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Polycyclic Aromatic Hydrocarbons Profile of Kitchen Dusts

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Abstract Concentrations and profiles of polycyclic aromatic hydrocarbons (PAHs) were determined in thirty dust samples collected from kitchens that use wood cook system (WCS), kerosene stove cook system (KSCS) and butane gas cook system (BGCS). The total PAHs concentrations ranged from 52 to 497, 39 to 96 and 37 to 155 μg kg^{-1} for WCS, KSCS and BGCS respectively. The results indicate predominance of lower molecular weight (2–3 rings) over higher molecular weight PAHs and users of wood cook system are more exposed to higher levels of PAHs than the users of either kerosene cook system or butane gas cook system.

Keywords Kitchen dusts · Fuel cook systems · Polycyclic aromatic carbons · Health risk

Household dust is a heterogeneous matrix, consisting of a variety of inorganic, organic and biological materials. Once pollutants are adsorbed onto house dust particles' they either do not degrade at all or degrade at rates that are relatively slower than their ambient counterparts (Butte 2003, 2004; Ong et al. 2007). Thus, household dust is more or less a sink for pollutants, which may be inhaled through re-suspension into air, ingested accidentally by children or absorbed through skin. Studies have shown that people are in one indoor environment or the other for 80% of the day (Ayoko et al. 2004). It is therefore of immense importance for the assessment of indoor environmental quality. Information obtained for such exercise would be necessary for understanding the real and potential effects of indoor pollutants, and to develop appropriate control strategies.

Polycyclic aromatic hydrocarbons (PAHs) were ranked as the ninth most threatening compounds to human in 2001 (King et al. 2002; Samimi et al. 2009). Polycyclic aromatic hydrocarbon (PAHs) compound are class of complex organic chemicals, which include carbon and hydrogen with fused ring structure containing at least two benzene rings. PAHs may also contain additional fused rings that are not six-sided (Ravindra et al. 2008). These compounds are widely distributed in the atmosphere and are one of the first atmospheric pollutants to have been identified as suspected carcinogen. Considering the increasing evidence of the ubiquitous presence of PAHs and health risk associated with their exposure, studies on the profiles and levels of polycyclic aromatic hydrocarbon in environmental matrices have attracted substantial research interest in the last three decades because many of them are carcinogenic and mutagenic, causing irreversible changes in structures and functioning of living organisms (Marynowski et al. 2004; Ong et al. 2007). As the molecular weight increases, the carcinogenicity of PAHs also increases, and acute toxicity decreases. PAHs known for their carcinogenic and teratogenic properties are benzo[a]anthracene and chrysene; benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k]fluoranthene and benzo[a]pyrene; indeno[1,2,3c,d]pyrene and dibenzo[a,h]anthracene(Ravindra et al. 2008).

The major anthropogenic sources of polycyclic aromatic hydrocarbons in the environment include combustion processes such as wood burning, vehicular emission, cigarette smoking, cooking and agricultural waste burning. In Nigeria, the three major fuel types used for cooking include (1) wood cook system (WCS), (2) kerosene stove cook system (KSCS) and (3) butane gas cook system (BGCS). Combustion of these fuels during cooking results to the

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release of significant quantity of polycyclic aromatic hydrocarbons into the indoor environment. The objective of the present study is to examine the levels and profiles of polycyclic aromatic hydrocarbons in kitchen dusts from the different fuel cook systems.

Materials and Methods

Thirty bulk dust samples were collected from kitchens using (1) wood, (2) kerosene and (3) butane gas as fuel for cooking in urban and rural areas of Delta State. The dust samples were collected using a clean plastic dustpans and a brush from shelves, tables, ceilings and wooden rays in the kitchens. 5 g of the dust samples was extracted with hexane (90%) and dichloromethane (99.8% analar grade BDH, Poole, England) in an accelerated solvent extractor (ASE 200, Dionex, Sunnyvale, C.A). Extraction cells were filled with solvent, pressurized to 14 MPa and heated to 120°C for 6 min. Pressure and temperature was held constant for extraction time of 5 min and cells were rinsed with cold solvent (60% of cell volume) and purged with argon for 150 s. The static extraction and purge steps were performed twice for each sample and the extracts were combined (Wilcke et al. 2005; Pies et al. 2007). The extracts were evaporated to 1 mL and purified by solid phase extraction with 2 g of aluminum oxide (5% deactivated upper part) and 2 g of silica gel (5% deactivated lower part). The PAHs were subsequently eluted with 15 mL of hexane, 5 mL of hexane and dichloromethane (9:1) and 20 mL of hexane and dichloromethane (4:1). The eluted fractions were combined and evaporated to approximately 0.5 mL. Eight deuterated PAHs (NAP-D_8, ACE-D_{10}, FLU-D_{10}, PYR-D_{10}, CHR-D_{12}, PERY-D_{12}, BGP-D_{12}) as internal standards, to check the recovery of the internal standards FLT-D_{10} was added to extract before injection into gas chromatography. The mean recoveries were greater than 94.8%. PAHs were detected with gas chromatography (HP 6890 Palo Alto,CA) equipped with a HP5 (cross linked PHME siloxane) (0.25 μm film thickness, 0.25 mm × 30 m) and flame ionization detector (FID). The carrier gas was helium with a flow rate of linear velocity 30 cm/s. Initial temperature of 100°C and increased finally to 310°C at a rate of 4°C/min. One μL of each sample was injected in split less mode. The detection limits for PAHs is 1 μg kg^{-1}. All results were calculated at dry weight basis.

