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Assessment of PAHs Emissions from Domestic Cooking Fuels on Indoor Air in Nigeria

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Abstract

Due to Nigeria's high electricity cost, biomass fuels (gas and kerosene) are thought to be more cost-effective, less stressful, and commonly utilized in cooking in urban areas. Thus, this results in higher polycyclic-aromatic-hydrocarbons (PAHs) concentrations in indoor areas, posing a health risk. This study investigated the contribution of gas and kerosene stoves to the indoor level of PAHs in two selected household kitchens. Furthermore, their concentrations were calculated to investigate PAH dispersion patterns and evaluate the carcinogenic risk it poses to health. The gas and kerosene stoves used were placed in different rooms of equal sizes and allowed to burn for 3 hours daily, assuming an average cooking time per day. Passive sampling with polyurethane foam (PUF) disks was used. The disks were removed after 3, 7, and 14 days for Gas Chromatography-Mass Spectrometer (GC-MS) analysis to determine the PUF disks' PAHs concentration. The study results revealed that the indoor PAHs' average concentration after 3, 7, and 14 days is 0.28, 0.44, and 0.65 μg/m^3 for gas, respectively, and the corresponding average concentration for kerosene is 0.72, 0.94, and 1.33 μg/m^3, respectively. Although the gas stove showed a better performance than the kerosene, good ventilation in the kitchen will assist in reducing the PAH concentration from both gas and kerosene stove cooking in the kitchen for better health.

Keywords: Biomass fuels, indoor air pollution, PAHs, health effect, passive sampling.

1. Introduction

Polycyclic-aromatic-hydrocarbons (PAHs) are common environmental contaminants released by organic materials' incomplete combustion (such as petrol, oil, wood, and coal). The majority of PAHs in the environment are caused by anthropogenic activities such as industrial activity and the use of various household fuels [1]. However, some are caused by natural sources such as coal deposits or natural losses or seepage of petroleum, open burning, and volcanic activity [1]. The partitioning of PAH compounds in the atmosphere between particulate and gaseous phases substantially impacts their fate and movement in the atmosphere and how they reach the human body [2].

Incomplete combustion and pyrolysis of solid fuels are the primary sources of PAHs in the environment [1]. In urban and rural households, various fuels are used for cooking, some are significant pollution sources [3,4]. Emission from domestic cooking fuel has significantly threatened society's health. This range from smoke from wood-burning (i.e., the primary means of cooking back in the days that's is firewood and coal) and the current method of cooking, i.e., gas, kerosene etc. [5]. In cookstoves, solid fuel burning produces a complex mixture of particulate and gaseous species such as carbon monoxide (CO), particulate matter (PM), sulphur oxides (SOx), and nitrogen oxides (NOx). Many of these pollutants contain carcinogenic compounds, which pose serious risks to human health.

PAHs are most commonly found in food and indoor air [3]. PAHs, like many other air contaminants, have a negative impact on indoor air quality. When PAH-contaminated air is inhaled, it can cause some harm to the environment's inhabitants. Human exposure to PAHs is greatly increased by inhaling fumes from home cooking fuels. Consumption of certain foods that have undergone processing methods such as smoking, frying, and roasting are also possible sources of PAHs [6]. Skin disease or skin cancer, lung issues, reproductive system disorders, and other health impacts in people could result from PAH exposure. The extent of exposure (length of time and/or concentration), the innate toxicity of the PAHs, and whether exposure happens through skin contact, ingestion or inhalation will all influence human health [3,7].

Due to the community not paying utmost attention and neither is there a proper orientation on vehicular emission from cooking fuel in Nigerian domestic homes, the concentration of PAHs is higher than the average to be emitted. Therefore, it has

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increased the risk of disease and health issues (e.g., cancer, lung, eye problems, etc. [7]. The increasing human health risks and, most notably, the prevalence of cancer in recent times have necessitated the need to study this pollution and emission.

