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Bioaccumulation of PAHs and Heavy Metals by Waterleaf and Fluted Pumpkin Harvested in four Communities Around Hairdressing Salon Facilities in Abia State, Nigeria.

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Abstract

The measure of polycyclic aromatic hydrocarbons (PAHs) and heavy metals in vegetables harvested around hairdressing salon facilities is increasingly alarming, as majority of the populace (Urban communities, Aba South & Umuahia South and Rural communities, Isuikwuato & Ohafia) depend on them for daily dietary nutrients. The Study investigated about 19 various PAHs in the waterleaf and fluted pumpkin leaves using the Gas Chromatograph (GC) including about 20 different metals using the Atomic Absorption Spectrophotometer (AAS). The results were compared with the Control obtained from the Study areas as well as FEPA (1995) and FAO/WHO (2011) Standards. Results showed that essential macro-mineral such as Ca and micro-mineral such as Fe, Zn, Mo, Co, and Cu were either lacking or found in minute quantities. Whereas toxicity of metals in vegetables were highly observed in Ag, Ni, Mg, Mn, Cd, Hg, Cr, As, Al, Se, Na, K, Pb, and V for all the communities at different levels. Moreover, the levels of PAHs such as dichloromethane, chloroform, chlorofluorocarbons, benzene, xylene, glycol, alkylolamides, propanol and propane were found to exceed the permissible limits, hence toxic for human consumption

Keywords: Polycyclic aromatic hydrocarbon; waterleaf; fluted pumpkin; heavy metals; hairdressing salon facilities; toxic.

Introduction

Hairdressing salon is a business usually owned by the female gender across the globe. Hairdressing salon facilities is associated with potential hazards, some of which are easily observed and others that are contriving harm. Majority of hairdressers use a wide range of cosmetic products on their clients, such as shampoos, hair conditioners, hair dyes, hair relaxer creams and curl activators, hair oil treatments, hair sprays, hair styling gels, hair setting lotions, hair mousse, age control, straighteners and bleaches supposedly to boost self-confidence and maintain elegance. Others include synthetic hairs (wigs, weavons, hair braid extensions / attachments) that contain hundreds of chemicals [28]. These services generate both solid and liquid wastes (hairdressing salon effluents) in form of alkalis, acids, relaxer, dyes and other organic and inorganic substances [53] which can greatly affect the ecosystem [19]. These wastes which are hazardous in nature are frequently discharged without treatment into water bodies or nearby land location. Incidentally, areas in which some of these hairdressing salons are sited have farms close by (particularly in rural areas) where many people plant vegetables such as waterleaf and fluted pumpkin that are consumed by

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unsuspecting people. The consumption of these vegetables from these environments invariably can have negative effects on health of the populace. Most heavy metals and polycyclic aromatic hydrocarbons (PAHs) can be very toxic even at low concentrations since there is no efficient mechanism of excretion from the body [52]. It has been reported that the major cause of heavy metal load and PAHs in vegetables could be due to its uptake from polluted soil [56]. With the numerous hairdressing salons located in Abia State, Nigeria, it is therefore a thing of interest to investigate the level of heavy metals and PAH distribution on vegetables harvested around these areas. This will provide baseline information on the level of harm faced by the people living within that region and for Environmental Health design.

Materials and Methods

In line with the International Institute of Tropical Agriculture [35] heavy metal content of waterleaf (*Talinum triangulare*) and fluted pumpkin (*Telfairia occidentalis*) plants were analyzed using Atomic Absorption Spectrophotometer (AAS) standard analytical procedure.

(i) Sampling: Matured waterleaf and fluted pumpkin plants were harvested within and around the hairdressing salon facilities in Abia State. The samples were oven dried at 1050C for 24 h. The dried samples were crushed and powdered. Then 50 g of crushed and powdered portion was taken in China dish and heated in a muffle furnace for 6 h at 6000C for ashing. After which the ashes were transferred into 250 ml beaker; 50 ml of deionized water and 5 ml of concentrated nitric acid were then added. The sample was then returned to a hot plate and kept heated, adding additional acid as necessary until digestion was completed. The sample was filtered into a 250 ml volumetric flask and was made up to the mark with deionized water [17].

(ii) Analysis of Sample: The Atomic Absorption instrument was set up and flame condition and absorbance were optimized for the analyte. Then blanks (deionized water) standards, sample blank and samples were aspirated into the flame in AAS (Model Agilent Technologies 200 Series AA). The calibration curves was obtained for concentration vs. various elements [38].

(iii) The determination of PAHs in waterleaf (Talinum triangulare) and fluted pumpkin (Telfairia occidentalis) plants were determined using Gas Chromatography-Mass Spectroscopy (GC-MS Model 910) according to the methods described by APHA[7].

Results

Table 1 and Figure 1 shows the levels and representations of various heavy metal (silver, nickel, magnesium, cobalt, manganese & cadmium) in the waterleaf (*Talinum triangulare*) and fluted pumpkin (*Telfairia occidentalis*) samples in the four locations studied.

Table 2 and Figure 2 shows the levels and representations of various heavy metal (mercury, copper, zinc, chromium, iron & lead) in the waterleaf (Talinum triangulare) and fluted pumpkin (Telfairia occidentalis) samples in the four locations studied.

Table 3 and Figure 3 shows the levels and representations of various heavy metal (arsenic, molybdenum, aluminum, selenium, sodium & potassium) in the waterleaf (Talinum triangulare) and fluted pumpkin (Telfairia occidentalis) samples in the four locations studied.

Table 4 and Figure 4 shows the levels and representations of various heavy metal (calcium, vanadium, dichloromethane, acenaphthylene, acetone & chloroform) and chemical components (PAHs) in the waterleaf (*Talinum triangulare*) and fluted pumpkin (*Telfairia occidentalis*) samples in the four locations studied.

Table 5 and Figure 5 shows the levels of composition and representations of various chemical (PAHs) components (chlorofluorocarbons, toluene, benzene, xylene, carbon tetrachloride & glycol) in the waterleaf (*Talinum triangulare*) and fluted pumpkin (*Telfairia occidentalis*) samples in the four locations studied.

Table 1: Heavy Metals in Edible Crops.

Edible crops	Silver (ppm)	Nickel (ppm)	Magnesium (ppm)	Cobalt (ppm)	Manganese (ppm)	Cadmium (ppm)
Aba South (Waterleaf)	$0.32±0.00^d$	$0.69±0.01^f$	$20.16±0.00^f$	$0.00±0.00^a$	$0.54±0.00^a$	$0.30±0.00^c$
Aba South (Fluted Pumpkin)	$0.00±0.00^a$	$0.39±0.01^e$	$17.78±0.00^e$	$0.00±0.00^a$	$0.83±0.00^d$	$0.26±0.00^b$
Umuahia South (Waterleaf)	$0.01±0.00^a$	$0.01±0.00^a$	$10.76±0.01^a$	$0.00±0.00^a$	$0.64±0.00^b$	$1.00±0.00^e$
Umuahia South (Fluted Pumpkin)	$0.00±0.00^a$	$0.03±0.00^b$	$11.45±0.00^b$	$0.00±0.00^a$	$0.93±0.00^e$	$0.59±0.00^d$
Ohafia (Waterleaf)	$0.92±0.00^f$	$0.89±0.00^g$	$42.13±0.00^h$	$0.00±0.00^a$	$10.10±0.00^g$	$2.17±0.00^g$
Ohafia (Fluted Pumpkin)	$0.35±0.00^e$	$0.41±0.00^e$	$39.03±0.00^g$	$0.00±0.00^a$	$13.20±0.00^h$	$1.72±0.00^f$
Isuikwuato (Waterleaf)	$0.14±0.00^c$	$0.17±0.00^d$	$13.35±0.00^d$	$0.00±0.00^a$	$0.74±0.00^c$	$0.26±0.00^b$
Isuikwuato (Fluted pumpkin)	$0.04±0.01^b$	$0.09±0.00^c$	$12.23±0.00^c$	$0.00±0.00^a$	$1.00±0.00^f$	$0.14±0.00^a$

Results are represented as Mean ± SEM; Means with same alphabet / superscript are not significantly different at P<0.05

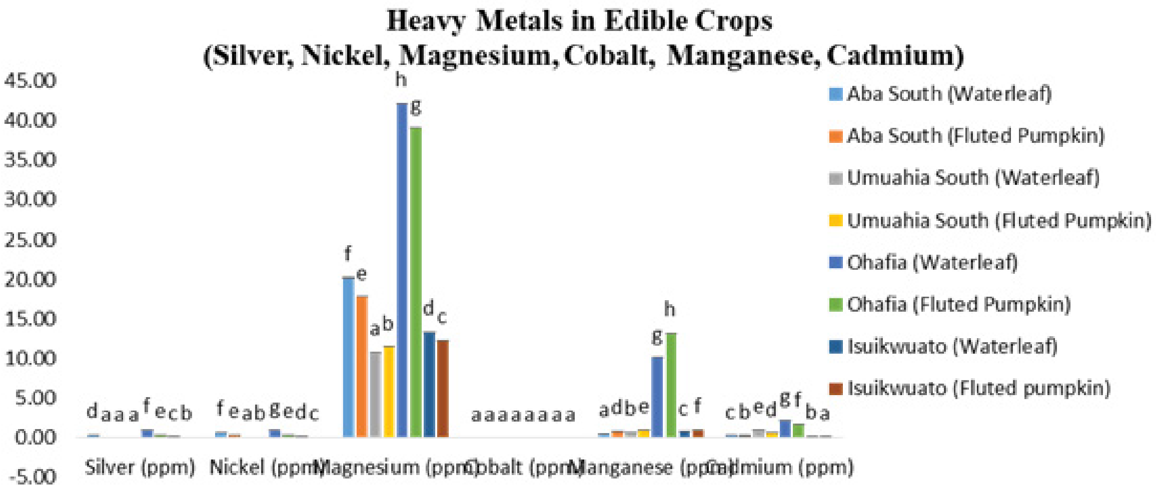

Figure 1: Heavy Metals in Edible Crops.

