UNDER PEER REVIEW

Review Paper

Risk Assesment of Polycyclic Aromatic Hydrocarbons In Water Sample From Dadin Kowa Dam, Gombe State, Nigeria

ABSTRACT

Water sample were collected from Dadin Kowa Dam, Gombe state, Nigeria during dry and rainy seasons for assessing the levels of polycyclic aromatic hydrocarbons (PAHs) residues. Extraction and clean-up of water, sample were carried out in accordance with standard procedures and instrumental analysis of PAHs were carried out using Gas Chromatography-Mass Spectrophotometer. The concentration of PAHs in the water samples during the dry season ranged from 6.60E-01 to 1.01E+00 µg/L, while during the rainy season the concentration ranged from 7.60E-01 to 1.26E+00 µg/L. In the present study, the higher molecular weight (HMW) (4-6 ringed) PAHs were generally predominant compared to the lower molecular weight (LMW) PAHs (2-3 ringed). The study further revealed that in the dry and rainy season, the total PAHs for the water sample in all the sampling points were above the permissible limit. Due to the carcinogenic and mutagenic nature of PAHs, the population that depends on this Dam as a means of survival may be exposed to PAH toxicity by drinking water and using it to prepare food. The result from the estimated incremental lifetime cancer risk (ILCR) for adult and children users of water from the study area during the rainy and the dry seasons via ingestion of water ranged from 1.06E-02 to 2.58E-02 µg/l for adult and 8.00E-03 to 1.39E-02 µg/l for children due chronic exposure of carcinogenic PAHs, this means that between 1 to 3 out of 100 adult and 1 out of 100 or 8 out of 1000 children users are likely to suffer cancer-related illness in their lifetime due to PAHs exposure respectively, the cancer risk (CR) values for children were lower than that of adults.

UNDER PEER REVIEW

Keywords: Dadin Kowa Dam; Water; Pollutant; PAHs; ILCR; CR

Introduction

Polycyclic aromatic hydrocarbons are characterized by their high toxicity for aquatic organisms and their high environmental bio monitoring because they can be easily bio accumulated. The principal source of pollution of water bodies has been the runoff from the agricultural land. PAHs have complex chemical structures so they do not break down easily and are persistent in the environment. ~~PAHs~~ generally have low solubilities and high octanol-water partition coefficients, and therefore often have a short residence time in water. PAHs can easily penetrate biological membrane and accumulate in the organisms. Moreover, these compounds are important environmental pollutants because of their ubiquitous presence and carcinogenicity. ~~PAHs are widely distributed and found throughout the environment in the air, water and soil and can remain in the environment for months or years (Cirillo *et al.*, 2009). Owing to their lipophilic nature, PAHs can easily penetrate biological membrane and accumulate in the organisms. Moreover, these compounds are important environmental pollutants because of their ubiquitous presence and carcinogenicity. PAHs are widely distributed and found throughout the environment in the air, water and soil and can remain in the environment for months or years (Cirillo *et al.*, 2009~~

Nigeria's vast water resources especially the Dadin kowa Dam are among those most affected by environmental stress imposed by human population growth anthropogenic activities in agriculture, industrialization, the disposal and management of waste. ~~Unsystematic utilization of chemical pesticides, especially has influenced on man and atmosphere and improved the load of chemicals in the atmosphere due to non-biodegradability (Tripathy, 1992; Kumar *et al.*, 2006).~~