Several researchers have investigated cooking-related emissions using laboratory or real-life kitchens plus various types of fuels and burners, taking into account or not taking into account cooking procedures and with or without ventilation [2,8-9]. Factors such as location, economy, availability and accessibility majorly influence the choice of fuel source in Nigerian household kitchens. While those in rural areas use firewood and charcoal as the primary source of cooking as it is readily available, people in the less civilized areas go for coal pots or kerosene stoves depending on their pockets, while those in urban majorly opt in for kerosene or gas [7,10].

Air pollution was investigated in Taiwanese household cooking [11]. The study revealed that several milligrams of PAHs were released through cooking activities. This may contribute to a cumulative lifelong cancer risk greater than the permissible limit if prolonged exposure is sustained. Several conditions, including limited ventilation, a restricted area, and a pan fire, were reportedly believed to have exacerbated the situation. Another study was carried out on the concentrations of 16 PAHs generated while cooking in an indoor and outdoor kitchen in rural families in Beijing and Shanxi, North China [12]. High PAH concentrations were discovered in the kitchen air during cooking periods, mainly due to the cooking fuel and ventilation.

With a view to quantifying the carcinogenic risk of PAHs to people, their concentrations were further assessed to look at the distribution patterns and sources of PAHs. A comparative investigation of PAH emissions from homes in a remote area in Northeast China was conducted, and their concentrations were evaluated further to investigate patterns of distribution and PAHs' sources to estimate PAHs carcinogenic risks to mortal [13]. The outcomes of the study revealed that the principal sources of PAHs were mixed biomass and coal combustion, emissions from motor vehicles, and residential trash combustion. At the same time, the amount of PAH pollution indoors poses a carcinogenic hazard to the health of the Northeast's rural people. Also, Adesina *et al.* investigated the indoor PAHs' level at local restaurants in Nigeria's southwestern region, with kitchens close to client seating areas [14]. They discovered that while the results are lower than the WHO's acceptable level, prolonged exposure to them can pose a considerable danger to health.

As a result of the alleged rise in the prevalence of cancer-related illnesses, it's critical to advance our knowledge of PAH emissions from cooking in real residential kitchens to evaluate the carcinogenic risks posed to humans. The current research focused on PAH concentrations in indoor air in kitchens using two different cooking fuels under the same ventilation condition. The findings will help design measures to reduce the possible threats presented by PAHs in household cooking.

2. Materials and Methods

2.1 Materials and Sample Collection

The passive sampling method was used to collect ambient pollutants since the technique is inexpensive and straightforward to construct. Passive sampling is a technique that involves the movement of contaminant molecules or ions from a sampling medium to a collecting medium based on Fick's law of diffusion. The passive sampler comprises two sizes of stainless-steel bowls and polyurethane foams (PUF). A steel rod held together the stainless-steel bowls of diameters of 32 cm and 26 cm (Fig. 1).

Fig. 1. The locally fabricated PUF passive sampler (inset shows the PUF)

The rods were fabricated with a support system for firm vertical uphold; they were used to hold the stainless-steel bowl with a stopping system (bolt, nut and washer). In-between the stainless-steel bowl is the PUF used to collect the sample while also allowing the sampler to stabilize in a vertical position. The necessary fabrication is carried out at the Osun State University Mechanical Engineering workshop.

The PUF filters are manufactured of white, non-coloured polyurethane foam, commonly used in furniture. The PUF Filters used are of 105 cm^2 surface area and a density of 0.030 g/cm^3. Prior to assembling, the PUF filter was washed with distilled water, then with acetone and petroleum ether in two successive 24-hour operations. The PUFs were carried to the testing rooms after being dried in a desiccator and wrapped in aluminium foil. The PUF passive sampler was fabricated by adopting the method described by Pozo *et al.* [15].

