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Full Length Research Paper

Distribution and risk assessment of polycyclic aromatic hydrocarbons in vegetables and agricultural soils from two communities in Rivers State, Nigeria

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Abstract

The present study investigated the polycyclic aromatic hydrocarbon (PAH) contents of farm soils and three commonly consumed vegetables grown in farmlands in two communities- Alakahia and Eleme,Rivers state, Nigeria and their potential impacts on human health. The total PAH concentrations in vegetables and soil ranged from 1.34 to 9.51 and 51.02 to 93.14 µg/kg, respectively. Samples from the Eleme community had higher PAH concentration than samples from Alakahia community. Pyrene and Fluoranthene were the predominant PAH in the farm soil samples from Alakahia and Eleme respectively. The profile of PAH in the vegetable samples were dissimilar at both communities when compared to the farm soil samples. The Low molecular weight PAH to High molecular weight PAH ratio (LMW-PAH/HMW-PAH) showed that the high molecular PAH were predominant in the Alakahia farm soil while the low molecular PAH dominated the Eleme soil sample. The carcinogenic Potency equivalent concentration (µg/kg) were estimated to be 0.31- 1.51 and 0.37 - 0.97 for vegetablescollected from Alakahia and Eleme communities respectively. These values exceeded the screening value (0.23) for vegetables, thus indicating that the consumption of such vegetables is risky for the exposed population.

Keywords: PAH, Vegetables, Rivers state, Health risk, Carcinogenic.

INTRODUCTION

Environmental pollution has become a serious problem confronting scientists and regulators around the world. It is a problem both in developed and developing countries. Industrialization and population growth are key factors that invariably place greater demands on the environment and stretch the use of resources to the maximum (Gray, 2011). Land pollution particularly the contamination of agricultural lands with environmental pollutants such as heavy metals, polycyclic aromatic hydrocarbons, polychlorinated biphenyls etc have far reaching implication on human health. These pollutants possess the ability to persist in the environmental medium for a long time. They can be actively taken up by plants grown on such contaminated lands. Consumption of such contaminated plants can result to a myriad of health problems ranging from minor discomfort to severe disabilities and depletion of essential nutrients in man and animals (Arora*et. al*, 2008).

In the report released in 2012 by the Nigerian Bureau of Statistics for consumption pattern in Nigeria, root tubers & plantain accounted for 23.23% while vegetables accounted for 17.81% of food consumed (National Bureau of Statistics, 2012). Together, root tubers and vegetables accounted for 41.04% of the food consumed in the country. Specifically, in the South-South region where Rivers state is situated, vegetables, tuber and plantain consumption are 14.00% and 35.09% respectively. Together, they represent approximately half of the total foods consumed in the region. Information on the polycyclic aromatic hydrocarbon contents of locally consumed is relatively scanty.

Incomplete combustion, pyrolysis of organic materials by industry, agriculture and traffic, diagenetic alteration of natural organic matter, long-term wastewater irrigation, reused sewage sludge and fertilizer use in agricultural production result in high concentrations of Polycyclic aromatic hydrocarbons (PAHs) in farmland soil (Northcott& Jones, 2001; Li *et al*, 2009; Ling *et al*, 2009). The United State Environmental Protection Agency (USEPA) and International Agency for Research on Cancer classify seven PAHs (benzo[a]pyrene, benz[a]anthracene, chrysene, benz[b]fluoranthene, benzo[k]fluoranthene, dibenz[a,h]anthracene and indeno[1,2,3-cd]pyrene as probable human carcinogens (USEPA Class B2). Other PAHs may also contribute to carcinogenic risk and should not necessarily be assumed to be non-carcinogens (Nisbet&LaGoy, 1992). Uptake by roots from the soil is also a possible pathway through which PAHs can enter plants (Tao *et al*., 2004; Wild *et al*, 1992). The leafy vegetables can accumulate more PAHs than root vegetables.

In view of this, the present study was designed to provide an insight into the current scenario of polycyclic aromatic hydrocarbons contamination in farm soils and selected vegetables consumed by the population at Alakahia and Eleme communities in Rivers state Southern Nigeria.

