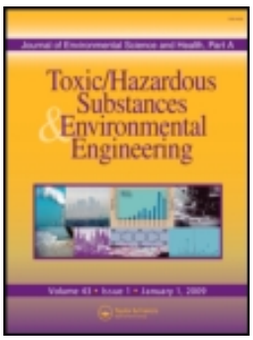

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Journal of Environmental Science and Health, Part A
Toxic/Hazardous Substances and Environmental Engineering

ISSN: 1093-4529 (Print) 1532-4117 (Online) Journal homepage: https://www.tandfonline.com/loi/lesa20

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To cite this article: Samuel Obiri , Samuel J. Cobbina , Frederick A. Armah & Isaac Luginaah (2013) Assessment of cancer and noncancer health risks from exposure to PAHs in street dust in the Tamale Metropolis, Ghana, Journal of Environmental Science and Health, Part A, 48:4, 408-416, DOI: 10.1080/10934529.2013.728914

To link to this article: https://doi.org/10.1080/10934529.2013.728914

Journal of Environmental Science and Health, Part A (2013) **48**, 408–416

ISSN: 1093-4529 (Print); 1532-4117 (Online)
DOI: 10.1080/10934529.2013.728914

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Assessment of cancer and noncancer health risks from exposure to PAHs in street dust in the Tamale Metropolis, Ghana

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This study is part of a broader initiative to characterize, quantify and assess the human health risk associated with exposure to polycyclic aromatic hydrocarbons (PAHs) in street dust along the Trans-ECOWAS highway in West Africa. In the first part, PAHs were characterized and quantified in low- and high-traffic zones. In this study, cancer and noncancer human health risks from exposure to (PAHs) in street dust in the Tamale metropolis, Ghana were assessed in accordance with the USEPA risk assessment guidelines. The results of the study as obtained from inhalation of benzo [a] anthracene (BaA), benzo [a] pyrene (BaP), benzo [k] fluoranthene (BkF) and chrysene via central tendency exposure parameters (CTE) by trespassers (street hawkers including children and adults) in street dust within low traffic zones in the Tamale metropolis are 1.6E-02, 4.7E-02, 1.8E-03, and 1.6E-04 respectively. For reasonable maximum exposure parameters (RME), risk values of 1.2E-01, 3.5E-01, 1.3E-02 and 1.2E-03 respectively were obtained for benzo [a] anthracene, benzo [a] pyrene, benzo [k] fluoranthene and chrysene. Hazard index for acenaphthene, anthracene, fluoranthene, fluorine, naphthalene and pyrene in the CTE and RME scenarios were 2.2, 3.E-01, 2.6, 2.6, 100, 38 and 12, 1.7,15, 14, 550, 210 respectively. Generally, the cancer health risk associated with inhalation of benzo [a] anthracene, benzo [a] pyrene, benzo [k] fluoranthene and chrysene revealed that resident adults and children in the Tamale metropolis are at risk from exposure to these chemicals. The results of this preliminary assessment that quantified PAH related health risks along this part of the Trans-ECOWAS highway revealed that, there is the need for regulatory agencies to put in comprehensive measures to mitigate the risks posed to these categories of human receptors.

Keywords: Carcinogenic, non-carcinogenic, health risks, central tendency exposure, reasonable maximum exposure, benzo[a] anthracene, benzo [a]pyrene, dust.

Introduction

From ecological monitoring and human health perspectives, establishing information on presence, distribution, and quantities of contaminants in samples from different matrices such as water, soil, air, sediments, and biota provides useful information for environmental risk assessment.[1] Biota are considered as better indicators for use in the investigation of pollutant loads than other ecological receptors because of the significant levels of metals they bioaccumulate. Human beings are exposed to polycyclic aromatic hydrocarbons (PAHs) from occupational, environmental, medicinal and dietary sources.

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Received March 23, 2012.

PAHs consist of carbon and hydrogen atoms arranged in two or more fused aromatic rings. They exhibit zero or very slight dipole-moments, large molecular surface areas, and no capability for hydrogen-bonding. Consequently, low aqueous solubility, semi-volatility, high octanol–water partition coefficient (K*ow*), stability and their potential or proven carcinogenicity make them of considerable ecotoxicological concern.[2] PAHs are mainly generated from incomplete combustion and pyrolysis of organic material, such as wood, coal, oil, petrol and plastics.[3,4] Numerous studies have reported elevated PAH concentrations in urban soils and sediments.[5–7] Owing to their carcinogenic and noncarcinogenic properties and widespread distributions in the global environment, PAHs have attracted the attention of sundry environmental chemists and regulatory agencies for many years. Automobile exhaust, industrial emission and smoke from burning of wood, charcoal and tobacco contain high levels of PAHs.

