1.79E-11
Fluorene	1.69E-12	5.09E-13	3.11E-12	2.83E-11
Phenanthrene	2.77E-11	2.09E-13	3.52E-14	2.08E-11
Anthracene	4.11E-11	4.50E-14	3.13E-11	2.5E-10
Fluoranthene	1.45E-10	3.91E-11	1.40E-10	6.66E-11
Pyrene	2.36E-11	1.07E-12	1.76E-12	9.00E-13
Benzo(a)anthracene	6.35E-11	6.62E-09	2.54E-11	5.97E-09
Chrysene	3.12E-14	5.21E-13	5.35E-12	2.51E-11
Benzo(b)fluoranthene	7.5E-10	2.64E-11	8.99E-12	1.72E-09
Benzo(k)fluoranthene	8.60E-11	3.58E-12	6.93E-12	2.57E-09
Benzo(a)pyrene	4.76E-10	9.60E-10	6.92E-11	9.28E-09
Dibenz(a,h)anthracene	1.29E-10	1.69E-10	4.11E-11	9.29E-12
Indinolo(1,2,3-cd)pyrene	1.27E-11	2.37E-12	3.00E-12	8.41E-12
TDD	2.14E-09	8.32E-09	3.77E-10	2.04E-08

Table 12: Average Daily Dose (mg/kg day⁻¹) of Some Polycyclic Aromatic Hydrocarbon PAHs in Different Tissues of *Clarias gariepinus* from Gubi Dam, Bauchi State, Nigeria

Concentrations (mg/kg day ⁻¹)				
PAHs	Liver	Flesh	Intestine	Gills
Naphthalene	1.85E-10	2.25E-11	6.21E-12	6.38E-10
2-methylnaphthalene	2.28E-10	9.88E-13	1.13E-11	2.02E-12
Acenaphthylene	2.70E-12	5.63E-13	6.45E-12	2.50E-12
Acenaphthene	4.62E-13	2.44E-14	1.54E-10	2.40E-12
Fluorene	1.88E-12	3.16E-11	8.74E-12	4.89E-15
Phenanthrene	2.37E-12	8.74E-13	1.59E-13	7.92E-11
Anthracene	2.27E-11	6.53E-11	2.48E-12	2.54E-12
Fluoranthene	1.47E-11	5.76E-11	1.08E-10	3.91E-12
Pyrene	3.40E-13	1.26E-11	3.85E-11	8.62E-11
Benzo(a)anthracene	4.64E-11	9.78E-12	2.54E-11	9.22E-11
Chrysene	4.82E-13	3.22E-14	3.78E-12	1.56E-14
Benzo(b)fluoranthene	9.88E-14	4.23E-11	2.20E-10	2.45E-11
Benzo(k)fluoranthene	6.32E-12	1.35E-13	3.59E-10	1.54E-13
Benzo(a)pyrene	3.16E-10	3.52E-09	2.54E-09	3.29E-10
Dibenz(a,h)anthracene	2.79E-10	1.40E-09	7.15E-09	2.03E-10
Indinol(1,2,3-cd)pyrene	1.82E-11	2.08E-12	2.08E-12	3.57E-12
TDD	1.12E-09	5.17E-09	1.06E-08	1.47E-09

fluoranthene; 3.40E-13 to 8.62E-11 mg/kg
benzo(a)anthracene; 9.78E-12 to 9.22E-11 mg/kg
pyrene; 1.56E-14 to 3.78E-12 mg/kg chrysene;
9.88E-14 to 2.20E-10 mg/kg

benzo(b)fluoranthene; 1.35E-13 to 3.59E-10
mg/kg benzo(k)fluoranthene; 3.16E-10 to 3.52E-
09 mg/kg benzo(a)pyrene; 2.03E-10 to 7.15E-09
mg/kg dibenz(a,h)anthracene and 2.08E-12 to

1.82E-11 mg/kg indinol(1,2,3-cd)pyrene. The highest total daily dose of 1.06E-08 mg/kg was observed in the intestine, while the lowest total daily dose of 1.12E-09 mg/kg was recorded in the liver.

