Profiling of Polycyclic Aromatic Hydrocarbon in vegetables grown on contaminated soils in a Sub-saharan tropical environment –Lagos, Nigeria.

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ABSTRACT

Diet has been established as a major source of exposure to PAHs for humans especially non-smokers. Therefore their presence in plants constitutes a major health concern. This research aims to determinine the concentration and profile of sixteen US-EPA priority PAHs in tropical edible vegetables (*Corchorus olitorius* (*Ewedu*), *Celosia argentea* (*Soko*), *Amaranthus cruentus L* (*Grain amaranthus/ Tete*), *Telfairia occidentale* (*Ugwu*), *Basella alba* (*Amunu tutu/*White Spinash), *Lactuca Sativa* (Lettuce), *Allium* ascalonicum (Spring Onions/*Alubasa elewe*), *Talinum Triangulare* (Water leaf)), grown on potted contaminated soils. Vegetable grown on potted contaminated soils and contaminated soils were extracted using *n*-hexane/acetone mixture in ultrasonic bath. The extract was purified using a C_{18} solid-phase extraction cartridge (5 mL). The resultant extract was separated and the PAHs quantified on an Agilent 6890 Gas chromatography/mass spectrometer (GC/MS). Total PAH concentration in contaminated soils and plants grown on them were 200 - 250,000 ng g^{-1} and 100-5,000 ng g-1, respectively. Concentration of PAHs in plant roots was generally higher than in the stems. PAH concentration in plant stems was also generally higher than in plant leaves. Two and three ringed PAHs which are the less toxic were dominant in most of the plant parts. One of the vegetable samples *Telfairia*

occidentale (*Ugwu*) consistently grew on all the soils samples which suggest it possess some potential for phyto remediation.

KEYWORDS: Vegetables, polycyclic aromatic hydrocarbons, soils, gas chromtography –mass spectrophotometer

INTRODUCTION

In tropical Africa, over a hundred vegetables species are cultivated for consumption. Specifically in Nigeria and other sub-Saharan African countries tropical vegetables has been part of the food systems for generations. With the increased awareness of the health protecting properties of vegetables immense attention has been drawn to the consumption of vegetables in Nigeria. Vegetables are now among the most important cultivated food crops (1).

Diet has been established as a major source for polycyclic aromatic hydrocarbons (PAHs) exposure to humans especially for non-smokers (2, 3), therefore their presence in plants constitutes a major health concern (4, 5). Accumulation of PAHs by vegetable may be an indirect exposure pathway to humans. Plants through their roots can take up PAHs from soil and water, bio- concentrate and translocate them to their storage organs which are usually eaten by man and other organisms (6-10). The amount of PAHs taken up by plants is a function of many factors, including initial soil concentrations, microbial population and plant species. Typical responses of plants to PAHs contamination are poor germination and growth (11).

PAHs are ubiquitous compounds known as carcinogens and mutagens. They have been found in petroleum and its products as well as in many contaminated sites (12). Contamination of soils by PAHs are usually due to anthropogenic activities such as cracking of crude petroleum, burning of

fossil fuels, oil spills, incineration of industrial and domestic waste among others. They are persistent, resistant to bio degredation and can be transferred to water bodies, soil and plant.

Cancer has become a major source of morbidity and mortality globally. A total of 1,660,290 new cancer cases and 580,350 cancer deaths were projected to occur in the United States in 2013 by Siegel *et al.* (13). Badmus *et al* (14) reported the hospital prevalence rate of prostate cancer as 182.5 per 100,000 male admissions in South Western Nigeria. Age standardised breast cancer incidence rate at the Ibadan and Abuja cancer based registries of Nigeria were found to be 52.0 per 100000 and 64.6 per 100000, respectively while cervical cancer incidence rate were 36.0 per 100000 and 30.3 per 100000, respectively (15). Human health, agricultural development and the ecosystems are all at risk unless water, land systems are properly monitored and regulated.

Soil and water are usually monitored but plant monitoring for contaminants has been totally neglected in all regulations (16-17). PAH concentration of *Spartina alterniflora* plants grown in potted contaminated sediment (900 μgg^{-1} total PAHs) was 43 μgg^{-1} and 0.2 μgg^{-1} in root and leaf, respectively (18). Some studies on the uptake of PAHs by plants in Nigeria include those by Sojinua *et al*,(19) Ukiwe *et al* ((20) and Ezekwe *et al* (21). They studied higher plants (none edible plants) which are not leafy vegetables. Studies on the uptake of PAHs by locally consumed leafy Nigerian vegetables from contaminated soils are not available.