The sample collection was carried out in an indoor cooking environment in two different rooms similar to that of a standard household kitchen of (3 by 4 m) size, with sampling taking place over two weeks using two various cooking sources, kerosene and gas. Air samples were collected in September 2021 for two weeks. The majority of Nigerian homes in the urban area have aluminium sliding windows. These windows were opened halfway into the two testing rooms to simulate the typical cooking scenario in most homes. To achieve uniformity, the cooking operations in the two rooms began concurrently and ended after 3 hours. The samples of air were taken by utilizing passive PUF samplers that were evenly spaced from the burners. The PUFs were withdrawn after 3, 7, and 14 days since time-averaged concentrations of contaminants were provided by passive sampling during the sampler's deployment period.

2.2 Laboratory Analysis of the Sample for PAHs Evaluation and Quality Control

PAHs were extracted from the PAH-laden PUFs via the Soxhlet extraction technique using dichloromethane as a solvent over 24 hours. Cleaning and elution were implemented using 5 g of silica gel column and 40 mL of 1:1 DCM: Hexane, after which a rotary evaporator utilizing a nitrogen stream was used for the concentration. The extract was separated using a Varian GC-MS 4000/3800 gas chromatograph (Agilent Technologies, Palo Alto, CA) on an HP-1MS (Cross-linked PH ME siloxane) 19091S-933 with a 1 m column 60 m 0.32 mm and a stationary phase thickness. It was analyzed using a Varian GC-MS 4000/3800 mass spectrometer (Agilent Technologies) in selected ion Standard solutions with all 16 target compounds at a range of 0.5 to 50 pg/l concentrations used to calibrate the GC-MS (PAHs Standard).

The following temperature program was used to separate 16 PAHs: the initial temperature was set at 80 °C and held for 180 seconds, then it was linearly raised to 200 °C at a rate of 15 °C min^{-1}, then continuously to 300 °C at a rate of 8 °C min^{-1}, and lastly held for 300 seconds to condition the GC column. The GC-mass spectrometer transfer line was adjusted to 300 °C. The electron impact ionization source and quadrupole were held at all times at 280 °C and 150 °C, respectively. The energy ionization was held constant at 70 eV.

PAHs were measured in laboratory and field blanks and quantified using a standard external method. The samples were pre-extracted by spiking them with 25 mL of recovery standard (RS) containing 20 mg of phenanthrene d10 recovery ranged between 80 and 90%. No blank correction was necessary because field blanks for all compounds of interest were below the limit of detection. The PAH concentrations in the air were estimated by dividing the amount deposited on the PUF (g) by the air volume (m^3). The Global Atmospheric Passive Sampling (GAPS) network template was used to calculate the effective air volume [15]. The input parameters for the template were the deployment duration, mean temperature, and sampling rate.

3. Results and Discussions

Table 1 shows the concentration of PAHs obtained from the GCMS analysis in the kerosene PUFs samples for 3-days, 7-days, and 14-days of cooking. Ten of the sixteen key PAHs were discovered in the three burning scenarios (3, 7, and 14-days). The category of PAHs found was five low molecular weight: naphthalene (Nap), acenaphthene (Ace), anthracene (Ant), fluorene (Flu), phenanthrene (Phe); 4 medium molecular weight: benzo[a]anthracene (BaA), chrysene (Chr), fluoranthene (Fla), pyrene (Pyr) and one high molecular weight: benzo[k]fluoranthene (BkF). The undetected PAHs were of higher molecular weight: benzo[a]pyrene (BaP), benzo[b]fluroanthene (BbF), dibenzo[a,h]anthracene (DahA), benzo[g,h,i]perylene (BghiP) and indeno(1,2,3-cd)pyrene (IndP); and one low molecular weight acenaphthylene (Ace).

In the three burning scenarios, chrysene has the highest value all through, with a mean concentration of 0.1880, 0.2140, and 0.265 µg/m^3 at 3, 7, and 14-days of cooking, respectively; this contribution ranges from 20-26 % in the three scenarios considered. Other noticeable high mean concentration values seen are phenanthrene, naphthalene, and acenaphthene at 0.0950, 0.106 and 0.1330 µg/m^3 at 3-days respectively; naphthalene (0.145 µg/m^3) and acenaphthene (0.1520 µg/m^3) at 7-days and naphthalene (0.213 µg/m^3) and acenaphthene (0.2470 µg/m^3) at 14-days.

