SPATIAL AND TEMPORAL VARIATIONS OF POLYCYCLIC AROMATIC HYDROCARBONS AROUND A TYPICAL MEDICAL WASTE INCINERATOR

Adesina O. A.[1], Sonibare J[2], Paul N Diagboya[3]
[1]Department of Chemical and Petroleum Engineering, Afe-Babalola University, Ado-Ekiti, Ekiti State, Nigeria, +234
[2] Department of Chemical Engineering, Obafemi Awolowo University,Osun State, Nigeria, +234.
[3] Department of Chemistry, Vaal University of Technology, Vanderbijlpark, South Africa

1.0 Introduction

Polycyclic Aromatic Hydrocarbons (PAHs) are ubiquitous and introduced into the environment by various natural processes, but their concentrations have been enormously supplemented by various anthropogenic activities [1,2]. Industrialization related activities have been the major culprit for recent environmental PAHs increases [3,4,5]. Supplementation by anthropogenic activities is of serious concern because most PAHs are known to be toxic and some are mutagenic and carcinogenic; hence, several have been classified as priority pollutants [6,7,8]. Their effect on biota can be amplified by bioaccumulation in the food chain because PAHs like most organic pollutants are very soluble in fat.

The PAHs from incinerators occur subtly and their contribution is often underestimated. However, as environmental PAHs concentrations build-up, this may be a serious concern around the incinerator vicinity due to their potential consequences on ecosystems and human health. Incineration is the preferred method of disposal of infectious and toxic hospital wastes in Nigeria but one major challenge here is that most hospitals use locally fabricated Incinerators without air pollution control unit. This with the attendant increase in medical wastes as human population grow in Africa's sub-Sahara might lead to unprecedented amounts of PAHs around the incineration facility. The 12 PAHs included in this study are naphthalene (NAP), phenanthrene (PHE), pyrene (PYR), anthracene (ANT), azulene (AZU), fluorene (FLU), benzo[k]fluoranthene (BFA), benzo[e]pyrene (BeP), benzo[a]pyrene (BaP), perylene (PRL), benz[e]acephenanthrylene (BAP) and indeno[2,1-b]chromene (IDC).

2. Material and Methods

2.1 Sample collection, preparation and instrumental analysis

The Medical waste incinerator for this study was a Rotary Kiln type of incinerator for full thermal decomposition of waste, manufactured and supplied by Boskel Limited. Air samples were obtained from within the vicinity of the Obafemi Awolowo University teaching Hospital Waste Incinerator (HWI_0) site (4˚55′ E; 7˚518′ N). Considering the prevailing meteorological conditions (wind rose) around the HWI vicinity and the locations of major residential areas, five sampling locations were selected around the HWI_0. Duplicate samples were collected from each site described in Table 1.

Ambient air samples were collected using Polyurethane Foam (PUF) passive samplers [9]. Prior to deployment, PUF disks was pre-cleaned with distilled water and then washed with acetone in a Soxhlet extractor for 24h, followed by petroleum ether for another 24h [10]. The disks were dried in a dessicator, covered in aluminium foil and transported to the sampling locations. The duration of the sampling was 28 d. The filters in the PUF samplers were replaced after every 28 d for a one-year period (June, 2014–May, 2015). Stack gas samples were collected by adopting a modified [11] method. A filter-sorbent sampling system was used consisting of a sampling probe, filter and a packed column of Amberlite XAD-2 resin (adsorbent material). Samples were iso-kinetically withdrawn from the gas stream of the HWI into the sample train.

