Research Article

Journal of Chemistry Letters
journal homepage: www.jchemlett.com
ISSN (online) 2717-1892 (print) 2821-0123

Levels, Distribution and Risk Assessment of Polycyclic Aromatic Hydrocarbons in Varieties of Cereal in Yobe State, Nigeria

Baba Sadiq[a], Zakari Mohammed[a], Ayuba Maina Jatau[a], Joseph Clement Akan[a, *]

[a] *Department of Chemistry, University of Maiduguri, Maiduguri, Borno State, P.M.B 1069, Nigeria*

ARTICLE INFO

Article history:
Received
Received in revised form
Accepted
Available online

Keywords:
Levels
Distribution
Cereals
PAHs
Risk Assessment
GCMS

ABSTRACT

Cereal (corn, guinea corn and millet) samples from Bade and Karasuwa Local Government Area, Yobe State, Nigeria were collected for analysis of PAHs using GC/MS. The highest total mean concentration value of PAHs (1.56E-06 mg/kg) was observed in corn from Mashayan Bululu agricultural location, while millet from Wachakal Ngurodi agricultural location shows the lowest total concentration value of 7.93E-10 mg/kg. The levels of all the sixteen PAHs in the cereal samples were below the maximum allowable concentrations (MACs). Data obtained from cancer risk assessment in cereal samples were below the regulatory standard cancer risk values of 10^{-5}. The highest average daily dose values in cereals from all the six agricultural locations were recorded in guinea corn from Mashayan Bululu agricultural location, while the lowest average daily dose values were observed in millet from Wachakal Ngurodi agricultural location in Bade and Karasuwa Local Govenrment areas respectively. The non-carcinogenic PAHs through the consumption of corn, guinea corn and millet from the study agricultural locations produced hazard quotient and hazard index of less than 1, which is the level described by USEPA as having no appreciable risk for the development of non-cancer health effects. Results from ILCRs was less than 10^{-4} and shows no health risk for now. However, continuous monitoring of PAHs in the cereals is necessary to identify the fate of PAHs and their effects on the residents that depends on these cereals as food.

1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) consist of two or more fused rings and are organic in nature. These compounds are toxic when in contact with human, aquatic life and to benthic organism and also in the presence of ultraviolent light the compound become more toxic. PAHs by nature are organic compound that do not undergoes biodegradation and exist in the environment for decades and can further course potential toxic effect to the environment. Literature have showed that the accumulation of PAHs by plants in soil is by absorbed through translocation or plant uptake. The absorption of PAHs by plant in soil is possible through the solubility, concentrations, water, types of soil and the environment [1]. PAHs are of environmental concern and have been identified to course cancer and mutation, and their sources and been identified in many study to originate from pyrogenic and petrogenic origin [2,3,4].

Bade and Karasuwa, whose headquarters are Gashua and Jajimaji respectively, are Local Government Areas in Yobe State situated in the North eastern part of Nigeria. Whereas Bade has an approximate area of 1,986 km^2 and a population of 125,000 according to 2006 census, Karasuwa has an approximate area of 1,162 km^2 and a population of 106,992. The two Local Government Areas are approximately 40 kilometers apart and are about 90 kilometers from Damaturu, the State Capital. Both of these Local Governments are on the Komadugu River a few miles below the convergence of the Hadejia River and the Jama'are River. In the northern region of Nigeria rainfall is less, and the study area fall within this region, and to meet up with crop production the Hadijia and Jama'are River is used for irrigation of crop. These Hadijia and Jama'are River have attracted many farmers to make used of the water for irrigation purposes. The Hadejia and Jama'are River received water from the highly industrial city of Kano and Jos which is formed by

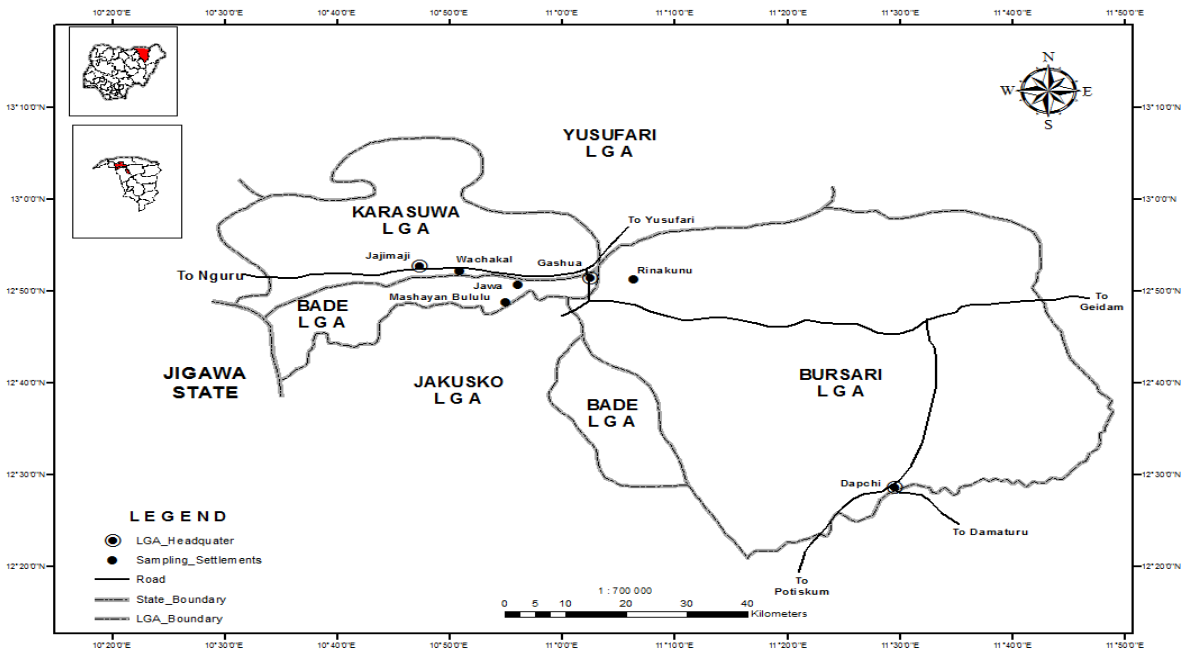
* Corresponding author. Tel.: +2348036000506; e-mail: joechemakan@yahoo.com

