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Polycyclic Aromatic Hydrocarbons in Water Sample from Dadin Kowa Dam, Gombe State, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author ZMC designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors JCA and LBI managed the analyses of the study. Author AIM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The purpose of this study was to investigate the concentrations of PAHs in water samples from Dadin Kowa Dam, Nigeria and to evaluate the risk associated with the ingestion of the water from the Dam. The concentrations of PAHs varied with the sample site and season; and the levels of PAHs at all site are found to be significantly below the maximum allowable concentrations (MACs) of 0.005 to 3.0 mg/l. The carcinogenic risks were higher than 10−6 threshold values, and the water from Dadin Kowa Dam is considered to pose significant health effects to children and adult. However, the carcinogenicity risks rating decrease in the order of children > adult. The study further demonstrated that Dadin Kowa Dam requires a substantial PAHs pollution control program.

Keywords: Dadin Kowa Dam; PAHs; cancer risk, MAC.

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1. INTRODUCTION

Polycyclic aromatic hydrocarbons are characterised by their high toxicity for aquatic organisms and their high environmental bio-monitoring because they can be easily bioaccumulated. The principal source of pollution of water bodies has been the runoff from the agricultural land and industrial activities. 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 the water. 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 [1]. Owing to their lipophilic nature. 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 [1]. 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.

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 the toxicity of PAH compounds and increase toxicity to some aquatic species [2]. The PAHs composition of water 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 [3]. Nigeria's vast water resources especially the Dadin kowa Dam are among those most affected by environmental stress imposed by human growth anthropogenic activities in agriculture, industrialisation, the disposal and management of waste. Unsystematic utilisation of chemical especially has influenced man and atmosphere and improved the load of chemicals in the environment due to non-biodegradability [4,5].

2. STUDY AREA

Dadin Kowa Dam is the second largest Dam in Nigeria and located 5 km North of Dadin Kowa village (about 37 km from Gombe town, along Gombe-Biu road) in Yamaltu Deba local Government Area of Gombe State (Map 1). The area lies within longitude 11^{o} 30' E and 11^{o} 32' E, and Latitude 10^{o} 17' and 10^{o} 18' N of the equator [6]. The Dam got its source from River Gongola which originate from Jos Plateau. The waste generated from the Jos Plateau are discharged directly into the river Gongola which flows directly into Dadin Kowa Dam. Several research have revealed alarming concentrations of heavy metals in the water, sediment and fish from Dadin Kowa Dam. But, PAHs contamination of the Dadin Kowa Dam has not been taken into consideration and had been ignored generally. Hence, due to the alarming levels of heavy metals in the Dadin Kowa Dam, the objectives of this study are to determine the levels of PAHs in water samples with the rainy and dry season and to conduct a risk assessment of PAHs upon the ingestion of the water samples.

3. MATERIALS AND METHOD

3.1 Sampling and Their Treatment *In situ*

Sampling was carried out during the dry and rainy seasons. Water samples were collected from ten sampling site. Point S_1 is the point of flow of water into Dadin kowa Dam, the distance from each sampling point were 3 km away from each other to cover a substantial portion of the Dam and was the is human activities. The water samples were collected using amber glass bottle by dipping 1-5 cm below the top layer of the water and placed in an ice-block cooler as described by Boy'd and Tucker [7].

3.2 Sample Preparation

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 dichloromethane (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 2 g of silica gel. The sample extract was allowed to stand for about 30 minutes and then decanted and concentrated to 1 mL. The extract was transferred into the vials and analysed 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 were supplied for water samples.

Carcinogenic Risk Assessment of PAHs in Water Samples

Carcinogenic risk (CR) values of polycyclic aromatic hydrocarbon in water via the ingestion pathway was predicted from their chronic daily intake (CDI) obtained from the equation predicted by Caylak [8]

$$CR = \text{CDI x SF} \tag{1}$$

where:

$CR = Cancer\ Risk; SF = Slope\ factor;$
$CDI = Chronic\ daily\ Intake\ ingestion\ pathway$

Chronic daily intake via ingestion were calculated by equation

$$CDI = \frac{C\ x\ IR\ x\ EF\ x\ ED}{Bw\ x\ AT} \tag{2}$$

C is the concentration of BaP_{eq} in water (mg/L), IR is the water intake rate (L/day), EF is the exposure frequency (350 day/year), ED is the exposure duration (years), BW is the body weight (kg), and AT is the averaging time (70 yr×365day/yr).