MATERIALS AND METHOD

Study Areas

The study areas namely Alakahia and Eleme communities are situated in Obi-Akpor and Eleme Local Government Areas respectively.Obio-Akpor is in the metropolis of Port Harcourt, one of the major centres of economic activities in Nigeria, and one of the major cities of the Niger Delta, located in Rivers State. The Local Government Area covers 260 km^2 and at the 2006 Census held a population of 878,890. Eleme is located east of the Port Harcourt Local Government area. It is in the greater Port Harcourt metropolis. It covers an area of 138 km^2 and at the 2006 Census had a population of 190,884. The Eleme community is home to a number of industries including petrochemicals, oil refining, paint and fertilizer industries.

Collection of test samples

Fresh samples of three commonly consumed vegetables: *Telfairia occidentalis (Fluted Pumpkin),* Ocimum grattissimum (Scent leaf), Vernonia amygdalina (Bitter leaf) and 3 tubers: Cassava (Manihot esculenta), Cocoyam (Colocasia esculenta), Yam (Dioscorea rotundata)were collected from farms in Alakahia and Eleme (precisely Ogale) communities situated in Obi-Akpor and Eleme Local Government Area (LGA) respectively in Rivers state Nigeria. At each site six samples comprising of three vegetables and three tubers were collected, cleaned, wrapped in aluminum foils and transported to the laboratory for analysis.

Also, farm soil samples were collected from the 2 study areas namely Alakahia and Eleme communities situated in Obi-Akpor and Eleme Local Government Area (LGA) respectively in Rivers state Nigeria. Soil samples were collected in aluminum foils and transported to the laboratory for analysis. The soil samples were air dried and stored in air tight containers prior to extraction process.

Sample preparation

The peeled tubers and vegetables were cleaned. The tubers (Cassava, Yam and Cocoyam) samples were chopped into small pieces and then oven dried before they were crushed in a laboratory mortar and sieved using 0.5mm sieve. The cleaned vegetable samples were then ground with blender (National, MX 795N, Japan) and kept in air tight containers prior to extraction process.

Extraction of Samples for PAH Determination

2g of samples were weighed into a clean extraction container (50ml beaker). 10g of Sodium Sulphate was added and mixed together with the sample through wrist action. 10ml of extraction solvent (dichloromethane) was then added into the sample and mixed thoroughly and allowed to settle. The mixtures were carefully filtered into clean solvent rinsed extraction bottle, using filter paper fitted into Buchner funnels. The extraction were concentrated to 2ml and then transferred for cleanup/separation. The dichloromethane extract was cleaned up by passing through a column packed with anhydrous Na_2SO_4 salt. The resulting extract was concentrated on a rotary evaporator to give an oily residue; which was again dissolved in 1ml CH_2Cl_2 and 1µL was injected into the GC for analysis.

Gas Chromatography Analysis

The concentrated hydrocarbon fractions were transferred into labeled glass vials with Teflon rubber clip cap for gas chromatography analysis. 1ul of the concentrated sample was injected by means of hypodermic syringe through a rubber septum into the column. Separation occurred as the vapor constituent partition between the gas and liquid phase. The sample was automatically detected as it emerges from the column (at constant flow rate) by the FID detector whose response is dependent upon the composition of the vapor.

Chromatographic conditions

The gas chromatography was Hewlett Packed 6890N series, gas chromatography apparatus, coupled with flame ionization detector (FID) (Hewlett Packard, Wilmington, DE, USA), powered with HP Chemstation Rev. A 09:01 (10206) software to identify and quantify compounds. The GC operating conditions were as follow: fused silica column [30m*0.25μmfilmof HP-5(thickness)]; the inlet and injection temperature was set at 275^{o}C to 310^{0}C. Split injection was adopted with a split ratio of 8:1. Using rubber septum and volume injected was 1ul. The column temperature was programmed as follow; held at 65^{O}C for 2min; 65-260^{O}C at 12^{O}C /min; 260-320^{O}C at 15^{O}C /min and maintained at 310^{O}C for 8minutes and oven temperature was set at 65^{o}C. Nitrogen was used as carrier gas. The hydrogen and compressed air pressure was 30psi. The oven initial temperature was at 65^{0}C. Verification of peaks was carried out based on retention times compared to those of external PAHs. Procedural blank and solvent blanks were analyzed and quantified, but no PAHs were found in these blanks.