the confluence of the river Kano and Challawa at Tamburawa. The waste generated from these industrial cities are discharged directly into the river challlawa which flows into river Kano and to the study area. The rivers carries chemical pollutants, rich in PAHs to the study area which may cause advance effects on the consumers that depends on the cultivated cereals as food. Studies have been conducted on the levels of PAHs in the water, sediment and fish samples within the Hadijia, Jama'are, and Komadugu River by [2,4]. However, PAHs contamination of these cereals irrigated by the Hadijia, Jama'are, and Komadugu River has not been taken into consideration and had been ignored generally. Based on the levels of PAHs in the water, sediment and fish from the study areas, the objectives of this study are to determine the levels of PAHs in varieties of cereals and to conduct risk assessment of PAHs, using Hazard quotient (HQ), Hazard Index (HI) and cancer risk (CR) assessment.

2. Materials and methods

Cereal samples were collected in according to method adopted by [5]. Cereal samples (corn, guinea corn and millet) were collected from Mashayan Bululu, Jawa and Rina kunu villages in Bade Local Government Area and Wachakal, Jajimaji and Wachakal Ngurodi villages in Karasuwa Local Government Area, Yobe State Nigeria (Map 1). The cereal samples were transported to the Department of Chemistry Laboratory, University of Maiduguri and stored at 25 ^{O}C pending analysis.

Analysis for PAHs in cereal samples were carried out in accordance with [6] 8082 analytical method. Ten grams (10g) of the sample was dried using anhydrous sodium sulphate. Thirty mls (30mls) of methylene chloride was added and the sample extracted. The sample extract was subsequently filtered through glass wool containing anhydrous sodium sulphate in a glass funnel and allowed to concentrate at room temperature to 1ml volume. The extract was thereafter analyzed using Agilent 7890A GC/MS previously calibrated with PAHs standards. The equipment turned out the concentration of the PAHs as the sample details will be supplied for soil and cereal samples.



Source : Department of Geography, University of Maiduguri (2018).

Map 1: Map of study Areas Showing Sampling Locations

For this study, benzo(a)pyrene (BaP) equivalent dose of mixture of carcinogenic PAH compounds were calculated for carcinogenicity using the following equation adopted by World Bank, (2014).

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

These exposure assumptions were made to be consistent with EPA guidance on assumption on reasonable maximum exposure [7]. Where IR is the ingestion or intake rate of carcinogenic PAHs based on average fish consumption rate set at 68.5 g day-^{1} per person from the annual per capital fish consumption of 25 kg for Nigeria (FAO, 2008) CF is the conversion factor (0.000001 mg µg-^{1}) and average body weights (BW) in Nigeria is estimated to be 70. Risk associated with dietary exposure to non-carcinogenic PAHs was evaluated using hazard quotients approach. Hazard quotients represent a ratio of the exposure dose for each PAH divided by an oral chronic reference dose (RfD)**.** Hazard quotient (HQ) = Average daily dose (ADD)/RfD. The total risk due to exposure to mixture of carcinogenic PAHs is the product of the dietary carcinogen exposure dose (mg kg-^{1} BW d-^{1}) and benzo(a)pyrene's slope factor value.

Risk (carcinogenic) = Average daily dose x slope factor

3. Results and Discussion

3.1 Concentrations of Some Polycyclic Aromatic Hydrocarbons (PAHs) in Some Cereal

The mean concentration of some polycyclic aromatic hydrocarbons in some cereal from the three agricultural location, Bade Local Government Area, Yobe State, Nigeria are as presented in Table 1. Corn recorded the highest total concentration of 1.56E-06 mg/kg, while the lowest total concentration of 1.60E-07 mg/kg was observed in millet from Mashayan Bululu. For Jawa agricultural location, Corn also recorded the highest total concentration of 3.09E-08 mg/kg, while the lowest total concentration of 9.86E-10 mg/kg was observed in guinea corn. Corn from Rina Kunu agricultural location recorded the highest total concentration of 3.01E-09 mg/kg, while the lowest total concentration of 9.90E-10 mg/kg was observed in guinea corn. Results from Table 2 shows that among the cereals samples study, corn recorded the highest concentration, while the lowest total concentration was observed in millet.

Table 1: Mean Concentration of Polycyclic Aromatic Hydrocarbons (PAHs) in SomeCereal from Different Agricultural Locations, Bade Local Government Area, Yobe State, Nigeria