The PAHs trapped in PUF disks and Amberlite XAD-2 resins were extracted into dichromethane using a Sohxlet extractor. Clean-up step was carried out as described by [11]. The extracted PAHs were concentrated to 20 µL using rotatory evaporator under a gentle stream of Nitrogen. The analysis was done using gas chromatograph of 7890 of Agilent technology coupled with MS model 5975 with column dimension (28cm by 31cm by 16 cm) with internal diameter of 0.531 mm. The gas chromatograph was operated in splitless mode, and 1 µL of each sample extract was injected with helium as a carrier gas at a constant flow of 1.2 mL min^{-1}. The mass spectrometer was operated in positive electron impact ionization (EI+) mode and selective ion monitoring mode, with an electron impact energy of 35 eV and a resolution of 10000 [10]. Laboratory blanks (n = 4), field blanks (n= 6) and duplicate sample (n = 6) were collected and treated along with the sample to ensure high quality. All samples were corrected for the blank by subtracting the mean blank value from the estimated concentration in each sample. Statistical analysis was carried out using Principal Component Analysis (PCA) and Pearson correlation available on the XLSTAT program.

3 Results and Discussion

3.1 Spatial distributions of the various PAHs compared to the HWI_0

The monthly concentrations of all pollutants are shown in Fig. 1. It was observed that vitually in the pollutants observed, HWI_0 (source) concentration was the highest when compared with other sampled sites. 12 PAHs source (HWI_0) concentrations were in the range of NA – 10.9 ng/m^3 and generally higher than the for receptor points (HWIs); a trend attributed either proximity of HWIs to HWI_0 or differences in meteorological conditions of the HWIs. The average monthly concentrations (∑PAHs) at HWI_0 and the receptors– HWI_1, HWI_2, HWI_3, HWI_4 and HWI_5 were 73.0 ± 27.9, 60.4 ± 30.8, 42.5 ± 23.6, 38.7 ± 21.9, 35.0 ± 27.2 and 39.2 ± 22.9 ng/m^3, respectively.. This trend was likely due to proximity of the sampling points to HWI_0 as well as differences in meteorological conditions (wind speed and direction) associated with the various sampling points. Though the waste types incinerated were not sorted or recorded, the waste type incinerated could also be a determining factor for the type PAHs emitted from the in the incinerator [12,13,14,14,16].

3.3 Correlation between the HWI_0 emissions and other HWI concentrations

Multivariate receptor model analysis (Principal Component Analysis– PCA) was used in this study for the source (HWI_0) identification and contributions to ambient air receptors (HWIs) of the various PAHs. Fig. 5 shows the PCA variable plot in which Factor 1 explains 77.1 % of the total variance while Factor 2 explains 16.2 % of the total variance and a cumulative total variance of 93.3 %. For variables that are close to each other but far from the center, they may be said to be significantly positively correlated. However, if both variables are on the opposite side of the centre then they are significantly negatively correlated; but for variables that are orthogonal, they are not correlated. From the proximity (Fig. 2) between the HWI_0 and the HWI_1, HWI_2, HWI_3, HWI_4 and HWI_5, it may be inferred that they was correlation between PAHs concentrations in the stack emission and the ambient air at these sampling locations [17,18], implying that HWI_0 was the source of PAHs at these HWIs. Considering the distance of HWI_2 relative to other HWIs (Fig. 2), there is the possibility that the HWI_2 which is the University Staff Estate entrance may be prone to other PAHs emission sources, possibly from vehicular traffic [19]. Fig. 3 shows the PCA observation plot. Considering the proximity of each PAHs from the center, it can be inferred that these PAHs were from the HWI_0.

CONCLUSION

Results showed that the 12 PAHs source (HWI_0) concentrations were in the range of NA – 10.9 ng/m^3 and generally higher than the for receptor points (HWIs); a trend attributed either proximity of HWIs to HWI_0 or differences in meteorological conditions of the HWIs. The average monthly concentrations (∑PAHs) at HWI_0 and the receptors– HWI_1, HWI_2, HWI_3, HWI_4 and HWI_5 were 73.0 ± 27.9, 60.4 ± 30.8, 42.5 ± 23.6, 38.7 ± 21.9, 35.0 ± 27.2 and 39.2 ± 22.9 ng/m^3, respectively. The multivariate receptor model analysis indicated high correlations between source and the receptor points. These data suggest that incineration of medical wastes lead to substantial PAHs exposure and concentrations observed here are similar to those reported in several polluted cities around the world. The average PAHs concentrations in the HWIs as well as the cumulative exposure concentrations observed throughout the period are of major health concern because PAHs concentrations detected are several times higher than international limits. Within the limits of human error and other uncertainties, this assessment gives a general evaluation of the condition of PAHs pollution in the vicinity of a typical waste incinerator in Nigeria.