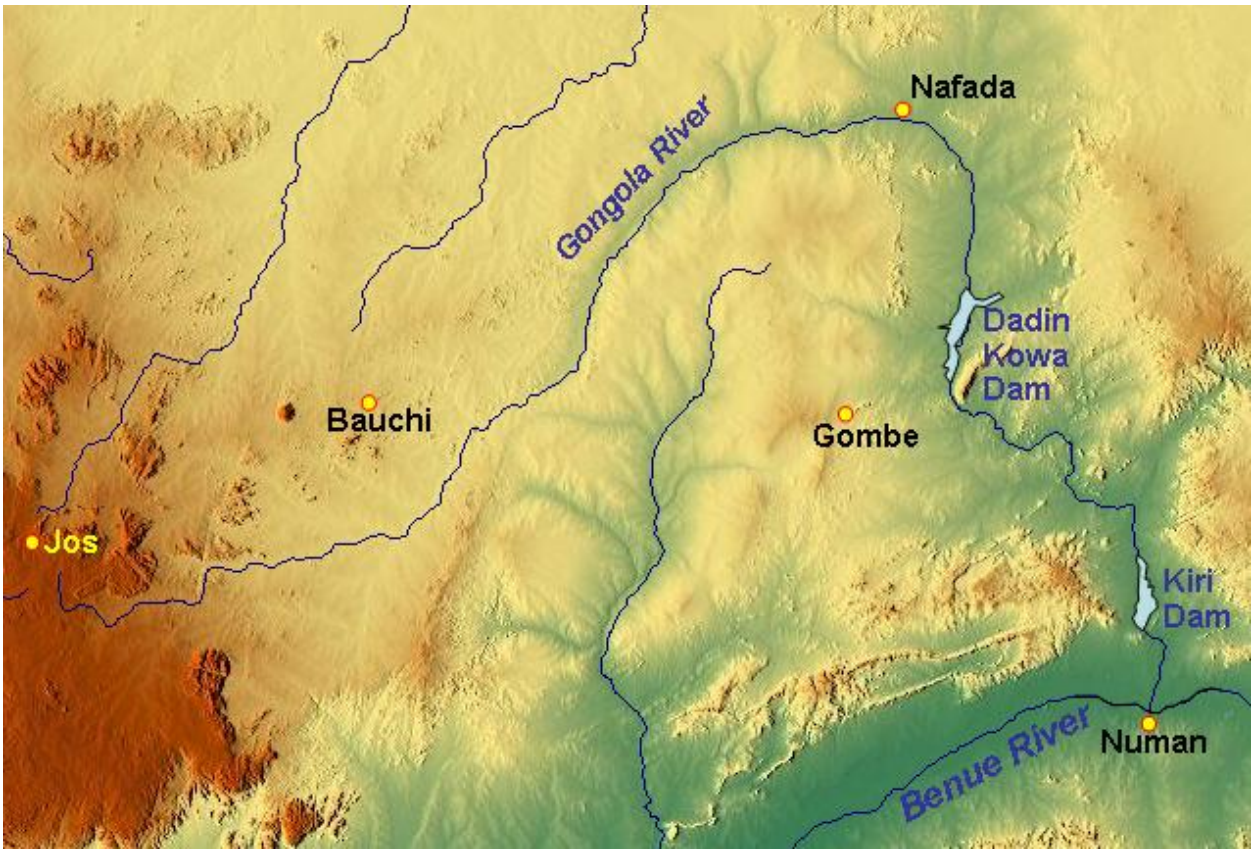
UNDER PEER REVIEW

Materials and Methods

Study Area

Dadin Kowa Dam is located 5km North of Dadin Kowa village (about 37km from Gombe town, along Gombe-Biu road) in Yamaltu Deba local Government Area of Gombe State ~~(Map 3.1)~~. The area lies within longitude 11° 30' E and 11° 32' E, and Latitude 10° 17' and 10° 18' N of the equator ~~(UBRDA, 1980)~~. The Dam got its source from River Dadin Kowa, which also got its source of water from River Gongola, its drainage basin is situated in North-Eastern Nigeria, with water capacity of 800 million cubes and surface area of 300 kilometers square has potential as a source of fish (Timawus, 2010) 26,000 people were displaced by the reservoir, receiving little assistance for resettlement (William, 1994). The source of the river is located on the Jos Plateau which has been described as the hydrological center of Nigeria. ~~Water drains radially from the plateau into the Lake Chad basin to the north, the river Niger to the west, the River Benue to the south and the Gongola River to the east. In parts the plateau rises to an elevation of over 1700 m but the general altitude is about 1200 m. After leaving the plateau the Gongola flows a north easterly direction across the Bauchi high plains for about 350 km to Nafada where the approximate elevation is 260 m. Near Nafada the river changes and flows southwards for about 100 km to Dadin kowa at an elevation of approximately 210 m. The River then follows roughly south easterly course for 150 km before joining the River Benue, which in turn is the major tributary of the River Niger.~~

UNDER PEER REVIEW



Map: Map of Gongola River showing the Main Source of the Dadin-Kowa Dam.
SOURCE**:** Encyclopedia Britannica. Retrieved 2010-05-21

Sampling

Sampling was carried out during the dry and rainy seasons. Water samples were collected from ten ~~(10)~~ sampling ~~point~~ ~~designated S_1 - S_{10}~~. Point S_1 is the point of flow if water into Dadin kowa dam, the distance from each sampling point were 3km away from each other. The water samples were collected using plastic containers by dipping 1-5 cm below the top layer of the water and placed in an amber glass bottle and store in an ice-block cooler as described by Boy'd and Tucker, (1992).

UNDER PEER REVIEW

~~**Collection of Water Samples**~~

~~Water samples were collected from ten (10) sampling point designated S_1 – S_{10}.~~ The distance from each sampling point were 3km away from each other. The water samples were collected using plastic containers by dipping 1-5 cm below the top layer of the water and placed in an amber glass bottle and store in an ice-block cooler as described by Boy'd and Tucker, (1992). ~~The sample were transported to the Department of Chemistry, University of Maiduguri and stored in a refrigerator pending extraction and analysis.~~

Sample Preparation

~~*Extraction and Clean-up of PAHs in Water Samples*~~

The Gas Chromatography (USEPA 8270) test method was adopted using GC MS. Sample extraction was effected by liquid-liquid extraction in a separatory funnel using dimethyl chloride (DCM) as solvent. The sample extract was subsequently filtered through glass wool containing anhydrous sodium sulphate in a glass funnel. This was followed by clean-up using about 2g of silica gel. The sample extract was allowed to stand for about 30 minutes and then decanted and concentrated to 1ml.

