



Evaluation of Polycyclic Aromatic Hydrocarbons (PAHS) Levels in Soil Contaminated with Electronic Waste (E-Waste), South-Eastern, Nigeria

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Abstract

E-waste is an emerging environmental problem, as it is composed of a heterogeneous mix of different metals, metalloid, glass and plastic, which are useful and hazardous to the environment. The article aimed at evaluating the levels of Polycyclic Aromatic Hydrocarbons (PAHs) in soil contaminated with e-waste obtained at different depths (0 – 10 cm, 10 – 20 cm & 20 – 30 cm) and the evaluation was done in soil samples with the help of gas chromatograph coupled with a mass analyzer. The concentrations of the 16 Polycyclic Aromatic Hydrocarbons ranged from 404 – 32, 250 µg/kg, There was significant variation in the mean values of the 16 PAHs under study across seasons. At 0 – 10 cm in the dry season, the mean values ranged from 30.0 µg/kg (benzo(k)fluoranthene) High Molecular Weight (HMW) PAHs to 1,675 µg/kg (acenaphthylene) Low Molecular Weight (LMW) PAHs. While in wet season, it ranged from non detectable limit (naphthalene) LMW PAHs to 3,934 µg/kg (phenanthalene) LMW PAHs. The trend of PAHs percentage distributions was 3-ring PAHs > 7-ring PAHs > 2-ring PAHs > 4-ring PAHs > 5-ring PAHs > 6-ring PAHs. The hazard index HI-non carcinogenic risk for children was > 1 and for adult is < 1. The trends of ILCR concentrations for both children and adults follow ingestion > dermal > inhalation. The PAHs cancer risk in this study revealed moderate to very high level. It can be concluded that the e-waste dumping activities have contributed contaminant of PAHs to the soil. Hence dumping activities should be properly monitored.

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Keywords: E-Waste; Polycyclic Aromatic Hydrocarbon; Dump Site; Contamination; Cancer risk.

1.0 Introduction

In Nigeria, like other countries, PAHs contamination via e-waste has spread all over the country. Persistent organic pollutants (POPs) like PAHs are very ubiquitous in nature due to their volatility, and contamination from this source is widespread due to high level of population growth, indiscriminate dumping of e-waste and burning of material containing POPs compounds (Eyenubo *et al.*, 2024). Contamination from e-waste as a result of uncontrolled disposal has become a general health issues in Nigeria since it is associated with hazardous substances. Uncontrolled burning releasing highly toxic fumes which impact on the neighborhood aesthetics, dismantling, and dumping leads to a variety of issues in our environment like the contamination of groundwater, atmospheric pollution and water pollution through immediate discharge or as a result of surface runoff . The rate of growth of domestic and imported e-waste in Nigeria, as reported by researchers, is on the average of 500 shipping containers with 400,000 computer monitors that enter Lagos port, Nigeria per year (Adebola and Peter, 2017).

Persistence organic pollutants like PAHs generated from e-waste accumulate in the soil as a result of their poor water solubility and strong chemical stability (Xi, *et al.*, 2022), other sources like particulate matter from the atmosphere can increase the concentration of PAHs in the soil via sedimentation, as such soil is known to be a major source of PAHs in the environment that affects plants, animals and humans health (Liu *et al.*, 2018, Xi, *et al.*, 2022). Pollution generated by PAHs has become a major environmental challenge across the world as a result of their potential carcinogenic, tetragenetic and mutagenic effects (Cao, *et al.*, 2019, Xi, *et al.*, 2022). Waste from electronics generally known

as e-waste is a generic term referring to those electrical electronics equipment that becomes obsolete or disposed of by the original users; phones, television, computer monitors, laptops, printers, scanners with their associated wiring (Khadijah, 2016). Emerging environmental issues like e-waste, composed of a heterogeneous mix of different metals, metalloids, glass and plastics from which some valuable metals such as aluminum, copper, gold, silver and iron are recovered via recycling which serve as environmental sustainability management (Robinson, 2019). Different hazardous substances like nickel (Ni), lead (Pb) polybrominated diphenyl ethers (PBDEs), polyaromatic hydrocarbons (PAHs), polychlorinated biphenyl (PCBs) etc has been released into the environment due to the inability to monitor the dumping of e-waste (Eyenubo, *et al.*, 2022)

Improper practices of e-waste disposal and dismantling like open dumping, open burning, acid baths and heating of circuit boards, have led to the emission and release of hazardous pollutants, including heavy metals, persistent organic pollutants (POPs), and volatile organic pollutants (VOCs) (Shengtao, *et al.*, 2021). During the past two decades, several research studies have been done on the environmental occurrence and fate, transformation and potential adverse health consequences of these hazardous chemicals from e-waste sites (Shengtao *et al.*, 2021). They found that dismantling employees and resident houses near the e-waste sites are highly exposed through dermal contact, inhalation and ingestion with this hazardous material, toxic fumes and toxic chemicals from contaminated soil, water and food. E-waste dismantlers are exposed to environmental pollutants via inhalation which is one of the

important exposure pathways (Shengtao, *et al.*, 2021).

The e-waste generates a large volume of toxic substances that affect the ecosystem. The material composition of e-waste contains various substances which are known to be hazardous and non-hazardous (Richard *et al.*, 2013). Occupational exposure to PAHs in Epidemiological studies has shown that they can generate induction of skin and lung cancers. Report have also shown that some PAH metabolites interact with deoxyribonucleic acid (DNA) and are genotoxic, generating malignancies and heritable genetic problems in humans (Adebola *et al.*, 2017). Lower molecular weight PAHs like naphthalene, fluorene, phenanthrene and anthracene (2 to 3 rings) generated significant acute toxicity to aquatic organisms, on the other hand higher molecular weight PAHs like chrysene and coronene (4 to 7 rings) do not generate acute toxicity, but are carcinogenic (Adebola *et al.*, 2017). The Food and Agriculture Organization of the United Nations and the Intergovernmental Technical Panel on Soils reported that many of world's soil resources will only be in better condition with 33% of the land resources being moderately to highly degraded (Panatda *et al.*, 2023). The dumping, recycling and even burning of e-waste lead to the leaching of toxic metals into the soil which then affect humans through ingestion or direct dermal exposure, combustion of e-waste at low temperature released toxic chemicals such as PAHs (Adebola and Peter, 2017). Limited information has been reported on the transformation and distribution of PAHs from e-waste dumpsite in Nigeria, but PAHs are lipophilic and accumulate in food chains associated with the contaminated dumpsites (Oliveira *et al.*, 2014, Adebola and Peter, 2017).

There are several studies of PAH contamination in soil contaminated with e-waste in decades dumpsite associated with burning and other refuge, currently there is no comprehensive seasonal variation analysis of PAHs in soil contaminated with e-waste without combustion and other interfering refuge in Nigeria. Hence this study is to evaluate levels of PAHs in soil obtained from an impacted e-waste dumpsite free from interference of other refuge, ascertaining the level of pollution the e-waste has impacted on the soil at tender age of 2 years.

2.0 Material and Methods

2.1 Description of the study Area

Abraka is a University town and is one of the most developed areas in Ethiopie East Local Government Area of Delta State, Nigeria. South-South, The town is bounded at the north by Obiaruku, at the south by Salubi in Eku, at the west by Edo state and at the east by Aragba Orogun. Abraka has low topography, and its geographical location is Latitude 06.23'01 450 N and Longitude 007.73'09 800 E. The town has an annual rainfall of 2324 mm.