Table 2: Heavy Metals in Edible Crops.

Edible crops	Mercury (ppm)	Copper (ppm)	Zinc (ppm)	Chromium (ppm)	Iron (ppm)	Lead (ppm)
Aba South (Waterleaf)	0.30±0.01^{a}	0.28±0.00^{e}	0.25±0.00^{b}	0.00±0.00^{a}	1.21±0.00^{b}	0.00±0.00^{a}
Aba South (Fluted Pumpkin)	0.38±0.01^{b}	0.08±0.00^{b}	0.38±0.01^{e}	0.06±0.00^{e}	6.19±0.00^{f}	0.00±0.00^{a}
Umuahia South (Waterleaf)	0.38±0.00^{b}	0.30±0.00^{b}	0.10±0.00^{a}	0.03±0.00^{c}	1.14±0.00^{a}	0.00±0.00^{a}
Umuahia South (Fluted Pumpkin)	0.42±0.00^{c}	0.09±0.00^{f}	0.15±0.01^{b}	0.01±0.00^{b}	5.46±0.00^{e}	0.00±0.00^{a}
Ohafia (Waterleaf)	1.01±0.00^{f}	0.34±0.00^{g}	0.37±0.00^{d}	0.38±0.00^{f}	7.42±0.00^{g}	7.26±0.00^{a}
Ohafia (Fluted Pumpkin)	1.98±0.01^{g}	0.16±0.00^{d}	0.40±0.00^{f}	0.52±0.00^{g}	10.63±0.00^{h}	5.01±0.01^{a}
Isuikwuato (Waterleaf)	0.58±0.00^{d}	0.14±0.00^{c}	0.10±0.00^{a}	0.00±0.00^{ab}	1.88±0.00^{d}	0.00±0.00^{a}
Isuikwuato (Fluted pumpkin)	0.87±0.00^{e}	0.03±0.00^{a}	0.14±0.00^{b}	0.05±0.00^{d}	1.34±0.00^{c}	0.00±0.00^{a}

Results are represented as Mean ± SEM; Means with same alphabet / superscript are not significantly different at P<0.05

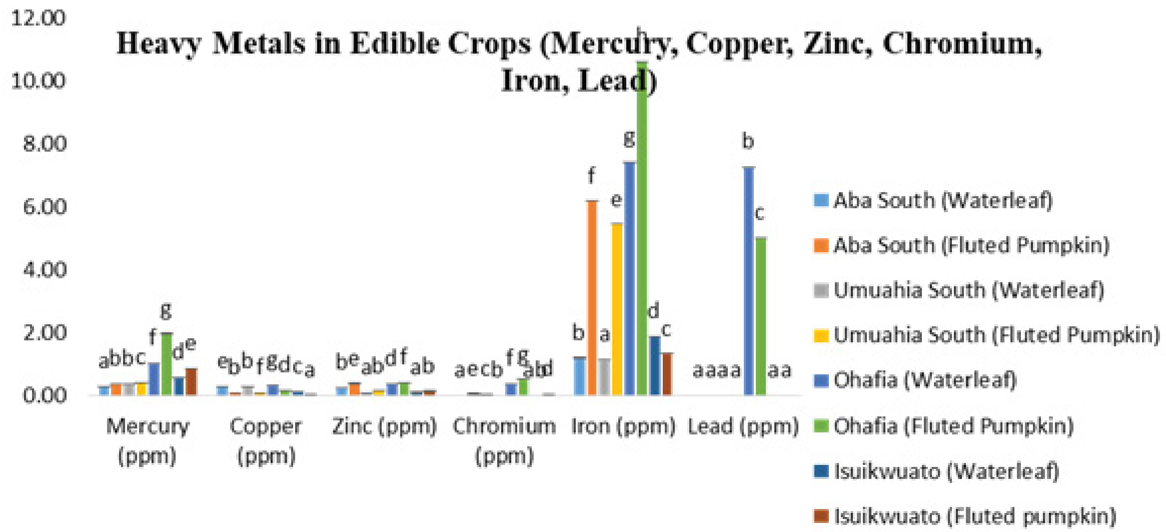

Figure 2: Heavy Metals in Edible Crops.

Table 3: Heavy Metals in Edible Crops.

Edible crops	Arsenic (ppm)	Molybdenum (ppm)	Aluminum (ppm)	Selenium (ppm)	Sodium (ppm)	Potassium (ppm)
Aba South (Waterleaf)	1.47±0.00^{b}	0.00±0.00^{a}	10.00±0.00^{e}	0.11±0.00^{b}	6.49±0.00^{e}	14.40±0.00^{f}
Aba South (Fluted Pumpkin)	1.72±0.00^{d}	0.00±0.00^{a}	1.70±0.00^{a}	0.28±0.00^{f}	3.98±0.00^{a}	12.51±0.01^{b}
Umuahia South (Waterleaf)	1.66±0.00^{c}	0.00±0.00^{a}	10.02±0.00^{f}	0.12±0.00^{c}	9.27±0.00^{h}	13.18±0.00^{c}
Umuahia South (Fluted Pumpkin)	1.92±0.00^{e}	0.00±0.00^{a}	1.73±0.00^{b}	0.29±0.00^{f}	4.77±0.00^{d}	11.08±0.00^{a}
Ohafia (Waterleaf)	0.01±0.00^{a}	0.00±0.00^{a}	11.21±0.00^{g}	0.10±0.00^{ab}	8.39±0.00^{g}	15.54±0.00^{g}
Ohafia (Fluted Pumpkin)	0.00±0.00^{a}	0.00±0.00^{a}	2.45±0.00^{c}	0.21±0.00^{e}	4.23±0.00^{c}	13.23±0.00^{d}
Isuikwuato (Waterleaf)	0.00±0.00^{a}	0.00±0.00^{a}	14.68±0.00^{h}	0.10±0.00^{a}	8.22±0.00^{f}	16.01±0.00^{h}
Isuikwuato (Fluted pumpkin)	0.00±0.00^{a}	0.00±0.00^{a}	5.90±0.00^{d}	0.17±0.00^{d}	4.12±0.00^{b}	14.25±0.00^{e}

Results are represented as Mean ± SEM; Means with same alphabet / superscript are not significantly different at P<0.05

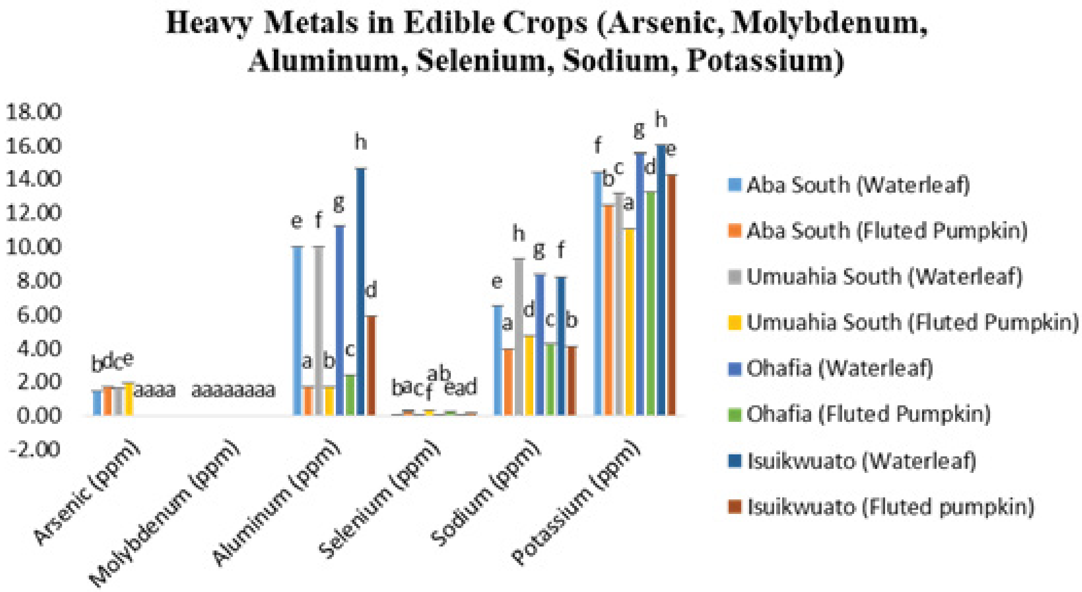

Figure 3: Heavy Metals in Edible Crops.