	Mashayan Bululu			Jawa			Rina Kunu		
PAHs	**Corn**	**Guinea Corn**	**Millet**	**Corn**	**Guinea Corn**	**Millet**	**Corn**	**Guinea Corn**	**Millet**
Naphthalene	1.03E-08	2.09E-08	1.00E-09	3.22E-10	2.11E-10	1.23E-09	1.00E-10	1.00E-11	2.32E-10
2-methyl Napthalene	1.03E-07	1.00E-08	1.00E-08	1.00E-10	1.00E-10	1.00E-10	1.00E-11	1.00E-11	1.03E-11
Acenapthylene	3.23E-08	1.08E-08	1.00E-09	1.00E-09	1.00E-11	2.11E-10	1.00E-10	1.00E-10	1.34E-12
Acenaphthene	3.25E-08	2.02E-07	2.03E-09	1.00E-10	1.00E-11	1.00E-11	1.00E-09	1.00E-11	1.00E-11
Fluorene	2.33E-07	3.84E-09	1.83E-08	1.00E-11	1.00E-11	1.00E-10	1.00E-10	1.00E-11	1.23E-10
Phenanthrene	1.09E-08	5.32E-08	1.00E-08	1.00E-09	1.00E-10	2.12E-10	1.00E-11	1.03E-10	1.04E-10
Anthracene	2.09E-09	3.00E-08	1.04E-08	1.00E-10	1.00E-10	1.03E-11	1.32E-10	1.00E-11	1.32E-10
Fluoranthene	2.22E-08	4.34E-08	1.44E-08	1.03E-09	1.03E-10	2.00E-10	1.32E-11	1.00E-10	1.22E-11
Pyrene	3.23E-07	5.33E-08	3.22E-08	1.09E-10	1.09E-11	1.00E-10	1.00E-10	1.00E-11	1.32E-11
Benz(a)anthracene	3.22E-07	1.23E-08	5.34E-08	1.00E-09	1.00E-11	2.43E-10	1.00E-11	1.32E-10	1.44E-12
Chrysene	4.93E-08	4.22E-09	3.22E-09	1.34E-11	1.00E-11	1.00E-10	1.00E-10	1.12E-10	1.43E-10
Benz(b)fluoranthene	3.98E-08	4.98E-08	1.03E-10	2.00E-10	1.00E-10	1.00E-11	1.00E-11	1.04E-10	1.00E-10
Benz(k)fluoranthene	3.23E-08	3.22E-07	1.03E-11	1.00E-10	1.00E-10	2.02E-10	2.13E-10	1.03E-11	1.34E-10
Benz(a)pyrene	3.23E-08	3.84E-08	1.03E-09	1.00E-10	1.00E-10	1.00E-11	1.00E-09	1.23E-10	1.34E-10
Dibenz(a,h)anthracene	3.98E-09	2.11E-08	1.44E-09	1.43E-09	1.00E-11	2.12E-10	1.00E-10	1.33E-10	1.33E-10
Indinol(1,2,3-cd)pyrene	3.11E-07	3.23E-07	1.33E-09	2.43E-08	1.00E-12	1.00E-11	1.00E-11	1.22E-11	1.00E-10
Total	**1.56E-06**	**1.20E-06**	**1.60E-07**	**3.09E-08**	**9.86E-10**	**2.96E-09**	**3.01E-09**	**9.90E-10**	**1.38E-09**

Table 2: Mean Concentration of Polycyclic Aromatic Hydrocarbons (PAHs) in Some Cereal from Different Agricultural Locations, Karasuwa Local Government Area, Yobe State, Nigeria

	Wachakal			Jaji Maji			Wachakal Ngurodi		
PAHs	**Corn**	**Guinea Corn**	**Millet**	**Corn**	**Guinea Corn**	**Millet**	**Corn**	**Guinea Corn**	**Millet**
Naphthalene	1.23E-10	2.11E-10	4.32E-10	4.02E-10	1.43E-10	1.00E-11	1.00E-10	1.32E-10	1.00E-11
2-methyl Napthalene	1.32E-11	2.44E-11	2.13E-11	1.34E-11	2.82E-10	1.02E-12	1.00E-11	1.22E-11	1.00E-10
Acenapthylene	2.33E-10	3.01E-10	2.02E-10	1.02E-10	5.34E-11	1.00E-10	1.12E-10	1.21E-12	1.00E-10
Acenaphthene	1.00E-10	1.03E-09	1.87E-10	3.34E-10	4.34E-10	1.00E-11	1.22E-11	1.00E-10	1.00E-10
Fluorene	2.04E-10	3.21E-10	3.22E-10	4.34E-10	2.34E-10	1.00E-11	4.22E-10	1.23E-11	1.00E-11
Phenanthrene	1.00E-11	3.11E-10	3.10E-10	2.34E-11	1.23E-11	1.00E-10	2.11E-11	1.04E-11	1.00E-11
Anthracene	1.00E-10	5.08E-11	3.02E-10	2.09E-10	1.98E-10	1.03E-10	1.11E-10	1.32E-11	1.00E-11
Fluoranthene	1.22E-10	3.11E-10	1.22E-10	3.34E-10	1.98E-11	1.00E-11	3.11E-10	1.22E-11	1.32E-11
Pyrene	2.04E-11	3.11E-10	1.87E-10	1.09E-11	3.34E-10	1.00E-11	1.39E-11	1.32E-10	1.00E-10
Benz(a)anthracene	1.00E-11	6.11E-11	1.12E-11	4.32E-11	7.00E-10	1.00E-10	2.32E-11	1.44E-11	1.00E-11
Chrysene	2.04E-10	4.01E-10	1.98E-10	2.23E-10	6.34E-11	1.32E-10	1.11E-10	1.43E-11	1.00E-10
Benz(b)fluoranthene	1.00E-10	4.32E-10	3.23E-10	3.87E-10	3.11E-10	1.00E-11	2.13E-10	1.23E-10	1.00E-11
Benz(k)fluoranthene	1.04E-11	1.00E-11	2.32E-11	1.02E-11	8.11E-11	1.00E-11	3.01E-10	1.00E-10	1.00E-10
Benz(a)pyrene	1.22E-10	5.01E-10	4.34E-10	2.23E-10	1.88E-11	1.00E-10	2.23E-11	1.00E-10	1.00E-11
Dibenz(a,h)anthracene	1.00E-10	2.21E-10	2.34E-11	1.11E-10	1.07E-10	1.02E-11	1.45E-11	1.00E-10	1.00E-10
Indinol(1,2,3-cd)pyrene	1.03E-11	1.19E-11	9.23E-10	3.23E-10	1.76E-19	1.00E-10	4.22E-11	1.12E-11	1.00E-11
Total	**1.48E-09**	**4.51E-09**	**4.02E-09**	**3.18E-09**	**2.99E-09**	**8.16E-10**	**1.84E-09**	**8.88E-10**	**7.93E-10**