2.2 Collection and preparation of Soil samples

A piece of land of 8 feet by 8 feet was impacted with an electronics waste for the period of 2 years, free from interference of other refuge. Eighteen soil samples were collected to form a composite of 9 samples at 0 – 10 cm, 10 – 20 cm and 20 – 30 cm. for each season, from an impacted dumpsite in Abraka communities from December – February (dry season) and May – July (wet season). A stainless hand held soil auger was used to collect the samples. Thereafter, they were conveyed to the laboratory, dried for 7 days, pulverized with mortar and pestle, sieve with 2 mm mesh sieved and then stored in a deep freezer at -20° C prior to further analysis.

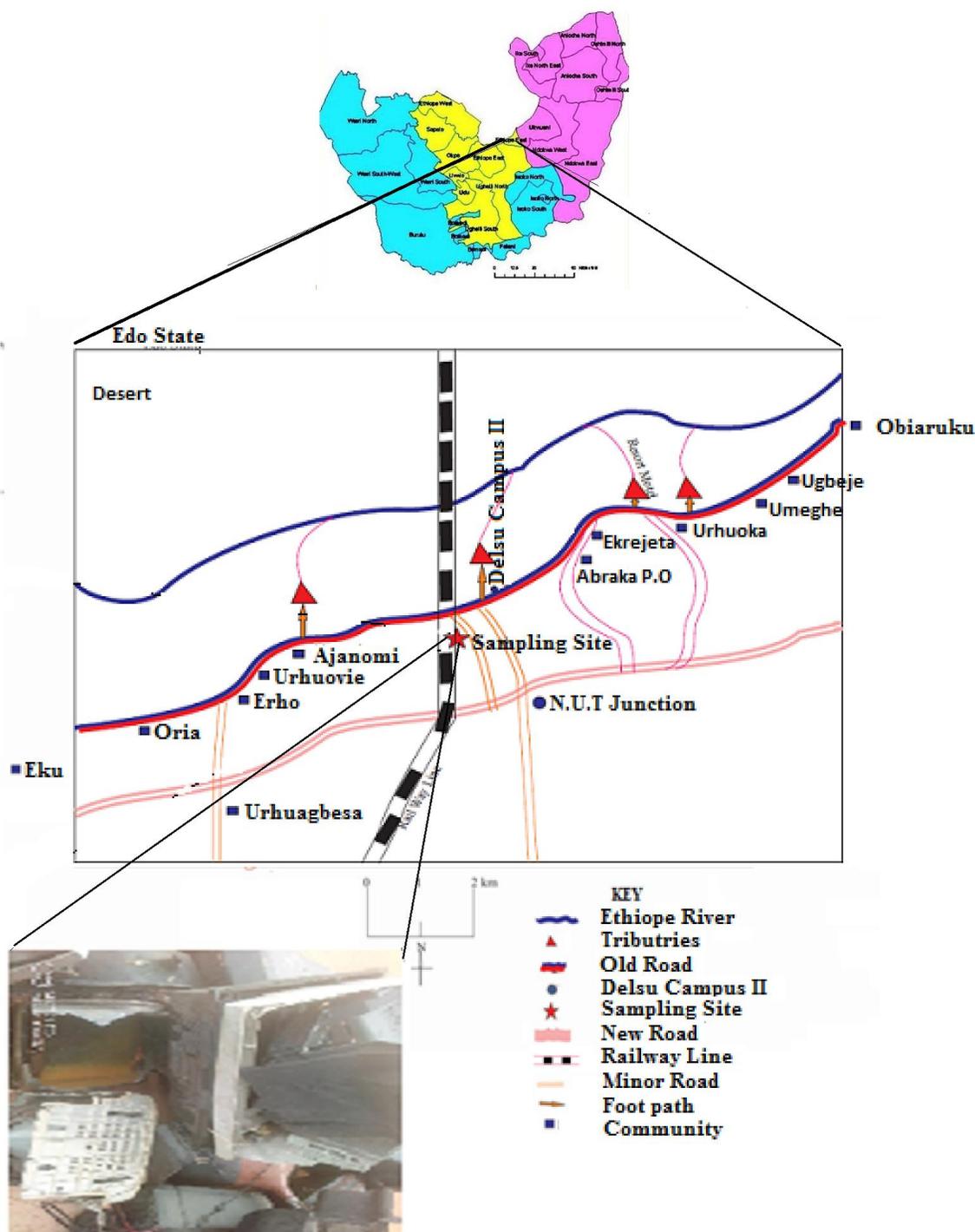


Fig. 1: Map of the study area showing the sampling location

2.2.1 Analytical Procedures

Three steps were involved in the determination of PAHs in samples collected from the dumpsite and these are extraction, purification/fractionation of the chromatographic separation and quantification.

2.2.2 Samples Extraction

10 g of the stored soil samples was mixed with 10 g of anhydrous sodium sulfate; 5 g aliquot was extracted three times by sonication with 15 ml of dichloromethane (1:1) in 20 min. Then there was concentration and fractionation of the

organic extract as water sample after centrifugation.

2.2.3 Extract clean - up

This was done with strong acid, thereafter partitioning was carried out with florisisil; 2 ml of concentrated sulphuric acid was mixed with 1 ml of the extract with thorough shaking to avoid co-extract interfering. The whole exercise was done severally until a colourless was observed in the acid phase. The extract was dried with anhydrous sodium sulfate before fractionation with florisisil. The packing of the glass column was done with 10 g of florisisil (60 – 100 mesh) with addition of 2 g of anhydrous sodium sulfate at upper part of the column to eliminate any amount of water present. 1 ml of the extract was inserted into the column followed by the elution of PAHs with 80 ml of hexane. The concentration of elute was carried out with a rotary evaporator and a gradual nitrogen stream. 1 ml of hexane was used to dissolve the PAH fraction and conveyed to vials of gas chromatograph awaiting gas chromatography analysis. GC – MS analysis was done in single ion monitoring (SIM) mode for assessing and quantifying of PAH congeners.

2.2.4 PAHs Congeners Determination

PAHs determination was done in soil samples with the help of Hewlett-Packard 7890 gas chromatograph coupled with a Hewlett Packard Model 5975 mass analyzer: quadrupled and automatic sampler. The column made up of fused silica capillary was a 30 m DB – 1 m (100% dimethylsiloxane) (Cj & W Scientific, CA, USA) (0.25 mm i.d. x 0.25 μ m of the thickness of film). The temperature of the oven was initially programmed at 100 °C (standing for 1 min) – 325 °C at the ratio of 15 °C/min and last for 5 min. The conditions under which the gas chromatograph was carried out were 250 °C injection temperature and 280 °C transfer line temperature. Helium is used as a carrier gas through a steady flow count of 1.2 ml/min, with

an elevated oven temperature of 120°C for 0.5 min to 210 °C at 30 °C/min to 6 °C/min for 5 mins. The running conditions of the mass spectrometer were 250 °C used for transfer line and ionization source temperature, 70 eV is used ionization voltage, the time used for scanning was 0.3s with 0.5s scanning delay and 5 min delay solvent. Statistical analysis for all data obtained were done using Microsoft excel (Microsoft Inc., USA) and SPSS 22.0 (SPSS Inc., Chicago II., USA).

2.2.5 PAHs Identification and Quantification

The analyzed compounds identification was based upon the ion ratio, the spectra and the retention time which was done by an internal standard procedure using peak areas. The MS analysis was done using single ion monitoring mode where by 2 masses were monitored in the mass spectrum. The chromatogram retention time shift was corrected with the use of internal standard retention time and agreement of about \pm 0.1 min of the retention time expected, for the positive confirmation of the analyte. The linear range of the detector, were evaluated by preparing several standard solutions which are injected at various concentration. The calibration curves are within the range of 10 – 200 ng/ml, the correlation coefficient (r^2) was above 0.999 for all compound analyzed.

