POLYCYCLIC AROMATIC HYDROCARBONS (PAHs) LEVEL AND HEALTH RISK EVALUATION OF ROAD DUST IN SANGO OTTA, OGUN STATE, NIGERIA

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Abstract

Polycyclic Aromatic Hydrocarbons (PAHs) are persistent toxic substance and omnipresent environmental contaminants causing toxic health effects to human and potential threats to the environment. This study determines the concentration and health risk of polycyclic aromatic hydrocarbons (PAHs) in industrial road. Ten samples were collected during the dry season from Sango Otta Ogun State in Southwest Nigeria. Dust particles that accumulated on surfaces of pavements and roadside within a 5m radius circle were collected and analyzed using standard method. Gas chromatography-mass spectrometry (GC-MS) were used to determine the twenty-four potential toxic congeners according to USEPA PAHs standard. The average concentration of PAHs in the dust samples were 1.80 mgkg^{-1}, with concentrations ranging from 23.31 mgkg^{-1} to 1.74 mgkg-1. The PAH level in Rubee Medical Road were the greatest, with 3-Methylcholanthracene being the highest PAH congener 10.47 mgkg-1, while the PAH level in Conoil Bus stop were the lowest (1.74 mgkg-1). Potential human health risk of the exposure to PAHs by inhalation and skin contact were evaluated using the Chronic Daily Intake (CDI), which ranged from 9.59×10^{-18} mgkg $^{-1}$day $^{-1}$ to 1.09 ×10 $^{-8}$ mgkg $^{-1}$day $^{-1}$, Hazard Quotient (HQ). Hazard Index (HI) and Cancer Risk (CR) of all PAH congeners has the highest HQ value. The PAHs' CR values were greater than the USEPA's allowed limit of 0.2 mg/m^3, indicating that they may be carcinogenic. This data reveals that the inhalation route is primarily responsible for the total carcinogenic risk of PAHs to humans.

Keywords: Polycyclic aromatic hydrocarbons, hazard quotient, cancer risk, health risk, urban

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The atmosphere of the planet earth is made up of particles from many sources, such as, dust carried by the wind, and volcanic eruptions. Dust is one of those particles in the atmosphere, it is a complex collection of sub-micro particles with varied chemical compositions caused by the interaction of solid, liquid, and gaseous components produced by various sources, processes, and anthropogenic activities (Singh *et al*., 2005).

Any mechanical processing of material, such as crushing, grinding, fast impact, handling, detonation, and degradation of organic and inorganic materials including metal, ore, and rock, produces the solid particles that make up road dust. Once dust becomes airborne, regularly as a result of wheel friction on unpaved dirt roads and paved highways with dust buildup, road dust begins to form (EPA, 2010).

Vehicles are mostly accountable for urban environmental pollution, which also includes soil, air, building materials, and industrial smoke.

