**Determination, Effects, and Health Risk Assessment of Heavy Metals and Polycyclic Aromatic Hydrocarbons Pollutants in Road Dust of Kaduna Metropolis, Nigeria**

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***Abstract:*** *This study assessed the effects and health risk assessment of PAHs and heavy metals on six major roads in Kaduna metropolis using Gas chromatography-mass spectrometry (GC-MC) and atomic absorption spectrometer (AAS). This study indicates that the areas around Ibrahim Yakowa Road (IYR), New Kachia Road (NKR), and Abuja Kaduna Zaria Express Way (ABKZEW) recorded the highest mean concentrations of PAHs, with highly carcinogenic PAHs such as B(a)P, B(k)F, and Chr being the most prevalent. Dermal contact and ingestion of contaminated particles were the most important pathways compared to inhalation in this study. The highest mean incremental lifetime cancer risk (ILCR) was 2.46E-01, considerably increasing the risk of cancer in children. Our findings suggest that children are subjected to a higher carcinogenic and mutagenic risk of PAHs. DBA and B(a)P were the most dominant compounds contributing to the total carcinogenic activity in the study area, suggesting the importance of B(a)P and DBA as surrogate compounds for PAHs in the road dust of Kaduna metropolis. Likewise, the metals analyzed were Cu, Cr, Fe, Pb, Ni, Sn, and Zn. Contamination assessment using the contamination factor and geo-accumulation index was carried out. The majority of potentially toxic metals (Pb, Cr, and Sn) were elevated compared to USEPA and background concentrations, with the exception of Cu, Fe, Ni, and Zn. Cr and Cu recorded the highest contamination factor, while Cu showed moderate. The geo-accumulation index shows that Cr is extremely contaminated by the IR road, while the NKR road is heavily contaminated by Pb.*

***KEYWORDS:*** *PAHs, Heavy metals, Pollutants, Road dust, Risk assessment*

1. **INTRODUCTION**

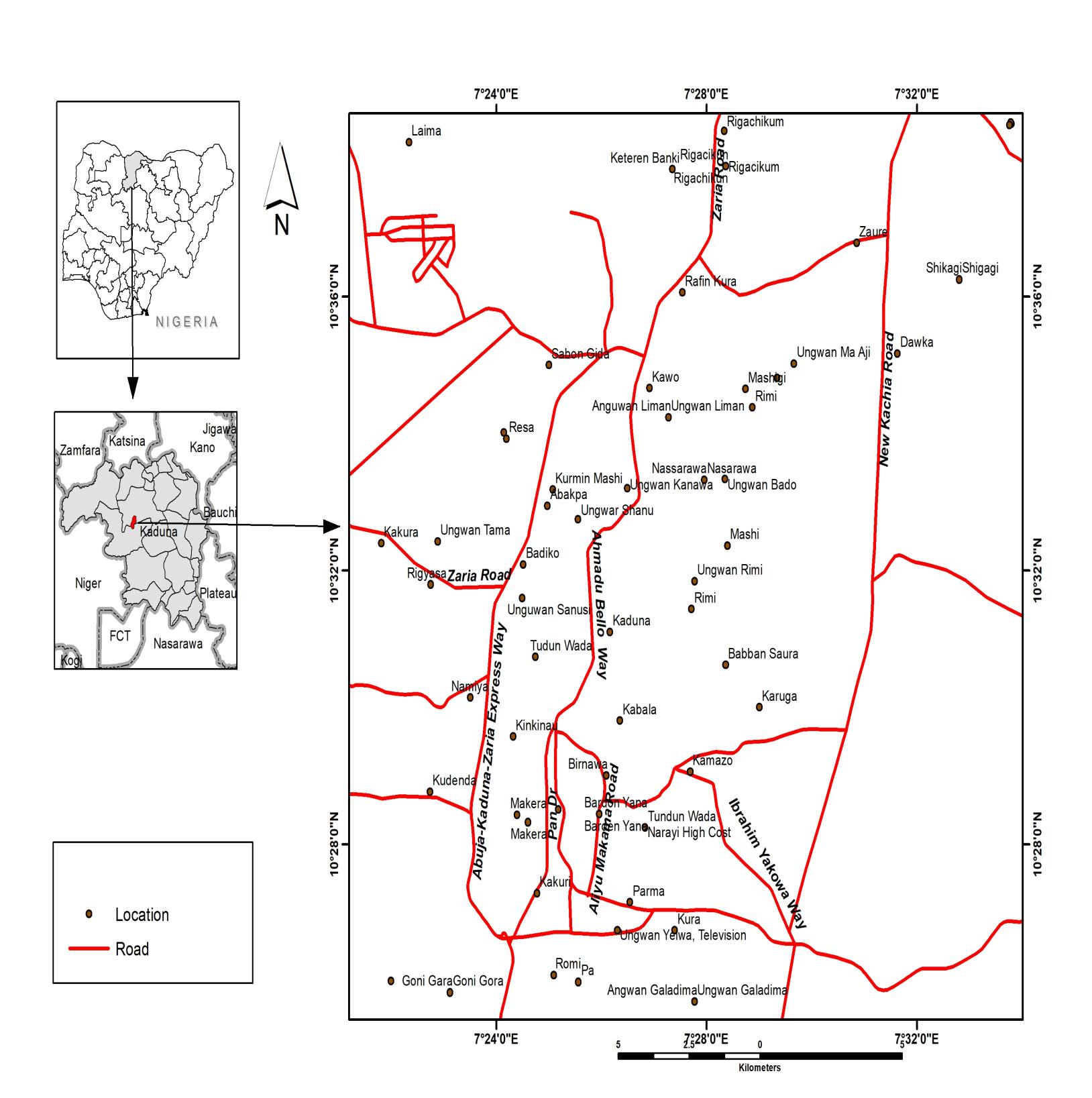
Urban road dust re-suspension can be a source of pollution and a means of transporting pollutants between various environmental compartments, endangering human health [1]. This phenomenon, which is frequently seen in arid and semi-arid nations like Nigeria, is regarded as the most important environmental threat [2]. There are several ways that people can become exposed to potentially dangerous heavy metals and PAHs: direct contact with the metal, vehicle emissions, the burning of coal and oil to generate electricity, industrial facilities, and home heating all contribute significantly to atmospheric, ingestion through the air, contaminating surface and groundwater drinking supplies, and transfer to plants and animals, which then become part of the human food chain [3, 4, 5]. According to [6], and [7], the urban environment's industrial and economic growth has led to an increase in the atmospheric concentrations of these pollutants.