Nigeria is faced with enormous environmental and agricultural challenges which threaten the livelihood of the tens of millions of its teeming population. One of the environmental challenges include contaminated lands as a result of oil (petroleum) spills (especially in the Niger Delta area of the South–Southern part country) spills of petroleum refined products during loading into tankers for distribution from the ports and tank farms in Lagos, South Western Nigeria, petroleum products

leakage from distribution tanks during accident or due to rust of tank and disposed lubricating oils in soils around automobile workshops among others (22-23).

Lagos, situated at the South-Western Coast of Nigeria is the fastest growing city in Africa. It is also densely populated. Approximately 60% of Nigeria's industrial and commercial activities are situated here (25). It is surrounded by water bodies and made up of many swampy areas. There is therefore a high demand for land. To meet the demand, land reclamation is the other of the day. Reclamation of swamps, former industrial sites, contaminated sites for use in transport, industrial/commercial, residential and allotment (refers to the provision of open space, commonly made by the local authority, for local people to grow fruit and vegetables for their own consumption and for sale to make a living) purposes have been ongoing. Some residents of residential areas from these reclaimed lands have private gardens. They are exposed to PAHs through consumption of food crops especially vegetables grown on them. Exposure risks in Nigeria are usually estimated without contribution from eating home grown vegetables. There is a dearth of information about PAHs in locally consumed vegetables from Nigeria. This research aims at determining the levels and profile of PAHs in locally consumed plants grown on potted contaminated soils from Nigeria.

METHODOLOGY

Chemicals and standards

A standard mixture of 16 USEPA PAHs and 2 alkylated PAHs (all 2,000 μgmL^{-1}) was obtained from Supelco (Bellefonte, PA, USA). The mixture contained naphthalene (NAP), 1-methylnaphthalene (1-MNAP), 2-methylnaphthalene (2-MNAP), acenaphthylene (ACY), acenaphthene (ACP), fluorene (FLR), phenanthrene (PHE), anthracene (ANT), fluoranthene (FLT), pyrene (PYR), benzo[a]anthracene (BaA), chrysene (CHR), benzo[b]fluoranthene (BbF),

benzo[k]fluoranthene (BkF), benzo[a]pyrene (BaP), indeno[1,2,3-cd]pyrene (IcP), dibenzo[a,h]anthracene (DaH) and benzo[g,h,i]perylene (BgP). However, 1-methylnaphthalene (1-MNAP), 2-methylnaphthalene (2-MNAP) were not monitored. Since they are not part of the 16 priority PAHs. The deuterated internal standard solution mixture (all 2,000 μgmL^{-1} in dichloromethane) contained d_{10}-acenaphthene, d_8-naphthalene, d_{10}-phenanthrene, d_{12}-chrysene, d_{12}-perylene and d_4-1,4-dichlorobenzene (Supelco). The certified reference materials, CRM 172-100G for USEPA PAHs used for method validation were from Supelco Analytical (Bellefonte, USA). All solvents were of HPLC grade or better and purchased from Fisher Scientific Ltd. (Loughborough, UK).

Soil Sampling

Contaminated composite surface soil samples were obtained from three locations in Lagos, Nigeria (A: N 06 X 30´ 56.31˝,E 003 X 23´ 58.5˝, B N 06 X27´ 31.0˝, E 003 X 21´ 36.2˝, C N 06 X26´ 26.25˝, E 003 X 19´ 49.5´) and a control was also obtained from outside Lagos Nigeria (D: N 06 X 41' 30", E 003 X 51' 46"). Location A was a site used as depot and loading point for used for black oil Iganmu/Orile, Apapa, Lagos, B was a Premium motor spirit and Kerosene depot, Apapa, Lagos, C was a Premium motor spirit and Kerosene depot, Apapa Lagos and the D the control was a forest outside Lagos between January 2012 and March 2012. The samples were transported to the laboratory where a portion was air dried for 4 days in the dark at ambient room temperature $\leq 32\ ^0C$ and sieved using 2 mm sized sieve and kept prior to analysis. Another portion was immediately prepared for planting and the remaining was kept for grain size analysis.

Physico-chemical analysis of soils

Particle size distribution of soils, were determined by the British Standard Method using wet sieving and sedimentation technique (25). Soil pH were determined in 0.01 mol L^{-1} $CaCl_2$ (10 mL:5 g of soil). Total organic carbon (TOC) and Soil organic matter (SOM) were determined using the Walkley-Black titrimetric method (26). Oil and grease in soil samples were extracted in acetone: *n*-hexane (50:50 v/v), with an ultrasonic and quantified gravimetrically (27).