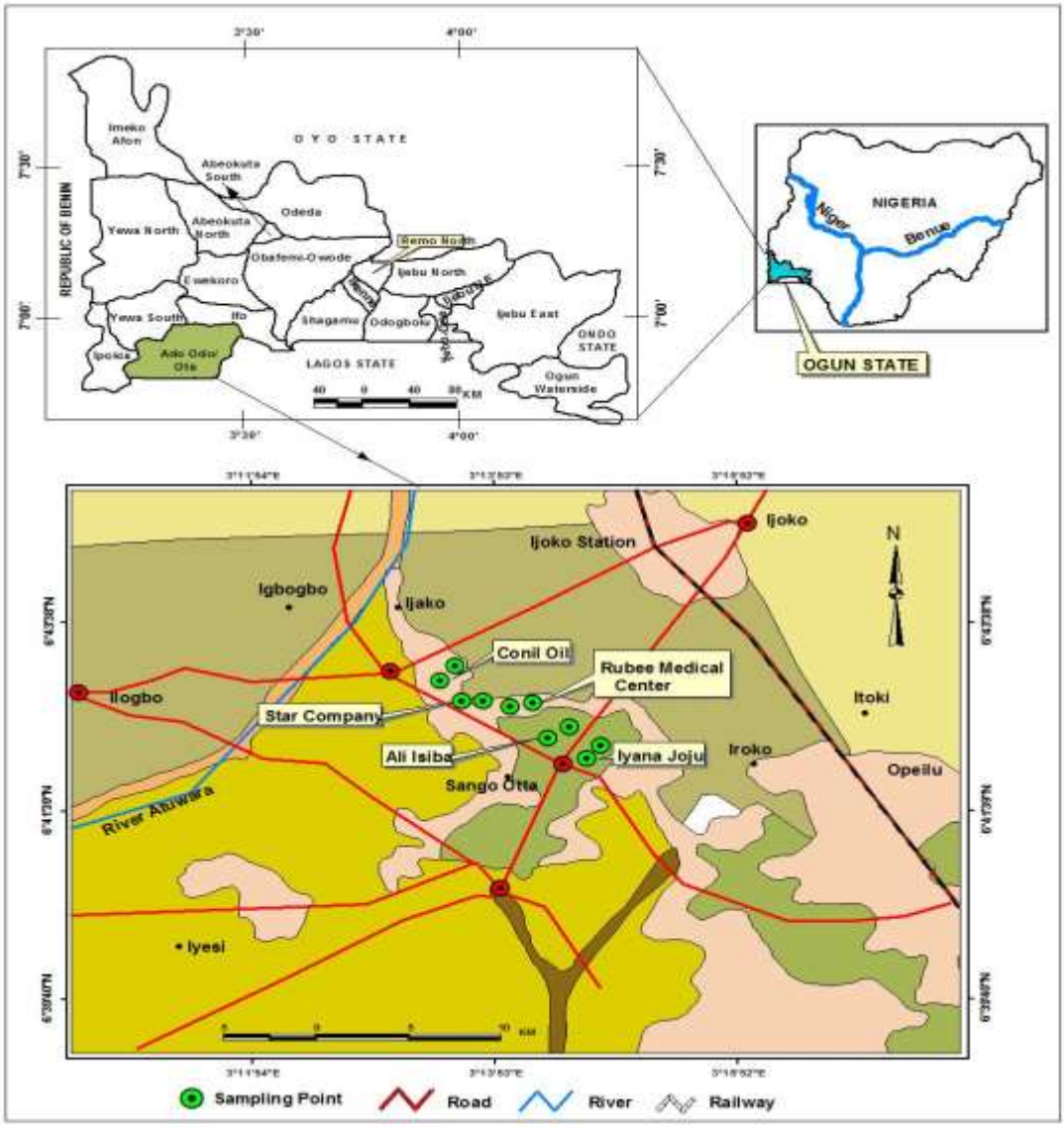
The term "polycyclic aromatic hydrocarbons" (PAHs) refers to a class of chemical compounds that have two or more fused aromatic rings arranged angularly, in a cluster, or linearly. In addition to sources associated with human activity (anthropogenic sources), such as coal combustion, car exhaust pollutants, engine lubricating oils, cigarette smoking, natural gas combustion, cooking, tobacco smoking, and refuse combustion, PAHs can also originate from unnatural sources like forest fires and volcanic emissions. The atmospheric distribution of PAHs is extensive. Numerous PAHs are harmful to the reproductive system, mutagenic, and/or carcinogenic (Crone & Tolstoy, 2010). Some PAHs are toxic to people, persistent, and bio-accumulative.

Dust and soot particles can reach the atmosphere when PAHs bind to them. High amounts of PAHs found in dust particles pose a health risk to people, especially children. (Yap *et al*., 2012; Meza-Figueroa *et al*., 2007). Street dust is a significant source of atmospheric deposition particle accumulation in metropolitan areas. As a result of direct contact with vehicle exhaust emissions, road dust may be the main source of PAHs particles (Mostafa *et al*., 2009; 2011). This study is set to determine the level and health risk of polycyclic aromatic hydrocarbons (PAHs) in road dust of an industrial area.

Materials and methods

Study Area

Sango Otta, Ogun state Nigeria and its environs has different industrial companies such as food processing, beverage – producing and allied. The yearly annual rainfall of sango Ota is 1718 mm while the lowest temperature is 26.2°C. The area has a tropical climate, with dry season and rainy seasons. The region is connected to other human activities including construction, commerce, transportation, and waste burning (Salako 1999). The GPS coordinates of samples location ranges between latitude 6.7151767 to 6.7095786 and longitudes 3.284820 to 3.2265415.



Sample Collection and Sample Preparation

All samples were collected from various locations in Sango Otta, using pavement surfaces as collection points. Dust were carefully swept into a dustpan after the samples were obtained using a brush. Each sample consisted of two

smaller samples, each weighing at least (100 g). The sample collection was made in the month of March, before the onset of rainfall. Samples were packed in polythene and paper bags for easy transportation to the laboratory. The dust samples were carefully mixed, sieved to eliminate foreign objects, and stored at room temperature until analysis.