2.3 Human Health Risk

2.3.1 Non-carcinogenic risk assessment using Hazard Index (HI)

The hazard index of PAHs in the soils was evaluated by using the USEPA standard methods assuming the three major routes of exposure; ingestion, dermal and inhalation (IDI) (USEPA, 2011). The hazard index was calculated from the summation of the individual hazard quotients through each route of exposure. The evaluation of the hazard index in terms of IDI was carried out by using the equations below.

$$\text{Hazard index (HI)} = \sum HQ = HQ_{ing} + HQ_{inh} + HQ_{derm} \quad (1)$$

where;

$$HQ_{ing} = \frac{CDI_{nc}}{RfD}; HQ_{inh} = \frac{CDI_{nc}}{RfC_{inh}}; HQ_{derm} = \frac{CDI_{nc}}{RfD \times ABS_{GI}} \quad (2)$$

$$CDI_{ing} = \frac{C \times IngR \times EF \times ED}{BW \times AT_{nc}} \times 10^{-6} \quad (3)$$

$$CDI_{inh} = \frac{C \times InhR \times EF \times ET \times ED}{PEF \times 24 \times AT_{nc}} \quad (4)$$

$$CDI_{derm} = \frac{C \times SA \times AF \times ABS \times EF \times ED}{BW \times AT_{nc}} \times 10^{-6} \quad (5)$$

where CDI_{ing} , CDI_{inh} , CDI_{dermal} are the chronic daily intake or dose contacted through ingestion, inhalation and dermal contact with soil respectively. RfD is the reference dose, RfD_{ing} (chronic oral reference dose), RfC_{inh} (chronic inhalation reference concentration), RfD_{dermal} (chronic dermal reference dose = $RfD \times ABS_{GI}$) through the three exposure pathway, CSF_{ing} is the chronic oral slope factors via ingestion, IUR is the chronic inhalation unit risk, ABS is dermal absorption factor, PEF is soil to air particulate emission factor, AT_{nc} is average time for non carcinogenic and C is the concentration of PAHs in soil. Hazard index value less than 1 indicate there is no adverse non-carcinogenic risk while

hazard index value greater than 1 indicates the presence of adverse non-carcinogenic risk (USEPA, 2011).

2.3.2 Carcinogenic risk assessment using Total Cancer Risk

Like the hazard index, total cancer risk of PAHs in the soil samples was evaluated by using the USEPA standard methods assuming the three major routes of exposure; ingestion, dermal and inhalation (IDI). The total cancer risk was calculated from the summation of the individual risks through each route of exposure. The equations and parameters for the evaluation of the total cancer risk are shown below.

$$CDI_{ing-ca} = \frac{C \times IngR \times EF \times ED}{AT_{ca}} \times 10^{-6} \quad (6)$$

$$IngR_{adj} = \frac{ED_{child} \times IngR_{child}}{BW_{child}} + \frac{(ED_{adult} - ED_{child})}{BW_{adult}} \times IngR_{adult} \quad (7)$$

$$CDI_{inh-ca} = \frac{C \times InhR \times EF \times ET \times ED}{PEF \times 24 \times AT_{ca}} \times 10^{-3} \quad (8)$$

$$CDI_{derm-ca} = \frac{C \times SA \times AF \times ABS_d \times EF \times ED}{AT_{ca}} \times 10^{-6} \quad (9)$$

$$DFS_{adj-ca} = \frac{ED_{child} \times SA_{child} \times AF_{child}}{BW_{child}} + \frac{(ED_{adult} - ED_{child}) \times SA_{adult} \times AF_{adult}}{BW_{adult}} \quad (10)$$

$$\text{Risk} = CDI_{ca} \times CSF \quad (11)$$

$$\text{Total Cancer Risk} = Risk_{ing} + Risk_{inh} + Risk_{derm} \quad (12)$$

where, AF is soil to skin adherences factor BW is average body weight, ED is exposure duration, EF is exposure frequency, ET is exposure time

AT_{ca} is average time for carcinogenic, CfS_{ing} is chronic oral slope factor via ingestion and C is the concentration of PAHs in soil respectively.

Generally, total cancer risk value 1×10^{-6} is also considered the carcinogenic target risk (USEPA, 2011, Luo *et al.*, 2012). Total cancer risk value less than 1×10^{-6} indicate no cancer risk but greater than 1×10^{-6} indicates the presence of adverse cancer risk.

Table 1: Values of variable for estimation of human health risk assessment

Parameters	Unit	Values		References
		Child	Adult	
EF	Day/Year	313	313	USEPA,2001
ED	Year	6	30	USEPA,2001
ET	h/d	8	8	USEPA, 1987
IngR	Mg/d	200	100	USDOE, 2011
SA	Cm ² /event	2800	5700	USDOE, 2011
ABS	-	0.13	0.13	USEPA, 2011
AF	mg/cm ²	0.2	0.07	USEPA, 2011
BW	Kg	15	60	Iwegbue <i>et al.</i> ,(2014)
ATnc & ATca	D	ED x 365 & LT x 365		USDOE, 2011
LT	Year	52 Years		World Bank, 2014
PEF	m ³ /Kg	1.36 x 10 ⁹		USDOE, 2011

2.4 Quality Assurance and Data Analysis

Blank sample analysis with recoveries of surrogate standard for each sample was done as a monitoring measure for all procedures. Each batch (4 per batch) was run with blank across all analytical phases. The mean recoveries for all the PCBs congeners were calculated. For extraction purpose, 10 g of muscle tissue and 2 g of soil were used to extract the PAHs. The data analysis was done with Microsoft excel Inc., USA by evaluating the principal component analysis, Pearson's correlation analysis, and assessing the relationship between the contaminant, the mean, median and standard deviation. The detection and quantification limit (LODs & LOQs) were determined with the ratio of 3 and 10 for signal-to-noise for all the concentrations, which ranged from 0.003 – 0.013 mg/kg (LODs) and 0.01 – 0.04 mg/kg (LOQs). From all the PCBs investigated, the blank were totally cleared. Calibration was done via injections of standard solutions of mixed PAHs at 6 concentration level.

3.0 Results and Discussions

The concentrations and statistical variations of PAHs with respect to months and depths are presented in Tables 2 and 3. The percentage distribution of PAHs on the soil collected from the e-waste dump site across depths and months is presented in Figure 2. Individual PAHs concentrations (Table 2) were analyzed for six months (3-months dry season and 3-months wet season). It was observed that high concentration of the individual PAHs with respect to depths and months were prominent in January and December at 0 – 10 cm and 10 – 20 cm for lower molecular weight (LMW) PAHs (naphthalene, acenaphthylene, acenaphthene, fluorine, anthracene and phenanthrene), which ranged from 78.0 µg/kg – 3588 µg/kg. The non detectable limit observed in some depths in February, May, June and July for LMW PAHs might have been evaporated from the soil as a result of their high volatility (Nganje *et al.*, 2014).