Extraction, clean-up and analysis of PAHs in soils

Between 0.5–5 g of each air dried soil samples (depending on the degree of contamination estimated by the oil and grease) were extracted for PAHs. Samples were spiked with deuterated internal standard (to evaluate the extraction efficiency) solution mixture which contained d_{10}-acenaphthene, d_8-naphthalene, d_{10}-phenanthrene, d_{12}-chrysene, d_{12}-perylene and d_4-1,4-dichlorobenzene solution (25 µL of 10 mg mL^{-1}) and extracted in an ultrasonic bath using three sequential extractions of acetone:n-hexane (1:1v/v). The combined extract (25 mL) was concentrated under nitrogen to about 500 µL. 200 mg C_{18}, Bond Elute, in 5 mL cartridge was used for clean–up under pressure. SPE cartridges were pre-conditioned with dichloromethane (DCM), methanol, methanol:water (1:1), water, (acetone : n-hexane: water (1:1 :1) and finally acetone: n-hexane (1:1) sequentially. The concentrated extract was then loaded and eluted with 5ml of DCM:n-hexane (1:1) at a flow rate of 1 mL min^{-1}. Eluates were evaporated to dryness under nitrogen and reconstituted in1 mL of n-hexane. Care was taken to ensure the cartridge did not dry during the conditioning and loading of sample extract. For quality control, sample series were made to include a CRM extract, one standard that has been treated similarly to the samples (recovery determination), six standards of varying concentrations (0-5000 µg mL^{-1}) which contain each of the 16 PAHs (10, 24, 28-29). Working standard solutions were prepared in n- hexane. An

Agilent GC/MS (6890N GC) equipped with split/splitless injector, fitted with a HP-5MS UI capillary column (30 m, 0.25 mm i.d. x 0.25 mm film thickness) and connected to a mass selective detector (Agilent 5975) was used for PAH separation and quantification. Samples were injected (2 µL) in splitless mode at an injection temperature of 290 ^{0}C. The column oven was held at 50 ^{0}C for 3.2 mins, raised to 150 ^{0}C at a rate of 30 ^{0}C min^{-1}. It was further raised to 238 ^{0}C at a rate of2 ^{0}C min^{-1}. From 238 ^{0}C it was raised to 272 ^{0}C at a rate of 3 ^{0}Cmin^{-1} and finally raised to 300 ^{0}C at a rate of 70 ^{0}Cmin^{-1}. At 300 ^{0}C it was held for 2.73 mins. Helium gas (the carrier gas) flowed at a constant flow rate of 1 mLmin^{-1}. Mass spectrum were acquired using electron ionization (EI) at 70 eV. The injector and auxiliary temperatures were set at 290 ºC and 300 ºC, respectively. Ion source temperature was 250 ºC. Identification and analysis of PAHs in soils were carried out by confirmation of retention time and abundance of quantification/confirmation ions compared to authentic standards. All the identified compounds were quantified using selective ion monitoring (SIM).

Soil Sample Preparation for Planting

The soil samples (A, B, C and D) were prepared for planting by removing large stones with the help of a farm sieve. Fertilizer (pink granular free flowing N.P.K 15-15-15) was added to the different soils in the ratio of 600 g to 40 kg and stored in the dark at room temperature for 4 days. Soils A, B, C, respectively were mixed with D the control in ratios of 1:9, 1:3, 1:1, 3:1 and 1:0 to obtain 10%, 25%, 50%, 75%, 100% contaminated soils of A, B, C. Control soil sample was also used for planting and tagged 100% D. 1.4 kg of each soil (including 100%D soil) was bagged in perforated black special planting nylons ready for planting in the green house. Each of these soil mixes were sampled and kept at -20^{0}C for analysis before planting commenced.

Seed sourcing and planting

Seeds of *Corchorus olitorius* (*Ewedu*), *Celosia argentea* (*Soko*), *Amaranthus cruentus L* (*Grain amaranthus/ Tete*) were sourced from National Horticultural Research Institute Nigeria (NIHORT) while *Basella alba* (*Amunu tutu/*White Spinash), *Lactuca sativa* (Lettuce), *Allium* ascalonicum (Spring Onions/*Alubasa elewe*), *Talinum triangulare* (Water leaf), *Telfairia occidentale* (*Ugwu*), were sourced from commercial farms in Lagos, Nigeria.

The seeds were pre-germinated and nursed using compost nursery in a green house at the botanical garden of the University of Lagos and were later identified in the Botany Laboratory of the University of Lagos at the 5 to 6 seed leaves stage (after two weeks from planting).

The seedlings were transplanted into bagged soils and their mixes in a green house at the Botanical garden of the University of Lagos, Nigeria to grow till maturation time. They were each planted for 7 weeks after which they were harvested and washed. Harvested plant samples were dried indoors at room temperature for a week and kept in double aluminium foil to protect them from sunlight. Packed samples were packed in labelled plastic bags and stored at 0 ^{o}C until analyses (30).