Road dust particles negatively impact the environment, the health of the local population, and their way of life since they contain contaminants such as polycyclic aromatic hydrocarbons and heavy metals [8]. Atmospheric airborne particles, such as heavy metals and PAHs, can pose a serious risk to human health [9]. It has been documented that exposure to potentially hazardous heavy metals and PAHs in road dust can affect human health through ingestion, skin contact, and inhalation over varying periods of time [10]. Accordingly, several studies have been conducted on the human health risks associated with toxic metal contamination in street dust and soil [11, 12, 13]**.** However, there is a paucity of information about the toxicological properties and related health effects of road dust, which is partly explained by the differences in their chemical makeup, composition, and size distribution [14, 15]. The purpose of this study is to investigate the levels of heavy metals and PAHs exposure through the dermal, ingestion, and inhalation by children and their adult parents in road dust, as well as the contamination level and pollution load index of heavy metals in the street dust of the Kaduna metropolis, which serves as a representative urban environment in northwest Nigeria.

**11. MATERIALS AND METHODS**

***2.1 Description of the Study Area***

The location of Kaduna city is situated between latitudes 100 22' 0'' N and 100 40' 00'' N and longitudes 70 20'00''E and 70 28' 00'' (Figure 1). Situated at a height of 645 meters above sea level, the city spans around 260 km2, with the distance between its eastern and western boundaries being around 14 km. The entire Kaduna north, the entire Kaduna south, and portions of Igabi and Chikun are the four local government areas that comprise the city [16]. According to statista.com, the population of Kaduna metropolis is close to two million now. [17], put the population of Kaduna and its environs at 2,004, 282 in 2016 using the growth rate 2.47 as recommended in annual growth rate software world for population growth (2003), from the 2006 population census which was 1,570,331.



**Figure 1:** Map of Roads within Kaduna Metropolis (Kaduna State University (GIS), 2023)

***2.2 Sample Collection and Preparation***

Six (6) road dust composite samples (500 g) were collected in Kaduna, selected in the driest months to avoid rain. The samples were collected near busy traffic zones and business areas. The samples were air-dried, passed through a mesh, and analyzed for heavy metals and PAHs.

***2.2.1 Heavy Metals***

The concentrations of seven heavy metals (Cu, Cr, Fe, Pb, Ni, Sn, and Zn) were determined by adding concentrated HNO3 and HClO4 to a Teflon container, heating, drying, shaking, filtering, and dilution. The solutions were stored at 4 oC until analysis day, and heavy metals analysis was performed using inductively coupled plasma mass spectrometry. The process involved heating, drying, shaking, filtering, and dilution [18].

***2.2.2 Polycyclic Aromatic Hydrocarbons***

Exactly, 2.5 mL of CH3OH and 2.5 mL of CH2Cl2 were added to a Teflon container, which was then placed in an ultrasonic bath set at a 20 kHz frequency (Elmasonic S 80 H) for 30 minutes in order to solubilize the PAHs. The solution sample was filtered and PAHs analysis was conducted using a gas chromatography/mass selective detector and fused silica capillary column.

***2.3 Human Risk Assessment of PAHs in Roads Dust***

***2.3.1 Evaluation of incremental lifetime cancer risk***

The incremental lifetime cancer risk (ILCR, unit less) of PAHs exposure in road dust via dermal, inhalation and ingestion uptakes are evaluated using equations 1, 2 and 3 as stipulated by [19], [20] and [21]. The BaPeq concentration of individual PAH analytes was estimated using Ci x TEFi were Ci (g/g) is the concentration of each analyte in the road dust whilst TEFi is the toxicity equivalency factors of each analyte. The sum of BaPeq for all PAH analytes in each sample is represented as (ΣBaPeq).