3.2 Average Daily Dose of Some Polycyclic Aromatic Hydrocarbons in Cereal

The average daily dose of some polycyclic aromatic hydrocarbons in some cereal from Mashayan Bululu, Jawa and Rina Kunu agricultural locations, Bade Local Government Area, Yobe State are presented in Table 3. Guinea corn recorded the highest total daily dose of 9.97E-13 mg/kg in Mashayan Bululu, while the lowest total daily dose was equally recorded in guinea corn with a value of 1.30E-15 mg/kg in Jawa agricultural locations. Table 4 show the average daily dose of some polycyclic aromatic hydrocarbons in some cereal from Wachakal, Jaji Maji and Wachakal Ngurodi agricultural locations, Karasuwa Local Government Area, Yobe State. Guinea corn recorded the highest total daily dose of 7.60E-15 mg/kg in Wachakal, while the lowest total daily dose was observed in corn with a value of 9.12E-16 mg/kg in Wachakal Ngurodi agricultural locations.

Table 3: Average Daily Dose (mg/kg day^{-1}) for Polycyclic Aromatic Hydrocarbons (PAHs) in Some Cereal from Different Agricultural Locations, Bade Local Government Area, Yobe State, Nigeria

	Mashayan Bululu			Jawa			Rina Kunu		
PAHs	**Corn**	**Guinea Corn**	**Millet**	**Corn**	**Guinea Corn**	**Millet**	**Corn**	**Guinea Corn**	**Millet**
Naphthalene	1.01E-16	2.05E-16	9.79E-18	3.15E-18	2.06E-18	1.20E-17	9.79E-19	9.79E-20	2.27E-18
2-methyl Napthalene	1.01E-15	9.79E-17	9.79E-17	9.79E-19	9.79E-19	9.79E-19	9.79E-20	9.79E-20	1.01E-19
Acenapthylene	3.16E-16	1.06E-16	9.79E-18	9.79E-18	9.79E-20	2.06E-18	9.79E-19	9.79E-19	1.31E-20
Acenaphthene	3.18E-16	1.98E-15	1.99E-17	9.79E-19	9.79E-20	9.79E-20	9.79E-18	9.79E-20	9.79E-20
Fluorene	2.28E-15	3.76E-17	1.79E-16	9.79E-20	9.79E-20	9.79E-19	9.79E-19	9.79E-20	1.20E-18
Phenanthrene	1.07E-16	5.21E-16	9.79E-17	9.79E-18	9.79E-19	2.07E-18	9.79E-20	1.01E-18	1.02E-18
Anthracene	2.05E-16	2.94E-15	1.02E-15	9.79E-18	9.79E-18	1.01E-18	1.29E-17	9.79E-19	1.29E-17
Fluoranthene	2.17E-16	4.25E-16	1.41E-16	1.01E-17	1.01E-18	1.96E-18	1.29E-19	9.79E-19	1.19E-19
Pyrene	3.16E-15	5.22E-16	3.15E-16	1.07E-18	1.07E-19	9.79E-19	9.79E-19	9.79E-20	1.29E-19
Benz(a)anthracene	3.15E-13	1.20E-14	5.23E-14	9.79E-16	9.79E-18	2.38E-16	9.79E-18	1.29E-16	1.41E-18
Chrysene	4.82E-16	4.13E-17	3.15E-17	1.31E-19	9.79E-20	9.79E-19	9.79E-19	1.10E-18	1.40E-18
Benz(b)fluoranthene	3.89E-14	4.87E-14	1.01E-16	1.96E-16	9.79E-17	9.79E-18	9.79E-18	1.02E-16	9.79E-17
Benz(k)fluoranthene	3.16E-14	3.15E-13	1.01E-17	9.79E-17	9.79E-17	1.98E-16	2.08E-16	1.01E-17	1.31E-16
Benz(a)pyrene	3.16E-13	3.76E-13	1.01E-14	9.79E-16	9.79E-16	9.79E-17	9.79E-15	1.20E-15	1.31E-15
Dibenz(a,h)anthracene	3.89E-14	2.06E-13	1.41E-14	1.40E-14	9.79E-17	2.07E-15	9.79E-16	1.30E-15	1.30E-15
Indinol(1,2,3-cd)pyrene	3.04E-14	3.16E-14	1.30E-16	2.38E-15	9.79E-20	9.79E-19	9.79E-19	1.19E-18	9.79E-18
TDD	**7.79E-13**	**9.97E-13**	**7.86E-14**	**1.87E-14**	**1.30E-15**	**2.64E-15**	**1.10E-14**	**2.75E-15**	**2.87E-15**

Table 4: Average Daily Dose (mg/kg day^{-1}) for Polycyclic Aromatic Hydrocarbons (PAHs) in Some Cereal from Different Agricultural Locations, Karasuwa Local Government Area, Yobe State, Nigeria