Extraction, clean-up and analysis of PAHs in Plants

All the harvested plants where divided into three parts namely the leaves, stems and roots but *Allium* Ascalonicum (Spring Onions/*Alubasa elewe*) and *Lactuca Sativa* (Lettuce) (which had only leaves and root) were divided into two parts. They were shredded with a domestic shredder and weighed for analyses. 0.5 – 5 g of plant materials were weighed into an amber glass bottles and extracted sequentially thrice in an ultrasonic bath using 5 mL of Hexane: acetone

(1:1,vol:vol). Extraction, clean up and analysis of PAHs were as in the analysis of soil above. The sum PAHs of the 16 priority USEPA PAHs were calculated based on dry weight of plants.

RESULTS AND DISCUSSION

Physico chemical properties of soil samples were determined and results are shown in Table 1. Particle size an important feature of soil, which affects soil physical and chemical properties such as structure, oxygen concentration and water content was determined (30-31). SOM for samples in this study were found to vary from 2.98 to 7.74%. Physical conditions of soil are impacted by SOM. Impacts of SOM include enhancing aeration, aggregation and water retention. SOM therefore provides suitable environments for plant growth (32). Soil samples in this study were predominantly sandy (49.71 to 84.73%). Clay fraction (<0.002 mm) of soil samples varied between 4.92 and 20.03% while silt fractions (0.05-0.002 mm) had a range of 0.06 to 29.01%. Oil and grease content for soil is a measure of soil pollution. Soil samples had 0.18 to 4.92 % oil and grease by weight. Analysis of the soil texture revealed a lack of systematic differences in grain size composition among the individual sites. Soil pH values measured in 0.01 $molL^{-1}$ $CaCl_2$ varied within the range of 6.8 to 8.0 for all the samples.

PAHs Concentration

To evaluate the extraction efficiency for the target compounds, recovery studies were carried out using 6 isotopically labelled PAHs, (d_{10}-acenaphthene, d_8-naphthalene, d_{10}-phenanthrene, d_{12}-chrysene, d_{12}-perylene and d_4-1,4-dichlorobenzene). The average surrogate recoveries were between 75 and 95 %. This demonstrates that there was no significant loss of analytes during sample preparation processes. Calibration curves were obtained using a series of varying

concentrations of a multi-component standard containing each of the 16 USEPA PAHs and the r^2value of the calibration curves had a range of 0.994 to 0.999. Limit of detection (LOD) and limit of quantification (LOQ) were obtained as concentrations of target compounds in a sample that results in a peak with signal-to-noise (S/N) ratio of 3:1 and 10:1, respectively (33). The LOD and LOQ for the PAHs in this study had a range of 1.2 ng/ml to 60ng/ml and 3.8 ng/ml to 200 ng/ml, respectively for individual USEPA PAHs (Table 2). The LOD was used as method detection limit. Recovery for the individual PAHs in CRM 172-100G soil analyses were between 75 to 105 %.

PAH concentrations of the composite soil samples were analysed. Base on PAHs summations of the 16 priority PAHs concentration in samples, Soil B is a contaminated soil (600-1000µgg^{-1}) while soil A and C is a heavily contaminated (> 1000gg^{-1}) (34). Sum concentrations of the 16 priority USEPA PAHs for the contaminated soils were 104443, 701 and 253922 ng g^{-1} for soils A, B and C, respectively while for the control a value of 201 ng g^{-1} was obtained. Concentrations of PAHs in the soils mixes were also determined and their results are shown in Table 3.

Eight different commonly consumed vegetables in south western Nigeria (*Corchorus olitorius* (*Ewedu*), *Celosia* a*rgentea* (*Soko*), *Amaranthus cruentus L* (*Grain amaranthus/ Tete*), *Basella alba* (*Amunu tutu*/White Spinash), *Lactuca sativa* (Lettuce), *Allium ascalonicum* (Spring Onions/*Alubosa elewe*), *Talinum triangulare* (Water leaf), *Telfairia occidentale* (*Ugwu*)) were planted on the various soils (A, B, C, D) and their mixes. *Celosia* a*rgentea* (*Soko*) grew only on three mixes of soils (B25%, B50%and C10%and the control (D100%). *Amaranthus cruentus L* (*Grain amaranthus/ Tete*) and *Allium ascalonicum* (Spring onions/*Alubosa elewe*) both grew on soils A10%, A25%, B25%, B50%, B75%, C10% and on the control (D100%) while *Basella Alba*

(*Amunu tutu*/White Spinash) grew on soils A10%, A25%, B25%, C10% and D100%. *Talinum triangulare* (Water leaf) grew on soils A10%, B25%, B50%, C10% and D100%. *Corchorus olitorius* (*Ewedu*) grew on soils A10%, B25%, B50%, B75% and on D100%. *Lactuca sativa* (Lettuce) grew on only two soils namely B25% and D100%. All the plants in this study grew on the control soil (D).