(1)

(2)

(3)

**Table 1:** Applicable Parameters for the Incremental Lifetime Cancer Risk Evaluation of PAHs

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameters** | **Units** | **Adult** | **Children** |
| Body weight (BW) | [kg] | 70 | 15 |
| Exposure frequency (EF) | [day year-1] | 180 | 180 |
| Exposure duration (ED) | [year] | 24 | 6 |
| Inhalation rate (IRinhalation) | [m3 day-1] | 20 | 10 |
| Dust ingestion rate (IRingestion) | [mg day-1] | 100 | 200 |
| Dermal exposure area (SA) | [cm2] | 5700 | 2800 |
| Dermal adherence factor (AF) | [mg cm-2] | 0.07 | 0.2 |
| Dermal adsorption fraction (ABS) | [unit less] | 0.13 | 0.13 |
| Particle emission factor (PEF) | [m3 kg-1] | 1.36E+09 | 1.36E+10 |
| Carcinogenic slope factor ingestion (CSFingestion) of BaP | [mg kg-1 day-1] | 7.3 | 7.3 |
| Carcinogenic slope factor dermal uptake (CSFdermal) of BaP | [mg kg-1 day-1] | 25 | 25 |
| Carcinogenic slope factor inhalation (CSFinhalation) of BaP | [mg kg-1 day-1] | 3.85 | 3.85 |
| Averaging life span (AT) | [years] | 64.2 | 64.2 |

### *2.4 Heavy Metal Pollution and Ecological Risk Assessment*

***2.4.1 Contamination factor (CF)***

The ratio of each measured heavy metal's concentration (Cn) to its background value (Cbn) is known as the contamination factor, and it was used to characterize the pollution level of road dust with a particular heavy metal [22, 23].

CF= (4)

Based on the results obtained for CF, the level of heavy metal contamination was established according to CF < 1, low; 1 ≤ CF ≤ 3, moderate; 3 ≤ CF < 6, considerable; and CF ≥ 6, very high.

***2.4.2 Geo-Accumulation Index (Igeo)***

The degree of metal pollution in road dust was assessed using the geo-accumulation index. This indicator is frequently used to evaluate how contaminated urban road dust is with heavy metals [21], [24]. Where *Cn* is the concentrate of *n*th chemical element in the sample, *BGn* is the geochemical background value, and factor 1.5 is the background matrix correlate factor due to natural fluctuation in the content of a given chemical element in the environment with minimum anthropogenic influence.

Igeo= log2 ( ) (5)

**Table 2:** Value, Classes and Qualitative Description of Geo-Accumulation Index (Igeo)

|  |  |  |
| --- | --- | --- |
| **Igeo Value (log2 (x))** | **Igeo Class** | **Qualitative Designation of Road Dust** |
| Igeo≤0 | 0 | Uncontaminated |
| 0<Igeo≤1 | 1 | Uncontaminated to moderately contaminated |
| 1<Igeo≤2 | 2 | Moderately contaminated |
| 2<Igeo≤3 | 3 | Moderately to heavily contaminated |
| 3<Igeo≤4 | 4 | Heavily contaminated |
| 4<Igeo≤5 | 5 | Heavily to extremely contaminated |
| Igeo>5 | 6 | Extremely contaminated |

**III**.**RESULTS AND DISCUSSION**

**Table 1:** Mean Concentrations (mg/kg) of Some Polycyclic Aromatic Hydrocarbons in Some Selected Roads Dust in Kaduna Metropolis, Kaduna State, Nigeria

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Concentrations (mg/kg) of Major Roads Dust Within Kaduna Metropolis** | | | | | |
| **PAHs** | **TEF** | **ABKZEW** | **NKR** | **IW** | **ABW** | **AMR** | **IYR** |
| Naphthalene | 0.001 | 2.21E+00 | ND | ND | 1.43E+02 | 3.90E-01 | 3.75E+00 |
| Acenaphthylene | 0.001 | ND | 2.57E+00 | 4.29E+00 | 2.81E+01 | 9.38E+00 | 7.70E-01 |
| Acenaphthene | 0.001 | 6.11E+01 | 5.00E-02 | 8.60E+00 | 7.80E+00 | ND | 3.18E+01 |
| Fluorene | 0.001 | 2.62E+01 | ND | 4.84E+01 | 3.00E-02 | 8.29E+00 | 7.10E-01 |
| Phenanthrene | 0.001 | ND | ND | 3.18E+01 | 8.21E+01 | ND | 5.30E-01 |
| Anthracene | 0.01 | 1.09E+00 | 1.56E+00 | 2.16E+01 | 1.61E+00 | 1.32E+00 | 1.02E+02 |
| Fluoranthene | 0.001 | 7.52E+01 | 1.50E+01 | 7.90E+00 | 9.00E+00 | 4.84E+01 | 7.20E-01 |
| Pyrene | 0.001 | 1.04E+02 | 7.20E-01 | 2.68E+01 | 2.29E+00 | 1.49E+01 | 1.22E+01 |
| Benzo(a)anthracene | 0.1 | 2.68E+00 | ND | 3.76E+01 | 4.84E+01 | 5.50E+00 | 1.24E+01 |
| Chrysene | 0.01 | 3.00E-02 | 6.14E+00 | 1.09E+01 | 8.65E+00 | 9.30E-01 | 2.10E+02 |
| Benzo(b)fluoranthene | 0.1 | ND | 1.88E+02 | 2.40E+01 | 1.40E-01 | 6.30E-01 | 7.90E+00 |
| Benzo(k)fluoranthene | 0.1 | 7.10E-01 | 1.54E+01 | ND | 8.45E+00 | 4.60E+01 | 7.87E+01 |
| Benzo(a)pyrene | 1 | 1.50E+02 | 1.08E+01 | 3.18E+01 | 4.10E+01 | 7.00E-01 | 8.00E+00 |
| Dibenz(a,h)anthracene | 0.1 | 6.11E+01 | 1.68E+01 | 2.86E+01 | 4.00E-02 | ND | 7.70E-01 |
| Indeno(1,2,3-cd)pyrene | 1 | 4.84E+01 | 6.00E-02 | 1.50E+02 | 2.13E+01 | 5.50E+00 | 4.00E-02 |
| Benzo(g,h,i)perylene | 0.01 | 5.30E-01 | 1.54E+01 | 7.80E+00 | 2.07E+01 | 2.88E+00 | 1.07E+00 |
| **Σ16PAH** |  | **5.33E+02** | **2.72E+02** | **4.40E+02** | **2.80E+02** | **1.45E+02** | **1.83E+02** |