The only higher molecular weight detected, benzo[k]fluoranthene (BkF), was only found at 7-day and 14-day with a lower concentration of 0.02 and 0.0045 µg/m^3, respectively. These findings showed that the PAH concentrations increased with the PUF's exposure time.

In this study it was observed that higher molecular weight: benzo[a]pyrene (BaP), benzo[b]fluroanthene (BbF), dibenzo[a,h]anthracene (DahA), benzo[g,h,i]perylene (BghiP) and indeno(1,2,3-cd)pyrene (IndP); and acenaphthylene (Ace), a low molecular weight were not detected throughout the testing of the three burning scenarios. PAHs have numerous environmental sources, and different authors have documented different concentrations of PAHs in the air depending on the origin of the emission.

Globally, over 3 billion people depend on solid fuels, including biofuels, to meet their energy needs, and indoor air pollution from solid fuel burning is known to be a significant health risk factor [7]. Solid fuel combustion, such as biomass, accelerates the pyrosynthesis of organic compounds, resulting in a huge concentration of PAHs being emitted into the room [13].

Chen *et al.* [16] discovered that PAH concentrations in indoor kitchens were substantially greater than in living rooms and outdoors, particularly when solid fuels were used for everyday cooking. Their work reported PAH concentration was up to 9000 ± 8393 ng/m3 in the kitchen indoors, with BaP were high as 131 ± 236 ng/mg. Thus, there was severe household air pollution from PAHs in the rural area of northern China due to the increased usage of solid fuels in cooking. Also, Yu *et al.* [11] investigated five Taiwanese families' indoor air pollution from gas cooking. Their report showed a higher concentration of PAHs of 56,900 ng/m^3 from the kitchen with a confined and closed space. This showing that the kitchen size thus assists in ventilation, which also affects the PAH concentration in return.

Table 2 shows the PAH concentration in the gas sample throughout the days of sample collection. Naphthalene has the highest mean concentration value of 0.0840, 0.1450 and 0.18 µg/m^3 on 3, 7 and 14 days of cooking, respectively. Other noticeable high concentrations are acenaphthene, Phenanthrene and Fluoranthene at 0.122, 0.071, and 0.069, respectively, at 14-days of cooking. Benzo[k]fluoranthene (BkF) and Benzo[b]fluoranthene (BpF) were only detected at 14-days of cooking at a concentration of 0.001 and 0.0025 µg/m^3, respectively.

Fig. 2 shows a comparative analysis of the two cooking methods used in the study, gas, and kerosene, at 14-days. It was so glaring that of all the PAHs detected, gas has a lower concentration than kerosene. Thus, gas could have been the best cooking source if the government could make it cheaper for the people, provided other factors were equal.

Since the toxicities of each PAH differ, the relative toxicity was estimated based on the assumption that benzo[a]pyrene is thought to be the most toxic and carcinogenic compound. The already established toxicity equivalent factors by Nisbet and Lagoy [17] were adopted in this work. Toxicity equivalency (TEQ) is obtained as a product of toxicity equivalent factor (TEF) and PAH concentration., as given by equation 1.

$$TEQ = TEF \times \bar{C} \tag{1}$$

where *TEQ* is the toxicity equivalency, *TEF* is the toxicity equivalent factor and $\bar{C}$ is the average concentration of each PAH (µg/m³).