Table 4: Heavy Metals and PAHs in Edible Crops

Edible crops	Calcium (ppm)	Vanadium (ppm)	Dichloro Methane	Acenaphthy lene	Acetone	Chloroform
Aba South (Waterleaf)	0.00±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{f}	0.00±0.00^{c}	0.00±0.00^{a}	0.09±0.00^{a}
Aba South (Fluted Pumpkin)	0.00±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{d}	0.00±0.00^{a}	0.00±0.00^{b}	0.09±0.00^{a}
Umuahia South (Waterleaf)	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{b}	0.00±0.00^{bc}	0.00±0.00^{a}	0.17±0.00^{d}
Umuahia South (Fluted Pumpkin)	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{b}	0.00±0.00^{b}	0.15±0.00^{c}
Ohafia (Waterleaf)	0.00±0.00^{a}	0.02±0.00^{a}	0.02±0.00^{g}	0.00±0.00^{d}	0.00±0.00^{a}	0.19±0.00^{e}
Ohafia (Fluted Pumpkin)	0.00±0.00^{a}	0.01±0.00^{a}	0.01±0.00^{e}	0.01±0.00^{g}	0.00±0.00^{b}	0.17±0.00^{d}
Isuikwuato (Waterleaf)	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{c}	0.01±0.00^{f}	0.00±0.00^{a}	0.10±0.00^{b}
Isuikwuato (Fluted pumpkin)	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{ab}	0.01±0.00^{e}	0.00±0.00^{b}	0.10±0.00^{b}

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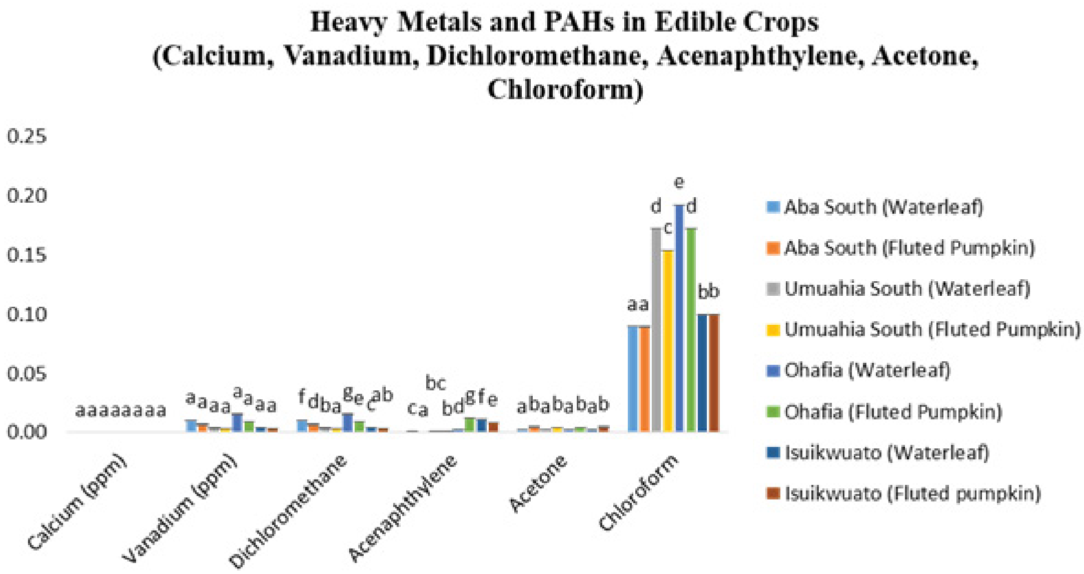

Figure 4: Heavy Metals and PAHs in Edible Crops.

Table 5: PAHs in Edible Crops.

Edible crops	Chlorofluoro carbons	Toluene	Benzene	Xylene	Carbon tetra chloride	Glycol
Aba South (Waterleaf)	0.19±0.00^{f}	0.00±0.00^{a}	0.02±0.00^{b}	0.04±0.00^{c}	0.00±0.00^{c}	1.97±0.00^{e}
Aba South (Fluted Pumpkin)	0.12±0.00^{b}	0.00±0.00^{a}	0.03±0.00^{f}	0.04±0.00^{c}	0.00±0.00^{bc}	0.00±0.00^{a}
Umuahia South (Waterleaf)	0.18±0.00^{d}	0.00±0.00^{b}	0.02±0.00^{a}	0.03±0.00^{b}	0.00±0.00^{abc}	1.37±0.00^{c}
Umuahia South (Fluted Pumpkin)	0.10±0.00^{a}	0.00±0.00^{b}	0.03±0.00^{e}	0.02±0.00^{a}	0.00±0.00^{abc}	0.96±0.00^{b}
Ohafia (Waterleaf)	2.00±0.00^{g}	0.00±0.00^{c}	0.03±0.00^{g}	0.05±0.00^{d}	0.00±0.00^{a}	0.00±0.00^{a}
Ohafia (Fluted Pumpkin)	0.12±0.00^{c}	0.00±0.00^{c}	0.03±0.00^{h}	0.05±0.00^{e}	0.00±0.00^{ab}	1.56±0.00^{d}
Isuikwuato (Waterleaf)	0.18±0.00^{e}	0.00±0.00^{b}	0.03±0.00^{d}	0.06±0.00^{f}	0.00±0.00^{bc}	2.32±0.00^{f}
Isuikwuato (Fluted pumpkin)	0.11±0.00^{b}	0.00±0.00^{b}	0.03±0.00^{c}	0.06±0.00^{g}	0.00±0.00^{c}	1.25±0.00^{b}

Results are represented as Mean±SEM; Means with same alphabet / superscript are not significantly different at $P<0.05$

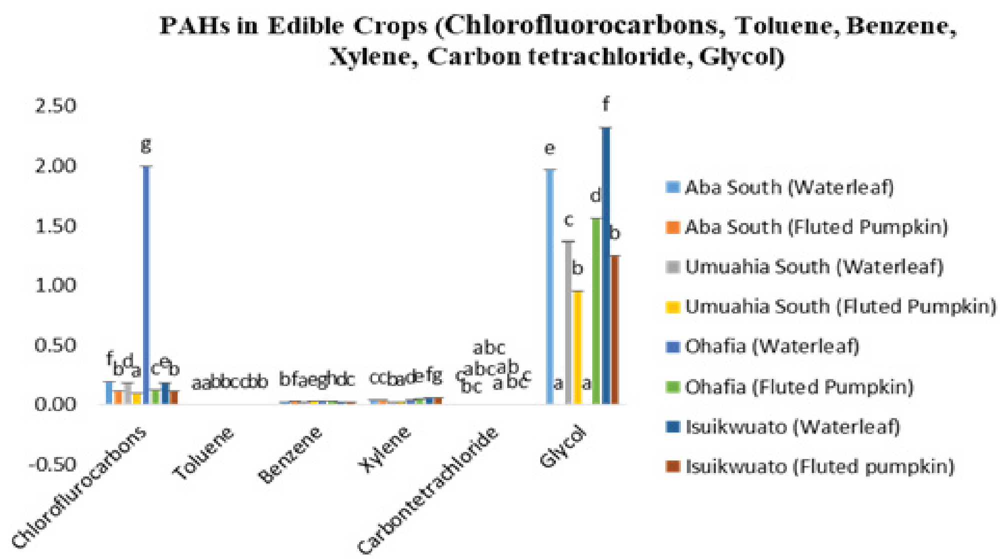

Figure 5: PAHs in Edible Crops.

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Table 6: PAHs in Edible Crops.

Edible crops	Alkylolamides	Naphthalene	Fluoranthene	1-2 Benzathracene	Propanol	Propane
Aba South (Waterleaf)	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{b}	0.00±0.00^{ab}	0.03±0.00^{e}
Aba South (Fluted Pumpkin)	0.00±0.00^{a}	1.83±0.00^{f}	0.00±0.00^{a}	0.00±0.00^{ab}	0.00±0.00^{b}	0.00±0.00^{b}
Umuahia South (Waterleaf)	0.00±0.00^{a}	0.17±0.00^{b}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{ab}	0.00±0.00^{b}
Umuahia South (Fluted Pumpkin)	0.00±0.00^{a}	1.72±0.00^{e}	0.00±0.00^{a}	0.00±0.00^{ab}	0.00±0.00^{ab}	0.01±0.00^{c}
Ohafia (Waterleaf)	7.48±0.00^{b}	0.00±0.00^{a}	0.00±0.00^{a}	0.01±0.00^{c}	0.03±0.00^{e}	0.03±0.00^{e}
Ohafia (Fluted Pumpkin)	8.86±0.00^{c}	0.00±0.00^{a}	0.00±0.00^{a}	0.75±0.00^{f}	0.03±0.00^{d}	0.03±0.00^{f}
Isuikwuato (Waterleaf)	0.00±0.00^{a}	1.12±0.00^{d}	0.00±0.00^{a}	0.03±0.00^{e}	0.02±0.00^{c}	0.00±0.00^{a}
Isuikwuato (Fluted pumpkin)	0.00±0.00^{a}	0.56±0.00^{c}	0.00±0.00^{a}	0.02±0.00^{d}	0.00±0.00^{a}	0.01±0.00^{d}