Automobiles especially the heavy duty vehicles run on diesel that release large concentrations of different types of PAHs into the ambient air in Tamale, Northern Ghana along high and low vehicular densities roads. With the establishment of the Trans ECOWAS (Economic Community of West African States) highway policy which seeks to link all member states by road in order to facilitate trade, investment and regional integration, the density of vehicles that ply Tamale metropolis is expected to rise.[8]

The Tamale metropolis lies along the ECOWAS (Economic Community of West African States) international highway. Most heavy duty vehicles running on diesel or petrol use road networks in the metropolis to land-locked countries like Burkina Faso, Niger and Mali. Yet, very little work has been conducted in the Tamale metropolis to determine the concentrations and the human health risk of PAHs in street dust.[9] Data derived from this study will serve as baseline for future studies. Quantification and characterization of different types of PAHs in vehicular fallouts in street dust is essential to pollution control and risk management.

According to a study by Obiri et al.,[9] 13 different PAHs were found in street dust from low and high vehicular densities in the Tamale metropolis. The PAHs are: benzo [a] pyrene, benzo [a] anthracene, chrysene, naphthalene, anthracene, fluorene, pyrene, fluoranthene, acenaphthylene, acenaphthene, phenanthrene, benzo [g,h,i] perylene and benzo [k] fluoranthene. According to US EPA classification of carcinogenic chemicals, benzo [a] pyrene, benzo [a] anthracene, benzo [k] fluoranthene and chrysene are known human carcinogens and as such their presence in the environment may pose significant health risk to residents of the Tamale metropolis. In this work, PAHs pollution from vehicular emissions was measured in street dust from high and low vehicular traffic densities in Tamale metropolis. The human health risks associated with exposure to the PAHs from the vehicular emissions in the street dust was quantified. Thus, the main thrust of this work was to assess human health risks associated with exposure to the PAHs in street dust at the selected traffic zones in Tamale metropolis.

Materials and methods

Study area

Tamale is an important agricultural region for the country, producing some of the most important food crops consumed in the country like maize, rice sorghum, millet, yam, cassava and groundnuts (Fig. 1).[10] Consequently, the already high vehicular movement within the area is expected to intensify as the Trans ECOWAS becomes more operational.

Sampling techniques

Random sampling technique was adopted in obtaining samples from road dust from high traffic (500 hundred vehicles per h) and low traffic (20 vehicles per h) points,

