



Distribution of Polycyclic Aromatic Hydrocarbons in Soils within Vicinity of an Electronic Waste Open Burning Workshop in Aba, South East Nigeria

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Abstract

Electronic waste (e-waste) workshops distributed in the commercial city of Aba, South East Nigeria, employ open burning to extract valuable sub-assemblies from the e-waste. Polycyclic aromatic hydrocarbons (PAHs) were studied in soils (0-5 cm) collected from three sampling points within an e-waste workshop vicinity: the e-waste open burning site (OBS-X), 30 m from the open burning site (OBS-30m) and 70 m from the open burning site (OBS-70m). Concentrations of 16 USEPA PAHs in the soils were characterized by dominance of high molecular weight (HMW) over low molecular weight (LMW). The most abundant PAHs were DA 26.45%, IP 13.82% and BbF 13.07% in OBS-X, BaA 19.78%, BbF 17.15% and BaP 16.80% in OBS-30m and Chr 23.73%, BP 14.26% and Nap 8.871% in OBS-70m. Source diagnostic PAH isomer ratios determined are Phe/Ant from 0.73 - 1.36, Fth/Pyr 1.52 - 3.79, BaA/Chr 0.29 - 28.27 and BkF/BaP 0.11 - 1.31. These results from PAH distributions and compositions indicated incomplete combustion source for pyrogenic PAHs in OBS-X and OBS-30m and mix combustion-petroleum source for PAHs in OBS-70m. In conclusion, the open burning of e-waste in Aba metropolis largely contaminated soils from the workshop vicinity, particularly with carcinogenic HMW PAHs.

Keywords: Aba; composition; diagnostic ratio; e-waste; open burning; PAHs.

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1. Introduction

The rapid development in the electronic industry has led to a large quantity of electronic appliances becoming obsolete or unwanted and discarded few years after production [1]. Electronic waste (e-waste) including televisions, refrigerators, audio-video equipment (radios and VCR/DVD/CD players), computers, electric irons, and mobile phones, are mostly exported to developing countries like China, Pakistan, India, Vietnam, Nigeria and Ghana, for recycling because of cheaper labour [2]. In Nigeria, particularly urban areas, e-waste provides income for the scavengers who search through e-waste for recyclable or reusable materials worth selling, repairers who fix broken-down appliances that are later resold cheap as second-hand products, and dismantlers who manually disassemble or openly burn e-waste to extract valuable sub-assemblies and reduce volume [3]. This has made the country an attractive destination for e-waste. The open burning of e-waste releases hazardous chemicals such as heavy metals, polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs), which contaminate soil, water and air, presenting health danger to humans, aquatic life, and harmful threat to the natural environment [4].

PAHs are a group of hydrocarbon compounds composed of two or more aromatic rings fused together [5]. They are derived from incomplete combustion of organic materials such as gasoline, diesel, tires, plastics, coal, wood and waste [6,7,8] as well as petroleum oil spill and asphalt processing plants [9,10,11]. The distribution and composition of PAHs vary according to source and are utilized in environment forensic for source characterization, identification and differentiation [12]. PAHs are soluble in non-polar organic solvents with increasing molecular weight, highly capable of accumulating in fat tissues of living organisms, possess carcinogenic, mutagenic, and toxic properties and persistent in the environment [13,14]. Consequently, the United State Environmental Protection Agency (US EPA) has listed 16 PAHs as priority pollutants which are routinely investigated in environmental samples [15].

Guiyu town in Southeast China is a major e-waste site where eighty percent of the population are engaged in recycling. Analysis of 16 US EPA priority PAHs in Guiyu soils, from different locations, indicated PAHs were mainly derived from incomplete combustion due to primitive open burning of e-waste [16]. Further studies from Guiyu e-waste site revealed that primitive recycling of e-waste by open burning polluted air, water, and soil as well as affected the health of workers and inhabitants [17]. Despite the inherent dangers on the health of e-waste workers and environmental degradation, e-waste disposal and open burning has continued in developing countries. The objective of this study is to determine the distribution, concentration and source of PAHs in soils within vicinity of an e-waste workshop in Aba metropolis, Nigeria.