Table 2: The PAHs ($\mu\text{g}/\text{kg}$) concentrations with respect to months and depths

Compounds	Nap	Achy	Ace	Flu	Ant	Phe	Flt	Pyr	BaA	Chry	BbF	BkF	BaP	DahA	IndP	BghiP	TOTAL	2R	3R	4R	5R	6R	7C	
JAN.	0-10 cm	1326	1332	398	1154	876	266	276	896	532	1854	276	70	98	916	1484	734	3718	ND	2350	1286	50	42	1326
	10-20 cm	1536	804	236	324	726	468	176	796	522	494	274	792	914	1112	1786	1838	4440	3126	844	436	16	26	444
	20-30 cm	362	620	492	328	308	1624	1626	1766	1244	544	486	1116	1408	1512	1628	208	404	ND	246	94	52	22	136
FEB.	0-10 cm	0	0	974	1070	94	50	162	1284	ND	ND	2	4	28	8	10	32	3718	ND	2350	1286	50	42	1326
	10-20 cm	1902	1224	714	ND	ND	ND	130	206	230	ND	ND	ND	ND	8	8	18	4440	3126	844	436	16	26	444
	20-30 cm	ND	ND	ND	ND	ND	ND	246	42	48	2	2	18	8	16	10	12	404	ND	246	94	52	22	136
MAY	0-10 cm	ND	32	ND	ND	ND	ND	ND	824	222	ND	250	274	ND	ND	ND	168	1770	ND	32	1046	524	168	1570
	10-20 cm	ND	114	264	256	222	384	3652	544	256	452	420	208	258	48	ND	104	7182	ND	1240	4904	934	104	2186
	20-30 cm	ND	28	186	204	624	42	460	980	596	976	984	994	284	1236	656	1010	9260	ND	1084	3012	3498	166 6	6050
JUN.	0-10 cm	ND	328	2342	1722	46	1724	712	886	1540	1282	810	216	1866	1136	838	1676	17124	328	6546	4518	4056	251 4	7736
	10-20 cm	ND	2	ND	ND	ND	1910	ND	430	268	ND	ND	ND	ND	ND	ND	ND	2610	2	1910	698	ND	ND	698
	20-30 cm	ND	28	166	166	ND	ND	360	28	332	ND	ND	ND	ND										
JUL.	0-10 cm	ND	328	ND	206	ND	6144	6712	6492	1540	1790	2498	2746	2118	ND	ND	1676	32250	328	1306 2	12320	4864	167 6	17184
	10-20 cm	ND	6	ND	21	11	19	483	27	13	23	23	6	713	ND	ND	2	1347	6	534	86	719	2	805
	20-30 cm	ND	1	9	10	41	102	397	802	240	175	92	150	108	62	94	ND	2283	1	559	1309	414	94	1629
DEC.	0-10 cm	352	3692	296	294	3588	888	464	138	98	34	20	16	154	24	24	138	10220	352	8758	754	214	162	410
	10-20 cm	392	78	894	894	3228	874	828	310	294	50	474	80	40	18	28	36	8518	392	5968	1956	612	64	726
	20-30 cm	100	356	100	100	72	156	122	86	138	60	110	256	64	90	106	76	1992	100	784	516	520	182	762

Naphthalene (Nap), Acenaphthylene (AcY), Acenaphthene (Ace), Fluorene (Flu), Anthracene (Ant), Phenanthrene (Phen), Fluoranthene (Flt), Pyrene (Pyr), Benzo(a)anthracene (BaA), Chrysene (Chry), Benzo(b)fluoranthene (BbF), Benzo(k)fluoranthene (BkF), Benzo(a)pyrene (BaP), Dibenzo(a)anthracene (DahA), Indeno 1,2,3-ed)perylene (IndP) and Benzo(ghi)perylene (BghiP), R = Rings.

Table 3: Statistical seasonal variations of PAHs ($\mu\text{g}/\text{kg}$) across depths and months

DRY SEASON (DEC., JAN. & FEB.)																								
Depths parameters	&	Nap	AcY	Ace	Flu	Ant	Phe	Flt	Pyr	BaA	Chry	BbF	BkF	BaP	DahA	IndP	BghiP	TOTAL	2R	3R	4R	5R	6R	7C
0-10 cm	MEAN	559	1675	556	839	1519	401	301	773	315	944	99.3	30.0	93.3	316	506	301	5885	352	4486	1109	105	82.0	1020
	SD	686	1869	365	474	1834	436	153	583	307	1287	153	35.2	63.2	519	847	378	3754	ND	3699	307	94.6	69.3	529
	MEDIA N	352	1332	398	107	876	266	276	896	315	944	20.0	16.0	98.0	24.0	24.0	138	3718	352	2350	1286	50.0	42.0	1326
	MIN	0	0	296	294	94	50	162	138	98	34	2	4	28	8	10	32	3718	352	2350	754	50	42	410
	MAX	132	3692	974	115	3588	888	464	1284	532	1854	276	70	154	916	1484	734	10220	352	8758	1286	214	162	1326
10-20 CM	MEAN	128	702	615	609	1977	671	378	43	349	272	374	436	477	379	607	631	5799	221	2552	943	215	38.7	538
	SD	788	57	340	403	1769	287	391	315	153	313	141	504	618	635	1020	105	2354	158	2958	878	344	21.9	163
	MEDIA N	1546	804	714	609	1977	671	176	310	294	272	374	436	477	18.0	28.0	36.0	4440	3126	844	436	16.0	26.0	444
	MIN	392	78	236	324	726	468	130	206	230	50	274	80.0	40.0	8.00	8.00	18.0	4440	392	844	436	16.0	26.0	444
	MAX	1902	1224	894	894	3228	874	828	796	522	494	474	792	914	1112	1786	1838	8518	3126	5968	1956	612	64.0	726
20-30 CM	MEAN	231	488	296	214	190	890	664	631	477	202	199	463	493	539	581	98.7	933	100	425	235	208	75.3	345
	SD	185	187	278	161	167	1038	834	983	666	298	254	578	793	843	908	99.9	917	ND	311	244	270	92.4	361
	MEDIA N	231	488	296	214	190	890	246	86.0	138	60.0	110	256	64.0	90.0	106	76.0	404	100	246	94.0	52.0	22.0	136
	MIN	100	356	100	100	72	156	122	42.0	48.0	2.00	2.00	18.0	8.00	16.0	10.0	12.0	404	100	246	94.0	52.0	22.0	136
	MAX	362	620	492	328	308	1624	1626	1766	1244	544	486	1116	1408	1512	1628	208	1992	100	784	516	520	182	762
WET SEASON (MAY, JUNE & JULY)																								
Depths parameters	&	Nap	AcY	Ace	Flu	Ant	Phe	Flt	Pyr	BaA	Chry	BbF	BkF	BaP	DahA	IndP	BghiP	TOTAL	2R	3R	4R	5R	6R	7C
0-10 cm	MEAN	ND	229	2342	964	46.0	3934	3712	2734	1101	1536	1186	1078	1992	1136	838	1173	17048	328	6546	5961	3148	1453	8830
	SD	ND	171	ND	1071	ND	3125	4242	3254	761	359	1170	1444	178	ND	ND	871	15240	ND	6515	5773	2308	1188	7864
	MEDIA N	ND	328	2342	964	46.0	3934	3712	886	1540	1536	810	274	1992	1136	838	1676	17124	328	6546	4518	4056	1676	7736
	MIN	ND	32.0	2342	206	46	1724	712	824	222	1282	250	216	1866	1136	838	168	1770	328	32	1046	524	168	1570
	MAX	ND	328	2342	1722	46	6144	6712	6492	1540	1790	2498	2746	2118	1136	838	1676	32250	328	13062	12320	4864	2514	17184
10-20 cm	MEAN	ND	40.7	ND	138	117	771	2068	334	179	238	222	107	486	48.0	ND	53.0	3713	4.00	1228	1896	826	53.0	1229
	SD	ND	63.5	ND	166	149	1003	2240	272	144	303	280	143	322	ND	ND	72.1	3069	2.83	688	2622	152	72.1	829
	MEDIA N	ND	6.00	ND	138	117	384	2068	430	256	238	221	107	486	48.0	ND	53.0	2610	4.00	1240	698	827	53.0	805
	MIN	ND	2.00	ND	21.0	11.0	19.0	483	27.0	13.0	23.0	23.0	6.00	258	48.0	ND	2.00	1347	2.00	534	86.0	719	2.0	698
	MAX	0	114	0	256	222	1910	3652	544	268	452	420	208	713	48	0	104	7182	6	1910	4904	934	104	2186
cm	MEAN	ND	14.5	146	88.0	41.0	102	397	802	240	175	92.0	150	108	62.0	94.0	ND	1322	14.5	445.5	1309	414	94.0	1629
	SD	ND	19.1	129	110	ND	1359	19.1	161	ND	ND	ND	ND											
	MEDIA N	ND	14.5	166	88.0	41.0	102	397	802	240	175	92.0	150	108	62.0	94.0	ND	1321	14.5	446	1309	414	94.0	1629
	MIN	ND	1.00	9.00	10.0	41.0	102	397	802	240	175	92.0	150	108	62.0	94.0	ND	360	1.00	332	1309	414	94.0	1629
	MAX	ND	28.0	264	166	41.0	102	397	802	240	175	92.0	150	108	62.0	94.0	ND	2283	28.0	559	1309	414	94.0	1629