~~*Determination of PAHs in Water Samples*~~

The extract was transferred into the vials and analyzed using Agilent 7890A/5975C GC/MS previously calibrated with PAH standards under specific temperature programmed inlet, oven and detector conditions. The equipment turned out the concentration of the PAHs as the sample details was supplied for water samples.

Carcinogenic Risk Assessment of PAHs in Water Samples

UNDER PEER REVIEW

Carcinogenic risk (CR) values of polycyclic aromatic hydrocarbon in water via ingestion pathway was predicted from their chronic daily intake (CDI) obtained from the equation predicted by (Caylak, 2012; USEPA, 1999)

CR = CDI x SF……(1)

$$where: CR = Cancer\ Risk; SF = Slope\ factor;$$

$$CDI = Chronic\ daily\ Intake\ ingestion\ pathway$$

Chronic daily intake via ingestion were calculated by equation

$$CDI = \frac{C\ x\ IR\ x\ EF\ x\ ED}{Bw\ x\ AT} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

ults

Mean Concentration of PAHs in Water Samples During the Dry and Rainy Season

Table 1 to 2 shows the mean concentrations of some polycyclic aromatic hydrocarbon in water samples for dry and rainy season from points S1 to S10 of Dadin Kowa Dam Gombe State Nigeria. ~~The concentration of naphthalene ranged from 1.00E-02 to 1.30E-01 mg/kg; 2.00E-02 to 7.00E-02 mg/kg 2-methylnaphthalene; 1.00E-02 to 4.00E-02 mg/kg acenaphthylene; 2.00E-02 to 4.00E-02 mg/kg acenaphthene; 1.00E-02 to 2.30E-01 mg/kg Fluorene; 1.00E-02 to 3.00E-02 mg/kg phenanthrene; 1.00E-02 to 2.00E-02 mg/kg anthracene; 1.00E-02 to 5.00E-02 mg/kg fluoranthene; 2.00E-02 to 1.30E-01 mg/kg pyrene; 3.00E-02 to 1.30E-01 mg/kg benzo(a)anthracene; 3.00E-02 to 8.00E-02 mg/kg chrysene; 2.00E-02 to 1.70E-01 mg/kg benzo(b)fluoranthene; 3.00E-02 to 1.60E-01 mg/kg benzo(k)fluoranthene; 2.00E-02 to 1.40E-01 mg/kg benzo(a)pyrene; 2.00E-02 to 2.70E-01 mg/kg dibenz(a.h)anthracene; 2.00E-02 to 2.70E-01 mg/kg benzo(g,h,i)perylene and 5.00E-02 to 1.80E-01 mg/kg indinol(1,2,3-cd)pyrene.~~ The highest total concentration of 1.44E+00 mg/kg was observed at point S8 during the rainy season, while point S9 shows the lowest total value of 6.60E-01 mg/kg during the dry season.

Carcinogenic Risk Values of Some PAHs in Water Samples During the Dry and Rainy

UNDER PEER REVIEW

Season from Different Sampling Points

The carcinogenic risk values of some PAHs in water samples for dry season and rainy season from Dadin Kowa Dam, Gombe State, Nigeria from points S1 to S10 based on adult and children are as presented in Table 3 to 6. T~~he value of benzo(a)anthracene ranged from 1.40E-04 to 1.05E-03; 1.40E-06 to 5.26E-04 chrysene; 1.34E-04 to 7.95E-04 benzo(b)fluoranthene;1.31E-04 to 1.05E-03 benzo(k)fluoranthene; 1.31E-03 to 8.54E-03 benzo(a)pyrene; 1.31E-03 to 1.25E-02 dibenz(a.h)anthracene and 2.81E-05 to 1.84E-04 indinol(1,2,3-cd)pyrene.~~ The highest value of all the PAHs were detected in the adult, while the lowest value were detected in children.