Human health risk assessment of polycyclic aromatic hydrocarbons

In estimating the carcinogenic risk from exposure to PAHs in vegetables, the USEPA guideline, as described by Cheung *et al.,* (2007), was followed. By this method, Benzo[a] Pyrene is used as a marker for the occurrence and effect of carcinogenic PAHs in foods and, therefore, the overall carcinogenic health risk from the measured PAHs was estimated based on toxic equivalency factors (TEFs) derived from the cancer potencies of individual PAH compounds relative to the cancer potency of Benzo[a] Pyrene. The product of the PAH concentration (μg/kg) and its TEF gives a Benzo[a] Pyrene equivalent concentration (BaPeq) for each PAH. All the individual Benzo[a]Pyrene equivalent were then summed up to give a carcinogenic Potency Equivalent Concentration (PEC) of all the PAHs according to equation (1) (Nisbet& Rasmussen, 1992).

PEC = ∑(TEF × Concentration) (1)

Potency equivalent concentration values were then compared with a screening value for carcinogenic PAHs. The screening value was calculated from Equation (2) Russell *et al*., (1997).

SV = [(RL/SF) × BW]/CR (2)

Where SV = screening value (μg/kg)

RL = maximum acceptable risk level (dimensionless)

SF = USEPA oral slope $^{-1}$ factor (μg/kg day)

BW = body weight (g)

CR = consumption rate (g/day).

Screening value (SV) is the threshold concentration of total PAHs in food crop that is of potential public health concern; BW is the average body weight (g) and was set to 60000 g (i.e. 60 kg) for the adult population (Jiang *et al*., 2005); CR is the consumption rate (g/day). Vegetable consumption rate was set to 345 g/day from the annual per capita vegetable. RL is the maximum acceptable risk level (dimensionless), which is set to 10^{-5} (USEPA, 2000) so that the maximum risk would be one additional cancer death per 100000 persons, if an adult weighing 60 kg consumed 345 g of vegetable daily with the same measured concentrations of PAHs for 70 years; SF is the USEPA oral slope factor for PAHs, used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime (70 years) exposure to carcinogenic PAHs and has a value of 0.00730 (μg/mg day)$^{-1}$ (USEPA, 1993). For safety reasons, a consumption rate of 1 g/day was used to estimate the minimum level that a consumer may be protected from the carcinogenic effects of PAHs detected in these vegetables.

DISCUSSION

The distribution of polycyclic aromatic hydrocarbons in the farm soils shown in Table 1 revealed that a total of 14 and 16

PAH were detected in the farm soil from Alakahia and Eleme respectively. The PAH concentration at both sites ranged from 0.00 – 47.45 μg/kg. The highest total PAH concentration was recorded in the farm soil collected from Eleme and Fluoranthene accounted for about 51% of the total PAH in the farm soil. Fluoranthene's release is high in areas with great anthropogenic activities. The polycyclic armatic hydrocarbon Pyrene accounted for 49% of the total PAH in the Alakahia farm soil. Pyrene's release to the environment is ubiquitous since it is a product of incomplete combustion. It is largely associated with particulate matter, soils and sediments. Although environmental concentrations are highest primary sources, its presence in places distant from those primary sources indicates that it is reasonably stable in the atmosphere and capable of long distance transport (Irwin *et al.*, 1997).