Naphthalene (Nap), Acenaphthylene (AcY), Acenaphthene (Ace), Fluorene (Flu), Anthracene (Ant), Phenanthrene (Phe), Fluoranthene (Flt), Pyrene (Pyr), Benzo(a)anthracene (BaA), Chrysene (Chry), Benzo(b)fluoranthene (BbF), Benzo(k)fluoranthene (BkF), Benzo(a)pyrene (BaP), Dibenzo (a) anthracene (DahA), Indeno 1, 2, 3-cd) perylene (IndP) and Benzo (ghi) perylene (BghiP), R = Rings

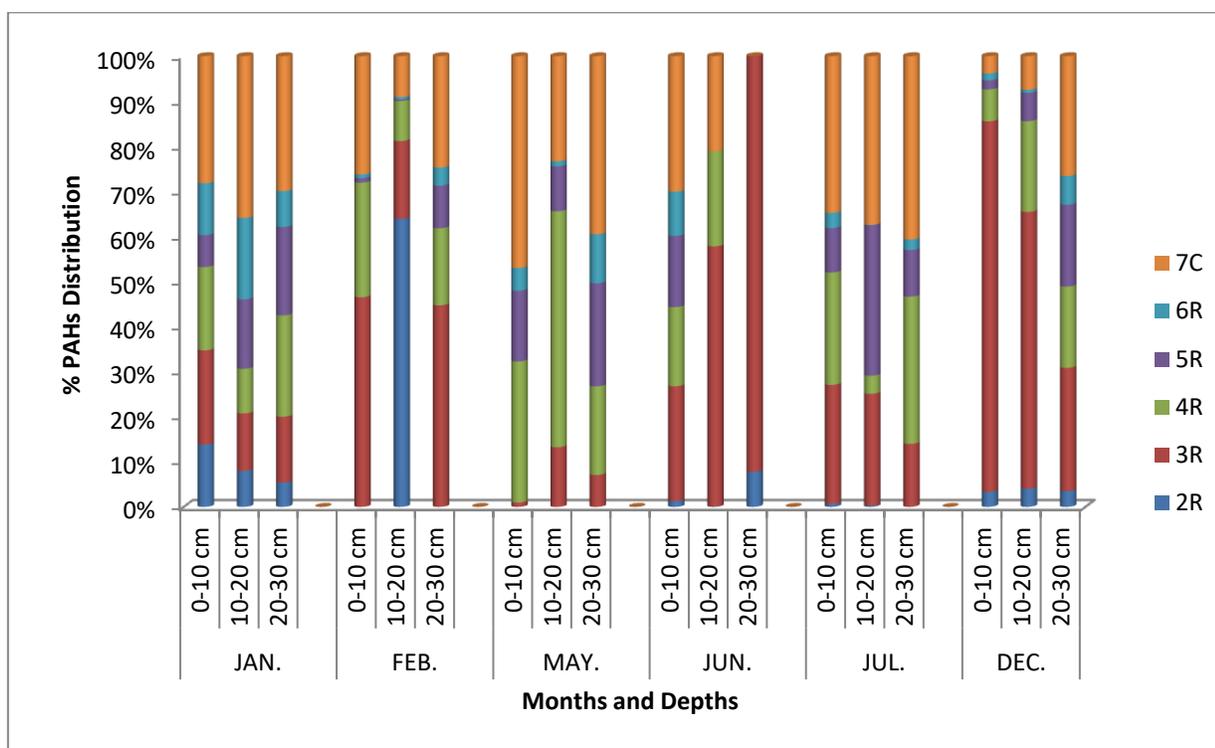


Figure 2: Displayed the percentage distribution of PAHs in six months (three months dry & three month wet) on soil from the e-waste dumpsite. JAN = January, FEB = February, May, JUN = June, JUL = July, DEC = December.

The highest PAHs concentration (6,144 $\mu\text{g}/\text{kg}$) was observed in phenanthrene at July for LMW PAHs and in fluoranthene at July (6,712 $\mu\text{g}/\text{kg}$) for higher molecular weight (HMW) PAHs. The trend of concentration across months was that high concentrations occur in wet season than in wet season across low and high molecular weight PAHs. These higher concentrations might be ascribed to too much deposit of these PAHs from the e-waste to the soil. Table 3 displays significant variation in the mean values of the 16 PAHs under study across the seasons. At 0 – 10 cm in dry season, the mean values ranged from 30.0 $\mu\text{g}/\text{kg}$ (benzo (k) fluoranthene) HMW PAHs to 1,675 $\mu\text{g}/\text{kg}$ (acenaphthylene) LMW PAHs. While in wet season, it ranged from non detectable limit (naphthalene) LMW PAHs to 3,934 $\mu\text{g}/\text{kg}$ (phenanthrene) LMW PAHs. At depths 10 – 20 cm in dry season, the values varied from non detectable limit on both high and low molecular weight PAHs to 2,068 $\mu\text{g}/\text{kg}$

(fluoranthene). At depth 20 -30 cm in dry season, the values ranged from 98.7 $\mu\text{g}/\text{kg}$ (benzo (g), h, i) perylene to 890 $\mu\text{g}/\text{kg}$ (phenanthrene, while in the wet season, the values varied from non detectable limit to 802 $\mu\text{g}/\text{kg}$ (pyrene). In all, the highest mean concentration was observed in the wet season. The mean and median values displayed relative closeness across depths and season, which implies that the data set was normally distributed. The percentage distribution of the 16 PAHs was presented in Figure 2.

The 2- ring PAHs constitute below detectable limit to 70.41 % (10 – 20 cm) at February of \sum 16, the PAHs, 3 – ring PAHs constituted 1.81% (0 – 10 cm) – 92.2 % (20 – 30 cm) at June, 4 – ring of below detectable limit to 68.28 % (10 – 20 cm) at May. The percentage distribution of the 5-ring PAHs constitute below detectable limit – 53.38 % (10 – 20 cm) at July and the percentage distribution for the 6 – ring of \sum 16 PAHs constitute below detectable limit – 27.69 % (10 –

20 cm) at January, while for 7 Ring PAHs, also constitute from below detectable limit to 88.7 % (0 – 10 cm) at May. The highest percentage was observed in the wet season at 10 – 20 cm and there is no definite trend in the percentage distribution across depths and months. The trend of PAHs percentage distributions was 3-ring

PAHs > 7-ring PAHs > 2-ring PAHs > 4-ring PAHs > 5-ring PAHs > 6-ring PAHs. The highest percentage observed in the wet season might be ascribed to rainfall and the poor drainage system of the site. The calculated PAHs hazards index in this work is displayed in Table 4.