Results are represented as Mean ± SEM; Means with same alphabet / superscript are not significantly different at P<0.05

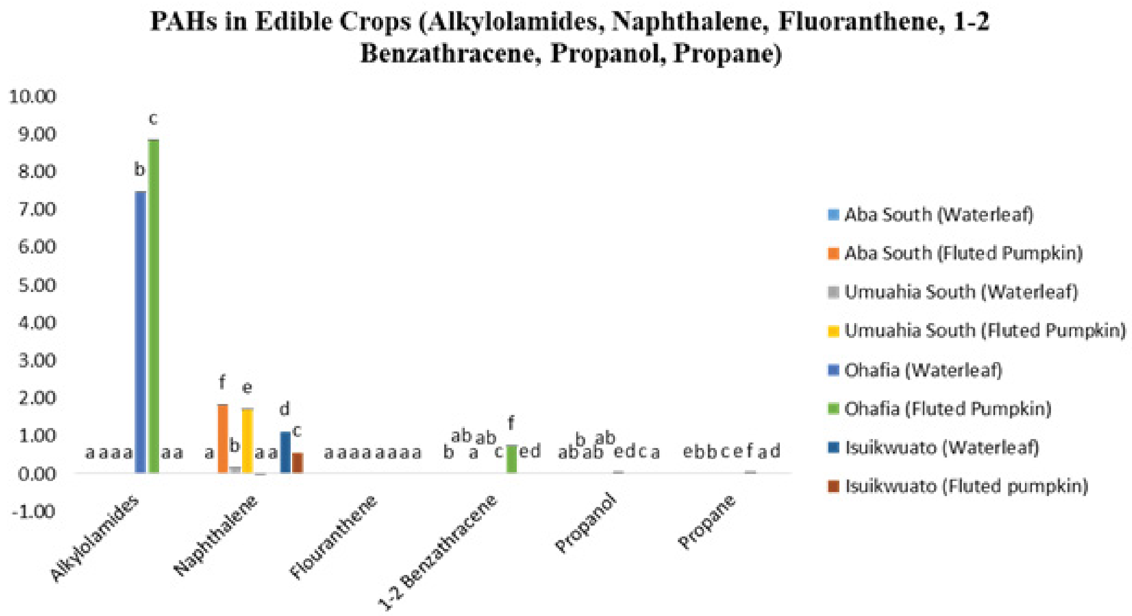

Figure 6: PAHs in Edible Crops.

Table 7: PAHs in Edible Crops.

Edible crops	Dimethyl ether	Hydantoin	Isopropyl alcohol
Aba South (Waterleaf)	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{d}
Aba South (Fluted Pumpkin)	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{d}
Umuahia South (Waterleaf)	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{c}
Umuahia South (Fluted Pumpkin)	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{csw}
Ohafia (Waterleaf)	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{b}
Ohafia (Fluted Pumpkin)	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
Isuikwuato (Waterleaf)	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
Isuikwuato (Fluted pumpkin)	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{cd}

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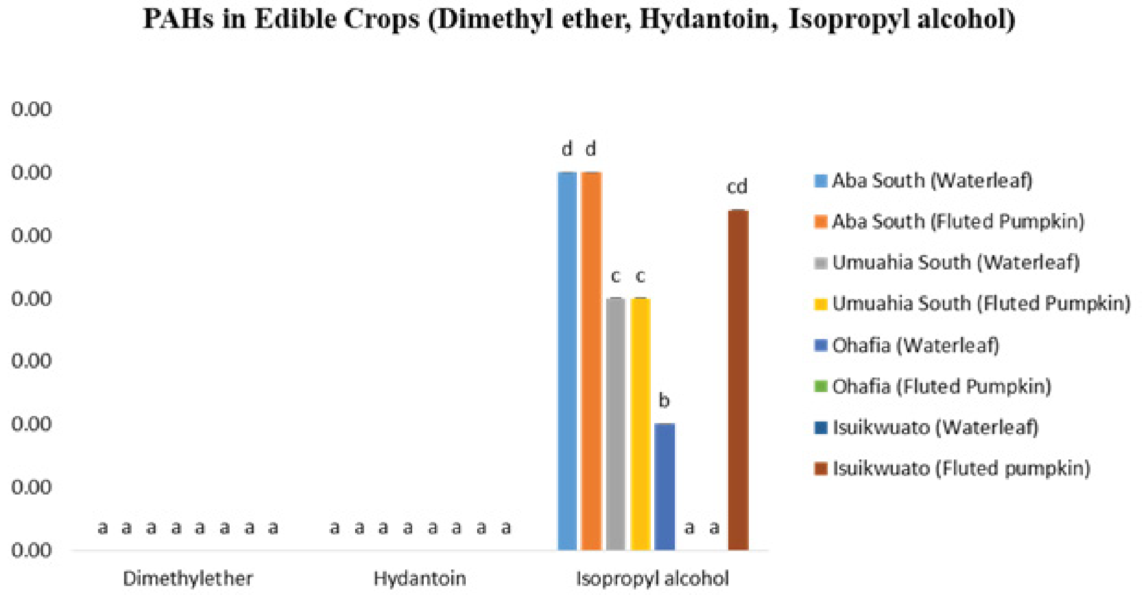

Figure 7: PAHs in Edible Crops.

Table 8: FAO/WHO (2011) Standards and Control for Heavy metals in vegetables

Heavy Metal	Fluted Pumpkin	Waterleaf	FAO & WHO (2011)
Calcium	38.51 ± 0.15	19.21 ± 0.10	-
Magnesium	10.24 ± 0.07	10.27 ± 0.03	-
Potassium	4.01 ± 0.03	2.21 ± 0.03	-
Sodium	2.17 ± 0.04	3.54 ± 0.05	-
Cadmium	0.00 ± 0.00	0.01 ± 0.00	0.02 mg/kg
Copper	2.70 ± 0.03	2.97 ± 0.03	10.0 mg/kg
Iron	197.3 ± 1.89	412.7 ± 2.77	425.5 mg/kg
Manganese	3.79 ± 0.18	1.80 ± 0.02	5.00 mg/kg
Lead	0.01 ± 0.00	0.00 ± 0.00	0.3 mg/kg
Zinc	10.24 ± 0.06	10.31 ± 0.01	60.0 mg/kg
Chromium	0.00 ± 0.00	0.00 ± 0.00	1.3 mg/kg
Mercury	0.00 ± 0.00	0.00 ± 0.00	0.03 mg/kg
Silver	0.00 ± 0.00	0.00 ± 0.00	0.01 mg/kg
Nickel	0.00 ± 0.00	0. 00 ± 0.00	0.1 mg/kg
Cobalt	0.00 ± 0.00	0.00 ± 0.00	0.01 mg/kg
Arsenic	0.00 ± 0.00	0.01 ± 0.00	0.5 mg/kg
Molybdenum	0.00 ± 0.00	0.00 ± 0.00	-
Aluminum	0.00 ± 0.00	0.00 ± 0.00	2 mg/kg
Selenium	0.00 ± 0.00	0.00 ± 0.00	0.4 mg/kg
Vanadium	0.00 ± 0.00	0.00 ± 0.00	0.03 mg/kg

Table 9: FEPA (1995) Standards for PAHs in Vegetables

Component	FEPA, 1995
Dichloromethane	0.01µg/kg
Acenaphthylene	0.01µg/kg
Acetone	0.03µg/kg
Chloroform	0.02µg/kg
Chlorofluorocarbons	0.01µg/kg
Toluene	0.01µg/kg
Benzene	0.01µg/kg
Xylene	0.02µg/kg
Carbon tetrachloride	0.03µg/kg
Glycol	0.02µg/kg
Alkylolamides	0.01µg/kg
Naphthalene	0.01µg/kg
Fluoranthene	0.01µg/kg
1-2 Benzathracene	0.02µg/kg
Propanol	0.02µg/kg
Propane	0.01µg/kg
Dimethyl ether	0.01µg/kg
Hydantoin	0.01µg/kg
Isopropyl alcohol	0.01µg/kg

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Table 6 and Figure 6 shows the levels of composition and representations of various chemical (PAHs) components (alkylolamides, naphthalene, fluoranthene, 1-2 benzathracene, propanol & propane) in the waterleaf (Talinum triangulare) and fluted pumpkin (Telfairia occidentalis) samples in the four locations studied.

Table 7 and Figure 7 shows the levels of composition and representations of various chemical (PAHs) components (dimethyl ether, hydantoin, & isopropyl alcohol) in the waterleaf (Talinum triangulare) and fluted pumpkin (Telfairia occidentalis) samples in the four locations studied.