Table 1: Mean Concentrations of Some Polycyclic Aromatic Hydrocarbons in Water Samples During the Dry Season

			Concentrations (µg/L)									
PAHs	No of Rings	**MAC'S**	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Naphthalene	2	3	2.00E-02	2.00E-02	1.00E-02	2.00E-02	1.00E-02	3.00E-02	2.00E-02	1.00E-02	2.00E-02	1.00E-02
2-methyl Napthalene	2	3	3.00E-02	4.00E-02	2.00E-02	4.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	3.00E-02	2.00E-02
Acenapthylene	3	3	2.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02	1.00E-02
Acenaphthene	3	3	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	3.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02
Fluorene	3	3	5.00E-02	3.00E-02	2.00E-02	3.00E-02	2.00E-02	4.00E-02	1.00E-02	3.00E-02	3.00E-02	4.00E-02
Phenanthrene	3	3	3.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	1.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02
Anthracene	3	3	2.00E-02	1.00E-02	2.00E-02	1.00E-02	2.00E-02	2.00E-02	1.00E-02	2.00E-02	1.00E-02	3.00E-02
Fluoranthene	4	3	5.00E-02	3.00E-02	2.00E-02	3.00E-02	2.00E-02	4.00E-02	2.00E-02	1.00E-02	3.00E-02	2.00E-02
Pyrene	4	3	2.00E-02	4.00E-02	3.00E-02	4.00E-02	3.00E-02	3.00E-02	3.00E-02	3.00E-02	2.00E-02	2.00E-02
Benz(a)anthracene	4	0.005	6.00E-02	5.00E-02	8.00E-02	5.00E-02	7.00E-02	7.00E-02	4.00E-02	6.00E-02	3.00E-02	5.00E-02
Chrysene	4	-	5.00E-02	3.00E-02	7.00E-02	4.00E-02	4.00E-02	6.00E-02	5.00E-02	8.00E-02	4.00E-02	6.00E-02
Benz(b)fluoranthene	5	0.005	7.00E-02	6.00E-02	9.00E-02	4.00E-02	8.00E-02	9.00E-02	4.00E-02	5.00E-02	2.00E-02	7.00E-02
Benz(k)fluoranthene	5	-	8.00E-02	9.00E-02	8.00E-02	8.00E-02	5.00E-02	6.00E-02	3.00E-02	7.00E-02	5.00E-02	8.00E-02
Benz(a)pyrene	5	0.005	1.10E-01	1.20E-01	1.30E-01	1.40E-01	1.10E-01	7.00E-02	8.00E-02	9.00E-02	7.00E-02	6.00E-02
Dibenz(a,h)anthracene	5	0.005	1.30E-01	8.00E-02	1.40E-01	1.10E-01	1.50E-01	9.00E-02	1.10E-01	1.10E-01	9.00E-02	9.00E-02
Benzo(g,h,i)perylene	6	3	9.00E-02	1.20E-01	1.10E-01	1.50E-01	1.20E-01	7.00E-02	8.00E-02	8.00E-02	6.00E-02	7.00E-02
Indinol(1,2,3-cd)pyrene	6	0.005	1.30E-01	9.00E-02	1.40E-01	1.20E-01	8.00E-02	6.00E-02	7.00E-02	9.00E-02	1.10E-01	1.30E-01
TOTAL			**9.80E-01**	**8.60E-01**	**1.01E+00**	**9.50E-01**	**8.70E-01**	**8.00E-01**	**6.60E-01**	**8.00E-01**	**6.60E-01**	**8.00E-01**

Table 2: Mean Concentrations of Some Polycyclic Aromatic Hydrocarbons in Water Samples During the Rainy Season