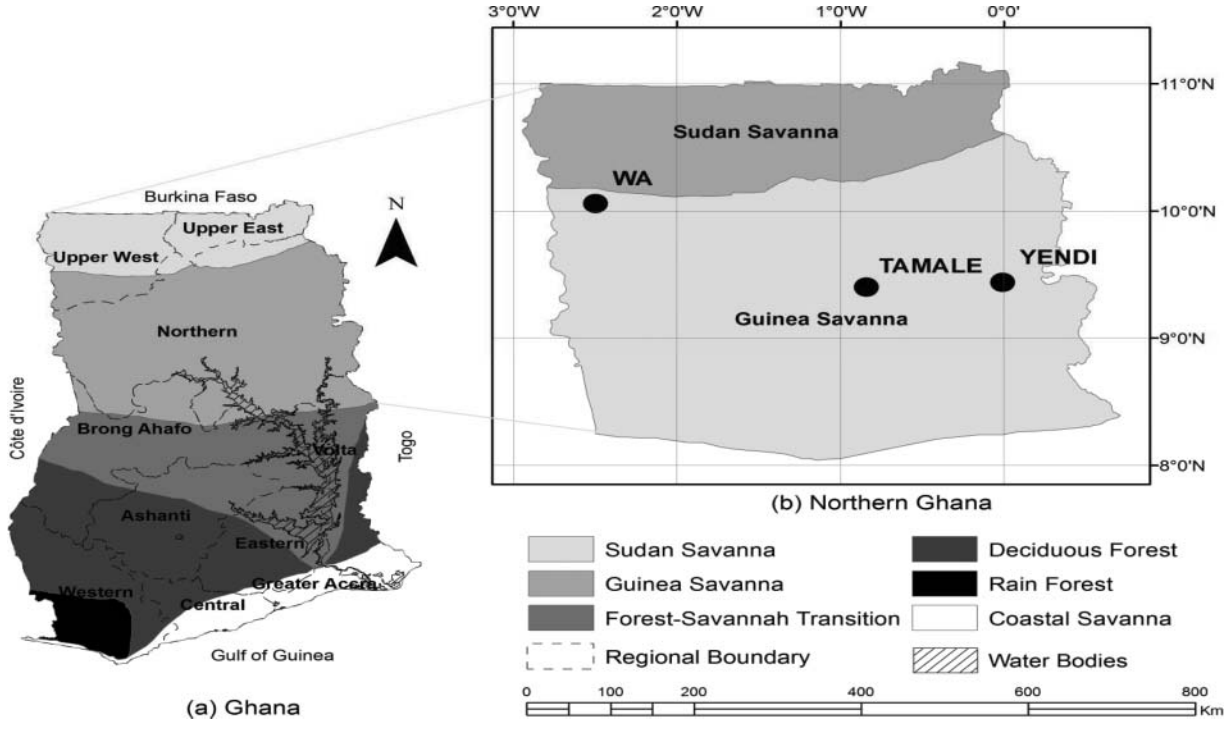

Fig. 1. Map of the Northern region of Ghana showing Tamale source.

Table 1. Total number of samples collected for the study.

	Zones				
Sample category	*Zone 1*	*Zone 2*	*Zone 3*	*Zone 4*	*Total*
High Vehicular Traffic	16	16	16	16	64
Low Vehicular Traffic	16	16	16	16	64
Total	32	32	32	32	128

respectively, in the metropolis. Each traffic point was zoned into four different categories using air samplers. In all 128 atmospheric dust samples were taken from different streets in each zone in 2010 as shown as in Table 1. The samples were put together after which a representative sample (laboratory sample) was obtained from the composite sample.

Sample collection and preparation

The samples were obtained from street dust from each of the four zones using aluminium foil. The samples were put into amber glass containers and sealed with an aluminium foil. The samples were stored in an ice chest at 4°C and conveyed to the laboratory. In the laboratory the samples were freed from stones and other foreign materials and air-dried to a constant weight, ground with mortar and pestle and then sieved through a 200 μm mesh.

Analysis of PAHs

First, 10 g of a crushed, air-dried and homogenized sample was put into of a Soxhlet thimble. 120 mL of dichloromethane was put into a round-bottom flask. The Soxhlet apparatus was assembled and the spiked sample was extracted for PAHs for 6 h. The Soxhlet apparatus was cooled to room temperature before removing the solvent.

For high-level contaminated samples, the solvent was carefully and quantitatively transferred from the round–bottom flask into a stoppered measuring cylinder. The flask was rinsed with 2 mL dichloromethane and added to the content of the measuring cylinder. The contents of the measuring cylinder were thoroughly mixed. Then, 5 mL of this solution was pipetted into 50 mL beaker and 0.5 g of activated alumina was added to it. The content of the beaker was swirled and then allowed to evaporate. A glass-fritted chromatographic column was set up containing activated silica gel to a depth of 60 mm, and covered with 0.5 g of activated alumina containing 5 mL of the PAH extract to a depth of 30 mm. the column was conditioned by passing 20 mL of pentane through the column.

The pentane eluate was discarded, after which 25 mL of dichloromethane was added to the silica gel column. The eluate was collected and was quantitatively transferred into a rotary evaporation apparatus. The flask was rinsed with 10 mL of dichloromethane and was then added to the Soxhlet apparatus. The volume was reduced to 1.0 mL, and was quantitatively transferred to a GC-MS vial. 200 μL of working deuterated p-terphenyl PAH internal standard was added to the GC-MS vial. The vial was sealed tightly with a crimp top for the chromatographic determination of various types of PAHs.

For low-level contaminated samples, the solvent in the round-bottom flask was quantitatively transferred into a rotary evaporation apparatus. The flask was rinsed with 2 mL of dichloromethane and the solvent was added to the rotary evaporation apparatus. The contents of the rotary evaporatory were rinsed with 10 mL of dichloromethane and the solvent was added to the beaker. The alumina residue was transferred from the beaker to the top of the column containing the alumina and silica gel and eluted with 20 mL of pentane, the pentane eluate was discarded.

A clean rotary evaporation apparatus was placed beneath the column and the PAHs eluted from the column with 25 mL of dichloromethane. The eluate was collected. The extract was rinsed with 2 mL of dichloromethane and then the solvent added to the rotary evaporatory apparatus. The volume was reduced to 1.0 mL, after which the solution was quantitatively transferred to GC-MS vial. Then, 200 μL of working deuterated p-terphenyl standard was used as an internal standard was added to the GC-MS vial. The vial was sealed tightly with crimp top for the chromatographic determination using the GC-MS chromatogram. The efficiency of the solvent extraction process was determined as 87.54%.