Table 1. Concentrations of PAHs from kerosene stove (µg/m^3)

PAHs	**Average Concentration**		
	3-days	**7-days**	**14-days**
Naphthalene (Nap)	0.106 ± 0.05^{a}	0.145 ± 0.05^{a}	0.213 ± 0.01^{b}
Acenaphthene (Ace)	0.133 ± 0.00^{a}	0.152 ± 0.01^{b}	0.247 ± 0.04^{c}
Anthracene (Ant)	0.044 ± 0.01^{a}	0.048 ± 0.04^{a}	0.081 ± 0.02^{b}
Fluorene (Flu)	0.054 ± 0.03^{a}	0.088 ± 0.02^{b}	0.123 ± 0.01^{c}
Phenanthrene (Phe)	0.095 ± 0.01^{a}	0.115 ± 0.01^{a}	0.172 ± 0.01^{b}
Benzo[a]anthracene (BaA)	0.020 ± 0.02^{a}	0.028 ± 0.02^{a}	0.036 ± 0.02^{b}
Chrysene (Chr)	0.188 ± 0.01^{a}	0.214 ± 0.02^{a}	0.265 ± 0.02^{b}
Fluoranthene (Fla)	0.043 ± 0.01^{a}	0.099 ± 0.01^{b}	0.129 ± 0.01^{c}
Pyrene (Pyr)	0.042 ± 0.03^{a}	0.051 ± 0.02^{a}	0.059 ± 0.01^{b}
Benzo[k]fluoranthene (BkF)	0.000 ± 0.00^{a}	0.002 ± 0.00^{b}	0.029 ± 0.00^{c}
Benzo[b]fluoranthene (BpF)	NA	NA	NA
Acenaphthylene (Acy)	NA	NA	NA
Benzo[a]pyrene (BaP)	NA	NA	NA
Dibenzo[a,h]anthracene (DahA)	NA	NA	NA
Benzo[g,h,i]perylene (BghiP)	NA	NA	NA
Indeno[1,2,3-c,d]pyrene (IcdP)	NA	NA	NA

Value with different superscript (^{a,b,c}) between the days shows significant difference ($p < 0.05$)

Table 2. Concentrations of PAHs from gas stove (μg/m^3)

PAHs	**Average Concentration**		
	3-days	**7-days**	**14-days**
Naphthalene (Nap)	0.084 ± 0.01^a	0.145 ± 0.01^b	0.190 ± 0.01^c
Acenaphthene (Ace)	0.052 ± 0.01^a	0.073 ± 0.01^b	0.123 ± 0.02^c
Anthracene (Ant)	0.035 ± 0.04^a	0.046 ± 0.02^a	0.059 ± 0.01^b
Fluorene (Flu)	0.215 ± 0.01^a	0.033 ± 0.01^a	0.055 ± 0.02^b
Phenanthrene (Phe)	0.033 ± 0.02^a	0.045 ± 0.02^b	0.070 ± 0.01^c
Benzo[a]anthracene (BaA)	0.001 ± 0.01^a	0.003 ± 0.01^a	0.008 ± 0.02^b
Chrysene (Chr)	0.012 ± 0.01^a	0.025 ± 0.01^b	0.045 ± 0.01^c
Fluoranthene (Fla)	0.034 ± 0.02^a	0.050 ± 0.01^b	0.070 ± 0.02^c
Pyrene (Pyr)	0.010 ± 0.02^a	0.021 ± 0.02^b	0.029 ± 0.03^c
Benzo[k]fluoranthene (BkF)	NA	NA	0.003 ± 0.00
Benzo[b]fluoranthene (BpF)	NA	NA	0.001 ± 0.00
Acenaphthylene (Acy)	NA	NA	NA
Benzo[a]pyrene (BaP)	NA	NA	NA
Dibenzo[a,h]anthracene (DahA)	NA	NA	NA
Benzo[g,h,i]perylene (BghiP)	NA	NA	NA
Indeno[1,2,3-c,d]pyrene (IcdP)	NA	NA	NA

Value with different superscript (^{a,b,c}) between the days shows significant difference ($p < 0.05$)