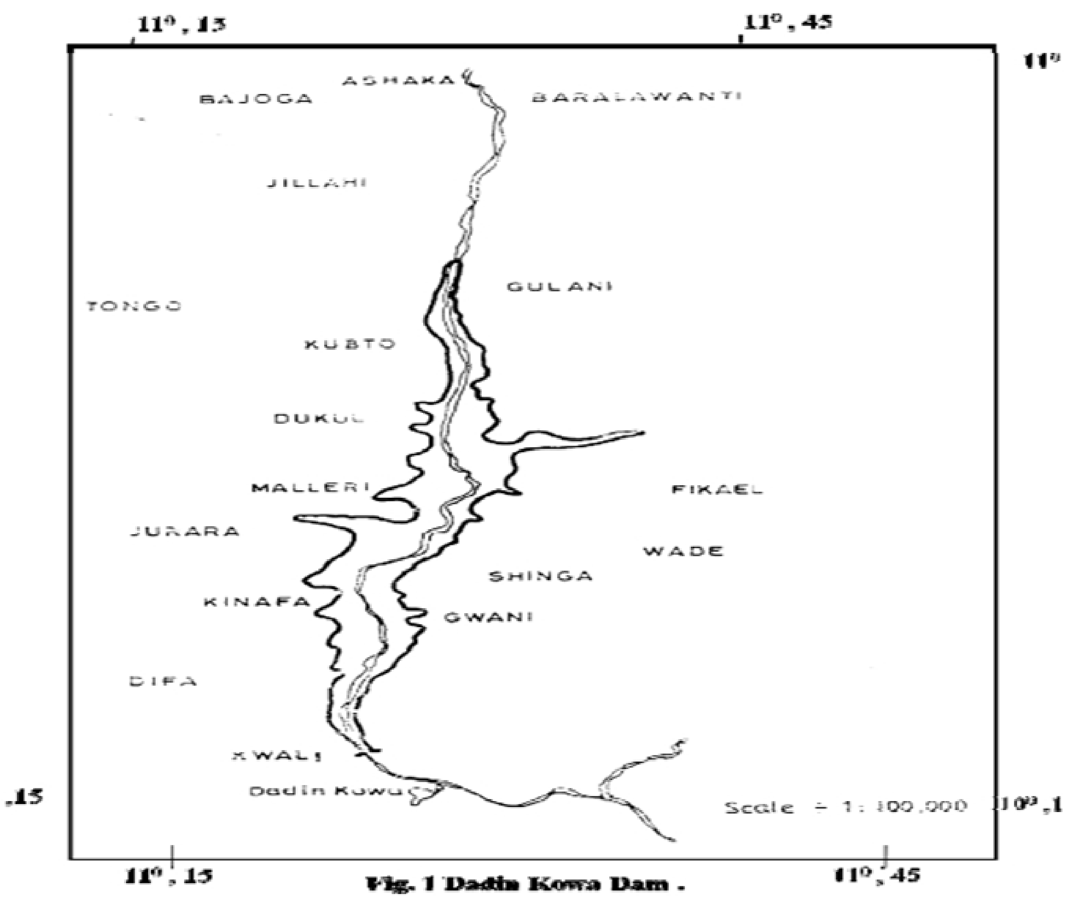

Fig. 1. Map of Gongola River showing the Main Source of the Dadin-Kowa Dam.

Table 1. Mean concentrations of some polycyclic aromatic hydrocarbons in water samples during the dry season from Dadin Kowa Dam

			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

Table 2. Mean concentrations of some polycyclic aromatic hydrocarbons in water samples during the rainy season from Dadin Kowa Dam

			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

			Concentrations(µg/L)							
PAHs	**No of rings**	**MAC'S**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
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

Table 3. Cancer risk values of some carcinogenic polycyclic aromatic hydrocarbon in water sample during the dry 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	3.94E-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

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

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

Table 6. Cancer risk values of some carcinogenic polycyclic aromatic hydrocarbon in water samples during the rainy 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	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

4. RESULTS AND DISCUSSION

4.1 Mean Concentration of PAHs in Water Samples

Tables 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 highest concentration was observed at point S8 during the rainy season, while point S9 shows the lowest value during the dry season. The results of the present study show 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 highest concentrations of PAHs in water samples was observed during the rainy season. 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 vapour pressure. Also, 2-3 ring PAHs are more easily biodegraded and volatilized compared with 4-6 ring [9,10]. Areas with chronic or prolonged contamination often have much higher PAHs concentrations in the water. Results from the present study show that in the dry and rainy season, the total PAHs for the water sample in all the sampling points were below the maximum allowable concentrations (MACs) permissible limit.

4.2 Carcinogenic Risk Values of Some PAHs in Water Samples

The carcinogenic risk values of some PAHs in water samples for dry season and the rainy season from Dadin Kowa Dam, Gombe State, Nigeria from points S1 to S10 based on adult and children are as presented in Tables 3 to 6. The highest value of all the PAHs calculated was observed in adult, while the lowest value was detected in children. 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. 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 3 to 6) using carcinogenic risk (CR) values of polycyclic aromatic hydrocarbon in water via the ingestion pathway was predicted from their chronic daily intake (CDI) obtained from the equation predicted by Caylak [8], USEPA [11]. 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 Caylak [8], Inam et al. [12]. 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 [13]. 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 [14] 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}.

5. CONCLUSION

PAHs were detected in all the sampling point, and were mainly due to the cumulative discharged from industrial and residential sources into the Dam. 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 were within the ILCR value of 10^{-4} and shows substantial health risk. This indicates a potential health concern for consumers of water from the Dam. The computed ILCR values show that the Dam may likely pose a high carcinogenic risk to the consumers of the investigated water samples. Hence, long-term monitoring of PAHs along the Dam is important.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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