Extraction Procedure: 5 g of properly homogenized samples were accurately weighed in a beaker, along with 10 ml of a 1:1 n-hexane: acetone solution. After that, the beaker was placed in an ultrasonic bath for 20 minutes. The solvent layer was decanted and reduced to 2 mL using a rotary evaporator.

Cleanup Procedure: These method is based on EPA Method 3630C. Into a 5 g activated silica gel (Mesh Size 60-200A) packed into a glass column, 1g of anhydrous Na_2S0_4 was added. 20 ml n-Hexane was added to the column and eluted into a beaker. The 2 ml sample extract was added to the top of the column quantitatively. Another 10 ml of n-Hexane was added to the column and eluted to trash. 10ml (1:1) Dichloromethane : Hexane were added, and the eluent were collected, before the column head dried off. Using a rotary evaporator, the eluent were then concentrated to 2ml and was analyzed using Gas Chromatography Mass Spectroscopy (GC-MS). (EPA Method 3630C).

Risk Assessment

Inhalation, ingestion and dermal contact is the three major routes of absorption for toxicant in the body. Dermal or skin contact and inhalation is the major pathway for dust particles that populations are exposed to in road dust. The USEPA (1991, 2002, and 2007) emphasized the following formulae for the calculation of health risk for dermal and inhalation.

$$\text{CDI dermal} = \frac{C \times SA \times AF \times ABS \times EFED}{BW \times AT} \times CF$$

$$\text{CDI inhale} = \frac{C \times InhR \times EF \times ED}{PEF \times BW \times AT}$$

Where CDI is the Chronic Daily Intake of PAHs.

C is the concentration of PAHs in dust ($mgkg^{-1}$)

CF; Conversion factor is 1×10^{-6},

BW; the average body weight is 70 kg,

AT; the averaging time is 25,550 days.

EF; the exposure frequency is 180 days per year.

ED; exposure duration is 24 years,

InhR; the inhalation rate is 20 m^3day^{-1}

PEF; the particle emission factor is 1.35×109 m^3kg^{-1}.

SA; the skin surface area is 3300 cm^{-2},

AF; the skin adherence factor is 0.07 $mgcm^{-2}$,

ABS; the dermal absorption factor is 0.13

The Risk characterization were calculated for non-carcinogenic and carcinogenic

Hazard Quotient (HQ)

The hazard quotient is the ratio of a substance's potential exposure to the concentration at which no negative consequences are predicted. If the Hazard Quotient is assessed to be less than 1, then exposure is not anticipated to have any negative consequences on health. HQ will be calculated for both the dermal contact and inhalation.

$$HQ = \frac{CDI}{RfD}$$

where;

HQ is the Hazard Quotient

CDI is the Chronic Daily Intake of PAHs.

RfD is the Reference Dose

Hazard Index

The total of the HQs for all routes and equivalent harmful consequences is known as the Hazard Index (HI). For any particular route, an HQ of 0.2 and an HI of 1.0 are frequently regarded as appropriate (USEPA, 2000). HI will be calculated for both the dermal contact and inhalation.