**Keys:** ABKZEW; Abuja Kaduna Zaria Exprees Way, NKR; New Kachia Road, IW; Independence Way, ABW; Ahmadu Bello Way, AMR; Aliyu Makama Road, IYR; Ibrahim Yakowa Road, TEF;Toxic Equivalent Factor, ND; Not Detected

**Table 2:** Carcinogenic Risk Assessment of PAHs in Road Dust of Kaduna Metropolis for Adults and Children via Dermal, Inhalation and Ingestion

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **DERMAL** | | | | | | | | | | | |
|  | **Adults** | | | | | | **Children** | | | | | |
| **PAHs** | **ABKZEW** | **NKR** | **IW** | **ABW** | **AMR** | **IYR** | **ABKZEW** | **NKR** | **IW** | **ABW** | **AMR** | **IYR** |
| Nap | 2.75E-08 | - | - | 1.78E-06 | 4.86E-09 | 4.67E-08 | 3.22E-07 | - | - | 2.08E-05 | 5.69E-08 | 5.47E-07 |
| Acy | - | 3.20E-08 | 5.35E-08 | 3.50E-07 | 1.17E-07 | 9.60E-09 | - | 3.75E-07 | 6.25E-07 | 4.10E-06 | 1.37E-06 | 1.12E-07 |
| Ace | 7.62E-07 | 6.23E-10 | 1.07E-07 | 9.72E-08 | - | 3.96E-07 | 8.91E-06 | 7.29E-09 | 1.25E-06 | 1.14E-06 | - | 4.64E-06 |
| Flu | 3.27E-07 | - | 6.03E-07 | 3.74E-10 | 1.03E-07 | 8.85E-09 | 3.82E-06 | - | 7.06E-06 | 4.37E-09 | 1.21E-06 | 1.04E-07 |
| Phe | - | - | 3.96E-07 | 1.02E-06 | - | 6.61E-09 | - | - | 4.64E-06 | 1.20E-05 | - | 7.73E-08 |
| Ant | 1.36E-07 | 1.94E-07 | 2.69E-06 | 2.01E-07 | 1.65E-07 | 1.27E-05 | 1.59E-06 | 2.27E-06 | 3.15E-05 | 2.35E-06 | 1.92E-06 | 1.49E-04 |
| Fla | 9.37E-07 | 1.87E-07 | 9.85E-08 | 1.12E-07 | 6.03E-07 | 8.98E-09 | 1.10E-05 | 2.19E-06 | 1.15E-06 | 1.31E-06 | 7.06E-06 | 1.05E-07 |
| Pyr | 1.30E-06 | 8.98E-09 | 3.34E-07 | 2.85E-08 | 1.86E-07 | 1.52E-07 | 1.52E-05 | 1.05E-07 | 3.91E-06 | 3.34E-07 | 2.17E-06 | 1.78E-06 |
| BaA | 3.34E-06 | - | 4.69E-05 | 6.03E-05 | 6.86E-06 | 0.00E+00 | 3.91E-06 | - | 5.48E-04 | 7.06E-04 | 8.02E-05 | 1.81E-04 |
| Chr | 3.74E-09 | 7.65E-07 | 1.36E-06 | 1.08E-06 | 1.16E-07 | 2.62E-05 | 4.37E-08 | 8.95E-06 | 1.59E-05 | 1.26E-05 | 1.36E-06 | 3.06E-04 |
| BbF | - | 2.34E-04 | 2.99E-05 | 1.75E-07 | 7.85E-07 | 9.85E-06 | - | 2.74E-03 | 3.50E-04 | 2.04E-06 | 9.19E-06 | 1.15E-04 |
| BkF | 8.85E-07 | 1.92E-05 | - | 1.05E-05 | 5.73E-05 | 9.81E-05 | 1.04E-05 | 2.25E-04 | - | 1.23E-04 | 6.71E-04 | 1.15E-03 |
| BaP | 1.87E-03 | 1.35E-04 | 3.96E-04 | 5.11E-04 | 8.73E-06 | 9.97E-05 | 2.19E-02 | 1.57E-03 | 4.64E-03 | 5.98E-03 | 1.02E-04 | 1.17E-03 |
| IP | 7.62E-05 | 2.09E-05 | 3.57E-05 | 4.99E-08 | - | 9.60E-07 | 7.06E-05 | 2.45E-04 | 4.17E-04 | 5.83E-08 | - | 1.12E-05 |
| DBA | 6.03E-04 | 7.48E-07 | 1.87E-03 | 2.66E-04 | 6.86E-05 | 4.99E-07 | 7.06E-03 | 8.75E-06 | 2.19E-02 | 3.11E-03 | 8.02E-04 | 5.83E-06 |