Recovery and reproducibility studies were conducted during which the sample was cautiously spiked by adding 1.00 mL of working deuterated surrogate standard solution (i.e., 100 g of deuterated p – terphenyl) in the thimble. The thimble was then placed in a clean soxhlet funnel. 98.6% recovery was recorded in the recovery and reproducibility studies.

Risk assessment process

Risk assessment is defined as the process of estimating the probability of the occurrence of an event and the probable magnitude of adverse health effects on human exposures to environmental hazards.[11– 13] Risk assessment for humans requires specific methods, which must reflect the peculiarities of human behaviour, physiology and biochemistry with respect to contaminant uptake and processing. It consists of four interactive steps, namely: the hazard identification, exposure assessment, toxicity assessment and risk characterization. This study assessed cancer and noncancer health risk to a resident adult, a trespasser and a child in the Tamale metropolis exposed to PAHs in street dust. The hazard identification process was accomplished through field sampling of contaminated street dust, and the subsequent determination of the contaminant levels for PAHs in these samples.

Exposure assessment

The exposure assessment identifies the pathways by which humans are potentially exposed to toxicants and estimates the magnitude, frequency and duration of these actual and/or potential exposures. Relevant human exposure pathways include inhalation of soil particles, skin contact or ingestion.[14–16] Generally, different intake routes concomitantly contribute to an overall exposure, but to variable extents dependent on occupational or recreational activities and on age-specific behaviours. Contaminant inhalation of soil as particulate matter is considered of minor importance.[17] Ingestion of soil is of particular relevance for children playing at contaminated sites due to their hand-to-mouth activities.[18] Additionally, it is being discussed that children could be more susceptible to toxic effects than adults.[19,20]

In this study, the exposure assessment involved the analysis contaminant releases, identifying exposed populations, identification of potential pathways of exposure, estimating exposure point concentrations for specific pathways and estimating contaminant intakes for specific pathways. The average daily dose (ADD) of the contaminant via the identified pathways (i.e., inhalation, oral and dermal exposure pathways) is the quantity of PAH ingested per kilogram of body weight per day that resident children in the study area are exposed to.[11,12] In calculating the average daily dose, Eq. 1 was used:

$$\mathrm{ADD} = \frac{\mathrm{C} \times \mathrm{IH_C} \times \mathrm{ED} \times \mathrm{EF}}{\mathrm{BW} \times \mathrm{AT} \times 365} \qquad (1)$$

where C is the concentration of the contaminant in the environmental media (mg/kg or mg/L), IH_c is the inhalation rate per unit time (mg/m^3/day), ED is the exposure duration (years), EF is the exposure frequency (days/year), BW is the body weight of the receptor (kg), and AT is the averaging time (years), equal to the life expectancy for noncarcinogen, and 365 is the conversion factor from year to days. The values of C, IR, ED, EF, BW and AT which were used in equation (1) above have been presented in Table 2. With the exception of BW, the rest were default values in Human Health Risk Assessment Computerized Software, RISC version 4.02 developed by US EPA for the Superfund sites.

The exposure scenario evaluated in this study is a residential setting. In this scenario, inhalation of PAHs in street dust in the study area by resident children, trespassers and adults were evaluated based on both Central Tendency Exposure (CTE) and Reasonable Maximum Exposure (RME) parameters, respectively. The CTE exposure parameters were used so that health risks associated with typical or average exposures to the constituents of concern (COCs) could be calculated based on the 50th percentile of the mean concentration of the COCs. RME parameters were also used to calculate the health risks associated with high-end exposures also based on 95th percentile of the mean concentration of the COCs. The potential receptors evaluated in this study are resident children aged between 2 and 19 years, whilst the adults were between the ages 20–60 years. The trespassers are adults who sell along the high and low vehicular traffic points in Tamale Metropolis.

Toxicity assessment

To evaluate carcinogenic and noncarcinogenic health risk associated with exposure to PAHs in street dust by resident children and adults in the study area, toxicity assessment was carried out using oral reference dose from IRIS (Integrated Risk Information Systems) database. Default values from RISC 4.02 human health evaluation software were used. The basis for these values has been described in detail in the USEPA Child - Specific Exposure Factors Handbook.[21] The oral Reference Dose (RfD) is based on the assumption that thresholds exist for certain toxic effects such as cellular necrosis or tremor. It is expressed in units of mg/kg-day. In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.[22]

Table 2. Exposure factors for a resident child and adult in Tamale metropolis.