Samples Location	**Conoil Stop**		**BusThe company**		**starRubee Road**		**medicalAli Isiba**		**Iyana Joju Road**	
Congeners	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
Naphthalene	0.01	0.00	0.01	0.00	0.28	0.01	0.22	0.01	0.01	0.00
Acenaphthylene	0.01	0.00	0.01	0.00	0.20	0.00	0.30	0.11	0.01	0.00
Acenaphthene	0.01	0.00	0.01	0.01	0.32	0.11	0.25	0.11	0.01	0.00
Fluorene	0.01	0.00	0.01	0.00	0.61	0.20	0.23	0.10	0.01	0.00
Phenanthrene	0.01	0.01	0.01	0.00	0.16	0.20	0.23	0.10	0.01	0.00
Anthracene	0.02	0.01	0.02	0.01	0.27	0.10	0.23	0.01	0.02	0.00
Fluoranthene	0.02	0.00	0.03	0.01	0.33	0.11	0.24	0.01	0.02	0.00
Pyrene	0.01	0.00	0.00	0.00	0.26	0.02	0.22	0.00	0.01	0.00
Benzo[c]phenanthrene	0.05	0.03	0.06	0.03	0.49	0.02	0.30	0.10	0.15	0.10
Benz[a]anthracene	0.05	0.01	0.05	0.01	0.41	0.01	0.25	0.10	0.15	0.10
Chrysene	0.04	0.02	0.05	0.02	0.63	0.42	0.27	0.01	0.04	0.02
Benzo[a]pyrene	0.10	0.00	0.10	0.02	0.81	0.01	0.33	0.00	0.13	0.01
Indeno[1,2,3,-cd]pyrene	0.10	0.01	0.11	0.01	1.16	1.10	1.07	1.01	0.12	0.01
Dibenz[a,h]anthracene	0.18	0.10	0.18	0.12	1.16	1.10	1.07	1.01	0.14	0.01
Benzo[ghi]perylene	0.09	0.04	0.09	0.06	0.72	0.21	0.33	0.10	0.13	0.01
Dibenzo[a,l]pyrene	0.23	0.10	0.24	0.11	0.61	0.11	0.24	0.01	0.32	0.11
Dibenzo[a,i]pyrene	0.35	0.20	0.35	0.20	2.33	2.00	0.68	0.01	0.25	0.10
Dibenzo[a,h]pyrene	0.32	0.12	0.32	0.12	ND	ND	ND	ND	0.22	0.10
Benzo[h]fluoranthene	ND	ND	ND	ND	0.57	0.23	0.35	0.11	ND	ND

Benzo[j]fluoranthene	ND	ND	ND	ND	0.47	0.21	0.23	0.01	ND	ND
Benzo[k]fluoranthene	ND	ND	ND	ND	0.47	0.21	0.23	0.10	ND	ND
3-Methyl cholanthracene	ND	ND	ND	ND	10.47	1.48	1.59	1.10	ND	ND
∑PAH	1.74	0.85	1.80	0.77	23.31	7.81	9.06	3.63	1.90	0.66

$$HI = \sum_{i=1}^{n} HQ$$

Where,

HI = Hazard Index

i = 1….n

N = numbers of element observed

HQ>1 denotes non-carcinogenic adverse health effects, HQ<1 denotes no adverse effects,

Cancer Risk

CR = CDI ×SF

SF = Slope factor

Results and discussions

Table1: The Concentration of PAH constituents in the dust along Otta Road, Ogun State, Nigeria.

Table 2: Chronic Daily Intake of Selected PAH for dermal contact and inhalation

Sample	CDI ($mgkg^{-1}$)	Anthracene	Benzo(c) Phenanthrene	Benzo(a) anthracene	Benzo(a) pyrene	Indeno(1, 2.3- cd)pyrene
A1	Dermal	1.45E-9	3.36E-9	3.63E-9	7.25E-9	7.35E-9
	Inhalation	7.11E17	1.78E15	1.78E15	3.55E18	3.55E-8
A2	Dermal	1.45E-9	4.35E-9	3.63E-9	7.25E-9	7.89E-9
	Inhalation	7.11E17	2.13E18	1.78E15	3.55E-8	8.91E18
A3	Dermal	1.96E-8	3.55E-8	2.97E-8	5.88E-8	8.41E-8
	Inhalation	9.59E18	1.74E18	1.46E19	2.88E19	4.12E19
A4	Dermal	1.67E-8	2.18E-8	1.8E-8	2.39E-8	7.76E-8
	Inhalation	8.17E18	1.06E19	8.88E18	1.17E19	3.80E19
A5	Dermal	1.45E-9	1.09E-8	1.09E-8	9.43E-9	8.7E-9
	Inhalation	7.11E17	5.33E18	5.33E18	4.62E18	4.26E18

A1= Conoil Bus Stop, A2 = The star company, A3 = Rubee medical Road, A4 = Ali Isiba A5 = Iyana Joju Road

Table 3: Hazard Quotient

Sample	HQ	Anthracene	Benzo(a) Anthracene	Benzo(a) Pyrene	Indeno(1,2,3-cd) Pyrene	HI
A1	Dermal	4.83E.-9	3.63E-9	2.42E-5	2.42E-7	1.49E21
	Inhalation	2.37E18	1.78E15	1.18E22	1.18E20	
A2	Dermal	4.83E-9	3.63E-9	2.42E-5	2.66E-7	1.49E21
	Inhalation	2.37E18	1.78E15	1.18E22	1.30E20	
A3	Dermal	6.53E-8	2.97E-8	1.96E-4	2.8E-6	1.2E22
	Inhalation	3.2E10	1.46E10	9.6E22	1.37E21	
A4	Dermal	5.27E-8	1.81E-8	8.0E-5	2.59E-6	5.0E21
	Inhalation	2.72E19	8.88E18	3.9E22	1.29E21	
A5	Dermal	4.83E-9	1.09E-8	3.14E-5	1.42E22	3.9E21
	Inhalation	2.37E18	5.33E18	1.54E22	1.42E21	

A1= Conoil Bus Stop, A2 = The star company, A3 = Rubee medical Road, A4 = Ali Isiba A5 = Iyanu Joju Road

Table 4: Cancer Risk for dermal contact and inhalation.