Discussion

In Table 1, the concentrations of the heavy metal silver in waterleaf (*Talinum triangulare*) and fluted pumpkin (*Telfairia occidentalis*) showed varying levels of the metal toxicity. The concentrations of silver in waterleaf ranged from 0.01±0.00 mg/kg to 0.92±0.00 mg/kg. Ohafia had the highest values for silver in waterleaf samples (0.92±0.00 mg/kg) while, Umuahia South had the least (0.01±0.00 mg/kg). All the values recorded for silver in waterleaf fell above the control (0.00±0.00 mg/kg) and the FAO and WHO (2011) permissible limits of 0.01 mg/kg for silver in vegetables; except Umuahia South (0.01±0.00 mg/kg) that was within the range of FAO and WHO (2011) standards. However, the levels of silver in fluted pumpkin, revealed that the two urban locations (Aba South & Umuahia South) showed no components of silver. Whereas, the rural areas, Ohafia (0.35±0.00 mg/kg) and Isuikwuato (0.04±0.01 mg/kg) deciphered some composition of silver in fluted pumpkin. Ohafia had the highest value of silver in fluted pumpkin samples (0.35±0.00 mg/kg) while, Isuikwuato had the lowest (0.04±0.01 mg/kg). These values exceeded that of the control (0.00±0.00 mg/kg) and the FAO and WHO [27] permissible limits. Generally, it was observed that Ohafia (See Table 1 & Figure1) had the highest values of silver concentrations both in waterleaf and fluted pumpkin (waterleaf, 0.92±0.00 mg/kg & fluted pumpkin, 0.35±0.00 mg/kg). Acute symptoms of over exposure to silver nitrate are decreased blood pressure, diarrhoea, stomach irritation and decreased respiration while, chronic symptoms from prolonged intake of low doses of silver salts are fatty degeneration of the liver and kidneys and changes in blood cells. According to Fung and Bowen [29] long term inhalation or ingestion of soluble silver compounds or colloidal silver may cause argyria or argyrosis; also soluble silver compounds are capable of accumulating in small amounts in the brain and in muscles.

The concentrations of the heavy metal nickel (Ni) in waterleaf showed that the four locations studied, all had some compositions of nickel (0.01±0.00 mg/kg to 0.89±0.00 mg/kg). Ohafia had the highest concentration of nickel in waterleaf samples (0.89 ± 0.00 mg/kg) while, Umuahia South had the least (0.01±0.00 mg/kg). All the values recorded for nickel in waterleaf were above the control 0.00±0.00 mg/kg and the FAO and WHO [27] acceptable limit of 0.1 mg/kg for nickel in vegetables; except Umuahia South (0.01± 0.00 mg/kg) that was within the range of FAO and WHO standards. In addition, the concentrations of nickel in fluted pumpkin showed that all the locations studied exhibited varying levels of nickel (0.03±0.00 mg/kg to 0.41±0.00 mg/kg). Ohafia had the highest value of nickel in fluted pumpkin samples (0.41±0.00 mg/kg) while, Umuahia South had the lowest (0.03±0.00 mg/kg). It was observed that Aba South (0.39±0.01 mg/kg) and Ohafia (0.41±0.00 mg/kg) locations exceeded the control and the FAO and WHO [27] permissible limit. Whereas, Umuahia South (0.03±0.00 mg/kg) and Isuikwuato (0.09±0.00 mg/kg) were below the permissible limits. Generally, it was noted that Ohafia (See Table 4.6a & Figure 4.6a) had the highest values of nickel concentrations both in waterleaf (0.89±0.00 mg/kg) and fluted pumpkin samples (0.41±0.00 mg/kg). While, Umuahia South had the lowest concentrations in both waterleaf (0.01±0.00 mg/kg) and fluted pumpkin samples (0.03±0.00 mg/kg). According to Alkhatib, Qutob, Kattan, Malassa and Qutob [5] acute ingestion of nickel compounds has been associated with various morbidity such as cough and shortness of breath, vomiting, nausea, diarrhoea cardiovascular diseases, cancer (including lung and nasal cancer) dermatitis, headache and kidney diseases. In severe cases, ingestion of large amounts of a nickel compound may cause death. However, chronic oral exposure to nickel or nickel compounds has not been characterized in humans.

The magnesium (Mg) concentrations of the waterleaf samples ranged from 10.76±0.01 mg/kg to 42.13±0.00 mg/kg. These values were found to exceed that of the control (10.27±0.03 mg/kg). Ohafia had the highest values of magnesium in waterleaf samples (42.13±0.00 mg/kg) while, Umuahia South had the least values (10.76±0.01mg/kg). Furthermore, the concentrations of magnesium in the fluted pumpkin samples (11.45±0.00 mg/kg to 39.03±0.00 mg/kg) were also higher than that of the control (10.24±0.07 mg/kg). Ohafia had the highest values of magnesium in fluted pumpkin samples (39.03±0.00 mg/kg) whereas, Umuahia South had the lowest (11.45±0.00 mg/kg). These findings were higher than those reported by Ogbuji, Ndulaka and David-Chukwu [55] and Odoh, Yebpella, Udegbunam and Archibong [54] for magnesium in waterleaf and fluted pumpkin. Generally, it was noted that Ohafia (See Table 1 & Figure 1) had the highest values of magnesium concentrations both in waterleaf and fluted pumpkin samples. While Umuahia South had the lowest concentrations in both waterleaf and fluted pumpkin samples. According to Diana, Concettina, Giovanna and Cecilia [22] magnesium is an essential macronutrient that plays a key role in many body processes, including muscle, nerve and bone health, and mood. However, a high intake of magnesium can

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lead to gastrointestinal problems such as diarrhoea, nausea or cramping. Others are kidney problems, low blood pressure, and depression, including a loss of central nervous system (CNS) control, cardiac arrest, and possibly death.

The heavy metal cobalt (Co) was not detected in the waterleaf samples. All the locations recorded zero concentrations of cobalt (Aba South, 0.00±0.00 mg/kg; Umuahia South, 0.00±0.00 mg/kg; Ohafia, 0.00±0.00 mg/kg & Isuikwuato, 0.00±0.00 mg/kg). This is in tandem with the control (0.00±0.00 mg/kg). The FAO and WHO [27] permissible limits for cobalt in vegetables is 0.01 mg/kg. Similarly, cobalt was also not detected in the fluted pumpkin samples (See Table 1). Laura [40] reported that exposure to cobalt can be harmful to the eyes, skin, heart and lungs; and can trigger cancer.

The concentrations of manganese (Mn) in the waterleaf samples (0.74±0.00 mg/kg to 10.10±0.00 mg/kg) were shown to be lower than that of the control (1.80±0.02 mg/kg) and the FAO and WHO [27] permissible limits of 5.00 mg/kg in vegetables; except Ohafia (10.10±0.00 mg/kg) that exceeded the control and recommended values for manganese. Ohafia had the highest values of manganese in the waterleaf samples (10.10±0.00 mg/kg) while, Aba South had the least (0.54±0.00 mg/kg). The concentrations of manganese in the fluted pumpkin samples were also found to be lower than that of the control (3.79±0.18 mg/kg) and the FAO and WHO permissible limits; except Ohafia (13.20±0.00 mg/kg) that fell above the permissible limits. These finding is in agreement with Ogbuji, Ndulaka and David-Chukwu [55] but, varied with that reported by Asaolu et al. [10] that documented a lower concentration in fluted pumpkin for manganese. Such variation could possibly be due to the differences in soil composition and the plant source. Ohafia had the highest value of manganese in fluted pumpkin samples (13.20±0.00 mg/kg) while, Aba south had the lowest value (0.83±0.00 mg/kg). According to ATSDR [15] ingestion of high levels of manganese can damage the nervous system and has been associated with symptoms such as irritability, aggressiveness, and hallucinations.

The concentrations of cadmium (Cd) in the waterleaf samples (0.26±0.00 mg/kg to 2.17±0.00 mg/kg) showed that all the locations studied were higher than the control (0.01±0.00 mg/kg) including the FAO and WHO [27] permissible limits of 0.02 mg/kg for cadmium in vegetables. Ohafia had the highest values of cadmium in waterleaf samples (2.17±0.00 mg/kg) while, Isuikwuato had the least (0.26±0.00 mg/kg). Similarly, the concentrations of cadmium in fluted pumpkin (0.14±0.00 mg/kg to 1.72±0.00 mg/kg) were shown to be higher than that of control (0.00±0.00 mg/kg) as well as the FAO and WHO acceptable limits for cadmium in vegetables. Ohafia had the highest values of cadmium in fluted pumpkin samples (1.72±0.00 mg/kg) while, Isuikwuato had the least (0.14±0.00 mg/kg). These findings agree with that of Oguh and Obiwulu [57] for cadmium in waterleaf and fluted pumpkin. But, varied with that of Alkhatib et al. [5] and Ogbuji et al. [55] that never detected cadmium in vegetables. However, Odoh et al. [54] documented low concentrations for cadmium in waterleaf. According to Odoh et al. [54] cadmium is bio-persistent and once absorbed remains resident for many years. Since, cadmium accumulates in the intestine, liver and kidney; over-consumption of this metal in food has been reported to cause proximal tubular disease and osteomalacia including problems in the synthesis of haemoglobins, damage to the kidneys, gastrointestinal tract, reproductive system and the nervous system as well as death.