Telfairia occidentale (*Ugwu*) consistently grew on all the soils and their mixes. This suggests *Telfairia occidentale* (*Ugwu*) has some special properties which enabled it grow even when planted heavily contaminated soils (A100% and C 100%) with high oil content of 4.92 % and 1.41 % where other plants failed to grow. This ability of *Telfairia occidentale* (*Ugwu*) makes it a potential crop in the phyto remediation of PAH contaminated sites. *Lactuca Sativa* (Lettuce) thrived only on two soils (B25 % and D100 %) and *CelosiaArgentea* (*Soko*) also grew on four soils (A25 %, A50 %, C10 % and 100 %). The soils and soils mixes on which *Lactuca Sativa* (Lettuce) and *CelosiaArgentea* (*Soko*) grew were the least contaminated soils. Their ability to grow on soils with low contamination makes them a potential bio indicator for polluted soils.

The 16 priority USEPA PAHs were analysed in the different plants parts and the results are shown in Table 3. PAH concentrations in plants grown on contaminated soils compared with the control soils were higher. The PAHs concentrations of roots were for most plants higher than in their stems and the PAHs concentrations of stems were higher for leaves (Table 3). This finding was similar to that of other researchers who worked on PAH(s) uptake by plant (30-32). Vácha *et al*., (35) studied the influence of soil load with PAHs on their contents in selected plants (*Raphanus sativusvar* and *Radiculaduo* variety and carrot (*Daucus carota*). The roots of tested plants were loaded with PAHs especially the lower molecular weight PAHs compared with the higher molecular weight PAHs predominant in soils. In another study by Zitka *et al.*, (36) the uptake of

fluroanthrene by plants was highest in roots exposed to contaminated soils compared to other parts. They attributed the high concentrations of fluoranthrene in root to the lipophilicity of PAH. Fluoranthrene (like other PAHs) because of its lipohilic property accumulates in the cellular compartments such as plasma membrane and membrane-based organelles known to contain lipids. When plants grow on PAH contaminated soils, PAHs initially adsorb to plant cell walls and they later gradually diffuse into subcellular fractions of tissues. Therefore, transpiration and the lipid content of root cell fractions are the main drivers of the subcellular partition of PAHs in roots and also determine accumulation of lipophilic compounds in plants. Concentration gradient from soil to plant also plays a majour role in plant uptake of PAHs. Immobilisation and accumulation of PAHs in the roots compared to the leaves and stem may be because of chemical modification. PAHs interacts with numerous hydroxyl groups in polysaccharides (such as cellulose, hemicelluloses and pectin) of plant cell (37). Un-Nisa and Rashid (38) in their study found that the Vetiver grass (*Vetiveria zizanioides*) effectively removes PAHs from soil and that the levels were significantly higher in root and shoot of contaminated soils compared to the levels in the control. In some plants, PAHs concentration were higher than the soil where it was planted. This is probably due to bioaccumulation of the PAHs by the plants.

PAH profiles in plants harvested and soils on which plants grew.

There were variations in the PAH profiles of soils samples (Figure 1a) and plant samples (Figures 1b, 1c, 2 and 3). Four to six-ring PAHs made up 25 % - 75 % of all the PAHs found in composite soil samples studied. No specific trend was observed in soil. Generally two and three-ring PAHs were higher in most of the plants compared with the higher membered rings. However, the PAH profiles in the various plant samples were not similar. Concentrations of two and three-ring PAHs were generally higher than the concentration of four, five and six-ring PAHs in plant samples. Similar observations has been previously described by Bakker *et al*, (39) and Sojinua *et al*, (20,

40) who proposed that it may have been as a result of wind drift and wash-off or the low absorption of the higher membered ringed PAHs from the leaves surfaces. This may also as a result of the lipohilcity of PAHs. The liphophilic property of PAHs increases with increase in ring size. Since plant is made up of predominantly water and less oils, more of the less lipohilic PAHs (2 and 3 rings) will move through the plant system by translocation from the root.

CONCLUSION

The levels of PAHs in plants grown on contaminated soils were higher than in plants grown on the control soils. Soils with higher PAHs concentrations also had higher levels of PAHs in plants grown on them. The amount in roots were generally higher than in leaves and stem in all the plants. *Telfairia occidentale* (*Uguw*), consistently grew on all the soils studied (contaminated and non-contaminated soils). This ability of *Telfairia occidentale* (Ugwu) makes it a potential crop in phyto remediation of PAH contaminated sites. The soils and soils mixes on which *Lactuca Sativa* (Lettuce) and CelosiaArgentea (Soko) grew were the least contaminated soils. Their ability to grow on soils with low contamination makes them potential bio indicators for polluted soils.