Naphthalene was the highest occurring LMW-PAH at the Alakahia farm soil. Most of the naphthalene entering the environment is discharged to the air. The largest releases result from the combustion of wood and fossil fuels and the off-gassing of naphthalene-containing moth repellents (EPA, 2001). Naphthalene in the atmosphere is subject to a number of degradative processes, including reaction with photochemically produced hydroxyl radicals. Naphthalene has a short half-life in most natural waters and soils because of its tendency to volatilize and biodegrade. As a consequence of these processes, there is little tendency for naphthalene to build up in the environment over time (ATSDR, 2009). The occurrence of Naphthalene at the Alakahia site could be attributed to recent combustion and/ or run-offs from the diesel powered plants situated close to the farmland. The

RESULTS

Table 1: PAH Concentrations (µg/kg wet wt.) in Alakahia and Eleme Farm Soil Samples.

PAH	ALAKAHIA	ELEME
Naphthalene*,Δ	7.68	0.92
Acenaphthylene*,Δ	0.00	0.31
2-Methyl naphthalene*,Δ	0.28	1.10
Acenaphthene*,Δ	0.00	0.09
Fluorene*,Δ	4.50	0.36
Phenanthrene*,Δ	2.24	0.74
Anthracene*,Δ	0.05	0.15
Fluoranthene*,Δ	4.92	47.45
Chrysene*,β	0.18	23.70
Pyreneγ,Δ	25.22	15.78
Benzo[b]fluorantheneγ,β	0.62	0.21
Benzo[k]fluorantheneγ,β	1.72	0.57
Dibenz[a,h]anthraceneγ,β	0.44	0.24
Benzo[a]pyreneγ,β	0.01	0.18
Indeno[1,2,3-cd]pyreneγ,β	2.84	1.03
Benzo[g,h,i]peryleneγ,β	0.32	0.31
Benzo[a]anthraceneγ,β	0.00	0.00
Total PAH	51.02	93.14
Σ LMW-PAH	19.67	51.12
Σ HMW-PAH	31.35	42.02
LMW-PAH/HMW-PAH ratio	0.63	1.21

*denotes low molecular weight (LMW) PAH, γ- high molecular weight (HMW) PAHΔ- Non-carcinogenic PAH, β- Carcinogenic PAH.

Table 2: PAH Concentrations (µg/kg wet wt.) in *T. occidentalis* collected from Alakahia and Eleme.

PAH	ALAKAHIA	ELEME
Naphthalene$^{*,\Delta}$	0.26	0.00
Acenaphthylene$^{*,\Delta}$	0.01	0.00
2-Methyl naphthalene$^{*,\Delta}$	0.24	0.00
Acenaphthene$^{*,\Delta}$	0.00	0.00
Fluorene$^{*,\Delta}$	0.01	0.00
Phenanthrene$^{*,\Delta}$	0.00	0.00
Anthracene$^{*,\Delta}$	0.01	3.46
Fluoranthene$^{*,\Delta}$	0.29	0.00
Chrysene$^{*,\beta}$	0.02	0.00
Pyrene$^{\gamma,\Delta}$	0.91	0.00
Benzo[b]fluoranthene$^{\gamma,\beta}$	0.08	0.00
Benzo[k]fluoranthene$^{\gamma,\beta}$	0.33	0.00
Dibenz[a,h]anthracene$^{\gamma,\beta}$	0.04	0.00
Benzo[a]pyrene$^{\gamma,\beta}$	0.02	0.00
Indeno[1,2,3-cd]pyrene$^{\gamma,\beta}$	0.50	0.00
Benzo[g,h,i]perylene$^{\gamma,\beta}$	0.01	0.00
Benzo[a]anthracene$^{\gamma,\beta}$	0.00	0.00
Total PAH	2.73	3.46
Σ LMW-PAH	0.82	3.46
Σ HMW-PAH	1.91	0.00
LMW-PAH/HMW-PAH ratio	0.42	3.46

*****denotes low molecular weight (LMW) PAH, γ- high molecular weight (HMW) PAH $^{\Delta-}$ Non-carcinogenic PAH, β- Carcinogenic PAH.