In Table 2, the concentrations of the heavy metal mercury in waterleaf samples showed that the four locations (Aba South, 0.30±0.01 mg/kg; Umuahia South, 0.38±0.00 mg/kg; Ohafia, 1.01±0.00 mg/kg & Isuikwuato, 0.58±0.00 mg/kg) exceeded the control values of 0.00±0.00 mg/kg and the FAO and WHO [27] permissible limits of 0.03 mg/kg for mercury in vegetables. Ohafia had the highest values of mercury in waterleaf samples (1.01±0.00 mg/kg). While, Aba South had the lowest value of 0.30±0.01 mg/kg. In the same vein, the concentrations of mercury in the fluted pumpkin samples were also higher than that of the control (0.00±0.00 mg/kg) and the FAO and WHO permissible limits for mercury in vegetables. Ohafia also had the highest values of mercury in the fluted pumpkin samples (1.98±0.01 mg/kg). While Aba South had the least (0.38±0.01 mg/kg). This is consistent with the findings by Oguh and Obiwulu [57] that reported much higher levels of mercury in waterleaf and fluted pumpkin. According to WHO [67] mercury is one of the top ten chemicals or groups of chemicals of major public health concern and exposure to mercury even in small amounts; can harm the nervous, digestive and immune systems, including damage to lungs, kidneys, skin and eyes as well as birth defects and developmental problems.

The concentrations of copper (Cu) in the waterleaf samples were found to be lower than that of the control (2.97±0.03 mg/kg) and the FAO and WHO [27] permissible limits of 10.0 mg/kg for copper in vegetables. Ohafia had the highest values of copper in waterleaf samples (0.34±0.00 mg/kg). While Isuikwuato had the lowest (0.14±0.00 mg/kg). Furthermore, the concentrations of copper in the fluted pumpkin samples were shown to be much lower than that of the waterleaf samples, the control (2.70±0.03 mg/kg), including the FAO and WHO permissible limits for copper in vegetables. Ohafia had the highest values of copper in fluted pumpkin samples (0.16±0.00 mg/kg) while, Isuikwuato had the least (0.03±0.00 mg/kg). These findings is similar to that reported by Ogbuji et al. [55] for levels of copper in waterleaf and fluted pumpkin; but lower than that reported by Odoh et al. [54] for copper in vegetables. Though, copper is essential for plant growth, but high concentrations can lead to liver

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and kidney damage, metabolic disorders, anaemia, stomach and intestinal irritation, vomiting and nausea including diarrhoea [5]. High levels of copper in plants, leads to chlorosis, oxidative stress and growth retardation. However, in microorganisms, copper disrupts cellular function and inhibits enzyme activities [23].

The concentrations of zinc (Zn) in the waterleaf samples were shown to be lower than that of the control (10.31±0.01 mg/kg) and the FAO and WHO [27] permissible limits of 60.0 mg/kg for zinc in vegetables. Ohafia had the highest values of zinc in waterleaf samples (0.37±0.00 mg/kg). While Isuikwuato and Umuahia South had the least (0.10±0.00 mg/kg). Moreover, the concentrations of zinc in the fluted pumpkin samples were also found to be lower than that of the control (10.24±0.06 mg/kg) and the FAO and WHO permissible limits. Ohafia had the highest values for zinc in fluted pumpkin samples (0.40±0.00 mg/kg) while, Isuikwuato had the lowest values (0.14±0.00 mg/kg). These findings is in conformity with that documented by Ogbuji et al. [55] for zinc composition in waterleaf and fluted pumpkin. But, in contrast with the findings by Odoh et al. [54] which reported higher values of zinc in waterleaf and fluted pumpkin. The low zinc levels studied could be attributed to the activities of the hairdressing salon operations in the various locations. Zinc is an essential trace element that poses great importance in human dietary nutrition and health [32]. However, acute exposure to overly high concentration of zinc could manifest to nausea, vomiting, diarrhoea, fever and lethargy. While long-term chronic exposure to excessive zinc levels could result in metabolic interference with other trace elements leading to depression, seizures, impotence, kidney and liver failure and prostate cancer [69]. Zinc deficiency in plants affects photosynthesis, inhibits growth rate, reduce chlorophyll content, germination rate and plant biomass [5].

The concentrations of chromium (Cr) in the waterleaf samples showed that chromium was not detected in Aba South and Isuikwuato (0.00±0.00 mg/kg) respectively. The other two locations (Umuahia South & Ohafia) recorded values higher than the control (0.00±0.00 mg/kg) but lower than the FAO and WHO [27] permissible limits of 1.3 mg/kg for chromium in vegetables. Ohafia had the highest values of chromium in the waterleaf samples (0.38±0.00 mg/kg) while, Umuahia South had the least (0.03±0.00 mg/kg). Conversely, the concentrations of chromium in the fluted pumpkin samples showed that all the locations had varying compositions of chromium which were higher than the control (0.00±0.00 mg/kg) but, lower than the FAO and WHO recommended limits. Ohafia had the highest values for chromium in fluted pumpkin (0.52±0.00 mg/kg) while, Umuahia South had the least (0.01±0.00 mg/kg). According to Barakat [18] high dose of chromium has been associated with Bronchopneumonia, chronic bronchitis, irritation of the skin, diarrhoea, itching of respiratory tract, renal failure, liver diseases, nausea, vomiting, lung cancer, emphysema and headache. Whereas, chromium effects on plants include chlorosis, wilting, delaying senescence, biochemical lesions, reduced biosynthesis germination, stunted growth and oxidative stress [16].

The concentrations of Iron (Fe) in the waterleaf samples were found to be lower than the control (412.7±2.77 mg/kg) and the FAO and WHO [27] permissible limits of 425.5 mg/kg for Fe in vegetables. Ohafia had the highest values of iron in waterleaf samples (7.42±0.00 mg/kg) while, Umuahia South had the lowest (1.14±0.00 mg/kg). In the same vein, the concentrations of iron in the fluted pumpkin samples were also noted to be lower than the control (197.3±1.89 mg/kg) as well as the FAO and WHO permissible limits for vegetables. Ohafia had the highest values of iron in fluted pumpkin (10.63±0.00 mg/kg) while, Isuikwuato had the least (1.34±0.00 mg/kg). These findings is in contrast with the report by Ogbuji et al. [55] that documented high levels of iron in fluted pumpkin and waterleaf. But, synonymous with Odoh et al. [54] that reported low levels of iron in both waterleaf and fluted pumpkin. Iron deficiency is a more common problem for humans, since, it leads to anaemia. Shah et al. [62] recommends an average daily intake of 7 mg of iron for males and 11 mg for females in a normal diet. Exposure to high levels of iron could lead to the development of a benign pneumoconiosis, conjunctivitis and lung cancer [63]. Iron (Fe) deficiency chlorosis in plants is a major nutritional disorder for crops leading to decrease in vegetative growth and marked yield and quality losses [42]. However, excess iron in plants can produce symptoms of stunted growth and discolored bronzing, foliage [31].

The concentrations of lead (Pb) in the waterleaf samples showed that lead was not detected in the various locations (See Table 2) except, Ohafia. The values of waterleaf samples for lead in Ohafia was 7.2±0.00 mg/kg; which is higher than the control (0.00±0.00 mg/kg) including the FAO and WHO [27] permissible limits of 0.3 mg/kg for lead in vegetables. Similarly, the concentrations of lead in the fluted pumpkin samples showed that lead was also not detected in the four locations (Aba South, 0.00±0.00 mg/kg; Umuahia South, 0.00±0.00 mg/kg & Isuikwuato, 0.00± 0.00 mg/kg) except, Ohafia. The values of fluted pumpkin samples for lead in Ohafia was 5.01±0.01 mg/kg. These values were above the control (0.01±0.00 mg/kg) and the FAO and WHO permissible limits of lead in vegetables. From this findings, the consumption of waterleaf and fluted pumpkin in Ohafia areas may constitute severe health hazards. The high levels of the heavy metal Pb, might be a reflection of severe pollution of soil from the release of wastes (solid & liquid) which could be organic or inorganic from hairdressing salon activities and consequently taken up by the plants growing on the soil [6]. These findings is in contrast with Odoh et al. [54] and Ogbuji et al. [55] that reported very low levels of lead in waterleaf and

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fluted pumpkin. But, corroborates with Oguh, and Obiwulu [57] for lead in waterleaf and fluted pumpkin. For, as far as we know, lead fulfills no essential function in the human body and since lead (Pb) exposure is through direct contact; care needs to be taken in the consumption of lead contaminated vegetables. According to Alkhatib et al. [5] and Odoh et al. [54] lead can cause serious injury to the brain, nervous system, red blood cells, low intelligent quotient, impaired development, loss of memory, reduced fertility, renal system damage, nausea, insomnia, anorexia and weakness of the joints. In addition, this heavy metal can also have adverse effects on plants through delayed photosynthesis and growth, inhibition of enzyme activities and seed germination as well as evidence of chlorosis [51].