Factor/Parameter	*Symbol*	*Units*	*Exposure scenario*	*Data source*
Exposure Duration	ED	20 years	Outdoor setting (trespassers)	[21,22]
Exposure Frequency	EF	365 days/years	”	[21,22]
Dust Inhalation rate	Ihc	mg/m^3/day	”	[21,22]
Body Weight	BW	13.5 kg	”	[23]
Contaminant Concentration	C	mg/kg	”	Please refer to Table 3 for the analytical concentrations of PAHs in the samples
Averaging Time	AT	225 days	”	[21]

Table 3. Mean concentrations of PAHs in street dust from high and low vehicular traffic densities in Tamale Metropolis, Ghana.

		High traffic area		*Low traffic area*	
Compound	*m/e*	*Mean conc. mg/m³*	*Percentage of the PAH in the sample area (%)*	*Mean conc. mg/m³*	*Percentage of the PAH in the sample area (%)*
Naphthalene	128	52.352	1.78	20.207	2.65
Acenaphthene	154	478.693	16.25	31.493	4.12
Fluorene	166	128.319	4.36	24.442	3.20
Phenathrene	178	291.208	9.88	58.969	7.72
Anthracene	178	152.884	5.19	21.840	2.86
Fluoranthene	202	290.815	9.87	24.785	3.25
Pyrene	202	983.154	33.37	264.377	34.63
Benzo [a] anthracene	228	165.056	5.60	93.252	12.21
Chrysene	228	98.847	3.35	93.252	12.21
Benzo [k] fluoranthene	252	192.737	6.54	103.068	13.50
Benzo [a] pyrene	252	112.344	3.81	27.828	3.64

Risk characterisation

The noncarcinogenic health risk causes several harms to the human body and one of them is damage done to the central nervous systems due to exposures to neurotoxic chemicals. The extent of the harm incurred is expressed in terms of hazard quotient as shown in Eq. 2 here:

$$\text{Hazard Quotient (HQ)} = \text{ADD/RfD} \qquad (2)$$

where RfD_{oral} is the oral reference dose. The reference dose is the daily dosage that enables the exposed individual to sustain this level of exposure over a prolonged time period without experiencing any harmful effect.

In accordance with USEPA risk assessment guidelines,[23] hazard quotients are calculated for each receptor and exposure route, and then summed across the different exposure routes to calculate the hazard index. Hazard index (HI) indicates whether the estimated exposures for individual present a potentially significant noncancer health risk based on comparison to a USEPA recommended RfD_{oral}. If the HI is less than 1.0, then the noncarcinogenic adverse effect due to this exposure pathway or chemical is assumed to be negligible. In this study, default values from RISC 4.02 software were used as input values for oral reference dose, dermal reference dose and inhalation reference dose for the 13 different PAHs identified in street dust in Tamale metropolis.

Cancer risks are expressed as unitless probability (e.g., one in million, or 1×10^{-6}) of an individual developing cancer over a lifetime from exposure to carcinogenic PAHs

Table 4. Comparing the mean concentrations of PAHs in street dust from Tamale metropolis to the Kumasi metropolis.

		Tamale metropolis		
Compound	*m/e*	*Mean conc. (high and low traffic areas - μg/kg*	*Standard deviation*	*Kumasi metropolis mean conc. (high and low traffic areas - μg/kg*
Naphthalene	128	6,930	3,100.86	41,700
Acenaphthene	154	40,500	3,563.60	111,200
Fluorene	166	1.12E4	7.685E3	8,900
Phenathrene	178	24,050	1601.40	12,900
Anthracene	178	12,000	9,038.18	5,400
Fluoranthene	202	19,100	1,616.13	16,200
Pyrene	202	7.55E4	4.357E4	15,000
Benzo [a] anthracene	228	13,850	3,868.83	13,800
Chrysene	228	10,300	359.57	33,600
Benzo [k] fluoranthene	252	14,350	4,370.75	45,700
Benzo [a] pyrene	252	6,800	4,122.61	27,900
Carbazole	167	—	—	3,500
Perylene	252	—	—	57,200
Benzo [ghi] perylene	276	40,500	3,563.96	47,000
Acenaphthylene	152	8,200	4,821.72	99,300

in street dust in Tamale metropolis. In this study, the estimated intakes (from the exposure assessment) and the cancer slope factors (from the toxicity assessment) were combined to calculate the cancer health risk using Risk 4.02 Software developed by USEPA for Superfund Sites.[24,25]