	Wachakal			Jaji Maji			Wachakal Ngurodi		
PAHs	**Corn**	**Guinea Corn**	**Millet**	**Corn**	**Guinea Corn**	**Millet**	**Corn**	**Guinea Corn**	**Millet**
Naphthalene	1.20E-18	2.06E-18	4.23E-18	3.93E-18	1.40E-18	9.79E-20	9.79E-19	1.29E-18	9.79E-20
2-methyl Napthalene	1.29E-19	2.39E-19	2.08E-19	1.31E-19	2.76E-18	9.98E-21	9.79E-20	1.19E-19	9.79E-19
Acenapthylene	2.28E-18	2.95E-18	1.98E-18	9.98E-19	5.23E-19	9.79E-19	1.10E-18	1.18E-20	9.79E-19
Acenaphthene	9.79E-19	1.01E-17	1.83E-18	3.27E-18	4.25E-18	9.79E-20	1.19E-19	9.79E-19	9.79E-19
Fluorene	2.00E-18	3.14E-18	3.15E-18	4.25E-18	2.29E-18	9.79E-20	4.13E-18	1.20E-19	9.79E-20
Phenanthrene	9.79E-20	3.04E-18	3.03E-18	2.29E-19	1.20E-19	9.79E-19	2.06E-19	1.02E-19	9.79E-20
Anthracene	9.79E-18	4.97E-18	2.96E-17	2.05E-17	1.94E-17	1.01E-17	1.09E-17	1.29E-18	9.79E-19
Fluoranthene	1.19E-18	3.04E-18	1.19E-18	3.27E-18	1.94E-19	9.79E-20	3.04E-18	1.19E-19	1.29E-19
Pyrene	2.00E-19	3.04E-18	1.83E-18	1.07E-19	3.27E-18	9.79E-20	1.36E-19	1.29E-18	9.79E-19
Benz(a)anthracene	9.79E-18	5.98E-17	1.10E-17	4.23E-17	6.85E-16	9.79E-17	2.27E-17	1.41E-17	9.79E-18
Chrysene	2.00E-18	3.92E-18	1.94E-18	2.18E-18	6.20E-19	1.29E-18	1.09E-18	1.40E-19	9.79E-19
Benz(b)fluoranthene	9.79E-17	4.23E-16	3.16E-16	3.79E-16	3.04E-16	9.79E-18	2.08E-16	1.20E-16	9.79E-18
Benz(k)fluoranthene	1.02E-17	9.79E-18	2.27E-17	9.98E-18	7.94E-17	9.79E-18	2.95E-16	9.79E-17	9.79E-17
Benz(a)pyrene	1.19E-15	4.90E-15	4.25E-15	2.18E-15	1.84E-16	9.79E-16	2.18E-16	9.79E-16	9.79E-17
Dibenz(a,h)anthracene	9.79E-16	2.16E-15	2.29E-16	1.09E-15	1.05E-15	9.98E-17	1.42E-16	9.79E-16	9.79E-16
Indinol(1,2,3-cd)pyrene	1.01E-18	1.16E-18	9.03E-17	3.16E-17	1.72E-26	9.79E-18	4.13E-18	1.10E-18	9.79E-19
TDD	**2.31E-15**	**7.60E-15**	**4.96E-15**	**3.77E-15**	**2.33E-15**	**1.22E-15**	**9.12E-16**	**2.20E-15**	**1.20E-15**

3.3 Hazard Quotient and Hazard Index Polycyclic Aromatic Hydrocarbons in Cereal

The hazard quotient and hazard index of non-carcinogenic polycyclic aromatic hydrocarbons via consumption of some cereal from Mashayan Bululu, Jawa and Rina Kunu agricultural locations, Bade Local Government Area, Yobe State are presented in Table 5. Corn recorded the highest hazard index of 2.48E-13 mg/kg in Mashayan Bululu agricultural location, while guinea corn recorded the lowest hazard index of 1.19E-16 mg/kg in Rina Kunu agricultural location. Table 6 presents the hazard quotient and hazard index of non-carcinogenic polycyclic aromatic hydrocarbons via consumption of some cereal from Wachakal, Jaji Maji and Wachakal Ngurodi agricultural locations, Karasuwa Local Government Area, Yobe State, Nigeria. The highest hazard index of 7.79E-16 mg/kg was detected in guinea corn in Mashayan Bululu agricultural location, while millet recorded the lowest hazard index of 1.22E-16 mg/kg in Jaji Maji agricultural location.

Table 5: Hazard Quotient and Hazard Index (mg/kg day^{-1}) of Non-Carcinogenic Polycyclic Aromatic Hydrocarbons Via Consumption of Some Cereal from Different

	Mashayan Bululu			Jawa			Rina Kunu		
PAHs	**Corn**	**Guinea Corn**	**Millet**	**Corn**	**Guinea Corn**	**Millet**	**Corn**	**Guinea Corn**	**Millet**
Naphthalene	5.04E-15	1.02E-14	4.89E-16	1.58E-16	1.03E-16	6.02E-16	4.89E-17	4.89E-18	1.14E-16
2-methyl Napthalene	5.04E-14	4.89E-15	4.89E-15	4.89E-17	4.89E-17	4.89E-17	4.89E-18	4.89E-18	5.04E-18
Acenapthylene	1.58E-14	5.28E-15	4.89E-16	4.89E-16	4.89E-18	1.03E-16	4.89E-17	4.89E-17	6.56E-19
Acenaphthene	5.30E-15	3.29E-14	3.31E-16	1.63E-17	1.63E-18	1.63E-18	1.63E-16	1.63E-18	1.63E-18
Fluorene	5.70E-14	9.39E-16	4.48E-15	2.45E-18	2.45E-18	2.45E-17	2.45E-17	2.45E-18	3.01E-17
Phenanthrene	2.67E-15	1.30E-14	2.45E-15	2.45E-16	2.45E-17	5.19E-17	2.45E-18	2.52E-17	2.54E-17
Anthracene	6.82E-16	9.79E-15	3.39E-15	3.26E-17	3.26E-17	3.36E-18	4.31E-17	3.26E-18	4.31E-17
Fluoranthene	5.43E-15	1.06E-14	3.52E-15	2.52E-16	2.52E-17	4.89E-17	3.23E-18	2.45E-17	2.98E-18
Pyrene	1.05E-13	1.74E-14	1.05E-14	3.56E-17	3.56E-18	3.26E-17	3.26E-17	3.26E-18	4.31E-18
Hazard Index (HI)	**2.48E-13**	**1.05E-13**	**3.05E-14**	**1.28E-15**	**2.47E-16**	**9.17E-16**	**3.72E-16**	**1.19E-16**	**2.27E-16**