			Concentrations(µg/L)							
PAHs	**No of Rings**	**MAC'S**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
Naphthalene	2	3	1.00E-02	3.00E-02	1.00E-02	2.00E-02	2.00E-02	1.30E-01	1.10E-01	2.00E-02
2-methyl Napthalene	2	3	2.00E-02	3.00E-02	2.00E-02	4.00E-02	3.00E-02	3.00E-02	3.00E-02	3.00E-02
Acenapthylene	3	3	3.00E-02	2.00E-02	1.00E-02	1.00E-02	3.00E-02	2.00E-02	1.00E-02	4.00E-02
Acenaphthene	3	3	2.00E-02	2.00E-02	2.00E-02	2.00E-02	4.00E-02	2.00E-02	4.00E-02	2.00E-02
Fluorene	3	3	3.00E-02	3.00E-02	2.00E-02	3.00E-02	3.00E-02	2.30E-01	2.00E-02	3.00E-02
Phenanthrene	3	3	3.00E-02	2.00E-02	2.00E-02	2.00E-02	3.00E-02	2.00E-02	2.00E-02	2.00E-02
Anthracene	3	3	2.00E-02	2.00E-02	2.00E-02	1.00E-02	2.00E-02	2.00E-02	2.00E-02	1.00E-02
Fluoranthene	4	3	4.00E-02	3.00E-02	2.00E-02	3.00E-02	5.00E-02	3.00E-02	2.00E-02	3.00E-02
Pyrene	4	3	2.00E-02	2.00E-02	3.00E-02	2.00E-02	2.00E-02	2.00E-02	1.30E-01	2.00E-02
Benz(a)anthracene	4	0.005	5.00E-02	6.00E-02	6.00E-02	6.00E-02	6.00E-02	1.60E-01	1.60E-01	1.10E-01
Chrysene	4	-	7.00E-02	8.00E-02	5.00E-02	5.00E-02	8.00E-02	4.00E-02	5.00E-02	5.00E-02
Benz(b)fluoranthene	5	0.005	8.00E-02	1.20E-01	7.00E-02	6.00E-02	9.00E-02	1.20E-01	1.70E-01	6.00E-02
Benz(k)fluoranthene	5	-	6.00E-02	8.00E-02	1.10E-01	9.00E-02	1.60E-01	5.00E-02	1.10E-01	2.00E-02
Benz(a)pyrene	5	0.005	9.00E-02	1.30E-01	8.00E-02	6.00E-02	9.00E-02	1.30E-01	3.00E-02	6.00E-02
Dibenz(a,h)anthracene	5	0.005	7.00E-02	7.00E-02	9.00E-02	8.00E-02	2.70E-01	2.00E-02	1.90E-01	1.80E-01
Benzo(g,h,i)perylene	6	3	1.20E-01	6.00E-02	7.00E-02	9.00E-02	1.20E-01	6.00E-02	1.70E-01	2.00E-02
Indinol(1,2,3-cd)pyrene	6	0.005	8.00E-02	8.00E-02	6.00E-02	7.00E-02	1.20E-01	1.80E-01	1.60E-01	5.00E-02
TOTAL			**8.40E-01**	**9.00E-01**	**7.60E-01**	**7.60E-01**	**1.26E+00**	**1.28E+00**	**1.44E+00**	**7.70E-01**

Table 3: Cancer Risk Values of Some Carcinogenic Polycyclic Aromatic Hydrocarbon in Water Sample During the Dry Season for Adult and Children

PAHs	Concentration(µg/l)									
	S1		S2		S3		S4		S5	
	Adult	Children	Adult	Children	Adult	Children	Adult	Children	Adult	Children
Benz(a)anthracene	3.94E-04	2.81E-04	3.29E-04	2.34E-04	5.26E-04	3.74E-04	3.29E-04	2.34E-04	4.60E-04	3.27E-04
Chrysene	3.29E-06	2.34E-06	1.97E-06	1.40E-06	4.60E-06	3.27E-06	2.63E-06	1.87E-06	2.63E-06	1.87E-06
Benz(b)fluoranthene	4.60E-04	3.27E-04	3.94E-04	2.81E-04	5.91E-04	4.21E-04	2.63E-04	1.87E-04	5.26E-04	3.74E-04
Benz(k)fluoranthene	5.26E-04	3.74E-04	5.91E-04	4.21E-04	5.26E-04	3.74E-04	5.26E-04	3.74E-04	3.29E-04	2.34E-04
Benz(a)pyrene	7.23E-03	5.14E-03	7.89E-03	5.61E-03	8.54E-03	6.08E-03	9.20E-03	6.55E-03	7.23E-03	5.14E-03
Dibenz(a,h)anthracene	8.54E-03	6.08E-03	5.26E-03	3.74E-03	9.20E-03	6.55E-03	7.23E-03	5.14E-03	9.86E-03	7.02E-03
Indinol(1,2,3-cd)pyrene	8.54E-05	6.08E-05	5.91E-05	4.21E-05	9.20E-05	6.55E-05	7.89E-05	5.61E-05	5.26E-05	3.74E-05
TOTAL	**1.72E-02**	**1.23E-02**	**1.45E-02**	**1.03E-02**	**1.95E-02**	**1.39E-02**	**1.76E-02**	**1.25E-02**	**1.85E-02**	**1.31E-02**

Table 4: Cancer Risk Values of Some Carcinogenic Polycyclic Aromatic Hydrocarbon in Water Samples During the Dry Season for Adult and Children