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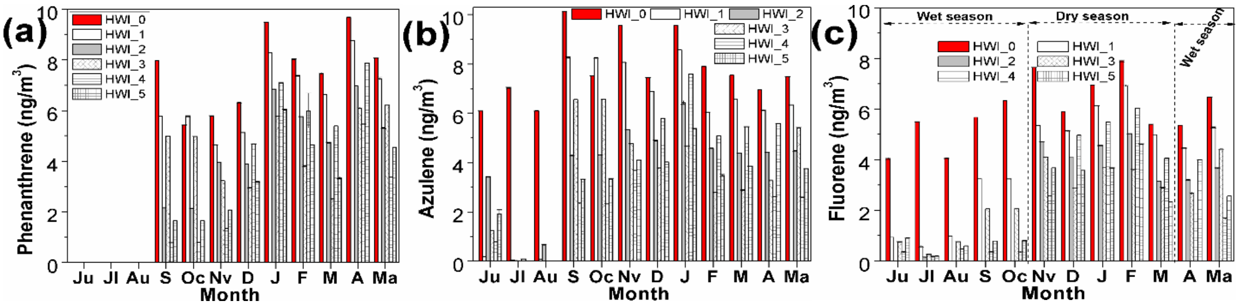

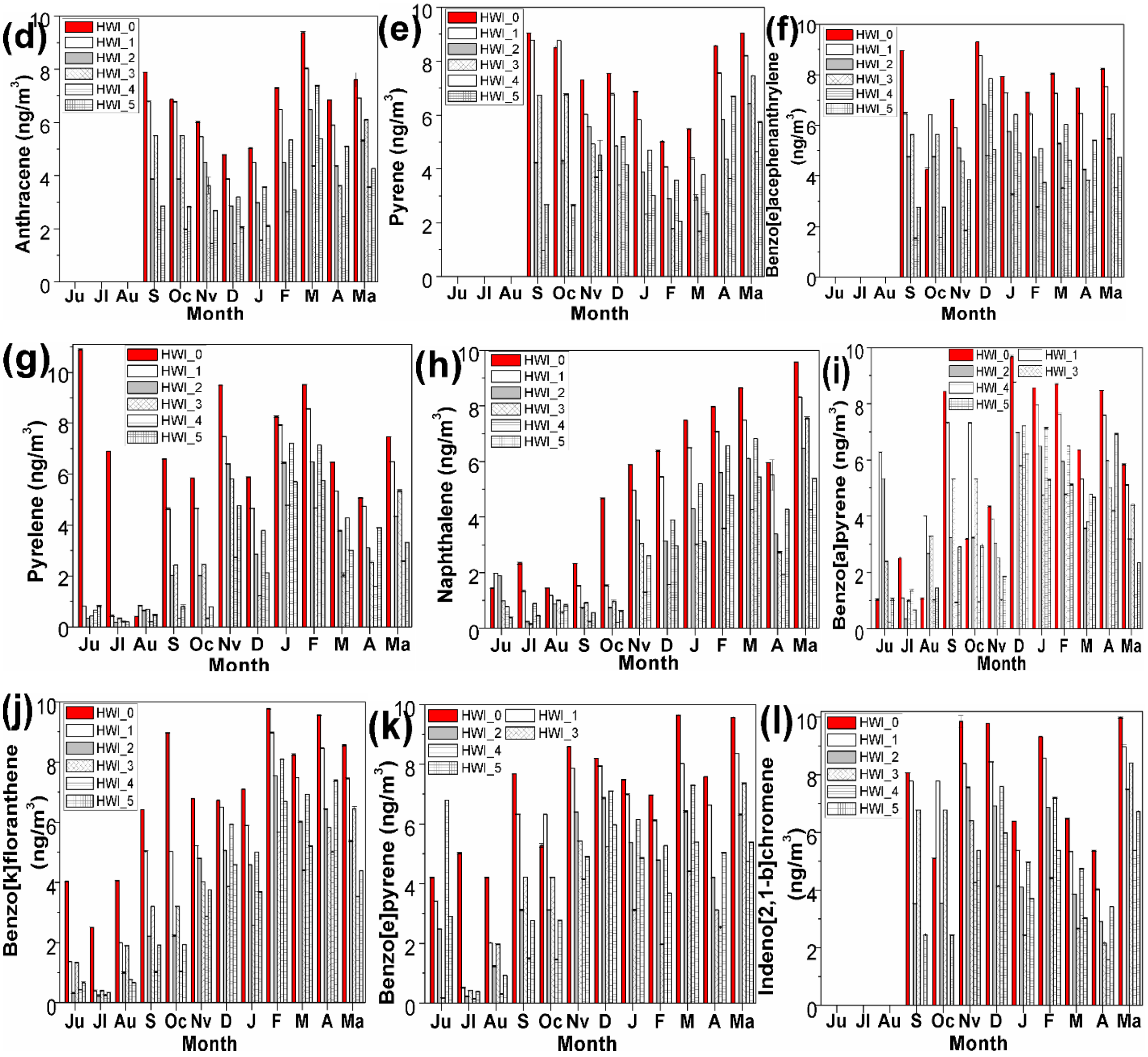

Fig. 1. Monthly concentrations of PAHs from the stack and various sampling points from June 2014 to May 2015

Table 1. Descriptions of sampling locations

Sampling Point	Sampling Point Description	Geographical Coordinate	Distance from HWI_0
HWI_0	HWI stack	7˚519′35" N; 4˚54′57" E	0.00km
HWI_1	Very close to HWI stack	7˚518′35" N; 4˚55′56" E	0.004km
HWI_2	University Staff Estate Entrance	7˚512′21" N; 4˚54′77" E	1.10km
HWI_3	Vicinity of Medical Student Hostel	7˚510′64" N; 4˚55′70" E	0.94km