Since the actual edible part for these vegetables are the leaves and not the root which had higher amounts of PAHs, less risk is associated with the consumption of these vegetable plants. However, data from this study will be used subsequently to access the actual risk associated with the consumption of contaminated vegetables.

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Table 1

	Grain particles size analysis						Physico–chemical properties	
Sample ID	Gravel (%)	Sand (%)	Clay (%)	Silt (%)	[a]TOC (%)	[b]SOM (%)	pH	Oil and grease (%)
A	28.52	66.50	4.92	0.06	1.73	2.98	8.0	4.92
B	13.79	74.67	11.54	6.37	2.23	3.84	7.3	1.41
C	4.99	84.73	10.20	0.08	2.40	4.13	7.1	3.96
D	1.25	49.71	20.03	29.01	4.50	7.74	6.8	0.18

a is Total organic carbon— TOC , b is Soil organic matter -SOM

Table 2

S/N	Compound	MS target Ion for Quantitation (M^+)	Other target ions (abundant ions) used for SIM	Group based on Retention Time and ion	R^2 Value	Calibration Range ng/ml	LOQ ng/ml	LOD ng/ml
1	NAP	128	126,127	Group 1(6mins)	0.995	0-5000	38.8	11.6
2	ACY	152	150, 76	Group 1 (6mins)	0.994	0- 5000	3.8	1.2
3	ACP	153*	154, 152	Group 2 (8mins)	0.995	0-4950	88.6	26.6
4	FLR	166	165,163	Group 2 (8mins)	0.995	0-4980	44.4	13.3
5	PHE	178	176, 152	Group 3 (12mins)	0.995	0-4990	12.0	3.6
6	ANT	178	176, 152	Group 3 (12mins)	0.996	0-5000	12.00	3.6
7	FLT	202	200, 201	Group 4 (22mins)	0.995	0-4970	90.0	27.0
8	PYR	202	200, 201	Group 4 (22mins)	0.999	0- 4950	90.0	27.0
9	BaA	228	226,113	Group5 (31.5mins)	0.996	0-4900	36.1	10.8
10	CHR	228	226,113	Group5 (31.5mins	0.999	0-5000	16.3	4.9
11	BbF	252	126, 250	Group6 (40mins)	0.996	0-4890	141.2	42.4
12	BkF	252	126, 250	Group6 (40mins)	0.997	0-4800	120.0	36.0
13	BaP	252	126,250	Group6 (40mins)	0.995	0-4900	114.3	34.3
14	DaH	276	274,138	Group7 (50mins)	0.998	0-4890	200.0	60.0
15	BgP	278	276,139	Group7 (50mins)	0.998	0-4800	187.6	56.3
16	IcP	276	126, 250	Group7 (50mins)	0.997	0-4900	50.0	15.0

*Except for Acenaphthene whose M^+ is 154

Table 3

Plant	Amount of sum 16 USEPA PAH plant parts and soil (ng g^{-1})				
Shoko	**Soil type**	**Leaves**	**Stems**	**Roots**	**Soil**
	A25%	440	400	187	**330**
	A50%	639	602	830	**454**
	C10%	1441	3743	2188	**25578**
	D100%	187	168	895	**207**
Tete	A10%	174	315	321	**10630**
	A10%	1336	1218	4240	**26266**
	B25%	1640	815	3192	**330**
	B50%	685	607	1678	**454**
	B75%	796	810	1877	**578**
	C10%	1224	666	1965	**25578**
	D100%	135	84	182	**207**
Spinach	A10%	735	651	82	**10630**
	A25%	3204	553	395	**26266**
	B25%	1409	2059	2021	**330**
	C10%	3217	298	1008	**25578**
	D100%	155	157	837	**207**
Orgwu	A10%	247	409	457	**10630**
	A25%	852	999	1357	**26266**
	A50%	718	1791	1986	**52325**
	A75%	842	812	1758	**78384**
	A100%	1346	1019	1971	**104443**
	B25%	832	855	1881	**330**
	B50%	1301	699	996	**454**
	B75%	952	259	572	**578**
	B100%	1279	832	129	**701**
	C10%	534	674	770	**25578**
	C25%	632	68	213	**63636**
	C50%	293	259	255	**127064**
	C75%	945	630	1143	**190493**
	C100%	914	1461	2832	**253922**
	D100%	161	484	495	**207**
Waterleaf	A10%	2855	7096	7490	**10630**
	B25%	1038	1648	1183	**330**
	B50%	3073	3448	5056	**454**
	C10%	3423	3168	3306	**25578**
	D100%	311	122	98	**207**
spring onions	A10%	1100		2342	**10630**
	B25%	979		1406	**330**
	B50%	1247		2068	**454**
	B75%	3061		5130	**578**
	C10%	423		1685	**25578**
	D100%	244		326	**207**
Lettuce	B25%	964		1512	**330**