Results and discussion

The results of the various types of PAHs identified in street dust from vehicular fallout in Tamale metropolis and their concentrations have been presented in Table 3. From Table 3, 11 different types of PAHs were identified in street dust from vehicular movement. The concentrations of the various types of PAHs identified in high vehicular traffic ranged from 52.352 mg/m^3 (naphthalene) to 983.154 mg/m^3 (pyrene), while in the case of low vehicular traffic, it ranged from 20.207 mg/m^3 (naphthalene) to 264.377 mg/m^3 (pyrene). The concentration of pyrene was the highest for both high vehicular traffic (i.e.983.154 mg/m^3) and low vehicular traffic density (i.e., 264.377 mg/m^3). This suggests that there is high persistence of this type of PAH in the environment.

Although health effects of breathing high concentrations of pyrene is not known, contact with the skin can cause several diseases such as blistering or redness of the skin, which may lead to peeling of the skin. Much concerted effort is required to reduce the levels of pyrene in the Tamale environment.

Again from Table 3, the concentration of benzo[a]pyrene in dust samples from high vehicular traffic point was 112.344 mg/m^3, yet that from low traffic point was 27.828 mg/m^3. Benzo [a] pyrene is a common PAH and is known to cause lung and skin cancer in laboratory animals. The United States of America Environmental Protection Agency (USEPA) has classified benzo [a] pyrene as a class B2 human carcinogen.[26] This implies that exposure to this carcinogenic chemical in Tamale metropolis by street hawkers will pose a health hazard to them.

According to Essumang et al.[26], 15 different PAHs were found in street dust in Kumasi metropolis of Ghana. The PAHs identified were naphthalene, acenaphthylene, acenaphthene, fluorine, carbazole, phenanthrene, anthracene, fluoranthene, pyrene, benzo [a] anthracene, chrysene, benzo [k] fluoranthene, benzo [a] pyrene, perylene and benzo [ghi] perylene. Table 4 compares the mean concentrations of PAHs measured in Kumasi metropolis with that obtained in this work.

The *t*-test was carried out to ascertain whether there were statistically significant differences between PAH concentrations in Tamale and Kumasi. The results indicated *p*-value $= 0.01569$ at α-level of 0.05. Consequently, the null hypothesis of no difference between the mean PAH concentrations in Tamale and Kumasi was rejected. Comparing the results of mean concentrations of the various types of PAHs from both high and low vehicular sampling points in Tamale metropolis with that of the Kumasi metropolis, it can be inferred that the concentrations of naphthalene, acenaphthylene, fluorene, phenanthrene, fluoranthene and pyrene in street dust in Tamale metropolis were higher than the levels obtained in Kumasi metropolis.

This is due to the fact that Tamale metropolis serves as host to the ECOWAS highway and as such receive a lot of high duty vehicles that runs on fossil fuels. Chemical finger printing are among the commonest techniques used to identify potential sources of PAHs based on the similarities and differences that exist between different PAH components.[27] For example, fluoranthene is a universal product of combustion of organic matter and is present in fossil fuel products while phenanthrene has petroleum combustion and diagenetic origin.[28]

Phenanthrene/anthracene and fluoranthene/pyrene ratios respectively can also be used to distinguish between PAHs of diverse origin. According to Wang et al.[29] the phenanthrene or anthracene is temperature dependent; hence, low ratios of phenanthrene/anthracene shows that the PAHs originated from pyrolytic processes such as fuel combustion in automobiles usually < 10. On the other hand, petrogenic PAHs, formed by the slow maturation of organic matter, typically show higher phenanthrene/anthracene ratios usually > 10.

Also, the ratio of the concentration of fluoranthene to pyrene can also be used to indicate whether the PAH is of pyrolytic or petrogenic origin. High concentration of fluoranthene over pyrene is classically related to the pyrolitic origin. In this study, phenanthrene/anthracene ratio and fluoranthene/pyrene ratio were used to identify whether PAHs measured in street dust from Tamale metropolis were from burning of wood or emitted from vehicles that ply the metropolis. The ratios of concentrations of phenanthrene/anthracene and fluoranthene/pyrene respectively have been presented in Table 5.

From Table 5, it can be seen that values corresponding to phenanthrene/anthracene ratio for both samples from high vehicular traffic and low traffic points in Tamale metropolis is less than 10. This indicates that exhausts from motor vehicle in the metropolis are the major source of PAHs measured in this study. Also, the fluoranthene/pyrene ratio as shown in Table 5 is 0.296 and 0.219, respectively, for both high- and low-vehicular traffic densities in the metropolis, which indicates that PAHs measured in this study are from exhausts of automobiles that ply the Tamale metropolis.