Table 3: PAH Concentrations (µg/kg wet wt.) in *O. grattissimum* collected from Alakahia and Eleme

PAH	ALAKAHIA	ELEME
Naphthalene*,Δ	**0.02**	**0.19**
Acenaphthylene*,Δ	**0.01**	**0.00**
2-Methyl naphthalene*,Δ	**0.11**	**0.00**
Acenaphthene*,Δ	**0.00**	**0.00**
Fluorene*,Δ	**0.03**	**0.31**
Phenanthrene*,Δ	**0.41**	**0.28**
Anthracene*,Δ	**0.01**	**0.00**
Fluoranthene*,Δ	**0.12**	**0.20**
Chrysene*,β	**0.01**	**0.13**
Pyrene γ,Δ	**0.11**	**2.41**
Benzo[b]fluoranthene γ,β	**0.06**	**0.06**
Benzo[k]fluoranthene γ,β	**0.14**	**0.53**
Dibenz[a,h]anthracene γ,β	**0.08**	**0.16**
Benzo[a]pyrene γ,β	**0.02**	**0.03**
Indeno[1,2,3-cd]pyrene γ,β	**0.18**	**0.76**
Benzo[g,h,i]perylene γ,β	**0.03**	**0.06**
Benzo[a]anthracene γ,β	**0.00**	**0.00**
Total PAH	**1.34**	**5.12**
Σ LMW-PAH	**0.71**	**0.98**
Σ HMW-PAH	**0.63**	**4.14**
LMW-PAH/HMW-PAH ratio	**1.09**	**0.24**

*denotes low molecular weight (LMW) PAH, γ- high molecular weight (HMW) PAH Δ- Non-carcinogenic PAH, β- Carcinogenic PAH.

Table 4: PAH Concentrations (µg/kg wet wt.) in *V. amygdalina* collected from Alakahia and Eleme.

PAH	ALAKAHIA	ELEME
Naphthalene*,Δ	0.13	**0.30**
Acenaphthylene*,Δ	0.00	**0.00**
2-Methyl naphthalene*,Δ	0.23	**0.00**
Acenaphthene*,Δ	0.00	**0.00**
Fluorene*,Δ	0.15	**0.23**
Phenanthrene*,Δ	0.25	**0.00**
Anthracene*,Δ	0.02	**0.00**
Fluoranthene*,Δ	0.46	**0.16**
Chrysene*,β	0.14	**0.05**
Pyrene γ,Δ	3.82	**0.77**
Benzo[b]fluoranthene γ,β	0.08	**0.08**
Benzo[k]fluoranthene γ,β	2.42	**0.71**
Dibenz[a,h]anthracene γ,β	0.23	**0.06**
Benzo[a]pyrene γ,β	0.04	**0.01**
Indeno[1,2,3-cd]pyrene γ,β	0.67	**0.30**
Benzo[g,h,i]perylene γ,β	0.87	**0.04**
Benzo[a]anthracene γ,β	0.00	**0.00**
Total PAH	9.51	**2.71**
Σ LMW-PAH	1.24	**0.69**
Σ HMW-PAH	8.27	**2.02**
LMW-PAH/HMW-PAH ratio	0.42	**0.34**

*denotes low molecular weight (LMW) PAH, γ- high molecular weight (HMW) PAH Δ- Non-carcinogenic PAH, β- Carcinogenic PAH.

Naphthalene concentration at Alakahia and Eleme farm soil were generally below the Canadian (0.10mg/kg) and Netherlands (0.14mg/kg) maximum permissible limit for Naphthalene in agricultural soils (Kalf*et al,* 2009).In this

Table 5: Distribution of Total Carcinogenic and Non-carcinogenic PAHs in the farm soils and vegetables.

SOIL	***T. occidentalis***		***O. grattissimum***		***V. amygdalina***			
	Alakahia	Eleme	Alakahia	Eleme	Alakahia	Eleme	Alakahia	Eleme
Σ Carcinogenic PAH	6.13	26.24	1.00	0.00	0.52	1.73	4.45	1.25
Σ Non-carcinogenic PAH	44.89	66.90	1.72	3.46	0.82	3.39	5.06	1.46
Total PAH	51.02	93.14	2.73	3.46	1.34	5.12	9.51	2.71
% Carcinogenic PAH	12.01	28.17	36.63	0.00	38.81	33.79	46.79	46.13

present study, the Benzo[a]Pyrene and total PAHs concentration in soil samples obtained at Alakahia and Eleme complied with the Danish and Canadian soil quality criteria for agricultural lands (CCME, 2010).