Agricultural Locations, Bade Local Government Area, Yobe State, Nigeria

Table 6: Hazard Quotient and Hazard Index (mg/kg day-1) of Non-Carcinogenic Polycyclic Aromatic Hydrocarbons Via Consumption of Some Cereal from Different Agricultural Locations, Karasuwa Local Government Area, Yobe State, Nigeria

	Wachakal			Jaji Maji			Wachakal Ngurodi		
PAHs	**Corn**	**Guinea Corn**	**Millet**	**Corn**	**Guinea Corn**	**Millet**	**Corn**	**Guinea Corn**	**Millet**
Naphthalene	6.02E-17	1.03E-16	2.11E-16	1.97E-16	7.00E-17	4.89E-18	4.89E-17	6.46E-17	4.89E-18
2-methyl Napthalene	6.46E-18	1.19E-17	1.04E-17	6.56E-18	1.38E-16	4.99E-19	4.89E-18	5.97E-18	4.89E-17
Acenapthylene	1.14E-16	1.47E-16	9.88E-17	4.99E-17	2.61E-17	4.89E-17	5.48E-17	5.92E-19	4.89E-17
Acenaphthene	1.63E-17	1.68E-16	3.05E-17	5.45E-17	7.08E-17	1.63E-18	1.99E-18	1.63E-17	1.63E-17
Fluorene	4.99E-17	7.85E-17	7.88E-17	1.06E-16	5.72E-17	2.45E-18	1.03E-16	3.01E-18	2.45E-18
Phenanthrene	2.45E-18	7.61E-17	7.58E-17	5.72E-18	3.01E-18	2.45E-17	5.16E-18	2.54E-18	2.45E-18
Anthracene	3.26E-17	1.66E-17	9.85E-17	6.82E-17	6.46E-17	3.36E-17	3.62E-17	4.31E-18	3.26E-18
Fluoranthene	2.98E-17	7.61E-17	2.98E-17	8.17E-17	4.84E-18	2.45E-18	7.61E-17	2.98E-18	3.23E-18
Pyrene	6.65E-18	1.01E-16	6.10E-17	3.56E-18	1.09E-16	3.26E-18	4.53E-18	4.31E-17	3.26E-17
Hazard Index (HI)	**3.18E-16**	**7.79E-16**	**6.95E-16**	**5.73E-16**	**5.43E-16**	**1.22E-16**	**3.36E-16**	**1.43E-16**	**1.63E-16**

3.4 Carcinogenic Risk Assessment of Some Polycyclic Aromatic Hydrocarbons in Cereal

The carcinogenic risk assessment of some polycyclic aromatic hydrocarbons in some cereal from Mashayan Bululu, Jawa and Rina Kunu agricultural locations, Bade Local Government Area, Yobe State are presented in Table 7. Guinea corn recorded the highest incremental life-time expectancy cancer risk (ILECR) of 4.34E-12 mg/kg in Mashayan Bululu agricultural location, while the lowest ILECR of 7.94E-15 mg/kg was equally recorded in guinea corn in Jawa agricultural location.

Table 8 shows the carcinogenic risk assessment of some polycyclic aromatic hydrocarbons in some cereal from Wachakal, Jaji Maji and Wachakal Ngurodi agricultural locations, Karasuwa Local Government Area, Yobe State, Nigeria. Guinea corn also recorded the highest ILECR of 5.19E-14 mg/kg in Wachakal agricultural location, while the lowest ILECR of 2.82E-15 mg/kg was recorded in corn in Wachakal Ngurodi agricultural location.

Table 7: Carcinogenic Risk Assessment (mg/kg day^{-1}) for Polycyclic Aromatic Hydrocarbons (PAHs) in Some Cereal from Different Agricultural Locations, Bade Local Government Area, Yobe State, Nigeria

	Wachakal			Jaji Maji			Wachakal Ngurodi		
PAHs	**Corn**	**Guinea Corn**	**Millet**	**Corn**	**Guinea Corn**	**Millet**	**Corn**	**Guinea Corn**	**Millet**
Benz(a)anthracene	7.14E-18	4.36E-17	8.00E-18	3.09E-17	5.00E-16	7.14E-17	1.66E-17	1.03E-17	7.14E-18
Chrysene	1.46E-20	2.86E-20	1.41E-20	1.59E-20	4.53E-21	9.43E-21	7.93E-21	1.02E-21	7.14E-21
Benz(b)fluoranthene	7.14E-17	3.09E-16	2.31E-16	2.76E-16	2.22E-16	7.14E-18	1.52E-16	8.79E-17	7.14E-18
Benz(k)fluoranthene	7.43E-19	7.14E-19	1.66E-18	7.29E-19	5.79E-18	7.14E-19	2.15E-17	7.14E-18	7.14E-18
Benz(a)pyrene	8.72E-15	3.58E-14	3.10E-14	1.59E-14	1.34E-15	7.14E-15	1.59E-15	7.14E-15	7.14E-16
Dibenz(a,h)anthracene	7.14E-15	1.58E-14	1.67E-15	7.93E-15	7.64E-15	7.29E-16	1.04E-15	7.14E-15	7.14E-15
Indinol(1,2,3-cd)pyrene	7.36E-19	8.50E-19	6.59E-17	2.31E-17	1.26E-26	7.14E-18	3.01E-18	8.00E-19	7.14E-19
ΣILECR	**1.59E-14**	**5.19E-14**	**3.30E-14**	**2.42E-14**	**9.71E-15**	**7.96E-15**	**2.82E-15**	**1.44E-14**	**7.88E-15**