	D100%	916		1473	**207**
Ewedu	A10%	1672	2362	2296	**10630**
	B25%	802	1881	4372	**330**
	B50%	1024	2963	3303	**454**
	B75%	1225	3001	3188	**578**
	D100%	802	1000	1891	**207**

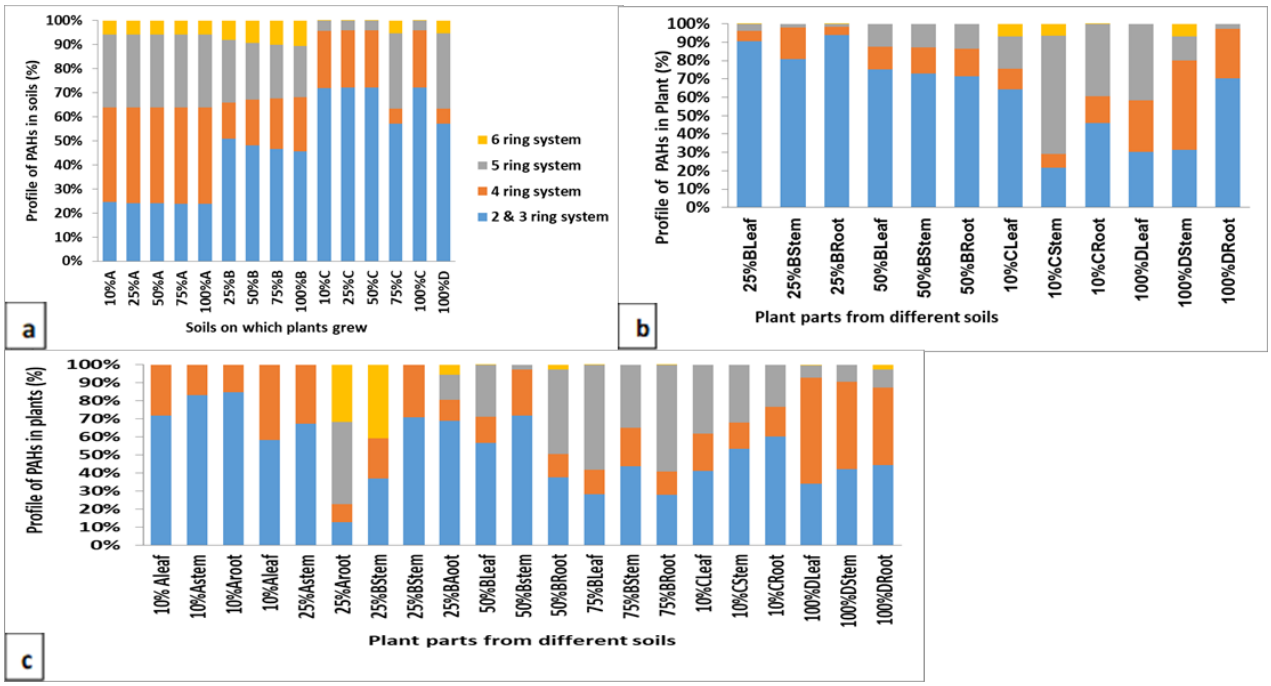