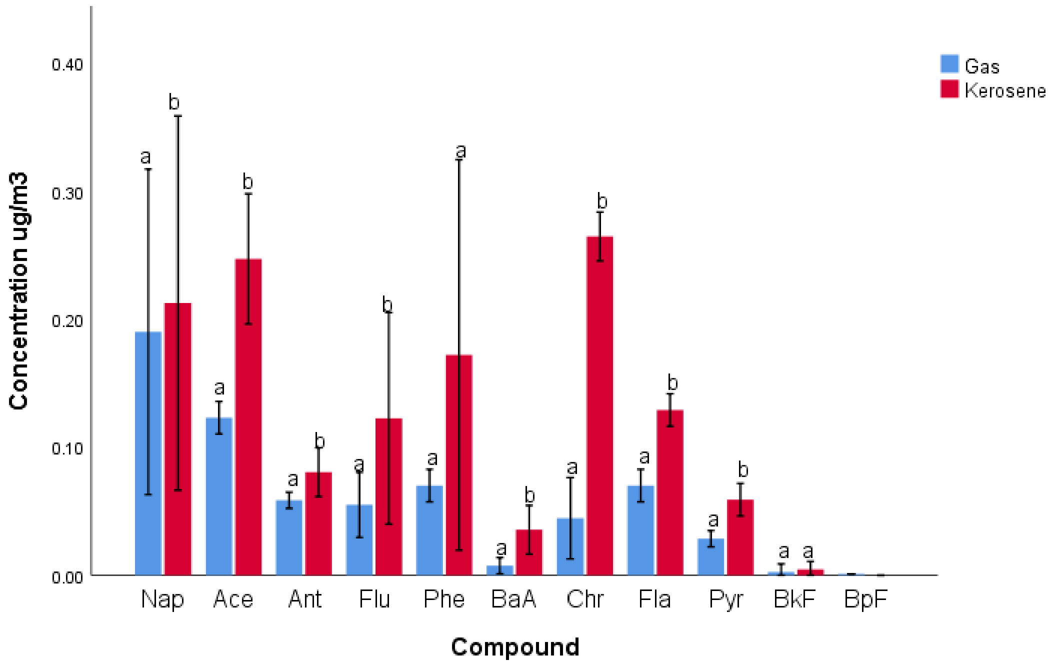

Fig. 2. Comparative analysis of concentrations of PAHs from gas and kerosene stove (μg/m^3) at 14 -days of cooking