Carcinogenic Risk Assessment of Some Polycyclic Aromatic Hydrocarbon in Tissues of Fish Samples

Table 13 present the carcinogenic risk assessment of some polycyclic aromatic hydrocarbon in different tissues of *Tillapia dageti* from Gubi Dam, Bauchi State, Nigeria. The concentrations

of benzo(a)anthracene ranged from 4.92E-11 to 5.78E-09 mg/kg; 2.28E-16 to 3.86E-14 mg/kg chrysene; 1.40E-11 to 5.23E-09 mg/kg benzo(b)fluoranthene; 2.89E-12 to 1.37E-10 mg/kg benzo(k)fluoranthene; 1.06E-11 to 1.75E-08 mg/kg benzo(a)pyrene; 1.33E-09 to 6.53E-09 mg/kg dibenz(a,h)anthracene and 8.32E-12 to 4.21E-11 mg/kg indinol(1,2,3-cd)pyrene. The highest ILECR value of 6.86E-08 mg/kg was observed in the intestine, while the lowest ILECR value of 3.65E-09 mg/kg was recorded in the liver.

Table 13: Carcinogenic Risk Assessment (mg/kg day⁻¹) of Some Polycyclic Aromatic Hydrocarbons (PAHs) in Different Tissues of *Tilapia dageti* from Gubi Dam, Bauchi State, Nigeria

PAHs	Cancer Risk Values (mg/kg day ⁻¹)			
	Liver	Flesh	Intestine	Gills
Benzo(a)anthracene	4.92E-11	1.38E-09	1.27E-10	5.78E-09
Chrysene	5.27E-16	2.78E-14	2.28E-16	3.86E-14
Benzo(b)fluoranthene	1.32E-10	1.73E-10	5.23E-09	1.40E-11
Benzo(k)fluoranthene	1.04E-11	2.89E-12	8.76E-12	1.37E-10
Benzo(a)pyrene	1.44E-09	1.06E-11	1.75E-08	4.16E-09
Dibenz(a,h)anthracene	2.72E-09	1.33E-09	3.95E-09	6.53E-09
Indinol(1,2,3-cd)pyrene	1.35E-11	8.32E-12	4.21E-11	1.62E-11
ΣILECR	3.65E-09	9.05E-09	6.96E-08	6.64E-08

ILECR= Incremental Live Time Expectancy Cancer Risk

Table 14 show the carcinogenic risk assessment in different tissues of *Tillapia zillii* from Gubi Dam, Bauchi State. The CR value of benzo(a)anthracene ranged from 4.05E-11 to 2.10E-09 mg/kg; 1.71E-15 to 1.65E-13 mg/kg chrysene; 1.61E-10 to 6.48E-10 mg/kg fluoranthene; 1.05E-12 to 3.22E-11 mg/kg benzo(a)pyrene; 1.59E-09 to 6.34E-09 mg/kg dibenz(a,h)anthracene and 2.96E-12 to 1.23E-10 mg/kg indinol(1,2,3-cd)pyrene. The highest ILECR value of 5.83E-08 mg/kg was recorded in the intestine while lowest ILECR value of 1.35E-09 mg/kg was recorded in the Liver. Table 15 present the carcinogenic risk assessment of some polycyclic aromatic hydrocarbon in different tissues of *Alestes baremoze* from Gubi Dam, Bauchi State. The concentration of benzo(a)anthracene ranged from 1.85E-11 to

4.85E-11 mg/kg; 2.27E-16 to 1.83E-13 mg/kg; chrysene; 6.56E-12 to 1.25E-08 mg/kg; benzo(b)fluoranthene; 2.61E-13 to 1.87E-10 mg/kg; benzo(k)fluoranthene; 5.05E-10 to 6.77E-08 mg/kg; benzo(a)pyrene; 6.78E-11 to 1.23E-09 mg/kg; dibenz(a,h)anthracene and 1.73E-12 to 9.27E-12 mg/kg indinol(1,2,3-cd)pyrene. The highest ILECR value of 4.81E-08 mg/kg was observed in the gills, while lowest ILECR of 3.28E-10 mg/kg was observed in the intestine. Table 16 show the carcinogenic risk assessment of some polycyclic aromatic hydrocarbons in different tissues of *Clarias gariepinus* from Gubi Dam, Bauchi State. The concentration of benzo(a)anthracene ranged from 7.13E-12 to 6.73E-11 mg/kg; 1.13E-16 to 2.75E-14 mg/kg; chrysene; 7.21E-14 to 1.60E-10 mg/kg; benzo(b)fluoranthene; 9.85E-15 to 2.62E-11