2. Materials and Methods

Sampling site description

The location of sampling is Aba, a commercial city in Abia State, south east Nigeria. The commercial city has notable markets like Ariaria International Market, Ahia Ohuru and Shopping Centre, as well as established industrial complex which manufactures textiles, pharmaceuticals, plastics, footwear etc. [18]. E-waste

processing workshops are distributed in Aba metropolis and employ open burning to dismantle and extract valuable materials and sub-assemblies as well as reduces the e-waste volume before disposal. During open burning of e-waste, dust and fumes produced at the site pollute the surroundings.

Sampling

Sampling was carried out within an e-waste open burning workshop vicinity at latitude 5° 06' 12.075" N and longitude 7° 22' 31.493" E in December, 2015. Soil samples were collected at surface (0-5 cm) from three sampling points within the vicinity of an e-waste workshop: the e-waste open burning site (OBS-X), 30 m from the e-waste open burning site (OBS-30m) and 70 m from the e-waste open burning site (OBS-70m). Four soil samples were collected from each sampling point and mixed to constitute one sample at that sampling point. The samples were collected using a stainless steel scoop and packed in pre-cleaned glass jars.

Sample extraction and analysis

Five (5) grams of each soil sample was weighed into an extraction bottle and 10mL of hexane added. The mixture was stirred, agitated with a vibrator for five hours, carefully filtered and the filtrate concentrated to 1 mL by evaporation at room temperature. The concentrated extract was transferred onto the top of a glass column (50 cm x 1 cm) stuffed with glass wool at the base and packed with 4 g of activated silica gel (mesh 100-200) for clean-up. 10 mL of dichloromethane was added to elute the aromatic hydrocarbons and the eluant evaporated to less than 2 ml under a gentle stream of dry nitrogen.

PAH analysis was performed on an Agilent 7890B gas chromatography (GC) system equipped with a HP-5 silica capillary column 30 m x 320 µm ID and 0.25 µm film thickness, flame ionization detector (FID), and a G4513A automatic liquid sampler (ALS). The eluants were transferred into labelled glass vials with teflon caps and 1µL injected into the GC capillary column with the aid of the ALS, using the splitless injection mode. Oven temperature was programmed from 35 °C to 325 °C at 10 °C/min with 2 min hold at 35 °C and 10 mins hold at 325 °C. PAHs were identified by their relative retention times in comparison with internal standard and quantification of each identified peak acquired by Chemstation OPEN LAB CDS Edition.

3. Results and Discussion

Distribution of PAHs

Sixteen US EPA PAHs, from 2 ring naphthalene to 6 ring benzo(*g,h,i*)perylene, were detected in soils within the e-waste open burning workshop vicinity in Aba metropolis and their concentrations listed in Table 1. Total PAH concentration in the soils were 117.6 mg/kg at the open burning site (OBS-X), 201.7 mg/kg at 30 m from the open burning site (OBS-30m) and 198.3 mg/kg at 70 m from the open burning site (OBS-70m).

Table 1: PAH concentrations in soils within an e-waste open burning workshop vicinity in Aba metropolis.

PAHs		Concentration (mg/kg)		
		OBS-X	OBS-30m	OBS-70m
Naphthalene	Nap	0.0	12.6	17.6
Acenaphthylene	Acy	0.0	1.3	1.4
Acenaphthene	Ace	0.0	4.5	5.1
Fluorene	Fle	3.6	3.2	1.9
Phenanthrene	Phe	1.4	9.3	13.6
Anthracene	Ant	2.0	11.7	10.1
Fluoranthene	Fth	9.4	22.4	10.3
Pyrene	Pyr	2.5	7.7	6.8
Benzo (α) anthracene	BaA	13.5	39.9	13.8
Chrysene	Chr	5.9	1.4	47.0
Benzo(b)fluoranthene	BbF	15.4	34.6	10.0
Benzo(k)fluoranthene	BkF	1.3	10.5	8.4
Benzo(a)pyrene	BaP	11.6	33.9	6.4
Indeno(1,2,3-cd)pyrene	IP	16.3	1.1	11.8
Dibenzo(a,h)anthracene	DA	31.1	5.5	5.9
Benzo(g,h,i)perylene	BP	3.8	2.2	28.3
Total PAH		117.6	201.7	198.3
LMW PAHs		7.0	42.6	49.6
HMW PAHs		110.7	159.1	148.6
HMW/LMW		15.92	3.74	2.99