Figure 1: Soil,shok oand tete

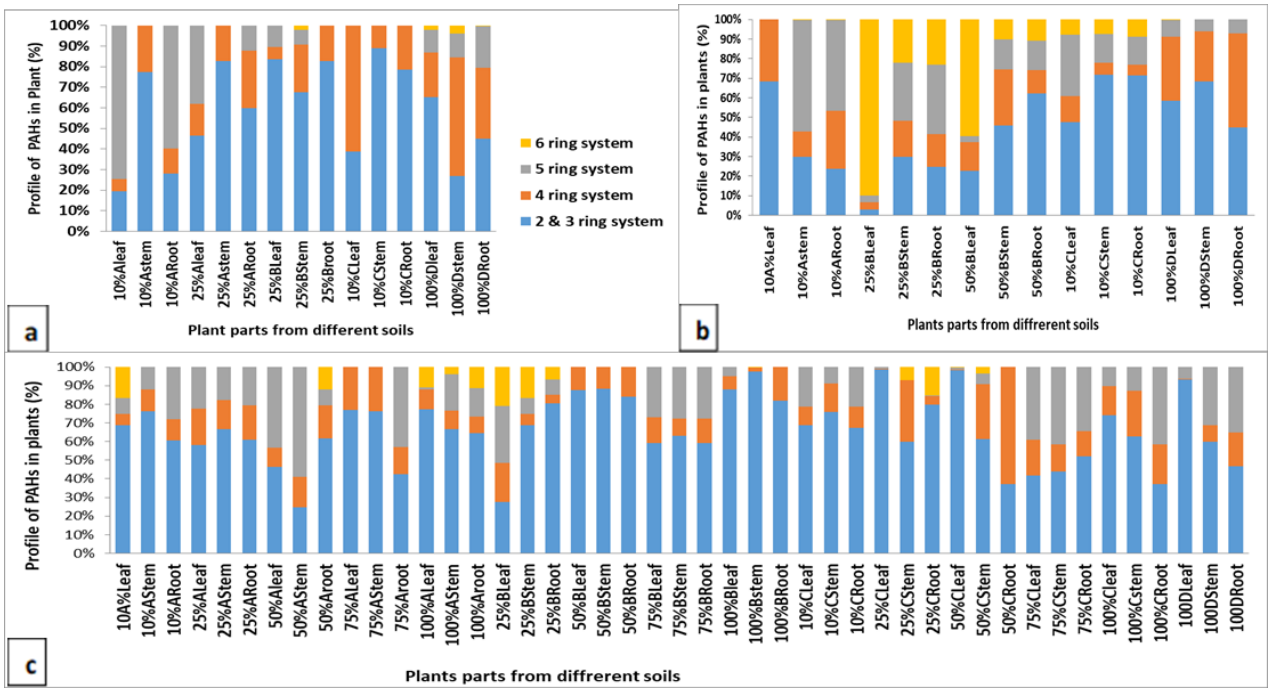

Figure 2: Spinach,water leaf and Ugwu

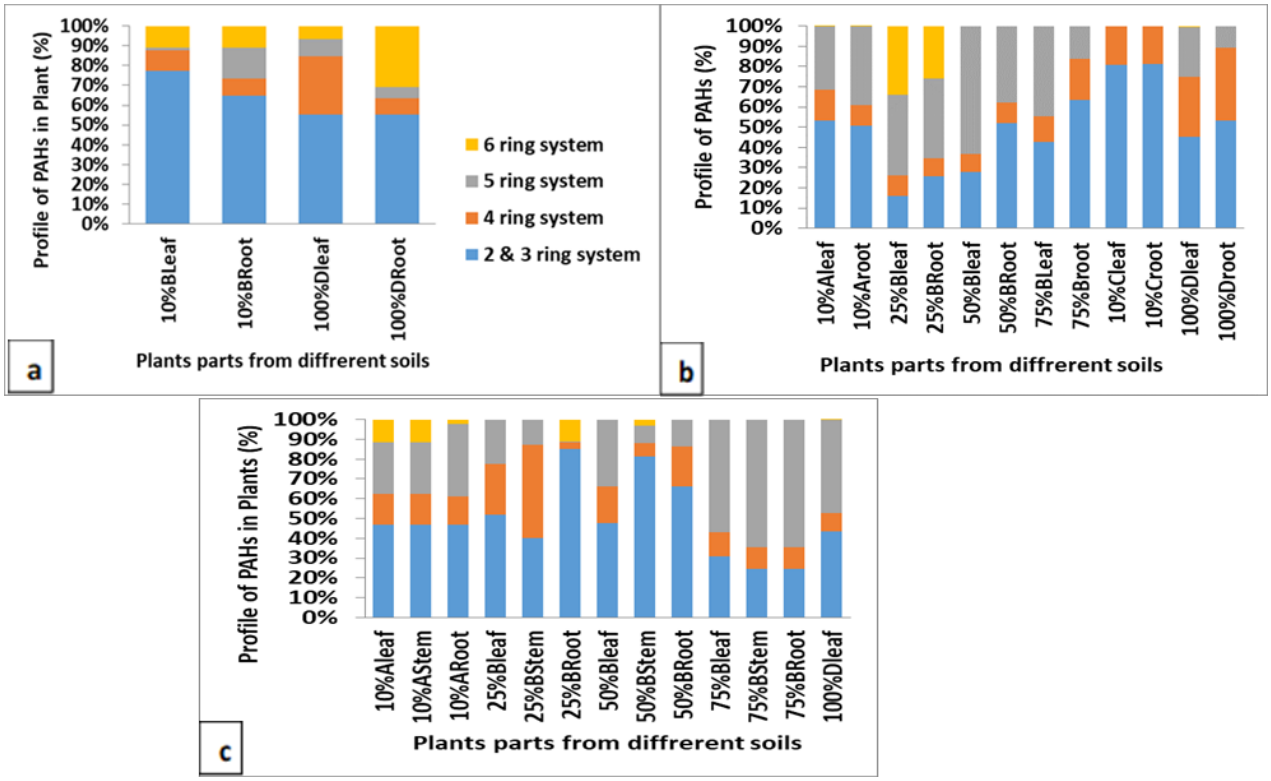

Figure 3: Lettuce,spring onions and ewedu