mg/kg; benzo(k)fluoranthene; 2.30E-09 to 2.56E-08 mg/kg; benzo(a)pyrene; 1.48E-09 to 5.21E-08 mg/kg; dibenz(a,h)anthracene and 1.51E-12 to 1.32E-11 mg/kg; indinol(1,2,3-cd)pyrene. The

highest ILECR value of 3.78E-05 mg/kg was recorded in the liver, while the lowest total ILECR value of 9.52E-09 mg/kg was observed in the gills

Table 14: Carcinogenic Risk Assessment (mg/kg day⁻¹) of Some Polycyclic Aromatic Hydrocarbon (PAHs) in Different Tissues of *Tilapia zillii* from Gubi Dam, Bauchi State, Nigeria

PAHs	Concentrations (mg/kg day ⁻¹)			
	Liver	Flesh	Intestine	Gills
Benzo(a)anthracene	1.40E-10	4.05E-11	6.22E-10	2.10E-09
Chrysene	4.41E-15	1.71E-15	1.07E-14	1.65E-13
Benzo(b)fluoranthene	2.77E-10	6.48E-10	4.07E-10	1.61E-10
Benzo(k)fluoranthene	2.97E-12	2.92E-11	1.05E-12	3.22E-11
Benzo(a)pyrene	3.70E-10	4.46E-09	3.32E-08	8.61E-10
Dibenz(a,h)anthracene	6.34E-09	5.78E-09	1.59E-09	3.25E-09
Indinol(1,2,3-cd)pyrene	4.53E-12	1.47E-11	2.96E-12	1.23E-10
∑ILECR	1.35E-09	0.97E-08	5.83E-08	5.27E-09

ILECR= Incremental Live Time Expectancy Cancer Risk

Table 15: Carcinogenic Risk Assessment (mg/kg day⁻¹) for Some Polycyclic Aromatic Hydrocarbon (PAHs) in Different Tissues of *Alestes baremoze* from Gubi Dam, Bauchi State, Nigeria

PAHs	Cancer Risk Values (mg/kg day ⁻¹)			
	Liver	Flesh	Intestine	Gills
Benzo(a)anthracene	4.63E-11	4.83E-09	1.85E-11	4.35E-09
Chrysene	2.27E-16	3.80E-15	3.90E-14	1.83E-13
Benzo(b)fluoranthene	5.51E-10	1.92E-11	6.56E-12	1.25E-08
Benzo(k)fluoranthene	6.27E-12	2.61E-13	5.05E-13	1.87E-10
Benzo(a)pyrene	3.47E-09	7.00E-09	5.05E-10	6.77E-08
Dibenz(a,h)anthracene	9.41E-11	1.23E-09	3.00E-10	6.78E-11
Indinol(1,2,3-cd)pyrene	9.27E-12	1.73E-12	2.19E-12	6.13E-12
∑ILECR	4.18E-09	1.31E-08	8.33E-10	8.48E-08

ILECR= Incremental Live Time Expectancy Cancer Risk

Table 16: Carcinogenic Risk Assessment (mg/kg day⁻¹) of Some Polycyclic Aromatic Hydrocarbon (PAHs) In Different Tissues of *Clarias gariepinus* from Gubi Dam, Bauchi State, Nigeria

PAHs	Cancer Risk Values (mg/kg day ⁻¹)			
	Liver	Flesh	Intestine	Gills
Benzo(a)anthracene	3.38E-11	7.13E-12	1.85E-11	6.73E-11
Chrysene	3.51E-15	2.35E-16	2.75E-14	1.13E-16
Benz(b)fluoranthene	7.21E-14	3.08E-11	1.60E-10	1.78E-12
Benz(k)fluoranthene	4.61E-13	9.85E-15	2.62E-11	1.12E-14
Benz (a)pyrene	2.30E-09	2.56E-08	1.85E-08	2.40E-09
Dibenz(a,h)anthracene	2.03E-09	1.02E-08	5.21E-08	1.48E-09
Indinol (1,2,3-cd) pyrene	1.32E-11	1.51E-12	1.51E-12	2.60E-12
∑ILECR	3.78E-09	5.84E-08	0.81E-08	9.52E-09