Table 4: Hazard index of PAHs exposure in the soil from the dump site

Months	Depths	PAHs CHILD NON CANCER RISK				PAHs ADULT NON CANCER RISK			
		HQ _{ing}	HQ _{inh}	HQ _{Dermal}	HI	HQ _{ing}	HQ _{inh}	HQ _{Dermal}	HI
DEC.	0-10cm	0.68	1.50x10 ⁻⁴	0.25	0.93	0.09	6.00x10 ⁻⁴	0.04	0.13
	10-20cm	1.68	6.36x10 ⁻³	0.61	2.30	0.21	0.03	0.11	0.35
	20-30cm	0.08	1.80x10 ⁻⁵	0.03	0.11	0.01	7.00x10 ⁻⁵	5.00x10 ⁻³	0.02
JAN.	0-10cm	0.04	9.30x10 ⁻⁶	0.02	0.06	0.01	3.00x10 ⁻⁵	3.00x10 ⁻³	0.01
	10-20cm	1.53	3.40x10 ⁻⁴	0.56	2.08	0.18	1.40x10 ⁻³	0.09	0.28
	20-30cm	0.34	7.50x10 ⁻⁵	0.13	0.47	0.07	3.00x10 ⁻⁴	0.02	0.10
FEB.	0-10cm	0.45	3.40x10 ⁻⁴	0.16	0.61	0.04	1.40x10 ⁻³	0.03	0.07
	10-20cm	0.05	4.80x10 ⁻⁵	0.02	0.06	6.00x10 ⁻³	2.00x10 ⁻⁴	3.00x10 ⁻³	0.01
	20-30cm	0.04	4.00x10 ⁻⁵	0.01	0.05	4.00x10 ⁻³	2.00x10 ⁻⁴	3.00x10 ⁻³	0.01
MAY	0-10cm	1.86	4.59x10 ⁻³	0.68	2.54	0.27	0.02	0.12	0.41
	10-20cm	1.63	5.20x10 ⁻³	0.59	2.23	0.22	0.02	0.11	0.34
	20-30cm	1.87	1.55x10 ⁻³	0.68	2.56	0.16	0.01	0.12	0.29
JUN.	0-10cm	2.12	4.70x10 ⁻⁴	0.77	2.89	0.18	1.90x10 ⁻³	0.14	0.32
	10-20cm	0.83	1.80x10 ⁻⁴	0.30	1.14	2.00x10 ⁻³	8.00x10 ⁻⁴	0.05	0.06
	20-30cm	0.09	2.10x10 ⁻⁵	0.03	0.13	0.01	8.00x10 ⁻⁵	0.01	0.02
JUL.	0-10cm	5.18	1.14x10 ⁻³	1.88	7.06	0.32	4.70x10 ⁻³	0.34	0.66
	10-20cm	0.17	3.80x10 ⁻⁵	0.06	0.23	0.02	2.00x10 ⁻⁴	0.01	0.03
	20-30cm	0.21	4.70x10 ⁻⁵	0.08	0.29	0.02	2.00x10 ⁻⁴	0.01	0.04

The hazard quotient values for HQ_{ing} ranged from 0.08 in December at depth 20 – 30 cm to 5.18 in July at 0 – 10 cm depth, HQ_{inh} values ranged from 9.30x10⁻⁶ in January at 0 – 10 cm to 5.20x10⁻³ in May at 10 – 20 cm and HQ_{dermal} values ranged from 0.01 in February at 20 – 30 cm to 1.88 in July at 0 – 10 cm for children. While for adult, HQ_{ing} values ranged from 2.00x10⁻³ in June at 10 – 20 cm to 0.32 in July at 0 – 10 cm, HQ_{inh} values ranged from 3.00x10⁻⁵ in January at 0 – 10 cm to 0.03 in December at 10 – 20 cm and HQ_{dermal} values ranged from 3.00x10⁻³ to 0.14 across depths and months. The hazard

quotient follows the trend of HQ_{ing} > HQ_{dermal} > HQ_{inh} for both children and adult. The total non cancer risk for children spanned from 0.05 at February to 7.06 at July, while for adult, the values ranged from 0.01 in February to 0.06 in July of which both follows the same trend. The hazard index obtained for children was > 1 in some depths and months, indicating that there is non- carcinogenic risk with PAHs exposure in this work at across some depths and months. While for adult, the hazard index is < 1 indicating that there is no non-carcinogenic risk associated with PAHs exposure across depths and months.

Table 5: Total Cancer Risk due to PAHs exposure in the dump site

Months	CHILD				ADULT				Total cancer risk
	Depths	ILCRing	ILCRinh	ILCRDermal	ILCRing	ILCRinh	ILCRDermal		
DEC.	0-10cm	4.39x10 ⁻²	1.13x10 ⁻⁹	1.59x10 ⁻²	5.99x10 ⁻²	3.55x10 ⁻⁴	3.46x10 ⁻⁹	1.56x10 ⁻³	1.92x10 ⁻³
	10-20cm	2.46x10 ⁻³	1.15x10 ⁻¹⁰	8.96x10 ⁻⁴	3.36x10 ⁻³	3.64x10 ⁻⁵	1.97x10 ⁻¹⁰	1.05x10 ⁻⁴	1.41x10 ⁻⁴
	20-30cm	5.13E-02	1.45x10 ⁻⁹	1.87x10 ⁻²	6.99x10 ⁻²	3.82x10 ⁻⁴	4.12x10 ⁻⁹	1.74x10 ⁻³	2.13x10 ⁻³
JAN.	0-10cm	1.79x10 ⁻²	1.36x10 ⁻¹⁰	6.54x10 ⁻³	2.45x10 ⁻²	1.56x10 ⁻⁴	1.37x10 ⁻⁹	6.35x10 ⁻⁴	7.91x10 ⁻³
	10-20cm	1.29x10 ⁻²	3.35x10 ⁻¹⁰	4.70x10 ⁻³	1.76x10 ⁻²	4.39x10 ⁻⁴	9.91x10 ⁻¹⁰	4.87x10 ⁻⁴	9.26x10 ⁻⁴
	20-30cm	1.79x10 ⁻²	4.98x10 ⁻¹⁰	6.52x10 ⁻³	2.45x10 ⁻²	2.28x10 ⁻⁴	1.42x10 ⁻⁹	6.81x10 ⁻⁴	9.09x10 ⁻⁴
FEB.	0-10cm	2.17x10 ⁻²	5.69x10 ⁻¹⁰	7.90x10 ⁻³	2.97x10 ⁻²	2.48x10 ⁻⁴	1.74x10 ⁻⁹	7.70x10 ⁻⁴	1.02x10 ⁻³
	10-20cm	1.65x10 ⁻³	3.84x10 ⁻¹¹	5.99x10 ⁻⁴	2.25x10 ⁻³	2.36x10 ⁻⁵	1.29x10 ⁻¹⁰	5.82x10 ⁻⁵	8.18x10 ⁻²
	20-30cm	1.43x10 ⁻³	3.25x10 ⁻¹¹	5.19x10 ⁻⁴	1.94x10 ⁻³	2.04x10 ⁻⁵	1.12x10 ⁻¹⁰	4.44x10 ⁻⁵	6.49x10 ⁻⁵
MAY	0-10cm	1.16x10 ⁻¹	3.89x10 ⁻⁹	4.23x10 ⁻²	1.59x10 ⁻¹	1.02x10 ⁻³	9.49x10 ⁻⁹	5.79x10 ⁻³	6.82x10 ⁻³
	10-20cm	2.14x10 ⁻¹	4.85x10 ⁻⁹	7.79x10 ⁻²	2.92x10 ⁻¹	1.52x10 ⁻³	1.69x10 ⁻⁸	9.57x10 ⁻³	1.11x10 ⁻²
	20-30cm	0.31x10 ⁻¹	6.57x10 ⁻⁹	1.11x10 ⁻¹	4.16x10 ⁻¹	2.50x10 ⁻³	2.40x10 ⁻⁸	1.11x10 ⁻²	1.36x10 ⁻²
JUN.	0-10cm	3.47x10 ⁻³	3.29x10 ⁻¹¹	1.27x10 ⁻³	4.74x10 ⁻³	1.83x10 ⁻⁵	2.68x10 ⁻¹⁰	1.29x10 ⁻⁴	1.47x10 ⁻⁴
	10-20cm	2.96x10 ⁻³	1.01x10 ⁻¹⁰	1.08x10 ⁻³	4.05x10 ⁻³	1.50x10 ⁻⁴	2.29x10 ⁻¹⁰	1.05x10 ⁻⁴	2.55x10 ⁻⁴
	20-30cm	2.82x10 ⁻³	7.87x10 ⁻¹¹	1.03x10 ⁻³	3.84x10 ⁻³	4.39x10 ⁻⁵	2.23x10 ⁻¹⁰	8.18x10 ⁻⁵	1.26x10 ⁻⁴
JUL.	0-10cm	4.66x10 ⁻³	2.31x10 ⁻¹⁰	1.69x10 ⁻³	6.35x10 ⁻³	2.70x10 ⁻⁴	3.52x10 ⁻¹⁰	1.65x10 ⁻⁴	4.35x10 ⁻⁴
	10-20cm	3.51x10 ⁻²	4.59x10 ⁻¹⁰	1.28x10 ⁻²	4.78x10 ⁻²	5.12x10 ⁻⁴	2.71x10 ⁻⁹	1.09x10 ⁻³	1.61x10 ⁻³
	20-30cm	1.64x10 ⁻¹	5.22x10 ⁻⁹	5.96x10 ⁻²	2.23x10 ⁻¹	1.62x10 ⁻³	1.32x10 ⁻⁸	4.06x10 ⁻³	5.69x10 ⁻³