| BghiP | 6.61E-08 | 1.92E-06 | 9.72E-07 | 2.58E-06 | 3.59E-07 | 1.33E-07 | 7.73E-07 | 2.25E-05 | 1.14E-05 | 3.02E-05 | 4.20E-06 | 1.56E-06 |
| **ΣILCR** | **2.56E-03** | **4.13E-04** | **2.39E-03** | **8.55E-04** | **1.44E-04** | **2.49E-04** | **2.91E-02** | **4.83E-03** | **2.79E-02** | **1.00E-02** | **1.68E-03** | **3.09E-03** |
|  | **INHALATION** | | | | | | | | | | | |
|  | **Adults** | | | | | | **Children** | | | | | |
| **PAHs** | **ABKZEW** | **NKR** | **IW** | **ABW** | **AMR** | **IYR** | **ABKZEW** | **NKR** | **IW** | **ABW** | **AMR** | **IYR** |
| Nap | 1.64E-07 | - | - | 1.06E-05 | 2.89E-08 | 2.78E-07 | 6.82E-09 | - | - | 4.41E-07 | 1.20E-09 | 1.16E-08 |
| Acy | - | 1.90E-06 | 3.18E-06 | 2.08E-06 | 6.94E-07 | 5.70E-08 | - | 7.93E-09 | 1.32E-08 | 8.67E-08 | 2.89E-08 | 2.37E-09 |
| Ace | 4.52E-06 | 3.70E-08 | 6.37E-07 | 5.77E-07 | - | 2.35E-06 | 1.88E-07 | 1.54E-10 | 2.65E-08 | 2.41E-08 | - | 9.81E-08 |
| Flu | 1.94E-06 | - | 3.58E-06 | 2.22E-09 | 6.14E-07 | 5.26E-08 | 8.08E-08 | - | 1.49E-07 | 9.25E-11 | 2.56E-08 | 2.19E-09 |
| Phe | - | - | 2.35E-06 | 6.08E-06 | - | 3.92E-08 | - | - | 9.81E-08 | 2.53E-07 | - | 1.63E-09 |
| Ant | 8.07E-07 | 1.15E-05 | 1.60E-05 | 1.19E-06 | 9.77E-07 | 7.55E-05 | 3.36E-09 | 4.81E-09 | 6.66E-08 | 4.97E-09 | 4.07E-09 | 3.15E-07 |
| Fla | 5.57E-06 | 1.11E-05 | 5.85E-07 | 6.66E-07 | 3.58E-06 | 5.33E-08 | 2.32E-07 | 4.63E-08 | 2.44E-08 | 2.78E-08 | 1.49E-07 | 2.22E-09 |
| Pyr | 7.70E-06 | 5.33E-07 | 1.98E-05 | 1.70E-07 | 1.10E-06 | 9.03E-07 | 3.21E-07 | 2.22E-09 | 8.27E-08 | 7.06E-09 | 4.60E-08 | 3.76E-08 |
| BaA | 1.98E-05 | - | 2.78E-04 | 3.58E-04 | 4.07E-05 | 9.18E-05 | 3.08E-08 | - | 1.16E-05 | 1.49E-05 | 1.70E-06 | 3.82E-06 |
| Chr | 2.22E-08 | 4.54E-06 | 8.07E-06 | 6.40E-06 | 6.88E-07 | 1.55E-04 | 9.25E-11 | 1.89E-08 | 3.36E-08 | 2.67E-08 | 2.87E-09 | 6.48E-07 |
| BbF | - | 1.39E-03 | 1.78E-04 | 1.04E-06 | 4.66E-06 | 5.85E-05 | 3.08E-08 | 5.80E-05 | 7.40E-06 | 4.32E-10 | 1.94E-09 | 2.44E-08 |
| BkF | 5.26E-06 | 1.14E-04 | - | 6.25E-05 | 3.40E-04 | 5.83E-04 | 3.08E-08 | 4.75E-06 | - | 2.61E-08 | 1.42E-07 | 2.43E-07 |
| BaP | 1.11E-02 | 7.99E-04 | 2.35E-03 | 3.03E-03 | 5.18E-05 | 5.92E-04 | 4.63E-04 | 3.33E-05 | 9.81E-05 | 1.26E-04 | 2.16E-06 | 2.47E-05 |
| IP | 4.52E-04 | 1.24E-04 | 2.12E-04 | 2.96E-07 | - | 5.70E-06 | 3.08E-08 | 5.18E-06 | 8.82E-06 | 1.23E-08 | - | 2.37E-07 |
| DBA | 3.58E-03 | 4.44E-06 | 1.11E-02 | 1.58E-03 | 4.07E-04 | 2.96E-06 | 1.49E-04 | 1.85E-07 | 4.63E-04 | 6.57E-06 | 1.70E-06 | 1.23E-08 |
| BghiP | 3.92E-07 | 1.14E-06 | 5.77E-07 | 1.53E-06 | 2.13E-07 | 7.92E-07 | 1.63E-09 | 4.75E-05 | 2.41E-08 | 6.38E-08 | 8.88E-06 | 3.30E-09 |