ILECR= Incremental Live Time Expectancy Cancer Risk

Hazard Quotient and Hazard Index of Non-Carcinogenic Polycyclic Aromatic Hydrocarbons (PAHs) Via Consumption of Fish

Table 17 show the hazard quotient and hazard index of polycyclic aromatic hydrocarbon in different tissues (gills, liver, flesh and intestine) of *Tilapia dageti* from Gubi Dam, Bauchi State. The hazard quotient of naphthalene ranged from 5.07E-09 to 1.08E-01 mg/kg; 1.64E-10 to 1.83E-05 mg/kg 2-methylnaphthalene; 4.46E-12 to

1.57E-09 mg/kg acenaphthylene; 5.91E-13 to 1.31E-11 mg/kg acenaphthene; 6.02E-12 to 1.03E-09 mg/kg fluorene; 1.24E-10 to 2.75E-09 mg/kg phenanthrene; 1.10E-12 to 1.52E-10 mg/kg anthracene; 9.67E-10 to 4.08E-08 mg/kg fluoranthene and 5.23E-10 to 4.53E-06 mg/kg pyrene. The highest hazard index of 1.00E-01 mg/kg was observed in the liver, while the lowest hazard index of 1.00E-01 mg/kg was observed in the intestine.

Table 17: Hazard Quotient And Hazard Index (mg/kg day⁻¹) of Non-Carcinogenic Polycyclic Aromatic Hydrocarbon (PAHs) in Different Tissues of *Tilapia dageti* from Gubi Dam, Bauchi State, Nigeria

Hazard Quotient And Hazard Index (mg/kg day ⁻¹)				
PAHs	Liver	Flesh	Intestine	Gills
Naphthalene	1.08E-01	5.70E-09	8.30E-09	4.22E-08
2-methylnaphthalene	1.64E-10	3.86E-08	2.90E-10	1.83E-05
Acenaphthylene	2.10E-06	4.64E-12	1.73E-10	1.57E-09
Acenaphthene	9.13E-13	1.31E-11	5.91E-13	6.68E-13
Fluorene	1.38E-11	6.02E-02	3.70E-11	1.03E-09
Phenanthrene	1.27E-10	1.98E-10	2.75E-09	1.24E-10
Anthracene	1.52E-10	9.76E-11	1.17E-12	1.10E-12
Fluoranthene	1.50E-09	9.67E-10	4.80E-08	4.67E-09
Pyrene	2.49E-09	5.23E-10	4.73E-09	4.53E-09

Table 18: Hazard Quotient and Hazard Index (mg/kg day⁻¹) of Non-Carcinogenic Polycyclic Aromatic Hydrocarbon (PAHs) in Different Tissues of *Tilapia zillii* from Gubi Dam, Bauchi State, Nigeria

Hazard Quotient and Hazard Index ((mg/kg day ⁻¹)				
PAHs	Liver	Flesh	Intestine	Gills
Naphthalene	5.05E-10	1.04E-10	7.10E-09	3.78E-08
2-methylnaphthalene	2.61E-09	1.77E-11	1.38E-10	2.67E-09
Acenaphthylene	2.59E-09	1.18E-10	1.18E-09	2.20E-08
Acenaphthene	6.10E-11	1.54E-11	1.31E-10	1.46E-12
Fluorene	2.03E-10	3.05E-11	1.05E-09	6.37E-09
Phenanthrene	5.17E-11	4.02E-12	4.72E-10	1.78E-11
Anthracene	2.45E-10	4.46E-11	6.30E-10	2.93E-11
Fluoranthene	6.87E-09	1.29E-09	1.35E-08	2.35E-09
Pyrene	3.02E-09	6.10E-12	5.33E-09	1.69E-09
Hazard Index (HI)	6.11E-08	6.36E-09	9.53E-08	2.93E-08
Hazard Index (HI)	1.00E-01	6.63E-02	4.28E-08	8.35E-05