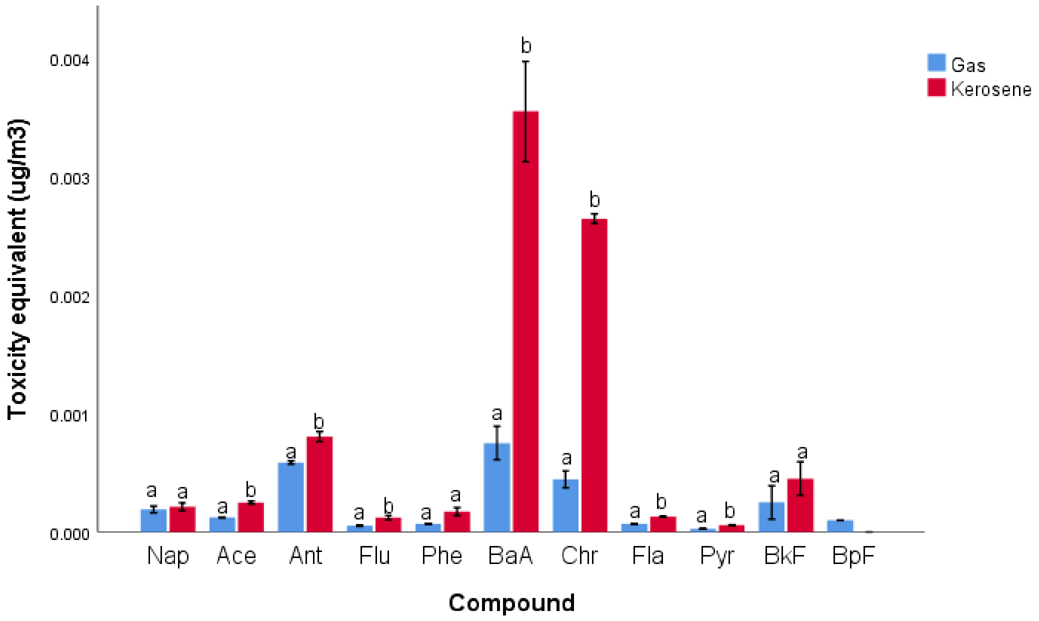

Fig. 3: Comparative analysis of toxicity equivalent of PAHs from gas and kerosene stove (µg/m^{3}) at 14-days of cooking

Table 3. Toxicity equivalent of PAHs from kerosene (µg/m^{3})

	Concentration (SD x10^{-3})			
PAHs	**TEF**	**3-days**	**7-days**	**14-days**
Naphthalene (Nap)	0.001	0.000110±0.05^{a}	0.000140±0.05^{a}	0.000210±0.01^{b}
Acenaphthene (Ace)	0.001	0.000130±0.01^{a}	0.000150±0.01^{b}	0.000250±0.04^{b}
Anthracene (Ant)	0.01	0.000440±0.05^{a}	0.000480±0.04^{a}	0.000810±0.02^{b}
Fluorene (Flu)	0.001	0.000054±0.03^{a}	0.000087±0.02^{b}	0.000123±0.07^{c}
Phenanthrene (Phe)	0.001	0.000100±0.01^{a}	0.000110±0.05^{a}	0.000170±0.01^{b}
Benzo[a]anthracene (BaA)	0.1	0.001950±0.02^{a}	0.002800±0.02^{a}	0.003500±0.02^{b}
Chrysene (Chr)	0.01	0.001890±0.01^{a}	0.002140±0.02^{a}	0.002700±0.02^{b}
Fluoranthene (Fla)	0.001	0.000043±0.05^{a}	0.000099±0.05^{b}	0.000129±0.01^{c}
Pyrene (Pyr)	0.001	0.000042±0.03^{a}	0.000051±0.02^{a}	0.000059±0.01^{b}
Benzo[k]fluoranthene (BkF)	0.1	0.000000±0.00^{a}	0.000200±0.00^{b}	0.000450±0.07^{c}
Benzo[b]fluoranthene (BpF)	0.1	NA	NA	NA
Acenaphthylene (Acy)	0.001	NA	NA	NA
Benzo[a]pyrene (BaP)	1	NA	NA	NA
Dibenzo[a,h]anthracene (DahA)	0.1	NA	NA	NA
Benzo[g,h,i]perylene (BghiP)	0.01	NA	NA	NA
Indeno[1,2,3-c,d]pyrene (IcdP)	0.1	NA	NA	NA
TTEQ		0.004736±0.02^{a}	0.006263±0.03^{b}	0.008392±0.03^{c}

Value with different superscript (^{a,b,c}) between the days shows significant difference ($p < 0.05$)

Table 4. Toxicity equivalent of PAHs from gas (μg/m^3)