At Alakahia community, the concentration of PAH in the *T. occidentalis* (Fluted pumpkin) ranged from 0.00 – 0.91 µg/kg, *in O. grattissimum* it ranged from 0.00 – 0.41 µg/kg and in *V. amygdalina*, it was 0.00 – 3.82 µg/kg. A higher trend was observed in Eleme community where PAH concentration in the vegetables ranged from 0.00-3.46 µg/kg in *T. occidentalis;* 0.00 – 2.41 µg/kgin *O. grattissimum* and 0.00 – 0.77µg/kg in *V. amygdalina*.The average total PAH level in *O. grattissimum* (1.32) was lower than in *T. occidentalis* (2.73) and *V. amygdalina* (9.51) collected from farmlands at Alakahia.Similarly, the same trend was observed in vegetables collected from the Eleme farmlands. The PAH with maximum concentration were Pyrene in *T. occidentalis* (0.91) and *V. amygdalina* (3.82) while Phenanthrene (0.41) had maximum concentration in *O. grattissimum.* The Eleme community has high industrial presence and the activities of these industries release a cocktail of atmospheric and land pollutants that find their way into the food chain. A study on the ambient air quality at the Eleme community revealed a total PAH concentration of about 9.0microg/m^3 thus ranking it among the highest in the world (Ana *et al.,* 2012). This is a serious health concern as the waxy surface of leafy vegetables in addition to root uptake can also concentrate PAHs.

The sum of low molecular weight PAHs were higher in the *T. occidentalis* (3.46)and *O. grattissimum* (0.98) collected from the Eleme community when compared to vegetables collected from the Alakahia community.This can be attributed to higher anthropogenic pressure at the Eleme community. Pyrene was the predominant high molecular weight PAH in the vegetables from both communities. It was also one of the predominant PAH in the soil samples analyzed thus suggesting that it was readily available to the vegetables from the soil. The Low Molecular Weight- PAH/High Molecular Weight-PAH (LMW-PAH/HMW-PAH) ratios indicate that the HMW-PAHs were generally predominant compared to the LMW-PAHs in the selected vegetables and tubers. The predominance of HMW-PAHs may be due to the fact that LMW-PAHs are preferentially degraded during PAH transport (Berto *et al.,* 2009). There was however an exception to this trend as the LMW- PAH/HMW-PAH ratios in *T. occidentalis (3.46).*

In the present study, the percentages of carcinogenic PAHs as shown in Table 5 were least in the farm soils from Alakahia and Eleme. The vegetables recorded higher % carcinogenic PAH ranging from 36.63 – 46.79 at Alakahia and 0.00 – 46.13 at Eleme. The high values reported for carcinogenic PAHs in the vegetables compared to the farm soil may be attributed to atmospheric deposition. Atmospheric deposition on leaves often greatly exceeds uptake from soil by roots as a route of PAH accumulation (Sims and Overcash, 1983).

The major approach advocated by regulatory agencies such as the USEPA (1993), California EPA (OEHHA, 1992), Netherlands (RIVM, 2000), the UK (UK Environment Agency, 2002), or Provinces of British Columbia and Ontario for assessing the human health risks of PAH-containing mixtures involves the use of “Potency Equivalence Factors” (PEFs), also referred to as “Relative Potency Factors” (RPFs) or “Toxicity Equivalence Factors” (TEFs). These factors are used to relate the carcinogenic potential of other PAHs to that of benzo[a]pyrene (B[a]P). The Benzo[a]Pyrene equivalent concentrations (PEC) as shown in Table 6 of the vegetables collected from Alakahia ranged from 0.31 – 1.51 µg/kg while PEC of the vegetables at Eleme ranged from 0.37 to 0.97 µg/kg. Dibenzo[a,h]anthracene had the highest B[a]P equivalent concentrations in the leafy vegetables collected Alakahia and Eleme. In this present study, the screening values have been calculated as 0.23 for leafy vegetables. The screening value is the threshold concentration of total PAH in the food crop that is of potential public health concern. The PEC values exceeded the Screening Value in the leafy vegetables from Alakahia and Eleme i.e. the PEC of the vegetables from both sites (0.31-1.51 µg/kg) was higher than the calculated SV (0.23 µg/kg) indicating that consumption of *T. occidentalis [TO], O. grattissimum [OG]* and *V.*