HWI_4	Vicinity of Patients' Ward	7˚507′89" N; 4˚56′88" E	1.88km
HWI_5	Teaching Hospital Staff Estate	7˚510′35" N; 4˚57′02" E	1.84km

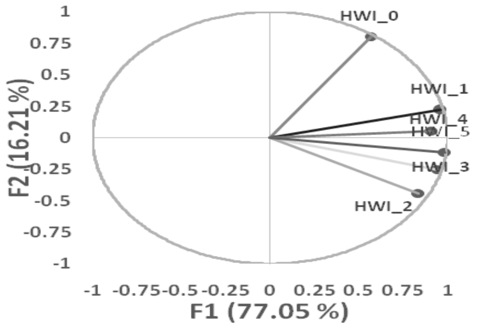

Figure 2. Variables plot for PCA showing all HWIs

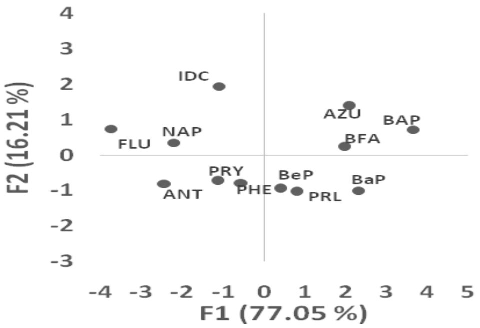

Figure 3. Observations plot of PCA indicating the positions of naphthalene (NAP), phenanthrene (PHE), pyrene (PYR), anthracene (ANT), azulene (AZU), fluorene (FLU), benzo[k]fluoranthene (BFA), benzo[e]pyrene (BeP), benzo[a]pyrene (BaP), perylene (PRL), benz[e]acephenanthrylene (BAP) and indeno[2,1-b]chromene (IDC).