		Concentration (SD x10^{-3})		
PAHs	**TEF**	**3-days**	**7-days**	**14-days**
Naphthalene (Nap)	0.001	0.000084±0.02^a	0.000015±0.05^b	0.000190±0.01^c
Acenaphthene (Ace)	0.001	0.000050±0.01^a	0.000070±0.03^b	0.000120±0.01^c
Anthracene (Ant)	0.01	0.000350±0.05^a	0.000460±0.01^b	0.000590±0.07^c
Fluorene (Flu)	0.001	0.000220±0.05^a	0.000330±0.02^b	0.000550±0.02^c
Phenanthrene (Phe)	0.001	0.000033±0.01^a	0.000045±0.01^b	0.000070±0.01^c
Benzo[a]anthracene (BaA)	0.1	0.000100±0.01^a	0.000250±0.05^b	0.000750±0.05^c
Chrysene (Chr)	0.01	0.000120±0.01^a	0.000250±0.03^b	0.000450±0.04^c
Fluoranthene (Fla)	0.001	0.000034±0.01^a	0.000500±0.01^b	0.000700±0.01^c
Pyrene (Pyr)	0.001	0.0000095±0.05^a	0.000021±0.02^b	0.000029±0.05^c
Benzo[k]fluoranthene (BkF)	0.1	NA	NA	0.000250±0.01
Benzo[b]fluoranthene (BpF)	0.1	NA	NA	0.000100±0.00
Acenaphthylene (Acy)	0.001	NA	NA	NA
Benzo[a]pyrene (BaP)	1	NA	NA	NA
Dibenzo[a,h]anthracene (DahA)	0.1	NA	NA	NA
Benzo[g,h,i]perylene (BghiP)	0.01	NA	NA	NA
Indeno[1,2,3-c,d]pyrene (IcdP)	0.1	NA	NA	NA
TTEQ		0.000799±0.02^a	0.001327±0.02^b	0.002667±0.03^c

Value with different superscripts (^{a,b,c}) between the days shows significant difference ($p < 0.05$)

The toxicity equivalent of the PAHs at 14-days is shown in Fig. 3. Fig. 3 shows that gas performs better than kerosene based on the PAH concentration emitted. In addition, the results of the toxicity equivalent factor for both kerosene and gas of the three-scenario investigated are presented in Table 3 and Table 4, respectively

Statistical analysis was carried out using IBM SPSS. A two-way analysis of variance (ANOVA) was performed on the data using the Duncan multiple range test with a significance of 0.05. In kerosene, there was a significant change in the concentration of Ace, Flu, Fla and BpF in 3, 7 and 14 days, while Nap, Ant, Phe, BaA, Chr, and Pyr, showed significant change between 3 and 7 days compared to after 14 days (Table 1). Also, in gas, there was a significant change in the concentration of Nap, Ace, Phe, Chr, Fla and Pyr in 3, 7 and 14 days, while Ant, Flu, and BaA, showed significant change between 3 and 7 days compared to after 14 days (Table 2). The statistical analysis performed on the toxicity equivalent also showed that Ace, Ant, Flu, BaA, Chr, Fla, Pyr and BpF were significantly different in gas compared to Kerosene. At the same time, there was no significant change in Nap, Phe and BkF in gas and kerosene (Table 3 and Table 4).

Clearly, it was revealed that the total toxicity equivalence (TTEQ) is in the order of KER14 (0.00839) > KER7 (0.00626) > KER3 (0.004736) > GAS14 (0.002667) > GAS7 (0.001327) > GAS3 (0.00078). Thus, gas cooking emitted fewer emissions in comparison to kerosene cooking. However, for both gas and kerosene cooking, the PAH concentration exceeded the permissible limit of 10 ng/m^3. In order to alleviate these concentrations, proper natural ventilation will assist a long way. Also, the kitchen space, cooking methods, and duration can substantially impact PAH concentration.

4. Conclusion

This study was conducted to compare the PAH emission characteristics of two household cooking methods applicable in Nigeria's urban kitchen, gas and kerosene. The passive sampling method was used to collect ambient pollutants, and the device was locally fabricated at Osun State University. This study is of necessity as the government needs to look further and reduce the cost of liquefied petroleum gas for cooking or provide an alternative cooking method through price reduction of electricity tariff. The statistical analysis performed on the toxicity equivalent revealed that Ace, Ant, Flu, BaA, Chr, Fla, Pyr and BpF were significantly different in Gas compared to kerosene. At the same time, for Nap, Phe and BkF, there was no significant change in gas and kerosene. However, for both gas and kerosene cooking, the PAH concentration exceeded the permissible limit of 10 ng/m^3. It was thus suggested that good ventilation and proper design of the cooking area (space) would also significantly assist in lowering the PAH concentration and making the environment safe for human health.

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