	Concentration(µg/l)									
PAHs	**S6**		**S7**		**S8**		**S9**		**S10**	
	Adult	**Children**	**Adult**	**Children**	**Adult**	**Children**	**Adult**	**Children**	**Adult**	**Children**
Benz(a)anthracene	4.60E-04	3.27E-04	2.63E-04	1.87E-04	3.94E-04	2.81E-04	1.97E-04	1.40E-04	3.29E-04	2.34E-04
Chrysene	3.94E-06	2.81E-06	3.29E-06	2.34E-06	5.26E-06	3.74E-06	2.63E-06	1.87E-06	3.94E-06	2.81E-06
Benz(b)fluoranthene	5.91E-04	4.21E-04	2.63E-04	1.87E-04	3.29E-04	2.34E-04	1.31E-04	9.35E-05	4.60E-04	3.27E-04
Benz(k)fluoranthene	3.94E-04	2.81E-04	1.97E-04	1.40E-04	4.60E-04	3.27E-04	3.29E-04	2.34E-04	5.26E-04	3.74E-04
Benz(a)pyrene	4.60E-03	3.27E-03	5.26E-03	3.74E-03	5.91E-03	4.21E-03	4.60E-03	3.27E-03	3.94E-03	2.81E-03
Dibenz(a,h)anthracene	5.91E-03	4.21E-03	7.23E-03	5.14E-03	7.23E-03	5.14E-03	5.91E-03	4.21E-03	5.91E-03	4.21E-03
Indinol(1,2,3-cd)pyrene	3.94E-05	2.81E-05	4.60E-05	3.27E-05	5.91E-05	4.21E-05	7.23E-05	5.14E-05	8.54E-05	6.08E-05
TOTAL	**1.20E-02**	**8.54E-03**	**1.33E-02**	**9.44E-03**	**1.44E-02**	**1.02E-02**	**1.12E-02**	**8.00E-03**	**1.13E-02**	**8.01E-03**

Table 5: Cancer Risk Values of Some Carcinogenic Polycyclic Aromatic Hydrocarbon in Water Samples During the Rainy Season for Adult and Children

	Concentration(µg/l)									
PAHs	**S1**		**S2**		**S3**		**S4**		**S5**	
	Adult	**Children**	**Adult**	**Children**	**Adult**	**Children**	**Adult**	**Children**	**Adult**	**Children**
Benz(a)anthracene	3.29E-04	2.34E-04	3.94E-04	2.81E-04	3.94E-04	2.81E-04	3.94E-04	2.81E-04	3.94E-04	2.81E-04
Chrysene	4.60E-06	3.27E-06	5.26E-06	3.74E-06	3.29E-06	2.34E-06	3.29E-06	2.34E-06	5.26E-06	3.74E-06
Benz(b)fluoranthene	5.26E-04	3.74E-04	7.89E-04	5.61E-04	4.60E-04	3.27E-04	3.94E-04	2.81E-04	5.91E-04	4.21E-04
Benz(k)fluoranthene	3.94E-04	2.81E-04	5.26E-04	3.74E-04	7.23E-04	5.14E-04	5.91E-04	4.21E-04	1.05E-03	7.48E-04
Benz(a)pyrene	5.91E-03	4.21E-03	8.54E-03	6.08E-03	5.26E-03	3.74E-03	3.94E-03	2.81E-03	5.91E-03	4.21E-03
Dibenz(a,h)anthracene	4.60E-03	3.27E-03	4.60E-03	3.27E-03	5.91E-03	4.21E-03	5.26E-03	3.74E-03	1.77E-02	1.26E-02
Indinol(1,2,3-cd)pyrene	5.26E-05	3.74E-05	5.26E-05	3.74E-05	3.94E-05	2.81E-05	4.60E-05	3.27E-05	7.89E-05	5.61E-05
TOTAL	**1.18E-02**	**8.41E-03**	**1.49E-02**	**1.06E-02**	**1.28E-02**	**9.10E-03**	**1.06E-02**	**7.56E-03**	**2.58E-02**	**1.83E-02**

Table 6: Cancer Risk Values of Some Carcinogenic Polycyclic Aromatic Hydrocarbon in Water Samples During the Rainy Season for Adult and Children

PAHs	Concentration(µg/l)									
	S6		S7		S8		S9		S10	
	Adult	Children	Adult	Children	Adult	Children	Adult	Children	Adult	Children
Benz(a)anthracene	1.05E-03	7.48E-04	1.05E-03	7.48E-04	7.23E-04	5.14E-04	7.89E-04	5.61E-04	7.23E-04	5.14E-04
Chrysene	2.63E-06	1.87E-06	3.29E-06	2.34E-06	3.29E-06	2.34E-06	3.29E-06	2.34E-06	3.29E-06	2.34E-06
Benz(b)fluoranthene	7.89E-04	5.61E-04	1.12E-03	7.95E-04	3.94E-04	3.27E-04	1.38E-03	3.27E-04	4.60E-04	3.27E-04
Benz(k)fluoranthene	3.29E-04	2.34E-04	7.23E-04	5.14E-04	1.31E-04	6.08E-04	7.23E-04	6.08E-04	8.54E-04	6.08E-04
Benz(a)pyrene	8.54E-03	6.08E-03	1.97E-03	1.40E-03	3.94E-03	2.81E-03	1.31E-03	2.81E-03	3.94E-03	2.81E-03
Dibenz(a,h)anthracene	1.31E-03	9.35E-04	1.25E-02	8.89E-03	1.18E-02	7.02E-03	7.23E-03	7.02E-03	9.86E-03	7.02E-03
Indinol(1,2,3-cd)pyrene	1.18E-04	8.42E-05	1.05E-04	7.48E-05	3.29E-05	2.34E-05	8.54E-05	2.34E-05	3.29E-05	2.34E-05
TOTAL	**1.21E-02**	**8.64E-03**	**1.75E-02**	**1.24E-02**	**1.71E-02**	**1.13E-02**	**1.15E-02**	**1.13E-02**	**1.59E-02**	**1.13E-02**