| ΣILCR | **1.52E-02** | **2.46E-03** | **1.42E-02** | **5.06E-03** | **8.53E-04** | **1.57E-03** | **6.13E-04** | **1.49E-04** | **5.89E-04** | **1.49E-04** | **1.48E-05** | **3.01E-05** |
|  | **INGESTION** | | | | | | | | | | | |
|  | **Adults** | | | | | | **Children** | | | | | |
| **PAHs** | **ABKZEW** | **NKR** | **IW** | **ABW** | **AMR** | **IYR** | **ABKZEW** | **NKR** | **IW** | **ABW** | **AMR** | **IYR** |
| Nap | 1.55E-06 | - | - | 1.00E-04 | 2.74E-07 | 2.63E-06 | 3.62E-06 | - | - | 2.34E-04 | 6.38E-07 | 6.14E-06 |
| Acy | - | 1.80E-06 | 3.01E-06 | 1.97E-05 | 6.58E-06 | 5.40E-07 | - | 4.21E-06 | 7.02E-06 | 4.60E-05 | 1.54E-05 | 1.26E-06 |
| Ace | 4.29E-05 | 3.51E-08 | 6.03E-06 | 5.47E-06 | - | 2.23E-05 | 1.00E-04 | 8.19E-08 | 1.41E-05 | 1.28E-05 | - | 5.21E-05 |
| Flu | 1.84E-05 | - | 3.40E-05 | 2.11E-08 | 5.82E-06 | 4.98E-07 | 4.29E-05 | - | 7.92E-05 | 4.91E-08 | 1.36E-05 | 1.16E-06 |
| Phe | - | - | 2.23E-05 | 5.76E-05 | - | 3.72E-07 | - | - | 5.21E-05 | 1.34E-04 | - | 8.68E-07 |
| Ant | 7.65E-06 | 1.09E-05 | 1.52E-04 | 1.13E-05 | 9.26E-06 | 7.16E-04 | 1.78E-05 | 2.55E-05 | 3.54E-04 | 2.64E-05 | 2.16E-05 | 1.67E-03 |
| Fla | 5.28E-05 | 1.05E-05 | 5.54E-06 | 6.32E-06 | 3.40E-05 | 5.05E-07 | 1.23E-04 | 2.46E-05 | 1.29E-05 | 1.47E-05 | 7.92E-05 | 1.18E-06 |
| Pyr | 7.30E-05 | 5.05E-07 | 1.88E-05 | 1.61E-06 | 1.05E-05 | 8.56E-06 | 1.70E-04 | 1.18E-06 | 4.39E-05 | 3.75E-06 | 2.44E-05 | 2.00E-05 |
| BaA | 1.88E-04 | - | 2.64E-03 | 3.40E-03 | 3.86E-04 | 8.70E-04 | 4.39E-04 | - | 6.16E-03 | 7.92E-03 | 9.00E-04 | 2.03E-03 |
| Chr | 2.11E-07 | 4.31E-05 | 7.65E-05 | 6.07E-05 | 6.53E-06 | 1.47E-03 | 4.91E-07 | 1.01E-04 | 1.78E-04 | 1.42E-04 | 1.52E-05 | 3.44E-03 |
| BbF | - | 1.32E-02 | 1.68E-03 | 9.82E-06 | 4.42E-05 | 5.54E-04 | - | 3.08E-02 | 3.93E-03 | 2.29E-05 | 1.03E-04 | 1.29E-03 |
| BkF | 4.98E-05 | 1.08E-03 | - | 5.93E-04 | 3.23E-03 | 5.52E-03 | 1.16E-04 | 2.52E-03 | - | 1.38E-03 | 7.53E-03 | 1.29E-02 |
| BaP | 1.05E-01 | 7.58E-03 | 2.23E-02 | 2.88E-02 | 4.91E-04 | 5.61E-03 | 2.46E-01 | 1.77E-02 | 5.21E-02 | 6.71E-02 | 1.15E-03 | 1.31E-02 |
| IP | 4.29E-03 | 1.18E-03 | 2.01E-03 | 2.81E-06 | - | 5.40E-05 | 1.00E-02 | 2.75E-03 | 4.68E-03 | 6.55E-06 | - | 1.26E-03 |
| DBA | 3.40E-02 | 4.21E-05 | 1.05E-01 | 1.49E-02 | 3.86E-03 | 2.81E-05 | 7.92E-02 | 9.82E-05 | 2.46E-01 | 3.49E-02 | 9.00E-03 | 6.55E-05 |
| BghiP | 3.72E-06 | 1.08E-04 | 5.47E-05 | 1.45E-04 | 2.02E-05 | 7.51E-06 | 8.68E-06 | 2.52E-04 | 1.28E-04 | 3.39E-04 | 4.71E-05 | 1.75E-05 |
| **ΣILCR** | **1.44E-01** | **2.32E-02** | **1.34E-01** | **4.81E-02** | **8.10E-03** | **1.49E-02** | **3.36E-01** | **5.42E-02** | **3.13E-01** | **1.12E-01** | **1.89E-02** | **3.58E-02** |