Table 18 shows the hazard quotient and hazard index of non-carcinogenic polycyclic aromatic hydrocarbon in different tissues of *Tilapia zillii* from Gubi Dam, Bauchi State. The hazard quotient of naphthalene ranged from 1.04E-10 to 3.78E-08 mg/kg; 1.77E-11 to 2.67E-09 mg/kg 2-methylnaphthalene; 1.18E-10 to 2.20E-16 mg/kg acenaphthylene; 1.46E-12 to 1.31E-10

mg/kg acenaphthene; 3.05E-11 to 6.37E-09 mg/kg fluorene; 4.02E-12 to 4.72E-10 mg/kg phenanthrene; 2.93E-11 to 6.03E-10 mg/kg anthracene; 1.29E-09 to 1.35E-08 mg/kg fluoranthene and 6.01E-12 to 5.33E-09 mg/kg pyrene. The highest hazard Index of 9.53E-08 mg/kg was observed in the gills, while the lowest

hazard index of 2.93E-08 mg/kg was observed in the intestine.

Table 19 shows the hazard quotient and hazard index for some non-carcinogenic polycyclic aromatic hydrocarbon in different tissues (gills, liver, flesh and intestine) of *Alestes baremoze* from Gubi Dam, Bauchi state. The hazard quotient of naphthalene ranged from 1.74E-08 to 9.85E-09 mg/kg; 4.02E-11 to 1.47E-08 mg/kg 2-methylnaphthalene; 1.61E-14 to 1.43E-09 mg/kg acenaphthylene; 8.63E-12 to 2.98E-10 mg/kg acenaphthene; 1.27E-11 to 7.07E-10 mg/kg fluorene; 8.08E-13 to 6.92E-10 mg/kg phenanthrene; 1.05E-13 to 8.05E-10 mg/kg anthracene; 9.77E-10 to 3.62E-09 mg/kg fluoranthene and 3.00E-11 to 7.86E-10 mg/kg pyrene. The highest hazard index of 7.10E-08 mg/kg was observed in the gills, while the lowest hazard index of 7.40E-09 mg/kg was observed in the intestine.

Table 20 shows the hazard quotient and hazard index for some non-carcinogenic polycyclic aromatic hydrocarbons via consumption of different tissues of *Clarias gariepinus* from Gubi Dam, Bauchi State. The hazard quotient of naphthalene ranged from 3.10E-10 to 3.19E-08 mg/kg; 4.94E-11 to 1.14E-08 mg/kg 2-methylnaphthalene; 2.81E-11 to 3.22E-10 mg/kg acenaphthylene; 4.06E-13 to 2.56E-09 mg/kg acenaphthene; 1.22E-13 to 7.09E-10 mg/kg fluorene; 3.97E-12 to 1.98E-09 mg/kg phenanthrene; 8.26E-12 to 2.17E-10 mg/kg anthracene; 9.77E-11 to 2.07E-09 mg/kg fluoranthene and 1.13E-11 to 2.87E-09 mg/kg pyrene. The highest hazard index of 7.12E-08 mg/kg was observed in the gills, while the lowest total hazard index of 0.87E-09 mg/kg was observed in the flesh.

Table 19: Hazard Quotient and Hazard Index (mg/kg day⁻¹) of Non-Carcinogenic Polycyclic Aromatic Hydrocarbon (PAHs) in Different Tissues of *Alestes baremoze* from Gubi Dam, Bauchi State, Nigeria

Hazard Quotient and Hazard Index (mg/kg day ⁻¹)				
PAHs	Liver	Flesh	Intestine	Gills
Naphthalene	1.74E-08	9.85E-09	1.71E-09	2.22E-08
2-methylnaphthalene	5.30E-11	1.47E-08	4.02E-11	6.05E-10
Acenaphthylene	1.43E-09	1.61E-14	2.25E-10	2.32E-10
Acenaphthene	8.63E-12	7.05E-11	2.36E-11	2.98E-01
Fluorene	4.22E-11	1.27E-11	7.77E-11	7.07E-10
Phenanthrene	6.92E-10	5.22E-12	8.80E-13	5.20E-10
Anthracene	1.37E-10	1.50E-13	1.04E-10	8.50E-10
Fluoranthene	3.62E-09	9.77E-10	3.50E-09	1.66E-09
Pyrene	7.86E-10	3.56E-11	5.86E-09	3.00E-11
Hazard Index(HI)	4.16E-08	5.65E-08	7.40E-09	7.10E-08