UNDER PEER REVIEW

Discussion

The results of the present study shows that all the PAHs were detected in the water samples during the dry and rainy seasons. The concentrations of the studied PAHs in water samples from the ten sampling point within the dry season ranged from 6.60E-01 to 1.01E+00 µg/L, while the rainy season ranged from 7.60E-01 to 1.26E+00 µg/L. The total highest concentrations of PAHs in water samples was observed during the rainy season with a value of 1.26E+00 µg/L, while the lowest concentration of 6.60E-01 µg/L was observed during the dry season. PAHs have complex chemical structures so they do not break down easily and are persistent in the environment. PAHs generally have low solubilities and high octanol-water partition coefficients, and therefore often have a short residence time in water. In the present study, the higher molecular weight (HMW) (4-6 ringed) PAHs were generally predominant compared to the lower molecular weight (LMW) PAHs (2-3 ringed). Such variation might be due to the fact that, LMW PAHs may be lost due to their possible volatilization to the atmosphere due to their relatively high vapor pressure. Also, 2-3 ring PAHs are more easily biodegraded and volatilized compared with 4-6 ring (Mastran *et al.,* 1994; Miller and Olejnik, 2001). Generally, higher molecular weight PAHs tend to be more stable, persist in the environment and are less water soluble and are more toxic. Exposure to UV light can increase toxicity of PAH compounds and increase toxicity to some aquatic species (Garrett, 2004). 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), while the PAHs from combustion processes (pyrolytic origin) often contain elevated concentrations of HMW (e.g. phenanthrene, fluoranthene, pyrene) and fewer LMW PAHs (Yan *et al.,* 2004). Areas with

UNDER PEER REVIEW

chronic or prolonged contamination often have much higher PAHs concentrations in the water. Results from the present study shows that in the dry and rainy season, the total PAHs for the water sample in all the sampling points were above the permissible limit. Due to the carcinogenic and mutagenic nature of PAHs, the population that depends on this Dam as a means of survival may be exposed to PAH toxicity by drinking water and using it to prepare food. The above finding is consistent with another study by En *et al.,* (2015), that the PAHs concentrations of the water samples were higher than the allowable values in China. A similar results obtained by Qu *et al., (*2014) is also in agreement with the present findings (USEPA, 1996). PAHs enter water bodies through atmospheric deposition and direct releases of substances through petroleum spills and use, municipal wastewater treatment plants, industrial discharges, storm water runoff, landfill leachate and surface runoff.

Cancer Risk Assessment Via Ingestion of Water

A human health cancer risk assessment was carried out on the PAHs (benzo(a)anthracene, Chrysene, benzo(b)fluoranthene, Benz(k)fluoranthene, Benz(a)pyrene, Dibenz(a,h)anthracene, Indinol(1,2,3-cd)pyrene) (Tables 4.15 to 4.18) using carcinogenic risk (CR) values of polycyclic aromatic hydrocarbon in water via ingestion pathway was predicted from their chronic daily intake (CDI) obtained from the equation predicted by (Caylak, 2012; USEPA, 1999). Since their presence in these water bodies is of concern because they have been classified by the International Agency for Research on Cancer (IARC) and Environmental Protection Agency (EPA) as probable human carcinogens. These water bodies are used for fishing and for some domestic purposes by the people living around the study area, exposing them to several dangers and the risk of getting cancer (ATSDR, 1995).

UNDER PEER REVIEW

The estimated incremental lifetime cancer risk (ILCR) for adult and children users of water from Dadin Kowa Dam, Gombe State, Nigeria during the rainy and the dry seasons via ingestion of water ranged from 1.06E-02 to 2.58E-02 for adult and 8.00E-03 to 1.39E-02 µg/l for children for chronic exposure of carcinogenic PAHs. This means that between 1 to 3 out of 100 adult and 1 out of 100 or 8 out of 1000 children user are likely to suffer cancer-related illness in their lifetime due to PAHs exposure respectively. The CR values for children were lower than that of adults, this might be due to age-group specific body weight published by (Inam *et al*., 2014; Caylak, 2012). It could also be explained by the higher water intake rate by adults than children. However, the susceptibility of children to ingested contaminants is higher because of their high food intake in proportion to their body weight (Ellman *et al.*, 2012). Rainy season recorded the higher total CR values when compared to the dry season, such variation might be due to excess discharge from river sources couple with atmospheric deposition. All the sampling points recorded higher CR values above the regulatory standard as specified by (USEPA, 1997) with CR value over 1.00E-05 indicates potential carcinogenic risk, while the safe level of risk which requires risk management decision is 10^{-6}.