The ILCR across soil depths and months via ingestion, inhalation and dermal for children and adult were presented in Table 5, the recorded values spanned from 1.43x10⁻³ to 3.05x10⁻¹ (ingestion), 3.29x10⁻¹¹ to 6.57x10⁻⁹ (inhalation), 8.96x10⁻⁴ to 7.79x10⁻² (dermal) and 1.83x10⁻⁵ to 2.50x10⁻³ (ingestion), 1.12x10⁻¹⁰ to 2.40x10⁻⁸

(inhalation), 4.44x10⁻⁵ to 9.57x10⁻³ (dermal) across depths and months for both children and adults. The trends of ILCR concentrations for both children and adults follow ingestion > dermal > inhalation. The total cancer risk across depths and months ranged from 2.25x10⁻³ to 4.16x10⁻¹ and 6.49x10⁻⁵ to 1.11x10⁻² for both

children and adults of which the total cancer risk for adults is lower than that for children. This might be as a result of the high tendency of dermal contact of children with soil particles (Emoyan, 2020). Considering the life time cancer risk based values classified by New York State Department of Health (NYS DOH, 2007), ($\geq 10^{-4}$ = very high, $> 10^{-3}$ to 10^{-1} = high, $\geq 10^{-4}$ to 10^{-3} =

moderate, $\geq 10^{-6}$ to 10^{-4} = low and $\leq 10^{-6}$ = very low). The PAHs cancer risk observed in this study indicate moderate to very high level for both children and adults. Since the values of cancer risk in this study are greater than approved value of 1×10^{-6} , this implies that the dump site is subject to generation of cancer to human via ingestion and derma contact routes.

Table 6: BaP_{TEQ} and BaP_{MEQ} concentrations ($\mu\text{g}/\text{kg}$) for the e-waste dump site across depths and months

Months	Depths	BaA	Chry	BbF	BkF	BaP	DahA	IndP	BaP _{TEQ}	BaA	Chry	BbF	BkF	BaP	DahA	IndP	BaP _{MEQ}
DEC.	0-10 cm	11.2	0.10	6.60	10.0	218	20.4	208	474	9.18	1.73	16.5	110	218	63.2	60.3	479
	10-20 cm	2.40	0.08	0.20	2.10	10.0	1.00	16.0	31.8	1.97	1.33	0.50	23.1	10.0	3.10	4.64	44.6
	20-30 cm	17.0	0.29	2.80	3.18	148	34.6	324	529	13.9	4.96	7.00	35.0	148	107	94.0	410
JAN.	0-10 cm	9.80	0.03	2.00	0.16	154	2.40	24.0	192	8.04	0.58	5.00	1.76	154	7.44	6.96	184
	10-20 cm	29.4	0.05	47.4	0.80	40.0	1.80	28.0	147	24.1	0.85	119	8.80	40.0	5.58	8.12	206
	20-30 cm	13.8	0.06	11.0	2.56	64.0	9.00	106	206	11.3	1.02	27.5	28.2	64.0	27.9	30.7	191
FEB.	0-10 cm	15.4	0.21	10.6	0.94	72.0	12.2	122	233	12.6	3.50	26.5	10.3	72.0	37.8	35.4	198
	10-20 cm	1.60	0.01	1.20	0.22	8.00	0.60	6.00	17.6	1.31	0.24	3.00	2.42	8.00	1.86	1.74	18.6
	20-30 cm	0.80	0.01	2.00	0.06	6.00	0.60	4.00	13.5	0.66	0.10	5.00	0.66	6.00	1.86	1.16	15.4
MAY	0-10 cm	53.2	1.85	27.6	0.70	98.0	91.6	1484	1757	18.2	ND	62.5	30.1	ND	ND	ND	111
	10-20 cm	52.2	0.49	27.4	7.92	914	111	1786	2899	20.9	7.68	105	22.9	258	14.9	ND	429
	20-30 cm	124	0.54	48.6	11.2	1408	151	1628	3372	48.9	16.6	246	109	284	383	190	1278
JUN.	0-10 cm	ND	ND	0.20	0.04	28.0	0.80	10.0	39.0	43.6	31.5	69.0	7.70	98.0	284	430	964
	10-20 cm	23.0	ND	ND	ND	ND	0.80	8.00	31.8	42.8	8.39	68.5	87.1	914	345	518	1983
	20-30 cm	4.80	ND	0.20	0.18	8.00	1.60	10.0	24.8	102	9.25	122	123	1408	469	472	2704
JUL.	0-10 cm	22.2	ND	25.0	2.74	ND	ND	ND	49.9	ND	ND	0.50	0.44	28.0	2.48	2.90	34.3
	10-20 cm	25.6	0.45	42.0	2.08	258	4.80	ND	332	18.9	ND	ND	ND	ND	2.48	2.32	23.7
	20-30 cm	59.6	0.98	98.4	9.94	284	124	656	1233	3.94	0.03	0.50	1.98	8.00	4.96	2.90	22.3

Table 6, displayed the estimated BaP equivalence (BaP_{TEQ}) and mutagenic equivalence (BaP_{MEQ}) values in relation to exposure to PAHs in soil obtained from e-waste dumpsite which spanned from 13.5 – 3,372 $\mu\text{g}/\text{kg}$, with significant contribution from BbF, BaP, DahA and IndP. The highest BaP_{TEQ} value was observed in May at depth 20 – 30 cm which shows that those PAHs contents penetrate into the soil due to rainfall and the poor drainage system of the site. While the lowest value was observed in February at 20 - 30 cm depth which indicate high

penetration ability and strong binding capacity of the soil to the PAHs contaminants. These values were similar to those reported by Chukwujindu *et al.* (2019) in a similar study. The values of BaP_{MEQ} observed in this study ranged from 18.6 – 2,704 $\mu\text{g}/\text{kg}$, the significant contribution of these values was also obtained from BbF, BaP, DahA and IndP as in the case of BaP_{TEQ}. These values corroborated the report of Emoyan (2020). The PCA results of PAHs in the soil are presented in Table 7. Four components were found and accounted for 90.111 % of the

variability in the data. Component 1 accounted for 31.902 % of the total variance and was characterized by high positive loading of Phen, Flt, Chry, BaA, BkF, IndP and DahA. BaA,

Chry, BkF and DahA are indicators for diesel-powered engines (Wang *et al.*, 2013; Yu *et al.*, 2014).