LMW PAHs = Σ 2 - 3 ring

HMW PAHs = Σ 4 - 6 ring

Total concentrations of low molecular weight (LMW) 2-3 ring PAHs, from Nap to Ant, were lower than high molecular weight (HMW) 4-6 ring PAHs, from Fth - BP, in all the samples (Table 1). This showed PAH abundance in soils within the e-waste open burning workshop vicinity, in Aba metropolis, were characterized by dominance of HMW over LMW. The 2-3 ring LMW PAHs are usually dominant in crude oils, while 4-6 ring HMW PAHs are very minor components, but dominant in combustion products [19]. HMW PAH composition of 94.09% of total PAHs in OBS-X and HMW/LMW ratio of 15.92 was higher than 78.89% in OBS-30m and 74.96% in OBS-70m, with significantly low ratios of 3.74 and 2.99 respectively. Also, during open burning, the distance travelled by PAHs generated and contained in dust and fumes decrease with increase in molecular weight of PAHs [20]. The PAH composition difference in the samples was due to increase in concentration of LMW PAHs (from 7.0 mg/kg in OBS-X to 49.6 mg/kg in OBS-70m; Table 1). These results indicate PAHs in soils within the workshop vicinity were combustion source generated from the open burning of e-waste.

Compositions of PAHs

Figure 1 shows the PAH composition in soils within the e-waste open burning workshop vicinity, in Aba metropolis. In OBS-X and OBS-30m, compositions of PAHs increased from 2 to 6 ring, while in OBS-70m, the distribution was bimodal (fig. 1).

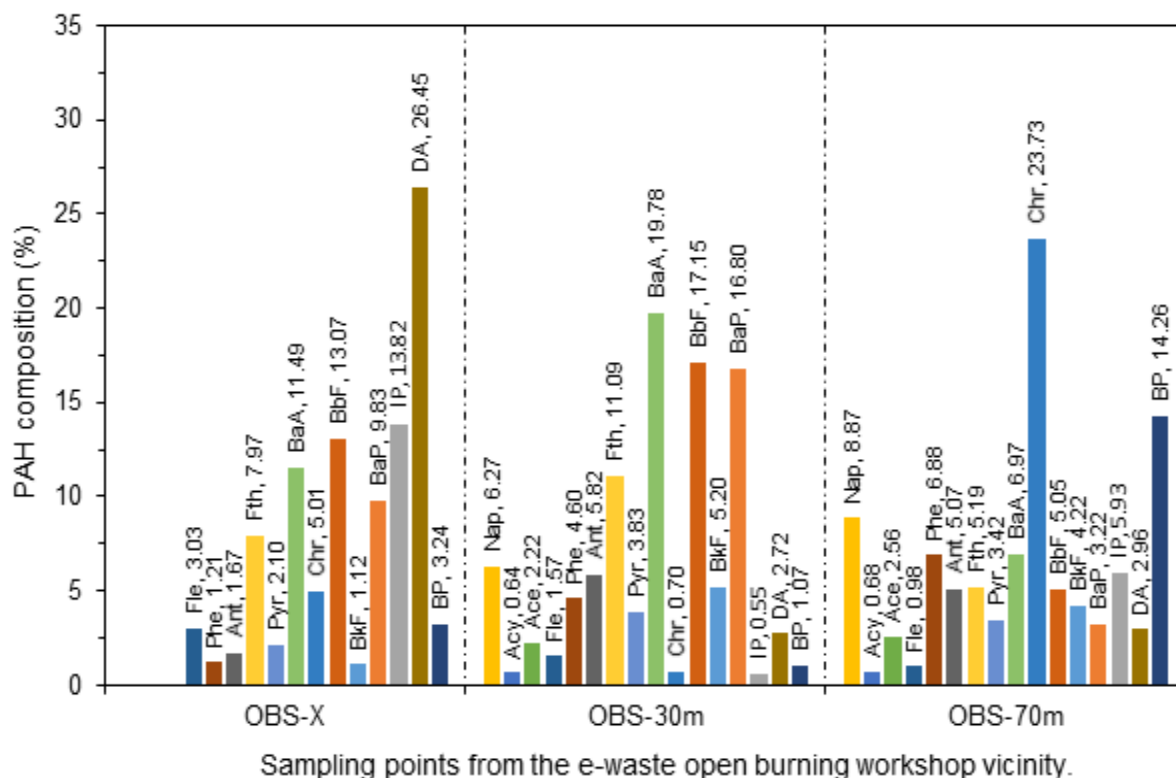


Figure 1: Composition of PAHs in soils within e-waste open burning workshop vicinity in Aba metropolis.