Sample	Cancer risk	Anthracene	Benz(a)Anthracene	Benzo(a) Pyrene	Indeno(1,2,3,- cd)pyrene
A1	Dermal	1.45E-9	2.65E-9	1.67E-8	5.29E-9
	Inhalation	7.11E17	1.30E15	8.17E18	2.59E18
A2	Dermal	1.45E-9	2.65E-9	1.67E-8	5.63E-9
	Inhalation	7.11E17	1.30E15	8.17E18	2.85E18
A3	Dermal	1.96E-8	2.17E-8	1.35E-7	6.14E-8
	Inhalation	9.59E18	1.07E19	6.62E19	3.01E19
A4	Dermal	1.67E-8	1.32E-8	5.5E-8	5.66E-8
	Inhalation	8.17E18	6.48E18	2.7E-19	2.77E19
A5	Dermal	1.45E-9	7.96E-19	2.17E-18	6.35E-19
	Inhalation	7.11E17	3.89E18	1.06E19	3.11E18

A1= Conoil Bus Stop, A2 = The star company, A3 = Rubee medical Road, A4 = Ali Isiba A5 = Iyanu Joju Road

Discussion

The values of PAH congeners in dust samples collected in Sango Otta ranged from 23.32 mg kg^{-1} - 1.75 mg/kg^{-1}, with an average of 1.75 mg/kg^{-1} as shown in Table 1. Rubee Medical Center Road had the greatest concentration of total PAHs, which were measured at 23.31 mgkg-1, whereas Con Oil Bus Stop Sango Otta had the lowest concentration, 1.74 $mgkg^{-1}$. 3-Methylcholanthracene (10.47±1.48 $mgkg^{-1}$) was the main congener identified in the Rubee Medical Center road dust sample. When exposed, it can cause hepatotoxicity, nephrotoxicity, and have harmful effects on the immune system. (USEPA 2002) ~~Additionally,~~ Dibenzo(a,i)pyrene (0.35±0.20 $mgkg^{-1}$) were the most significant PAH congener detected in the Con oil bus stop. This substance is carcinogenic in nature and has been linked to skin, lung, and bladder cancer in both people and animals (ATSDR. (1995). Dibenzo(a,i)pyrene (0.35±0.20 $mgkg^{-1}$) is another large congener that was detected at the Star Company site and puts people at risk for developing cancer. 3-Methylcholanthracene (1.59± .60 $mgkg^{-1}$) were the highest congener found in Ali Isiba which is carcinogen in nature producing neoplastic responses from various routes of exposures including dermal exposure, parenteral, subcutaneous, intravenous and oral. 3-Methylcholanthracene is also nephrotoxic, hepatotoxic and immunotoxic. 3-MC has also reported to cause anemia, agranulocytosis leukopenia (ATSDR. (1995).

Dibenzo(a,I)pyrene (0.32± .11 $mgkg^{-1}$) was the most significant congener detected in Iyana Joju Road and it is also carcinogenic. The operations of the industries along the road and the PAH deposits discharged into the atmosphere by nearby automobiles contributed to the elevated levels of PAH congeners. The road also has more dust since all the roads are not paved. The outcome is somewhat identical to that in Shanghai, where researchers characterized and identified road dust PAHs in southern China, in the Central Shanghai Area, ranging from 6.88 to 32.6 $mgkg^{-1}$ (Liu *et al*. 2007). Guangzhou (0.84to 12.3 $mgkg^{-1}$, and Dalia (1.89 to 17.1$mgkg^{-1}$ in China (Wang *et al.,* 2011; Wan *et al.,* 2006). The diffusion of PAHs in the atmosphere is greatly influenced by the weather condition.