Table 7: PCA of PAHs in the soil

PAHs	Components			
	1	2	3	4
Nap	-0.099	0.719	-0.065	0.612
Acy	-0.053	0.283	0.912	-0.038
Ace	-0.128	0.097	0.755	0.331
Flu	0.123	0.126	0.769	-0.131
Phen	0.825	0.053	0.646	0.112
Ant	0.336	0.472	-0.149	0.800
Flt	0.972	0.312	-0.341	0.124
Pyr	-0.042	0.910	-0.106	0.150
BaA	0.823	-0.005	0.111	-0.042
Chry	0.972	-0.005	-0.005	0.670
BbF	-0.030	0.020	-0.188	0.915
BkF	0.891	-0.119	0.173	0.124
BaP	-0.038	0.805	-0.149	0.150
IndP	0.709	0.150	-0.341	-0.042
DahA	0.845	-0.233	-0.005	-0.042
BghiP	-0.057	0.799	0.013	0.022
Variance %	31.902	22.649	19.109	16.451
Cumm %	31.902	54.551	73.660	90.111

Component 2 explained 22.649 % of the total variance and was characterized by high positive loading of Nap, Pyr, BaP and BghiP. Nap is a tracer for incomplete combustion processes (Yu *et al.*, 2014) while BaP and BghiP are indicative of automobile emissions (Liu *et al.*, 2017; Iwegbue *et al.*, 2017). Component 3 explained 19.109 % of the total variance and was characterized by high positive loading of Ace, Acy and Flu and moderate loading of Phen. These compounds are indicative of low temperature combustion processes such as burning of wood/biomass and liquidified petroleum gas, natural gas and coal (Guo *et al.*, 2003; Wang *et al.*, 2013). Component 4 was characterized by high positive loading of Ant and BbF and moderate loading of Nap and Chry and accounted for 16.451 % of the total variance. Nap is related to incomplete combustion processes

while Ant, Chry and BbF are tracers of coal combustion (Dong and Lee, 2009). All numbers appearing bold shows that those compounds generate the highest concentrations among the 16 PAHs under considerations. Figure 3 displays a significant and highly significant correlation between the sixteen (16) PAHs congeners at $p < 0.05$ and $p < 0.01$ levels. These correlations across the 16-PAHs at dry season certified the presence of hydrocarbon congeners with each other and gave a clear knowledge and insight of the PAH congeners on the surface of the soil. Phenanthrene (Phe) showed more positive correlation in relation to all other compound of PAHs, while Benzo (a) anthracene (BaA) showed a more negative correlation in relation to all other compounds of PAHs. The non-correlation observed implies that there is no significant effect with their persistence in the soil surface.

Figure 4 shows a strong, significant correlation ($p < 0.01$) between the sixteen (16) PAH congeners across all compounds, except for Anthracene (Ant), during the wet season compared to the dry season. The correlation level here certified the presence of hydrocarbon across each compound which gives a better understanding and a better

insight into PAHs congeners' movement within the soil surface. The non-significant correlation observed at Anthracene (Ant) might be an indication that there is no significant effect with the persistence of Ant congeners across the soil surface.

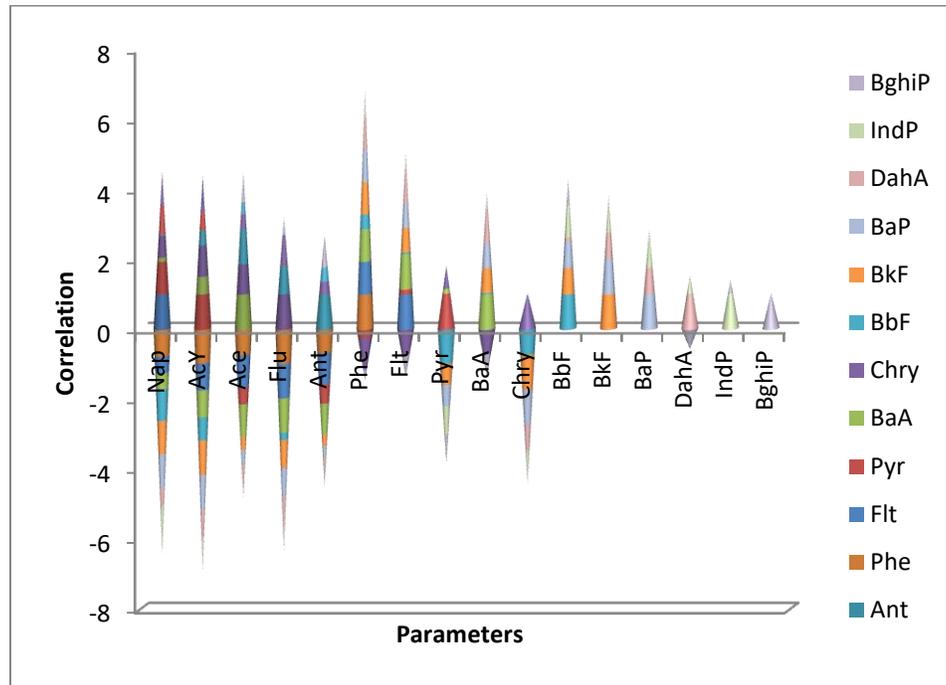


Figure 3: Pearson's correlation matrix of PAHs in relation to dry season

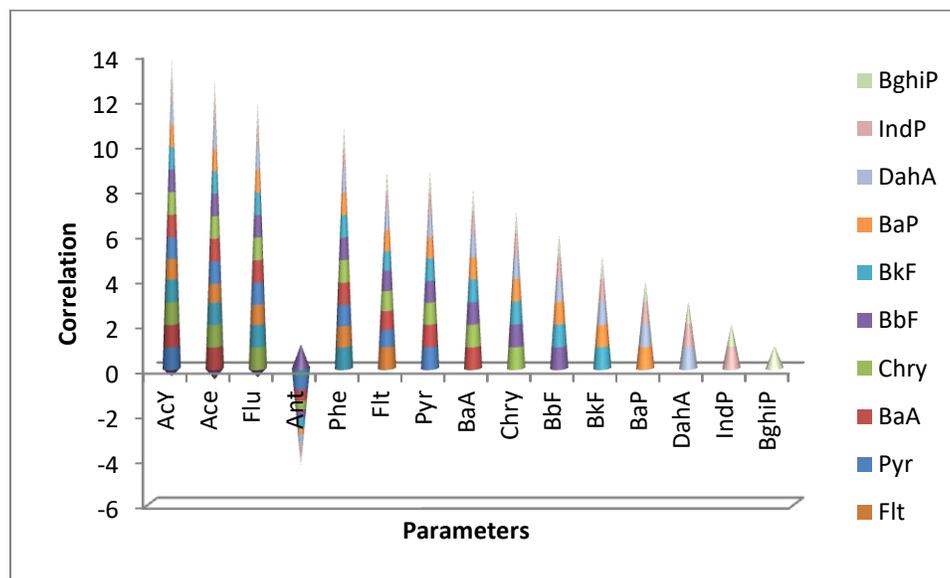


Figure 4: Pearson's correlation matrix of PAHs in relation to wet season

4.0 Conclusion

Due to the increase rate in dumping activities, e-waste contaminated soil deserved much concern to handle. The PAHs highest mean concentrations were observed in wet season with relative closeness to the median values, the highest percentage distributions were also observed in wet season across depths. The hazard quotient follows the trend of HQ Ing > HQ Derm > HQ Inh., for both children and adult and the total cancer risk for adult is lower than that of children in this study. It can be affirmed that e-waste dumping has contributed much contaminants of PAHs to the soil. Hence proper legal action in observing the environment should be put in place to avoid indiscriminate dumping of e-waste.

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