Table 5. Ratios of concentrations of phenanthrene/anthracene and fluoranthene/pyrene in Tamale Metropolis.

Sampling location	*Phenanthrene/ Anthracene*	*Fluoranthene/ Pyrene*
High Vehicular Traffic	1.905	0.296
Low Vehicular Traffic	2.70	0.219

Table 6. Total variance explained by principal components.

	Initial eigenvalues			*Extraction sums of squared loadings*		
Component	*Total*	*% of Variance*	*Cumulative%*	*Total*	*% of Variance*	*Cumulative%*
1	12.699	97.687	97.687	12.699	97.687	97.687
2	.282	2.168	99.855	.282	2.168	99.855
3	.011	.088	99.943	.011	.088	99.943
4	.003	.020	99.963	.003	.020	99.963
5	.002	.015	99.978	.002	.015	99.978
6	.001	.007	99.985	.001	.007	99.985
7	.001	.007	99.992	.001	.007	99.992
8	.000	.003	99.995	.000	.003	99.995
9	.000	.002	99.997	.000	.002	99.997
10	.000	.001	99.999	.000	.001	99.999
11	.000	.001	99.999	.000	.001	99.999
12	$6.250E-5$	.000	100.000	$6.250E-5$	.000	100.000
13	$1.280E-5$	$9.845E-5$	100.000	$1.280E-5$	$9.845E-5$	100.000

Extraction Method: Principal Component Analysis.

Table 7. Cancer health risk results from exposure to chrysene, benzo [a] anthracene, benzo [a] pyrene and benzo [k] fluoranthene in street dust by trespassers, adults and children in high traffic zone in Tamale metropolis.

		Cancer health risk					
		Resident adults		*Trespasser*		*Children*	
Parameter	*Exposure route*	*CTE*	*RME*	*CTE*	*RME*	*CTE*	*RME*
Benzo [a] anthracene	Inhalation	8.2E-02	$6.2E-01$	2.8E-02	2.1E-01	5.1E-01	5.6E-01
Benzo [a] pyrene	Inhalation	3.5E-01	4.2	1.9E-01	1.4	3.5E-01	38
Benzo [k] fluoranthene	Inhalation	9.6E-03	$7.3E-02$	3.3E-03	$2.4E-02$	6.0E-02	6.5E-01
Chrysene	Inhalation	4.9E-04	$3.7E-03$	1.7E-04	$1.2E-03$	3.1E-03	3.3E-03

Table 8. Cancer health risk results from exposure to chrysene, benzo [a] anthracene, benzo [a] pyrene and benzo[k] fluoranthene in street dust by trespassers, adults and children in low traffic zone in Tamale metropolis.

		Cancer health risk					
		Adults		*Trespasser*		*Children*	
Parameter	*Exposure route*	*CTE*	*RME*	*CTE*	*RME*	*CTE*	*RME*
Benzo [a] anthracene	Inhalation	4.6E-02	3.5E-01	1.6E-02	1.2E-01	2.9E-01	3.2
Benzo [a] pyrene	Inhalation	1.4	1.1	4.7E-02	3.5E-01	8.6E-01	9.4
Benzo [k] fluoranthene	Inhalation	5.1E-03	5.9E-02	1.8E-03	1.3E-02	3.2E-02	3.5E-01
Chrysene	Inhalation	4.6E-04	3.5E-03	1.6E-04	1.2E-03	2.9E-03	3.2E-02

Table 9. Hazard index (noncancer health risk) results from exposure to acenaphthene, anthracene, fluoranthene, fluorine, naphthalene and pyrene in street dust by trespassers, adults and children in low traffic zone in Tamale metropolis.

		Hazard index (Noncancer health risk)					
		Adults		*Trespasser*		*Children*	
Parameter	*Exposure route*	*CTE*	*RME*	*CTE*	*RME*	*CTE*	*RME*
Acenaphthene	Inhalation	6.6	150	2.2	12	61	670
Anthracene	Inhalation	9.1E-01	2.1	3.E-01	1.7	8.5	930
Fluoranthene	Inhalation	7.7	18	2.6	15	72	790
Fluorene	Inhalation	76	17	2.6	14	71	780
Naphthalene	Inhalation	290	670	100	550	260	3000
Pyrene	Inhalation	110	250	38	210	100	1100

Table 10. Hazard index health risk results from exposure to acenaphthene, anthracene, fluoranthene, fluorine, naphthalene and pyrene in street dust by tresspassers, adults and children in high traffic zone in Tamale metropolis.