**Table 3:** Mean Concentrations of Some Heavy Metals (mg/kg) in the Major Roads in Kaduna Metropolis

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **ROADS** | **Cu** | **Cr** | **Fe** | **Pb** | **Ni** | **Sn** | **Zn** |
| ABKZEW | 2.29E-01 | 6.20E-02 | 2.00E-03 | 6.30E-02 | 1.00E-01 | 1.66E+01 | 1.00E-01 |
| NKR | 3.10E-02 | 1.60E-01 | 5.64E-02 | 1.99E-03 | 5.20E-02 | 8.00E-02 | 7.24E-02 |
| IW | 2.10E-02 | 2.80E-01 | 8.70E-02 | 6.00E-02 | 5.10E-02 | 4.08E-01 | 3.06E-02 |
| ABW | 1.80E-03 | 3.00E-01 | 5.80E-02 | 5.10E-02 | 2.70E-02 | 9.20E-01 | 4.50E-03 |
| AMR | 2.00E-03 | 8.84E+00 | 2.13E-02 | 9.23E-01 | 2.04E-02 | 3.20E-02 | 9.80E-03 |
| IYR | 2.00E-03 | 1.77E+02 | 4.25E-03 | 9.23E-01 | 2.04E-02 | 6.40E-01 | 1.96E-03 |
| ∑HEAVY METALS | **2.87E-01** | **1.86E+02** | **2.29E-01** | **2.02E+00** | **2.71E-01** | **1.87E+01** | **2.19E-01** |
| Background | 1.40E-01 | 2.30E-01 | 0.41E+01 | 2.41E+01 | 4.11E+00 | 1.40E-01 | 5.56E+01 |
| USEPA, (2002) | 2.70E+02 | 1.10E+01 | 6.20E+03 | 2.00E+02 | 7.20E+01 | - | 1.10E+03 |

**Keys:** USEPA, United State Environmental Protection Agency

**Table 4:** Contamination Level of Some Heavy Metals in Kaduna Metropolis

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **ROADS** | **Cu** | **Cr** | **Fe** | **Pb** | **Ni** | **Sn** | **Zn** |
| ABKZEW | 2.29 | 0.00 | 0.00 | 0.00 | 0.02 | 4.29 | 0.01 |
| NKR | 0.31 | 0.01 | 0.01 | 0.00 | 0.01 | 0.57 | 0.00 |
| IW | 0.21 | 0.01 | 0.02 | 0.00 | 0.01 | 2.91 | 0.00 |
| ABW | 0.018 | 0.01 | 0.01 | 0.00 | 0.01 | 6.57 | 0.00 |
| AMR | 0.02 | 0.38 | 0.01 | 0.04 | 0.00 | 0.23 | 0.00 |
| IYR | 0.02 | 7.70 | 0.00 | 0.04 | 0.00 | 4.57 | 0.00 |

**Table 5:** Geo-Accumulation Indexof Heavy Metals in Road Dusts in Kaduna Metropolis

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **ROADS** | **Cu** | **Cr** | **Fe** | **Pb** | **Ni** | **Sn** | **Zn** |
| ABKZEW | 0.00 | 0.29 | 0.00 | 0.30 | 0.08 | 0.04 | 0.31 |
| NKR | 0.00 | 0.74 | 0.05 | 0.01 | 0.04 | 0.00 | 0.23 |
| IW | 0.00 | 1.29 | 0.07 | 0.29 | 0.04 | 0.01 | 0.10 |
| ABW | 0.00 | 1.38 | 0.05 | 0.25 | 0.02 | 0.03 | 0.01 |
| AMR | 0.00 | 40.80 | 0.02 | 4.46 | 0.02 | 0.00 | 0.03 |
| IYR | 0.00 | 816.91 | 0.00 | 4.46 | 0.02 | 0.02 | 0.01 |

***3.1 Levels of PAHs in Road Dust***

In Table 1, the mean BaPeq values in the road dust decreased in the following order: IYR(2.10E+02 mg/kg)>NKR(1.88E+02 mg/kg)>ABKZEW(1.50E+02 mg/kg)>IW(1.50E+02 mg/kg)>ABW(1.43E+02mg/kg)>AMR(4.84E+01mg/kg), clearly indicating a higher carcinogenicity PAHs Chr, B(k)F and B(a)P within the vicinity of IYR, NKR and ABKZEW. These expressways recorded the highest mean concentration of PAHs, possibly due to the heavy load of car emissions, indicating the impact of road activities in the study area [25]. The BaPeq calculation reveals that HMW-PAHs (5–6 rings) contribute the highest percentage of PAH carcinogenicity in road dust due to their higher TEFs values compared to LMW-PAHs (2–3 rings). HMW-PAHs have a higher tendency to adhere to street dust [26, 27]. Similarly, poor engine maintenance and fuel quality have a major impact on HMW-PAH emissions [6]. The concentrations of PAHs in road dusts from Kaduna metropolis were comparable to levels reported for Warri in Nigeria [28]; however, lower levels of PAHs were found in dusts from Kaduna metropolis than those of street dusts from Lagos, Nigeria [29] and Kumasi, Ghana [19].