Results and Discussion

Table 1 presents the mean concentrations and profiles of polyclic aromatic hydrocarbons in kitchen dust samples from three different fuel cook systems. The total polyclic aromatic hydrocarbons contents and profiles of the three fuel cook systems differed significantly. The total PAHs concentrations ranged from 52 to 479, 29 to 96 and 37 to 175 μg kg^{-1} for wood cook system (WCS), kerosene stove cook system (KSCS) and butane gas cook system (BGCS), respectively. According to Danish standards, the PAHs concentration of unpolluted mineral soil is 20–50 ng g^{-1} (Van Brummelen et al. 1996) and a total concentration of 200 ng g^{-1} is regarded as upper limits PAHs occurrences (Kabata-Pendias et al. 1995). The concentrations of PAHs in 60% of dust samples from wood cook system were above upper limits of natural occurrence. The total contents of PAHs in dust samples from the different fuel cook systems follow the order WCS > BGCS > KSCG.

In the WCS, naphthalene, 2-methynapthalene, fluorene are the most predominant species of PAHs in kitchen dusts from the wood cook system. The percentage compositions of NAP, 2-MNAP, FLU, ACY were 16%, 24%, 14.7% and 10.8%, respectively. In the dusts from kitchen that uses wood as fuel, benzo[a]anthracene was detected at mean concentration of 4 μg kg^{-1}. The coefficient of variations observed in concentrations of individual PAHs found in the kitchen dusts from wood cook system were higher than those obtained for KSCS and BGCS. The differences could be due to difference in the species of woody plants used for cooking. High NAP and 2 M NAP contents of kitchen dust samples from wood cook system is due to the fact that gaseous naphthalene is generated from open burning of woody plants and besides, woody plants are biological sources of naphthalene (Wilcke et al. 2003; Yu et al. 2006).

In the KSCS, the predominant species of PAHs are acenaphthalene, phenanthrene, anthracene and fluorine which constitutes 23.3%, 11.2%, 10% and 9.3%, respectively of total PAHs contents, whereas, in dust samples kitchens that uses butane gas as fuel the predominant species of PAHs are acenapthalene, flourene and anthrancene which were detected at mean levels of 32.2, 18.5, 11.9 μg kg^{-1}, respectively. ACE, FLU and ANT constitutes 36%, 21% and 13.5% of total PAHs contents of dust from kitchen that utilizes gas cook system.

In three fuel cook systems, the 3 rings PAHs showed predominant over 2 rings, 4-rings, 5 rings and 6-rings PAHs i.e. 3-rings > 2-rings > 4-rings > 5-rings ≈ 6-rings. However, in kerosene stove cook system 4-rings PAHs (pyrene) showed predominance over 2-rings PAHs. Amongst the 4-rings PAHs, pyrene (10 μg kg^{-1}) is predominant in the wood cook system, while fluoranthene is predominant species of PAHs in dusts from kerosene stove cook system (5.1 μg kg^{-1}) and butane gas cook system (2.5 μg kg^{-1}). Benzo[a]anthracene was detected in 60% and 40% of kitchen dust samples from wood system and kerosene stove cook system, respectively. The concentrations of benzo[a]anthracene in the kitchen dust samples

Table 1 Concentrations μg kg^{-1} of polycyclic aromatic hydrocarbons in kitchen dust samples