The most abundant PAHs in OBS-X were DA 26.45%, IP 13.82% and BbF 13.07%, and in OBS-30m were BaA 19.78%, BbF 17.15% and BaP 16.80%. In OBS-70m, the most abundant PAHs were Chr 23.73%, BP 14.26% and Nap 8.871% (fig. 1). Nap 2-ring and Chr 4-ring are petroleum characteristic and referred to as petrogenic PAHs. BaA, BbF, BaP, IP, DA and BP are 4-6 ring carcinogenic HMW PAHs generated via pyrolysis during incomplete combustion of organic materials and are referred to as pyrogenic PAH [21]. These PAH compositions suggest pyrogenic PAHs from combustion source mainly contaminated soils within the e-waste workshop vicinity with input of petrogenic PAHs, from petroleum source, at 70 m.

Diagnostic ratios

PAH isomers employed as source diagnostic parameters are 3-ring Phe and Ant; 4-ring Fth, Pyr, BaA and Chr; 5 ring BkF and BaP. Ratios derived from these PAHs are commonly employed in environmental forensic studies. Phe, Pyr, Chr and BkF are characteristic of petroleum from which they are derived (petrogenic source) and the dominant isomers, while Ant, Fth, BaA, and BaP are preferentially generated during combustion of organic material (pyrogenic source) and the dominant isomers [22,23]. Calculated PAH isomer ratios of soil samples

from the e-waste open burning workshop vicinity in Aba metropolis are presented in Table 2.

Table 2: PAH diagnostic ratios of soils within the e-waste open burning workshop vicinity in Aba metropolis.

PAH ratios	Phe/Ant	Fth/Pyr	BaA/Chr	BkF/BaP
OBS-X	0.73	3.79	2.29	0.11
OBS-30m	0.79	2.90	28.27	0.31
OBS-70m	1.36	1.52	0.29	1.31

From Table 2, Phe/Ant ratios from 0.73 - 1.36 revealed Ant was dominant in OBS-X and OBS-30m, while Phe was dominant in OBS-70m. Phe/Ant ratio >10 suggest crude oil source for PAHs, with degraded crude oil having ratios <10 and pyrogenic products ratios <1 [23,24]. This ratio suggest PAHs in OBS-X and OBS-30m were pyrogenic and in OBS-70m, degraded petroleum. Fth/Pyr ratios from 1.52 - 3.79 revealed Fth was dominant in all the samples. Fth/Pyr ratio >1 indicate combustion process for PAH, while ratio <1 suggest petroleum origin. This ratio suggest combustion process for PAH in soils within the e-waste workshop vicinity. BaA/Chr ratios from 0.29 - 28.27 and BkF/BaP ratios from 0.11 - 1.31 revealed BaA and BaP were dominant in OBS-X and OBS-30m and suggest pyrogenic PAHs, while Chr and BkF were dominant in OBS-70m and suggest petrogenic PAHs. From the diagnostic ratio results, combustion process via open burning of e-waste contaminated soils within the workshop vicinity with PAHs, in addition to input from petroleum source at 70 m.

4. Conclusion

Soils from the vicinity of an e-waste open burning workshop, in Aba metropolis, were contaminated with PAHs, which were characterized by dominance of HMW over LMW. The abundance of BaA, BbF, BaP, IP, DA and BP in the soils indicated pyrogenic source for PAHs, with abundance of Nap and Chr in OBS-70m suggesting input of uncombusted petroleum in soils at 70 m from the open burning site. PAH isomer source diagnostic ratios of Phe/Ant, Fth/Pyr, BaA/Chr and BkF/BaP suggested combustion source for pyrogenic PAH in OBS-X and OBS-30m, with mix combustion and petroleum sources for PAHs in OBS-70m. Therefore, the open burning of e-waste mainly contaminated soils within the workshop vicinity, in Aba metropolis, with PAHs.

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