Table 8: Carcinogenic Risk Assessment (mg/kg day^{-1}) for Polycyclic Aromatic Hydrocarbons (PAHs) in Some Cereal from Different Agricultural Locations, Karasuwa Local Government Area, Yobe State, Nigeria

	Mashayan Bululu			Jawa			Rina Kunu		
PAHs	**Corn**	**Guinea Corn**	**Millet**	**Corn**	**Guinea Corn**	**Millet**	**Corn**	**Guinea Corn**	**Millet**
Benz(a)anthracene	2.30E-13	8.79E-15	3.81E-14	7.14E-16	7.14E-18	1.74E-16	7.14E-18	9.43E-17	1.03E-18
Chrysene	3.52E-18	3.01E-19	2.30E-19	9.57E-22	7.14E-22	7.14E-21	7.14E-21	8.00E-21	1.02E-20
Benz(b)fluoranthene	2.84E-14	3.56E-14	7.36E-17	1.43E-16	7.14E-17	7.14E-18	7.14E-18	7.43E-17	7.14E-17
Benz(k)fluoranthene	2.31E-15	2.30E-14	7.36E-19	7.14E-18	7.14E-18	1.44E-17	1.52E-17	7.36E-19	9.57E-18
Benz(a)pyrene	2.31E-12	2.74E-12	7.36E-14	7.14E-15	7.14E-15	7.14E-16	7.14E-14	8.79E-15	9.57E-15
Dibenz(a,h)anthracene	2.84E-13	1.51E-12	1.03E-13	1.02E-13	7.14E-16	1.51E-14	7.14E-15	9.50E-15	9.50E-15
Indinol(1,2,3-cd)pyrene	2.22E-14	2.31E-14	9.50E-17	1.74E-15	7.14E-20	7.14E-19	7.14E-19	8.72E-19	7.14E-18
ΣILECR	**2.88E-12**	**4.34E-12**	**2.15E-13**	**1.12E-13**	**7.94E-15**	**1.61E-14**	**7.86E-14**	**1.85E-14**	**1.92E-14**

4. DISCUSSION

Sixteen PAHs were detected in cereal (corn, guinea corn and millet) samples from the six agricultural locations (Mashayan Bululu, Jawa, Rina Kunu, Wachakal, Jaji Maji and Wachakal Ngurodi) Tables 1 to 2, with indinol(1,2,3-cd)pyrene having a value of 6.61E-07 mg/kg as the most predominant PAH from all the agricultural locations. Among the samples analyzed in the present study, corn from Mashayan Bululu agricultural location shows the highest accumulation of PAH residues load with a value of 1.56E-06 mg/kg, while millet was observed to show the lowest total concentration with a value of 7.93E-10 mg/kg from Wachakal Ngurodi agricultural location. The above levels were comparatively lower than those reported by [8] with values ranging from 0.07 to 0.45 μg/kg.μg/kg and those of [9]. Similar results were reported in corn grains exposed to drying with firewood by [10]. All these values were below the maximum allowable concentrations (MACs).

All calculations for the determination of ADI were according to international guidelines [11]. The sixteen PAHs load from the study area in corn ranges from 9.79E-20 to 3.16E-13 mg/kg day^{-1}, 1.18E-20 to 3.76E-13 mg/kg day^{-1} in guinea corn and 1.31E-20 to 5.23E-14 mg/kg day^{-1} in millet Tables 7 to 8. Guinea corn samples recorded the highest concentration of the sixteen ΣPAHs load when compared with the other two cereals. The difference in PAH load is probably due to variation in accumulation ratio of the study cereals in the different agricultural locations. The total daily dose ranged between 1.20E-15 and 9.97E-13 mg/kg day^{-1}. According to [11], the estimated exposure limit of PAHs is 4.0 ng/kg body weight per day and the maximum limit is 10 ng/kg body weight per day. The result of the present study showed that the estimated daily intake for adults of 70kg average weight was 1.20E-15 mg/kg day^{-1} and the maximum value reached was 9.97E-13 mg/kg day^{-1}. The intake values obtained in the present study were lower when compared to estimates from similar studies carried out by [12] with values of 0.2ng/kg day^{-1} estimated exposure limit and 2.46 ng/kg day^{-1} for estimated maximum limit. Results of ADI obtained from the present study were lower than those reported by [8] with values ranging 0.01 to 0.19 μg/kg and results reported by [13].

It is especially important to note that a hazard quotient exceeding 1 does not necessarily mean that adverse effects will occur [14]. If the hazard quotient is calculated to be less than 1, then no adverse health effects are expected as a result of exposure. If the hazard quotient is greater than 1, then adverse health effects are possible. Calculated hazard quotient of non-carcinogenic PAHs in the present study ranges from 4.99E-19 to 1.05E-13 mg/kg day^{-1}, while exposure to non-carcinogenic PAHs resulting in hazard indexes ranges from 1.19E-16 to 2.48E-13 mg/kg day^{-1} across all the six agricultural locations Tables 7 to 8. The non-carcinogenic PAHs produced both hazard quotients and hazard indexes of less than 1; a level described by the EPA as generally having no appreciable risk for the development of non-cancer health through the ingestion of these hazardous PAHs from corn, guinea corn and millet. Similar studies have been carried out by [15] in which the hazard indexes were less than 1. Results from the present study are within the acceptable exposure limit.