***3.2 HEALTH RISK ASSESSMENT OF PAHS***

***3.2.1 Carcinogenic Risk Assessment for Human Health***

The human carcinogenic risks of PAHs were estimated and summarized in Table 2 based on human exposure through all routes (i.e., dermal, inhalation, and ingestion exposure). The values of ILCRtotal for adults ranged from 1.44E-04 to 2.56E-03 (dermal), 8.53E-04 to 1.52E-02 (inhalation), and 8.10E-03 to 1.44E-01 (ingestion), whereas for children, they ranged from 1.68E-03 to 2.91E-02 (dermal), 1.48E-05 to 6.13E-04 (inhalation), and 1.89E-02 to 3.36E-01 (ingestion). Dermal and ingestion contact increased cancer with a magnitude of 2.19E-02 and 2.46E-01 in dust sample considerably increasing the risk of cancer in children. According to epidemiological research, there is a link between extended exposure to PAHs and an increased risk of gastrointestinal, lung, and skin malignancies [30, 31, 32]. Road dust and other environmental media containing PAHs, such as soil, water, and airborne particulate matter, are simultaneously exposed to adults and children [33]. Adult skin contact was the most prevalent mode of exposure, followed by ingestion, since PAHs are easily absorbed into the body by dermal contact with dirt, contaminated water, soot, tar, or by applying a few oils that contain high quantities of PAHs to the body. This elevated risk was noteworthy [34]. Studies have demonstrated the potential damage that road dust containing PAHs poses [35, 36]. Certain occupational groups experience more frequent exposure than others, such as street sellers and road sweepers [35]. The results from this study suggested a risk ranging from negligible (ILCRs < 10-6) to potential (10-6 < ILCRs < 10-4) as affected by PAHs in road dust. ILCR values (unitless) should be noted that they could differ between researches by orders of magnitude, particularly when converting units [37].

***3.2.2 Concentrations of Some Heavy Metals in the Road Dust***

Table 3 revealed that Pb had the highest total mean concentrations (2.02E+00 mg/kg) in the road dust samples; this value is below the [20] acceptable limit (2.00E+01 mg/kg), while Fe had the lowest (2.29E-01 mg/kg). Given that Pb is the primary consequence of burning gasoline, this could be the case [38]. Previous studies showed that automobile exhaust emissions from gasoline combustion accounted for a sizable amount of the lead (Pb) detected in urban roadside soil [39, 40]. Comparably, along the AMR and ABKZEW highways, Cr and Sn had the greatest mean concentrations of 8.84E+00 mg/kg and 1.66E+01 mg/kg, respectively. These numbers were less than the average levels. These components have to do with traffic in cars [41, 42, 43]. AMR and ABKZEW roads could be pointed out as one of the most, if not the most influential, in congested traffic, commerce activities, heavy equipment workshops, and flowing traffic. The mean concentration of Cr and Sn observed in road dust samples was above the regulatory control limits of 1.10E+01 mg/kgas prescribed by[20], for the soils specified by the Nigerian regulatory body. It was observed that these findings were above those presented by [44, 45, and 46]

***3.2.2 Contamination Level of Some Heavy Metals in the Road Dust***

The contamination factor (CF) for all measured individual metals is presented in Table 4. The mean CF values of all metals were found in the following order: IYR (7.70: very high)> ABW (6.57: very high)> ABKZEW (2.29: moderate) AMR > (0.04: low), IW > (0.02: low), and NKR > (0.01: low) the study quantified that the road dust of the investigated areas was inclined with heavy metals. Most of the metals and sampling sites in Kaduna city's road dust showed moderate to substantial contamination, suggesting a potential risk to the surrounding ecosystems [47]. Based on the level of contamination, assessments of dusts' total contamination are completed [48].

***3.2.3 Geo-Accumulation Index of Heavy Metals in Road Dusts***

The Igeo values are depicted in Table 5. According to the examined areas, all the roads within Kaduna metropolis were unpolluted by Cu (Igeo< 0). However, the areas of congested traffic, commerce activities, and workshops for maintenance of heavy equipment were extremely contaminated (Igeo > 5) by Cr, namely samples 40.80 and 816.91 for AMR and IYR. The areas of AMR and IYR (4.46) were heavily contaminated by Pb (3<Igeo≤4). For Kaduna metropolis, the average Igeo values showed following pattern: Cr (816.91) > Pb (4.46) > Zn (0.31) > Sn (0.04) > Fe (0.07) > Cu (0.00). Based on our results, Cr and Pb can be considered priority heavy metals in Kaduna metropolis that need remediation and regular monitoring. Igeo results of this study were in accordance with a few previous studies [49, 50,51].

**IV. CONCLUSION**

The results of this study clearly indicated that Ibrahim Yakowa Road, New Kachia Road, and Abuja Kaduna Zaria Express Way recorded the highest mean concentrations of B(a)P, B(k)F, and Chr highly carcinogenic PAHs. Children are at a higher risk of cancer due to exposure to contaminated particles, with DBA and B(a)P being the most dominant compounds contributing to carcinogenic activity. The contamination factor and geo-accumulation index revealed elevated levels of potentially toxic metals, except for Cu, Fe, Ni, and Zn. B(k)F, and Chr. Children are at a higher risk of cancer due to exposure to contaminated particles, with DBA and B(a)P being the most dominant compounds contributing to carcinogenic activity. The contamination factor and geo-accumulation index revealed elevated levels of potentially toxic metals, except for Cu, Fe, Ni, and Zn.

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