Table 20: Hazard Quotient and Hazard Index (mg/kg day⁻¹) of Non-Carcinogenic Polycyclic Aromatic Hydrocarbon (PAHs) in Different Tissues of *Clarias gariepinus* from Gubi Dam, Bauchi State, Nigeria

Hazard Quotient and Hazard Index (mg/kg day ⁻¹)				
PAHs	Liver	Flesh	Intestine	Gills
Naphthalene	9.25E-09	1.12E-09	3.10E-10	3.19E-08
2-methylnaphthalene	1.14E-08	4.94E-11	5.65E-10	1.01E-10
Acenaphthylene	1.35E-10	2.81E-11	3.22E-10	1.25E-10
Acenaphthene	7.70E-12	4.06E-13	2.56E-09	4.00E-11
Fluorene	4.70E-11	7.90E-10	2.18E-10	1.22E-13
Phenanthrene	5.92E-11	2.18E-11	3.97E-12	1.98E-09
Anthracene	7.56E-11	2.17E-10	8.26E-12	8.46E-12
Fluoranthene	3.67E-10	1.44E-09	2.70E-09	9.77E-11
Pyrene	1.13E-11	4.20E-09	1.28E-09	2.87E-09
Hazard Index (HI)	1.35E-08	0.87E-09	9.67E-09	7.12E-08

DISCUSSION

Concentration of PAHs Among Fish Species.

Concentration of individuals' components of PAHs among tissues (liver, flesh, intestine, gills) of fish (*Tilapia dageti*, *Tilapia zilli*, *Alestes baremoze* and *Clarias gariepinus*) species are presented in Table (1 to 4). The concentration of PAHs in the liver of four fish samples ranged from 1.59E-02 to 1.19E-01 mg/kg, with *Tilapia zilli* recorded the highest (Table 2) while *Tilapia dageti* recorded the lowest concentration (Table 1). Similarly, in the flesh of the mentioned fish samples the concentrations ranged from 7.94E-03 to 6.77E-02 mg/kg with *Alestes baremoze* recorded the highest (Table 3), while *Tilapia zilli* recorded the lowest concentration Table 2. The concentrations of PAHs in the gills of four fish samples ranged from 1.00E-01 to 1.94E-01 mg/kg. with *Tilapia zilli* recorded the highest (Table 2), while *Alestes baremoze* recorded the lowest concentration (Table 3), similarly, in the intestine of the mentioned fish samples the concentrations were ranged from 4.97E-02 to 2.51E-01 mg/kg with *Tilapia dageti* recorded the highest (Table 1), while *Clarias Gariepinus* recorded the lowest concentration (Table 4). Among all the fish samples studied, the maximum concentration of PAH in marine fish species was found in *Tilapia dageti* (2.51E-01 mg/kg), other species such as *Tilapia zilli*, *Alestes baremoze* detected relatively moderate concentration, whereas the minimum concentration was detected in *Clarias gariepinus*. (4.97E-02 mg/kg.). The total PAHs concentration reported in fish samples from the present study appears to be lower than the concentration reported in edible fishes (0.207–3.365 ppm) of the Gomti river, Lucknow, India (Malik *et al.*, 2008). The PAHs concentration detected in the fish samples from present study is comparable with study reported in the muscles of the fish, from pound of the Pearl river Delta (49.5 ng/gwewt) Kong *et al.* (2005) and lower than the levels in the Mai Po Marshes Nature Reserve of