		Hazard index health risk					
		Adults		*Trespasser*		*Children*	
Parameter	*Exposure route*	*CTE*	*RME*	*CTE*	*RME*	*CTE*	*RME*
Acenaphthene	Inhalation	100	230	34	190	930	1000
Anthracene	Inhalation	6.4	14	2.2	12	59	650
Fluoranthene	Inhalation	91	210	31	170	850	930
Fluorene	Inhalation	40	91	140	750	370	410
Naphthalene	Inhalation	760	170	260	1400	7100	7800
Pyrene	Inhalation	110	250	38	210	1000	1100

Principal component analysis (PCA) was employed, which provides a means of reducing the complexity of the total PAH data set. The results of PCA analysis have been provided in Table 6. From Table 6, only component one had an Eigenvalue greater than 1, indicating the data is a one-component system. Component 1 explained almost all the variance observed in the data on PAH concentrations in dust, signifying that one source of PAH emission is dominant.

The results of the cancer health risk from exposure to chrysene, benzo [a] anthracene, benzo[a] pyrene and benzo [k] fluoranthene in street dust samples from high and low traffic zones respectively have been presented in Tables 7 and 8.

In Tables 7 and 8, the cancer health risk from inhalation of known human carcinogenic PAH compounds in street dust from low and high traffic areas in Tamale metropolis all exceeded USEPA acceptable cancer health range of 1×10^{-4} to 1×10^{-6} which means approximately, 1 case of cancer in every 10,000 people to 1 case of cancer in every 1,000,000 people.

From Table 7, the cancer health risk from exposure benzo [a] anthracene, benzo [a] pyrene, benzo [k] fluoranthene and chrysene by resident children in Tamale metropolis who reside in houses along the high and low vehicular traffic points were found to be higher than resident adults and trespassers. This is due to the fact that children are more prone to toxic effects of carcinogenic chemicals as their organs responsible for detoxify these toxic chemicals are still in their developing stage.

The potential risk of PAH exposure based on their levels in street dust may be underestimated if the interaction of some PAHs are synergistic rather than additive. Chemical degradation of PAH by ambient oxidants (ozone, hydroxyl radical, or nitrogen oxides) in the atmosphere as well as on the streets of Tamale metropolis during sampling could also underestimate the potential risks due to reduced measured PAH levels, as shown in several studies.[30,31] Furthermore, nitrated/oxygenated PAH compounds have not been measured in this study, underestimating the full carcinogenic and noncarcinogenic risk of PAH exposure. Young children can be exposed to PAH through other routes besides inhalation. These include ingesting food, nondietary ingestion of dust or soil through hand-to-mouth activity, or dermal contact with dust polluted by PAH.[32]

Although inhalation is an important pathway for inner-city children because of high levels of PAH measured in indoor and outdoor air, dietary ingestion and non-dietary ingestion pathways are thought to be more important for young children's exposure to heavier PAHs[29,30]. Thus, the values reported in this study may need to be considered as the lower limit of estimated potential PAH health risk resulted from inhalation of air. Further investigations are needed whether PAHs levels are associated with any observed health outcomes (i.e., skin cancer, respiratory or allergic symptoms etc.) within the residents of Tamale metropolis.

Conclusion

The study evaluated the cancer and non-cancer risk of resident adults and children in the Tamale metropolis of Ghana arising from PAHs. Both central tendency and reasonable maximum exposures constitute risks to human receptors along this stretch of the Trans-ECOWAS highway. Specifically, inhalation of benzo [a] anthracene, benzo [a] pyrene, benzo [k] fluoranthene and chrysene in street dust in Tamale metropolis is responsible for the high risks. In both exposure scenarios, the greatest risk is attributed to benzo [a] pyrene (BaP). There is therefore the need for regulatory agencies to mitigate the risks posed to these categories of human receptors.

Although the focus of this study was on PAHs, we acknowledge that there could be toxic chemicals in the study area which can be impacted upon by resident adult, children and trespassers to elicit the responses evaluated in this study. That is, we may have synergic chemicals, which can combine with the PAHs to give an additive cancer and noncancer effects evaluated in this study, giving rise to uncertainty in the results obtained.

Acknowledgments

We wish to thank the technicians at the Council for Scientific and Industrial Research-Water Research Institute, Tamale, Ghana for assisting us in data collection.

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