Conclusion

All of the PAHs studied in the sediments samples were significantly present. Rainy season was observed to show the highest concentrations of all the studied PAHs. The result from the estimated incremental lifetime cancer risk (ILCR) for adult and children users of water from the study area during the rainy and the dry seasons via ingestion of water ranged from 1.06E-02 to 2.58E-02 µg/l for adult and 8.00E-03 to 1.39E-02 µg/l for children due chronic exposure of carcinogenic PAHs, this means that between 1 to 3 out of 100 adult and 1 out of 100 or 8 out of

UNDER PEER REVIEW

1000 children users are likely to suffer cancer-related illness in their lifetime due to PAHs exposure respectively, the cancer risk (CR) values for children were lower than that of adults.

References

ATSDR. (Agency for Toxic Substance and Disease Registry) (1995). Toxicology Profile for Polycyclic Aromatic Hydrocarbons, US Department of Health and Human Services, Public Health Service, Atlanta, GA. **53(4):** 275-290.

Boy'd, C. E. and Tucker, C.S. (1992). Water Quality and Pond Soil Analysis for Aquaculture. Auburn University Alabama. Pp183.

Caylak, E. (2012). Health risk assessment for trace metals, polycyclic aromatic hydrocarbons and trihalomethanes in drinking water of Cankiri, Turkey. *E-journal of Chemistry*, **9**:(4)1976-1991.

Cirillo, T., Viscardi, V., Fasano, E., Farina, A. and Amodio-Cocchieri, R. (2009). Polychlorinated biphenyls, organochlorine pesticides and polycyclic aromatic hydrocarbons in wild, farmed and frozen marineseafood marketed in Campania, Italy. *Journal of Food Protection*, **72**(8):1677-1685.

Ellman, M. R., Wong, K. R. and Solomon, G. M. (2012).Seafood contamination after the BP Gulf oil spill and risk to vulnerable population: A critique of FDA risk assessment. *Environmental Health Perspective*, **120**:159-161.

Garrett, C. L. (2004). Priority substances of interest in the Georgia Basin: profiles and background information on current toxics issues: Report of the Canadian Toxics Work Group. GBAP Publication no. EC/ GB/04/79. Online at: georgia.basin@ ec.gc.ca.

Inam, E., Owhoeke, E. and Essien, J. (2014). Human carcinogenic risk assessment of polycyclic aromatic hydrocarbon in freshwater samples from Ogba/ Egbema / Andoni communities in River state, Nigeria. *Journal of Chemical Society of Nigeria,* **39**(2):15-22.

Kumar, M., Gupta, S.K., Garg, K.S. and Kumar, A. (2006). Biodegradation of hexachlorocyclohexane-isomers in contaminated soils. *Soil Biology and Biochemical*, **38:** 2318-2327.

Mastran, T. A., Dietrich, A. M., Gallagher, D. L. and Grizzard, T. J. (1994). Distribution of polyaromatic hydrocarbons in the water column and sediments of a drinking water reservoir with respect to boating activity, *Water Research,* **28**(11):2353-2366.

Miller, J. S. and Olejnik, D. (2001) Photolysis of polycyclic aromatic hydrocarbons in water, *Water Research,* **35**(1):233-243.

Timawus, M. (2010). Web Based Forecasting of Short Term Reservoir Inflow; "Jonathan Needs More Than Good Luck". Daily Trust. Retrieved 2010-05-23.

Tripathy, G. (1992). Effect of endosulfan and fenvalerate pollution on biochemical physiology of fish. *Indian Ecology of Polluted Waters*. A.P.H. Publication Corporation New Delhi, India. Pp.443- 452.

URBDA. (Upper Benue River Basin Development Authority) (1980). *Dadin-Kowa Resettlement Project, Draft final report,* **2**.

USEPA. (United State Environmental Protection Agency) (1997). Polycyclic aromatic hydrocarbon Exposure factors handbook. Washington D C, USA.

Refresh and write correctly references according journal guidelines.

UNDER PEER REVIEW

USEPA. (United States Environmental Protection Agency). (1999). Office of water, river and streams. Water assessment. pp. 9-22.

William, W. A. (1994). Microbial reductive dechlorination of trichlorobiphenyls in anaerobic sediment slurries. *Environmental Science and Technology*, **28**:630-635

Yan, B., Benedict, L., Chaky, A., Bopp, F. and Abrajano, T. (2004). Levels and patterns of PAHs distribution in sediments of the New York/New Jersey harbour complex. *Northeastern Geology and Environmental Science*, **26:** 113-126.