Hong Kong (49.7 ng/gwewt.) Liang *et al.* (2007). Similarly, chrysene: benzo(b)fluoranthene and benzo(k)fluoranthene were observed to be the most predominate PAHs which are mostly recorded in the liver and gills, while naphthalene, 2-methylnaphthalene and acenaphthylene were observed to show lower concentrations as compared to other PAHs which are mostly recorded in the intestine. However, higher levels reported in the fish muscles from the Red Sea Coast (12.29 ng/gwetwt.) DouAbul *et al.* (1997). Among the various components of PAHs, naphthalene was the most abundant detected as reported in other studies Deb *et al.* (2000) followed by fluorene and acenaphthene. The low detection of certain PAHs in the fish samples may be attributed to their rapid depuration or biotransformation (Deb *et al.*, 2000). The accumulation and depuration of PAHs in fish can be influenced by various factors including route and duration of exposure, lipid content of tissues, environmental factors, differences in species, age, and sex, and exposure to other xenobiotics (Varanasi *et al.*, 1987). Similarly, the levels of PAHs recorded in the present study were observed to be lower than the maximum allowable concentrations as proposed by ATSDR (2006), which are consider safe for consumption.

Dietary Intake of PAHs through Fish Consumption.

Calculated dietary intake concentration of PAHs through consumption of marine fish to human is presented in Table 9 to 12. The average intake of PAHs through fish consumption was estimated to be 1.77–10.7 ng/kg body weight. Among fish species analysed, *Tilapia dageti* contributed to the highest intake of total PAHs with a value of 1.31E-03 mg/kg/d, while *Alestes baremoze* recorded the lowest daily intake with a value of 1.02E-03 mg/kg/d. The amount of average dietary intake of PAH in humans through fishes estimated in Gubi Dam is far less compared to that in other countries. The estimated intake of PAHs from fish consumption reported for the

general populations in other countries such as Spain (626–712 ng/d), Kuwait (231 ng/d) Saeed *et al.* (1995), and Korea (13.8–16.7 ng/kg) body weight/d (Moon *et al.*, 2007). This result seems to be associated with the consumption rate and accumulation level of PAHs in the fish available in Gubi Dam. 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, 2008).

Contribution of PAHs to Total Toxic Equivalence (TEQs).

The estimated intake of TEQ-PAHs from fish consumption for the general population ranged from 6.38E-04 to 1.59E-04 in *Clarias gariepinus* fish species; for *Alestes baremoze* species, it ranged from 1.09E-07 to 8.79E-05 mg/kg 6.19E-08 to 8.89E-05 mg/kg *Tilapia zilli* and 2.76E-05 to 4.43E-03 mg/kg for *Tilapia dageti* (Table 5 to 8). These levels were higher than the levels reported in Korea through consumption of seafood (Moon *et al.*, 2007). PAHs concentration was proposed as one of the toxic chemicals in food, consumer products, and the environment CoT (2001). BaP is the only PAH for which toxicological data are sufficient for derivation of a carcinogenic potency factor among all known potentially carcinogenic PAHs (Agarwal *et al.*, 2009). To understand the magnitude of dietary exposure of PAHs by fish consumption, the toxic equivalency factors (TEFs) were used to quantify the carcinogenicity of other PAHs relative to BaP and to estimate BaP equivalent concentration (BaP_{eq}). The calculated TEF value is 0.001 for NaP, Any, Ana, Flu, Phe, Flt and Pyr, 0.01 for Ant, Chr and BghiP, 0.1 for BaA, BbF, BkF and IP, 1 for BaP and DahA (Liao and Chiang, 2006; Peng *et al.*, 2011). For PAHs, total concentrations of potentially carcinogenic PAHs, including BaA(6.89E-06), BkF(1.47E-05), BbF(1.87E-05), BaP(2.03E-05), DahA(3.82E=05), IP(1.90E-06) and Chr(7.38E-

09) (relatively weak carcinogens). This present study is in agreement with the study conducted by (Bhargava *et al.*, 2004; Nadal *et al.*, 2004) which shows weak carcinogene PAHs based on Bap TEQ.

Assessment of Excess Cancer Risk.