PAHs	Acronyms	Wood cook system (WCS)					Kerosene stove cook system (KSCS)					Butane gas cook system (BGCS)				
		Mean	Max	Min	SD	CV (%)	Mean	Max	Min	SD	CV (%)	Mean	Max	Min	SD	CV (%)
Naphthalene	NAP	47	101	4	36.0	76.6	2.5	4	2	0.7	28	3.2	5.0	2.0	0.8	25
2-methylnapthalene	2MNAP	69.4	199	8	79.4	114.4	5.6	14	3	3.9	69	4.5	3.0	9.0	1.8	40
Acenaphthalene	ACY	29.6	84	6	24.0	81.1	16.4	26	9	6.7	40.9	32.2	82.0	10	25.0	77.6
Acenaphthene	ACE	30.6	75	4	27.9	91.2	5.1	12	2	3.3	64.7	8.4	13.0	5.0	3.1	36.9
Fluorene	FLU	41.7	147	3	46.2	110.8	5.8	13	4	2.7	46.5	18.5	50.0	4.0	16.9	91.4
Phenanthrene	PHE	26.8	62	3	21.9	81.7	6.0	14	Nd	4.2	70	5.2	13.0	Nd	4.7	90.4
Anthracene	ANT	17.5	36	6	11.4	65.1	6.7	10	7	1.3	19.4	11.9	25.0	7.0	5.8	48.7
Fluoranthene	FLT	7.7	18	4	3.9	50.6	5.1	13	Nd	5.2	101.9	2.5	10.0	Nd	4.1	164
Pyrene	PYR	10.0	30	Nd	12.1	121.0	2.4	7	Nd	2.6	108.3	1.8	7.0	Nd	2.9	161
Benzo[a,b] anthracene	BAA	4.0	8.0	Nd	3.6	50	4.6	13	Nd	6.2	134.8	Nd	Nd	Nd	Nd	–
Chrysene	CHR	Nd	Nd	Nd	Nd	–	Nd	Nd	Nd	Nd	–	Nd	Nd	Nd	Nd	–
Benzo[b] fluoranthene	BBF	Nd	Nd	Nd	Nd	–	Nd	Nd	Nd	Nd	–	Nd	Nd	Nd	Nd	–
Benzo[a] pyrene	BAP	Nd	Nd	Nd	Nd	–	Nd	Nd	Nd	Nd	–	Nd	Nd	Nd	Nd	–
Benzo[k] fluoranthene	BKF	Nd	Nd	Nd	Nd	–	Nd	Nd	Nd	Nd	–	Nd	Nd	Nd	Nd	–
Indeno[1,2,3] perylene	IND	Nd	Nd	Nd	Nd	–	Nd	Nd	Nd	Nd	–	Nd	Nd	Nd	Nd	–
Dibenzo[a,h] anthracene	DAA	Nd	Nd	Nd	Nd	–	Nd	Nd	Nd	Nd	–	Nd	Nd	Nd	Nd	–
Benzo[g,h,i] perylene	BGP	Nd	Nd	Nd	Nd	–	Nd	Nd	Nd	Nd	–	Nd	Nd	Nd	Nd	–

ranged from nd-8 μg kg^{-1} and n-13 μg kg^{-1} for WCS and KSCS, respectively. Benzo[a]anthracene was not detected in dust samples from BGCS. This probability due to the fact the butane gas cook system is a more efficient combustion system than wood cook and kerosene stove coke systems. Chrysene, benzo[b]fluoranthene benzo[a]pyrene, indeno[1,2,3]-pyrelene, dibenzo[a,h]anthracene and benzo[g,h,i]perylene were not detected in kitchen dusts from the three cook systems. These types of PAHs (5-rings and 6-rings PAHs) are mainly produced from high temperature combustion processes (Fernardes et al. 1997; Baran et al. 2002) whereas lower molecular weight PAHs (LPAHs) may be derived from combustion of fossil fuel. It should be assumed the PAHs in the dust samples studied are processes related to fossil fuel combustion. The sum of the lower molecular weight (i.e. 2–3-rings) PAHs were higher than the sum of the higher molecular weight (4-rings) in the dust samples three fuel cook systems. PAHs derived from different sources have distinct compositions and hence the characteristic profiles of PAHs could be used as finger prints for identify their sources (Khalili et al. 1995; Soclo et al. 2000; Yu et al. 2006). For example, naphthalene and phenanthrene (LMW PAHs) are more thermodynamically stable compounds mainly derived from petrogenic sources (from the release of uncombusted petroleum such as gasoline, diesel fuel, fuel oil from vehicular traffic). However, FLT, PYR and BKF (HMW PAH) are typical pyrogenic products derived from high temperature condensation of low molecular PAHs. Therefore, the PAHs profiles of the kitchen dusts from 3 fuel cook systems suggest both petrogenic and pyrogenic sources of the PAHs.

This study showed that polycyclic aromatic hydrocarbons contents of kitchen dust samples from the three fuel cook systems exceeded concentrations found in unpolluted soil. The concentration profiles of PAHs in dust from different fuel cook systems showed remarkable differences. The dust samples from the wood cook system showed higher concentrations of individual PAHs than those of kerosene stove cook and butane gas cook systems except for acenaphthalene and anthracene, benzo[a]anthracene. The results indicate that users of wood cook system are more exposed to higher levels of PAHs than those that use kerosene stove cook or butane gas cook systems.

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