Table 6: Benzo[a] Pyrene equivalent concentration for polycyclic aromatic hydrocarbons in the vegetables

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	T. occidentalis		**O. grattissimum**		**V. amygdalina**	
PAH	ALAKAHIA	ELEME	ALAKAHIA	ELEME	ALAKAHIA	ELEME
Naphthalene	0.26E-3	0.00	0.02E-3	0.19E-3	0.13E-3	0.31E-3
Acenaphthylene	0.01E-3	0.00	0.01E-3	0.00	0.00	0.00
2-Methyl naphthalene	0.00	0.00	0.00	0.00	0.00	0.00
Acenaphthene	0.00	0.00	0.00	0.00	0.00	0.00
Fluorene	0.01E-3	0.00	0.03E-3	0.31E-3	0.15E-3	0.23E-3
Phenanthrene	0.00	0.00	0.41E-3	0.28E-3	0.25E-3	0.00
Anthracene	0.10E-3	0.37	0.10E-3	0.00	0.20E-3	0.00
Fluoranthene	0.29E-3	0.00	0.12E-3	0.20E-3	0.46E-3	0.16E-3
Chyresene	0.20E-3	0.00	0.10E-3	1.30E-3	1.40E-3	0.50E-3
Pyrene	0.91E-3	0.00	0.11E-3	2.41E-3	3.82E-3	0.77E-3
Benzo[b]fluoranthene	8.00E-3	0.00	6.00E-3	6.00E-3	8.00E-3	8.00E-3
Benzo[k]fluoranthene	3.30E-2	0.00	1.40E-2	5.30E-2	0.24	7.10E-2
Dibenz[a,h]anthracene	0.20	0.00	0.40	0.80	1.15	0.30
Benzo[a]pyrene	0.02	0.00	0.02	0.03	0.04	0.01
Indeno[1,2,3-cd]pyrene	0.05	0.00	0.02	0.08	0.07	0.03
Benzo[g,h,i]perylene	0.00	0.00	0.00	0.00	0.00	0.00
Benzo[a]anthracene	0.00	0.00	0.00	0.00	0.00	0.00
PEC	0.31	0.37	0.46	0.97	1.51	0.42

amygdalina [VA], at a rate of 345 g/day can have adverse health effects on the long run. The present findings from the carcinogenic health risk estimates of the PAHs suggest that the exposed population may experience significant health risk as a result of perennial dietary intake of vegetables from farmlands situated within close vicinity to industrial areas such as hospitals, industries or roads as observed in the Alakahia and Eleme sites. The Eleme community in Rivers, Nigeria is home to a number of industries including Petrochemicals, Paint, and Fertilizer production industry. The presence of these industries at Eleme increases the anthropogenic pressure thereby increasing health risk for the exposed population.

Although, the total PAH concentration in the vegetables were generally lower than the 10ppb recommended for foods of plant origin. There is still a cause for health concern as increased anthropogenic pressures and frequency of vegetable consumption by the populace in Alakahia and Eleme may increase the body burden of PAHs in the local populace.

CONCLUSION

The present study provides data on the distribution of PAH in farm soils and vegetables. The current levels of PAH in the vegetables and farm soils are not yet alarming as the below the WHO maximum permissible limit for PAH in vegetables and soil. However, considering the fact that these vegetables are still frequently consumed by the populace at Alakahia and Eleme, there is dire need to constantly monitor the PAH levels in farm soils and food crops over time and also develop strict strategies to prevent PAH accumulation in food crops that may ultimately minimize chronic health risk to exposed population.

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