In Table 3, the arsenic (As) levels of waterleaf samples showed that all the locations (Aba South, Umuahia South & Ohafia) had some arsenic compositions; except Isuikwuato in which arsenic was not detected. Moreover, Aba South (1.47±0.00 mg/kg) and Umuahia South (1.66±0.00 mg/kg) exceeded the control values (0.01±0.00 mg/kg) and the FAO and WHO [27] permissible limits of 0.5 mg/kg for arsenic in vegetables. Whereas, Ohafia (0.01±0.00 mg/kg) was within the control and FAO and WHO permissible limits. Umuahia South had the highest concentration of arsenic in waterleaf samples (1.66±0.00 mg/kg) while, Ohafia had the least (0.01±0.00 mg/kg). Furthermore, the concentrations of arsenic in the fluted pumpkin samples indicated that Ohafia and Isuikwuato had no trace of arsenic. Whereas, Aba South and Umuahia South recorded high levels of arsenic in the fluted pumpkin. Umuahia South had the highest values of arsenic in the fluted pumpkin samples (1.92±0.00 mg/kg) while, Aba South had the least (1.72±0.00 mg/kg). These values were found to be higher than the control (0.00±0.00 mg/kg) and the FAO and WHO permissible limits for arsenic in vegetables. Oguh and Obiwulu [57] reported higher values for arsenic in waterleaf and fluted pumpkin around auto mechanic workshop. According to WHO [68] the immediate symptoms of acute arsenic poisoning include vomiting, abdominal pain and diarrhoea, which are followed by numbness and tingling, muscle cramping and even death. Whereas long-term effects of arsenic include pigmentation changes, skin lesions and hard patches on the palms and soles of the feet, including lung and bladder cancer, developmental effects, diabetes, pulmonary disease and cardiovascular disease. At higher concentration, arsenic is toxic to plants through interference with metabolic processes by inhibiting plant growth and development as well as death through oxidative stress [71]. Arsenic is not essential for plant growth. However, it can accumulate in plants to toxic levels; thus can enter the food chain and pose health risk to humans [48].

The concentrations of molybdenum (Mo) in the waterleaf samples showed that none of the samples had any composition of molybdenum (See Table 3). The control values for molybdenum in waterleaf samples is 0.00±0.00 mg/kg. Similarly, the concentrations of molybdenum in the fluted pumpkin samples showed that molybdenum was not detected in any of the four locations studied. The above findings are in consonance with the report by Ogbuji et al. [55], Odoh et al. [54], Oguh and Obiwulu [57] and Alkhatib et al. [5] for absence of molybdenum in waterleaf and fluted pumpkin. But in contrast with Mohammed and Sharif [49] that reported low levels of molybdenum in leafy vegetables.

The concentrations of aluminum (Al) in the waterleaf samples showed that all the locations had varying levels of aluminum compounds. Isuikwuato had the highest values of aluminum in the waterleaf samples (14.68±0.00 mg/kg) while, Aba South had the lowest (10.00±0.00 mg/kg). All the values for aluminum in waterleaf samples exceeded that of the control (0.00±0.00 mg/kg) values as well as the FAO/WHO [27] permissible limits of 2 mg/kg for aluminum in vegetables. Moreover, the concentrations of aluminum in the fluted pumpkin samples also showed that all the locations had some components of aluminum. Isuikwuato had the highest value of aluminum in fluted pumpkin samples (5.90±0.00 mg/kg) while, Aba South had the least (1.70±0.00 mg/kg). All the values for aluminum in fluted pumpkin fell above that of the control (0.00±0.00 mg/kg) value and the FAO/WHO permissible limits except, Aba South (1.70±0.00 mg/kg) and Umuahia South (1.73±0.00 mg/kg) that were below the acceptable standards. According to Liang et al. [41] aluminum is a toxic metal without any function in the human and animal organism. Adverse effects of aluminum in humans include seizures, muscle weakness, bone diseases, nervous system and lung disorders, impaired iron absorption, Anaemia and brain disease and disorders [50]. On the other hand, aluminum toxicity in plants is associated with severe changes in the root system in which there is inhibition of root elongation.

The selenium (Se) concentrations of the waterleaf samples showed that all the locations had some compositions of selenium at levels higher than the control (0.00±0.00 mg/kg) but lower than the FAO/WHO [27] tolerable upper limit of 0.4 mg/kg. Umuahia South had the highest values for selenium in waterleaf samples (0.12±0.00 mg/kg) while, Ohafia and Isuikwuato had the least (0.10±0.00 mg/kg). In the same vein, the concentrations of selenium in the fluted pumpkin samples were also higher than the control (0.00±0.00 mg/kg) but lower than the FAO/WHO tolerable upper limit. Again, Umuahia South had the highest values for selenium in fluted pumpkin (0.29±0.00 mg/kg) while, Isuikwuato had the least (0.17±0.00 mg/kg). According to Kolbert [39] selenium is a widely distributed trace element with dual (beneficial or toxic) effects for humans, animals and plants. In humans, excess consumption of selenium may result in brittle nail, garlic breath, nausea and vomiting [2]. Selenium at low doses protects the plants from variety of abiotic stresses such as

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cold, drought, desiccation and metal stress; whereas high doses of selenium, induce oxidative stress, distorted protein structure and functions [45]. Most previous studies [5, 54, 55 & 33] documented zero report on the concentration of selenium in waterleaf and fluted pumpkin.

The Sodium (Na^{+}) concentrations of the waterleaf samples showed that the four locations had high levels of sodium when compared with the control (3.54±0.05 mg/kg) and some previous studies. Umuahia South had the highest values of sodium in the waterleaf samples (9.27±0.00 mg/kg) while, Aba South had the least (6.49±0.00 mg/kg). All the values for sodium in waterleaf exceeded that of the control values. Furthermore, the concentration of sodium in the fluted pumpkin samples were also shown to be higher than that of the control (2.17±0.04 mg/kg). Again, Umuahia South had the highest values for sodium in fluted pumpkin samples (4.77±0.00 mg/kg) while, Aba South had the lowest (3.98±0.00 mg/kg). These findings are in contrast with previous studies [5, 54, 26 & 55] for levels of sodium in waterleaf and fluted pumpkin. However, Samson and Isaac [60] reported a much higher concentration of sodium (96.3±0.01 mg/kg) in fluted pumpkin. The differences in the concentration of sodium could be ascribed to the fact that the vegetables were cultivated on soil with different load of sodium and physiochemical properties. According to Maathuis [44] sodium is not a plant nutrient; but can be beneficial to plants in many conditions, particularly when potassium is deficient. As such, it can be regarded a non-essential or functional nutrient. However, high levels of sodium indicate salinity problems or sodicity such as poor soil structure and consuming high levels of sodium has been linked to kidney stones, high blood pressure and cardiovascular diseases. Whereas, high levels of sodium in plants can impair their ability to uptake adequate moisture. Thus, build-up of sodium in plants lead to stunted growth and an inhibition of cell development.

The potassium (K) concentrations of the waterleaf samples showed that the four locations had high levels of potassium when compared with the control (2.21±0.00 mg/kg). Isuikwuato had the highest values of potassium in the waterleaf samples (16.01±0.00 mg/kg) while, Umuahia South had the lowest (13.18±0.00 mg/kg). All the values for potassium in waterleaf samples fell above the control values (See Table 3). Similarly, the concentrations of potassium in the fluted pumpkin samples were also higher than that of the control (4.01±0.03 mg/kg). Also, Isuikwuato had the highest values for potassium in fluted pumpkin samples (14.25±0.00 mg/kg). Whereas, Umuahia South had the least (11.08±0.00 mg/kg). The above findings were higher than that reported by Alkhatib et al. [5], Odoh et al. [54], Fadupin et al. [26] and Ogbuji et al. [55] for potassium in waterleaf and fluted pumpkin. However, Sampson and Isaac [60] documented higher values of 352 mg/kg for potassium in fluted pumpkin. Potassium is required for various biochemical and physiological processes that are responsible for plant growth and development [36]. Excess potassium is not literally viewed as a toxic effect on plants; but it can induce deficiencies of other nutrients particularly nitrogen, calcium and magnesium. The primary risk of excessive potassium is a nitrogen deficiency which will stunt the growth of the plant and lead to chlorosis between leaf veins [46]. In humans, high potassium levels can lead to hyperkalemia (a medical problem in which there is excessive level of potassium in the blood) [36].

In Table 4, the concentrations of calcium (Ca) in the waterleaf samples showed that none of the samples had any composition of calcium (See Table 4). The control values for calcium in the waterleaf samples is 19.21±0.10 mg/kg. In the same vein, the concentrations of calcium in the fluted pumpkin samples showed that the element calcium was not detected in the four locations studied. The control values for calcium in fluted pumpkin is 38.51±0.15 mg/kg. These findings are in contrast with those reported by previous studies [5, 60, 54, 26, 55, 10, 49 & 33] that high levels of calcium which are very nutritious were observed in both waterleaf and fluted pumpkin leaves. The absence of calcium in the present study could be due to the restriction of the root volume possibly occasioned by either high levels of sodium detected in all the vegetable samples (waterleaf & fluted pumpkin) or the hairdressing salon activities, especially the effluents comprising of various acids, alkalis, dyes, relaxer, bleaches and other organic and inorganic compounds [53].