Some studies have shown that heavy PAHs can induce dioxin-like activity and weakened estrogenic responses [16]. The cumulative distribution of calculated incremental life-time expectancy cancer risk (ILECR) for corn, guinea corn and millet from the agricultural locations are shown in Tables 11 to 12. ILECR values for corn ranges from 9.57E-22 to 2.31E-12 mg/kg day^{-1}, 1.26E-26 to 2.74E-12 mg/kg day^{-1} for guinea corn, while millet ILECR values ranges from 7.14E-21 to 1.03E-13 mg/kg day^{-1}. The ILECR values observed in all the cereals in the present study were lower than the acceptable risk level of 1.00E-06 mg/kg day^{-1}. The total ILECR of PAHs in corn with a value of 3.11E-12 mg/kg day-1 reveal that less than 1 out of 1,000,000 are likely to suffer from cancer-related illness in their lifetime due to consumption of corn from the study area. The total ILECR values observed in guinea corn was 4.44E-12 mg/kg day-1 which also means 1 out of 1.00E+12 are likely to suffer from cancer-related illness in their lifetime due to consumption of guinea corn, while total ILECR values observed in millet was 2.99E-13 mg/kg day-1, this revealed that less than 1 out of 1.00E+13 are likely to suffer from cancer-related illness in their lifetime due to the consumption of millet from the study area. The present study revealed that less than one in everyone million population are likely to suffer from cancer related illness over their life time as a result of consumption of corn, guinea corn and millet from the study area.

5. CONCLUSION

Results of the present study indicated the cereals are contaminated by PAHs because of the Hadijia, Jama'are, and Komadugu River, and the contamination was more pronounced around the Mashayan Bululu agricultural location. Based on the results of this study, industrial and commercial activities within the Kano and Jos area should be controlled. Results from ILCRs was less than 10^{-4} and shows no health risk for now. However, continuous monitoring of PAHs in the cereals is necessary to identify the fate of PAHs and their effects on the residents that depends on these cereals as food.

Funding

This research did not receive any funding from agencies of Government, public, commercial, and other sectors of the economy.

Conflict of Interest

The authors declare that they have no conflict of interest.

REFERENCES

[1] ATSDR. (Agency for Toxic Substance and Disease Registry), Public Health Statement. August 1995. Accessed 12-09-2010. (2010).

[2] J. C. Akan, Z. Mohammed, A. I. Mohammed and L. Jafiya, Source Identification and Ecotoxicological Risk Assessment of Polycyclic Aromatic Hydrocarbons in Sediment from Komadugu River Basin, Yobe State, Nigeria. *Canadian a. Journal of Pure and Applied Sciences, 11(3)* (2017) *4355-4365.*

[3] N. U. Benson, A. B. Williams, W. U. Anake, K. P. Eke, A. E. Adedapo, and A.A Olajire, Carcinogenicity and mutagenicity assessments of dietary exposure to PAHs in imported fish products in Nigeria. In: In: Sorial, G., Hong, J. (Eds.), Proceedings, 8th International Conference on Environmental Science and Technology, vol. 1. American Science Press, (2016b).

[4] Z. Mohammed, J. C. Akan, L. I. Bukar and A. M. Idi, Cancer and Non-Cancer Risk Associated With PAHs Exposure from Consumption of Fish from Komadugu River Basin, Yobe State, Nigeria. *Journal of Aquatic Pollution and Toxicology, 1(3)* (2017). *17*

[5] J. C. Akan, Mahmud, M. M., Waziri, M. and Z. Mohammed, Z, Residues of Organochlorine Pesticides in Watermelon (Citrulus lanatus) and Soil Samples from Gashua, Bade Local Government Area Yobe State, Nigeria. *Advances in Analytical Chemistry*, 5(3) (2015) 61-68.

[6] USEPA. (United States Environmental Protection Agency), Polychlorinated biphenyls(PCBs) by Gas Chromatography/Mass Spectrometry (GC/MS). Test Methods for Evaluating Solid Waste. Physical/Chemical Methods, (SW-846) Method 8082, (2000).

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

[8] A. U. Nnaemeka, N. I. Zelinjo, N. A. Rose. and E. O. Orish, Health Risk assessment and dietary exposure to polycyclic aromatic hydrocarbons (pahs), Lead and cadmium from bread consumed in Nigeria. Rocz Panstw Zakl Hig, 68(3) (2017) 269-280.

[9] H. Alomirah, S. Al-Zenki, S. Al-Hooti, S. Zaghloul, W. Sawaya, N. Ahmed and K. Kannan, a.Concentrations and dietary exposure to polycyclic aromatic hydrocarbons (PAHs) from grilled and smoked foods. Food Control., 22(12) (2010) 2028-2035.

[10] F. L. Rafael and W. R. Francisco, PAHs in corn grains submitted to drying with firewood. Journal of Food Chemistry, 215 (2017) 165-170.

[11] WHO (World Health Organization, Safety evaluation of certain food additives andcontaminants. Prepared by the Sixty-seventh meeting of the Joint FAO/WHO Expert Committee on Food Additives Food additives series: 58, (JECFA).), (2006).

[12] H. Ahmed, L. Hamzawy, K. Mona, M. E. Ashraf and R. S. Eglal, Estimated daily intake and health risk of polycyclic aromatic hydrocarbon by consumption of grilled meat and chicken in Egypt. *International Journal of Current Microbiology and Applied Sciences*, 5(2) (2016) 435-448.

[13] K. Dost and C. İdeli, Determination of polycyclic aromatic hydrocarbons in edible oils and barbecued food by HPLC/UV–Vis detection. Food Chem., 133(1) (2012) 193–199.

[14] NATA (National Air Toxics Assessment), USEPA'S comprehensive evaluation of air toxics in the United States. (2015).

[15] C. A. Kafeelah, A. Vicente, M. Evtyugina, C. A. Pio, A. Hoffer, G. Kiss, S. Decesari, R. Hillamo and E. Swietlicki, Characterisation of hydrocarbons in atmospheric aerosols from different European sites. *World Academic Science and Engineering Technology*, 33 (2015) 236-242.

[16] J. Villeneuva, N. Kazerouni, R. Sinha, H. Che-Han, A. Greenberg and N. Rothman, Analysis of 200 food items for benzo(a)pyrene and estimation of its intake in an epidemiologic study. *Food Chemistry and Toxicology*, 39 (2002) 423-436