PAHs in urban street dust are not readily dispersed due to a number of climatic conditions, including the low annual average temperature, wind, and rainfall. In the locations Con Oil bus stop, The Star Company, and Iyana Joju Road, naphthalene, acenaphthalene, and fluorene were not found. Con Oil bus stop and Iyana Joju road sites did not contain any acenaphthene or pyrene. Similar compounds are Anthracene, Fluoranthene, Benzo(c)phenanthrene, Benz(a)anthracene, Chrysene, Benzo(e)pyrene, and Indeno(1,2,3-cd).Pyrene and dibenzo(a,i)pyrene were the PAH compounds found in the dust the most often.

In Table 2, which shows the chronic daily intake of PAH found in dust samples, an adult weighing 70 kg is exposed to some level of dust 180 days out of every year. The outcome demonstrates that the maximum dosage of consumption 9.12×10^{18} $mgkg^{-1}day$ were obtained by inhalation, while the lowest dose 1.45×10^{-9} $mgkg^{-1}day$ were obtained through cutaneous exposure indeno(1,2,3-cd)pyrene and anthracene, respectively. The reason for this is that whereas PAHs applied to the skin do not immediately enter the bloodstream, those that are breathed do. Inflammation or swelling of the stomach and intestine are other symptoms of anthracene exposure, along with headaches, nausea, and appetite loss (ATSDR). Indeno(1,2,3-cd)pyrene is carcinogenic in humans because it has been shown to cause skin and lung cancer in animals, it also has the potential for causing reproductive damages in humans.

The daily intake of anthracene ranged from 1.45E-9 to 9.59E18 $mgkg^{-1}day^{-1}$; for benzo(c)phenanthrene, it ranged from 3.36E-9 to 5.33E18 $mgkg^{-1}day^{-1}$; for benzo(a)anthracene, it ranged from 7.25E-9 to 1.17E19 $mgkg^{-1}day^{-1}$; and Benz[a]pyrene ranges from 7.25E-9 to 4.12E19 $mgkg^{-1}day^{-1}$. The majority of the effects of exposure to these PAHs are cancer, but some of them can also have mutagenic, immunological, reproductive, and gastrointestinal effects (Philips *et al*., 1973).

The information about the hazards that are absorbed by the human body by inhalation and cutaneous exposure is shown in Table 3. The HQ values that were less than 1.0 indicate that exposure had no carcinogenic side effects. Due to the volume of anthropogenic activities, Rubee Medical Center and Ali Isiba Road were discovered to have the highest Benzo[a]pyrene (Bap) Hazard Quotients. One of the most dangerous PAHs is rap. Neuro-behavioral impacts, decreased fertility, and poor birth outcomes (such as lower birth weight and postnatal head size) are all non-carcinogenic negative consequences of Bap. (TOXNET 2017).

The cancer risk information for each PAH congener found in the dust samples are shown in Table 4. The largest cancer risk is associated with anthracene, which ranges from 1.45E-9 to 9.59E18. Since there is a significant quantity of anthracene in the dust sample near the Con oil bus stop, it is possible for people to get cancer over the course of their lifetimes from inhalation and skin exposure. Cancer risk levels were also found to be greater than the USEPA permissible limit of 0.2 mg/m3 when PAHs were examined in dust samples. Anthracene causes stomach and intestinal bloating, headaches, nausea, and decreased appetite. (ATSDR). Table 4 showed the total data for cancer risk (CR). The least is Benz(a)anthracene. The CR values in the dust are over USEPA's priority level. When subjected to, the highest values of CR have the potential to result in cancer.

Conclusion and recommendations

The concentration and main sources of PAHs, in Sango Otta are emissions from machinery and generators used by the local industries. Other sources include vehicle exhaust emissions, coal and petroleum combustion. This study was able to determine that the area with the highest PAH contamination were the Rubee Medical Center, where the congener with the highest concentration 3-Methylcholanthracene causes hepatotoxicity, nephrotoxicity, and immune toxicity when exposed and the area with the lowest contamination were the Con Oil Bus Stop. The presence of too many industries in the vicinity and the exhaust from (vehicular movement) were found to be the toxins' sources. As determined by the Hazard Quotient (HQ) of PAH in dust sample, there is no non-carcinogenic health concern. Anthracene and Benzo[a]pyrene were major contributors to the adverse effect in dust samples due to their

carcinogenicity. The components of road dust particles such as PAHs has been found to be related with many health effects.

Based on the result obtained, it is recommended that the public should be educated about the dangers of dust on their health and federal government should implement mitigation measures to regulate the amount of industrial effluent released into the environment.

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