Excess cancer risk values, estimated from individual fish consumption for the general population are presented in Table 13 to 16. Among the fish species of fish estimated, *Tilapia dageti* showed relatively highest risk with a value of 1.08E-01 mg/kg which are mostly observed in the liver while, *clarias gariepinus* shows the lowest cancer risk with a value of 2.35E-16 mg/kg day⁻¹ as recorded in the intestine. The excess cancer risk values estimated for fish samples recorded in the present study were observed to be lower than cancer risk guideline value (1×10^{-6}) (USEPA 1989). This result indicates that adverse effects from PAHs in fish could only be caused by lifetime consumption of fish. The concentration of PAHs was measured in commonly consumed types of fishes available in the study locations. The PAH levels in Gubi Dam, were moderate compared with those found in other countries, which revealed that an average of 1 in each one million are prone to cancer risk as a result of fish consumption from Gubi Dam, which indicate the consumption of fish from the study area are relatively safe based on cancer risk guideline of 10^{-6} . PAHs intakes by way of fish consumption by the general population were estimated. Intake of the TEQ values calculated from PAH concentrations showed that PAHs were the highest contributor to total TEQ intake. The results of the present study emphasize the importance of systematically monitoring of PAH levels and fish intake and comparing them with published guidelines to protect human health.

Estimation of Hazard quotient and Hazard Index

The hazard quotient values were calculated on the bases of the reference dose (RFD) for PAHs, while the hazard index is an index of risk for

residence of ingesting these PAHs by consuming fish from the study area. This is calculated by the summation of hazard quotient of all PAHs for each fish tissues as proposed by USEPA (2014). From the result of the present study, the highest and the lowest hazard quotient in all the tissues (liver, flesh, intestine and gills) of *Tilapia dageti*, *Tilapia zilli*, *Alestes baremoze* and *Clarias gariepinus* was observed in the gills and flesh of *Alestes baremoze* with a value of 2.98E-01 and 1.61E-14 mg/kg Table 19, Similarly, 1.00E-01 mg/kg was observed as the highest hazard index recorded in the liver of *Clarias gariepinus*, while the lowest hazard index value of 8.70E-10 mg/kg was recorded in the flesh of *Tilapia dageti* (Table 17). From the result mentioned above, both the hazard quotient and hazard indexes were observed to be less than 1. A level described by USEPA as generally having no appreciable health risk for the development of non-cancer health effect via consumption of PAHs residues from all the four fish samples studied from Gubi Dam. Result from the present study is in agreement with study carried in different fish organs by Zakari *et al.* (2017).

CONCLUSION

Polycyclic Aromatic Hydrocarbon (PAH) residues were analyzed in different tissues of fish samples from Gubi Dam, Bauchi State. The mean concentration, dietary intake, total toxic equivalent, excess cancer risk values, hazard quotient, and hazard index of 16 PAHs were estimated from the tissues (liver, flesh, intestine, and gills) of four fish species (*Tilapia dageti*,

Tilapia zilli, *Alestes baremoze*, and *Clarias gariepinus*) from Gubi Dam.

The highest concentration of PAHs was detected in *Tilapia dageti* (0.251 mg/kg), while the lowest concentration was recorded in *Clarias gariepinus* (0.0497 mg/kg). The dietary intake of PAHs via fish consumption was highest for *Tilapia dageti* (1.31E-03 mg/kg/day), and lowest for *Alestes baremoze* (1.02E-03 mg/kg/day). The total toxic equivalent (TEQs) of PAHs from fish consumption was highest in *Tilapia dageti* (4.43E-03 mg/kg) and lowest in *Tilapia zilli* (6.19E-08 mg/kg).

Excess cancer risk values indicated that *Tilapia dageti* poses the highest risk (1.08E-01 mg/kg/day), primarily from liver consumption, while *Clarias gariepinus* showed the lowest cancer risk (2.35E-16 mg/kg/day), primarily from intestine consumption. Both the hazard quotient and hazard index were observed to be less than 1, indicating no appreciable health risk for developing non-cancer health effects from consuming PAH residues in the four fish species studied from Gubi Dam.

These results suggest that fish from Gubi Dam, Bauchi State, are safe for consumption. Based on the findings, it is recommended that the government establish a committee to monitor PAH levels in the dam regularly. Further studies should be conducted to analyze PAH levels in the blood of people living around the dam to assess exposure within the community. Additionally, the local population should be educated about the dangers and health risks associated with PAHs.

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