The concentrations of the heavy metal vanadium (V) in the waterleaf samples showed that the metal was not detected in Umuahia South and Isuikwuato locations. The other two locations (Aba South & Ohafia) were found to have some compositions of vanadium that was higher than the control (0.00±0.00 mg/kg) but lower than the FAO and WHO [27] permissible limits of 0.03 mg/kg for vanadium in vegetables. Ohafia had the highest concentration of vanadium in the waterleaf samples (0.02±0.00 mg/kg). Whereas, the lowest concentration was in Aba South (0.01±0.00 mg/kg). Furthermore, the concentrations of vanadium in the fluted pumpkin samples showed that Umuahia South and Isuikwuato recorded no values for vanadium. However, Aba South and Ohafia locations had some levels of vanadium that was above the control (0.00±0.00 mg/kg) but lower than the FAO and who permissible limits. It was observed that Aba South (0.01±0.00 mg/kg) and Ohafia (0.01±0.00 mg/kg) had similar concentrations of vanadium. Previous studies [60, 54, 26, 55, 10, 49 & 33) showed no report of vanadium in waterleaf and fluted pumpkin. These, is in contrast with Alireza [4] that reported vanadium levels higher than the FAO and WHO [27] recommended safe limits in vegetables. According to Wu, Zhang, Yang and Jia [70] elevated vanadium in the environment adversely affects organisms, including plants, animals, and humans. Plants act as the main conduit for environmental vanadium to enter the food chain, and gradually their growth response characteristics reflect vanadium toxicity efficacy for plants. It has been reported that exposure to vanadium by oral route can lead to gastrointestinal disorders, abdominal pain, nausea, vomiting, diarrhoea, loss of appetite, weight reduction and green-black tongue. Whilst, the symptoms of exposure to vanadium through inhalation include rhinitis, chest pain, pharyngitis, bronchitis, pneumonia, bradycardia, cough, dyspnoea, bronchial asthma, headache, dizziness, conjunctivitis, blurred vision, apathy and depression [11]. Generally, it was observed that the mean levels of silver, nickel, cadmium, mercury, chromium, lead, arsenic, aluminum, selenium, sodium, magnesium and vanadium in the waterleaf and fluted pumpkin samples studied were found to be higher than the control and the recommended value proposed by the FAO and WHO indicating that they are potentially unsafe to consume. Consistent with our findings other studies involving different leafy vegetables [37] found that the levels of arsenic, cadmium, copper and chromium were significantly higher than the recommended safe limits. Our results are further supported by the findings of Luo et al. [43] all of which clearly showed that leafy vegetables accumulate potential toxic elements and to greater levels than non-leafy vegetables due to the large surface areas of their leaves.

In Table 4, the chemical compound dichloromethane was not detected in the waterleaf samples of Umuahia South and Isuikwuato locations; but were found in varying levels in Aba South and Ohafia. Ohafia had the highest values of dichloromethane in waterleaf samples (0.02±0.00 µg/kg) which was above the FEPA acceptable limits of 0.01 µg/kg for dichloromethane. Whereas, Aba South had the least (0.01±0.00 µg/kg) which was within the safe standards. In addition, the concentrations of dichloromethane in the fluted pumpkin samples also showed that Umuahia South and Isuikwuato had no trace of the chemical compound which were found in Aba South and Ohafia locations respectively. Both Aba South and Ohafia showed the same levels of dichloromethane compositions (0.01±0.00 µg/kg) in fluted pumpkin samples. These values were within the permissible limits. According to ATSDR [13] ingestion of dichloromethane from contaminated vegetables has been reported to cause nausea, vomiting, gastrointestinal ulceration and bleeding.

Note: There were no PAHs (Polycyclic Aromatic Hydrocarbons) detected in all the control for vegetables studied (i.e. the waterleaf and fluted pumpkin obtained from National Root Crop Research Institute, Umudike, Abia State, Nigeria). Information is scanty on levels of PAHs in leafy vegetables available in Nigeria, especially in reference to hairdressing salon activities. Moreover, to the best of our knowledge, this is the first attempt to report Polycyclic Aromatic Hydrocarbons (PAHs) in waterleaf (*Talinum triangulare*) and fluted pumpkin (*Telfairia occidentalis*) harvested around hairdressing salon facilities or locations. Previous studies [58, 61, 9, 24, 64, 53, 25, 3 &19] on hairdressing salon practices documented no report on PAHs in waterleaf and fluted pumpkin.

The chemical compound Acenaphthylene was not detected in the waterleaf samples, except in Isuikwuato (0.01±0.00 µg/kg) locations where it was found to be within the FEPA permissible limits of 0.01 µg/kg. However, for the fluted pumpkin samples, acenaphthylene was not found in Aba South and Umuahia South locations; but in Ohafia and Isuikwuato locations (0.01±0.00 µg/kg) respectively. These values were also observed to be within the acceptable limits.

The chemical substance Acetone was not found in the waterleaf samples in the four locations studied (Aba South, Umuahia South, Ohafia & Isuikwuato). The FEPA permissible limits for acetone is 0.03 µg/kg. Similarly, acetone was not detected in the fluted pumpkin samples in all the locations.

The chemical compound chloroform was detected in all the locations in varying compositions (See Table 4). Ohafia had the highest values of chloroform in waterleaf samples (0.19±0.00 µg/kg) while, Aba South had the lowest (0.09±0.00 µg/kg). The FEPA safe limit for chloroform is 0.02 µg/kg. All the values exceeded the acceptable standards. In addition, chloroform was also found in the fluted pumpkin samples. Again, Ohafia had the highest values of chloroform in the fluted pumpkin samples (0.17±0.00 µg/kg). Whereas, Aba South had the least (0.09±0.00 µg/kg). All the values fell above the FEPA limits for chloroform. According to IPCS [34] ingestion of chloroform in contaminated vegetables is associated with gastrointestinal irritation and abdominal discomfort, including nausea, vomiting and diarrhoea. Adachi et al. [1] noted that plants absorb organic compounds through the roots and accumulate these in the leaves; leafy vegetables can accumulate more PAHs than the root vegetables.

In Table 5, the chemical compound chlorofluorocarbons in the waterleaf samples were observed to be higher than the FEPA permissible limits of 0.01 µg/kg for chlorofluorocarbons. Ohafia had the highest values of chlorofluorocarbons in waterleaf samples (2.00±0.00 µg/kg) while, Umuahia South and Isuikwuato had the least (0.18±0.00 µg/kg). Moreover, the concentrations of chlorofluorocarbons in the fluted pumpkin samples showed that all the locations fell above the FEPA safe limits. Aba South and Ohafia had the highest values of chlorofluorocarbons in fluted pumpkin samples (0.12±0.00 µg/kg). Whereas, Umuahia South had the least (0.10±0.00 µg/kg). All the values for chlorofluorocarbons in waterleaf samples and fluted pumpkin samples were above the acceptable standards. According to ATSDR [12] ingestion of chlorofluorocarbons in contaminated food can cause nausea, vomiting, diarrhoea or other upset to the digestive tract

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including central nervous system depression. High levels of chlorofluorocarbons in these vegetables is a serious matter of public health concern in the studied locations. The presence of chlorofluorocarbons in these vegetables is possibly due to atmospheric exposure, soil uptake (from hairdressing salon effluents), fertilizer use in agricultural activities and traffic (from highways).

The chemical compound toluene was not detected in the waterleaf samples in the four locations studied. The FEPA permissible limits for toluene is 0.01 µg/kg. In the same vein, toluene was not found in the fluted pumpkin samples in all the locations.

The chemical compound benzene was found in the four locations at varying levels. The FEPA permissible limits for benzene is 0.01 µg/kg. Ohafia and Isuikwuato had the highest concentrations of benzene in waterleaf samples. (0.03±0.00 µg/kg) while, Aba South and Umuahia South had the least (0.02±0.00 µg/kg). All the values were above the FEPA acceptable limits. Furthermore, the concentrations of benzene in the fluted pumpkin samples showed that all the locations had similar compositions of 0.03±0.00 µg/kg respectively; which were above the FEPA permissible limits. This is in conformity with the findings by Zhang et al. [72] and Uchechi, Chika and Matthew [65] for higher levels of benzene in waterleaf and fluted pumpkin. According to USEPA [66] ingestion or consumption of foods or fluids contaminated with high levels of benzene can lead to dizziness, stomach irritation, vomiting, convulsions and rapid heart rate including death at times.

The chemical compound xylene was shown to be in the waterleaf samples in various levels. Isuikwuato had the highest concentration of xylene in the waterleaf samples (0.06±0.00 µg/kg). Whereas, Umuahia South had the lowest (0.03±0.00 µg/kg). The FEPA permissible limits for xylene is 0.02 µg/kg. All the values fell above the acceptable limits. Moreover, xylene was also detected in the fluted pumpkin samples. Again, Isuikwuato had the highest values of xylene in the fluted pumpkin samples (0.06±0.00 µg/kg) while, Umuahia South had the least (0.02±0.00 µg/kg). All the values here were also above the FEPA limits. According to ATSDR [12] ingestion of vegetables contaminated with xylene include depression of the central nervous system (headache, dizziness, ataxia, drowsiness, excitement, tremor and coma), acute pulmonary edema, respiratory depression, nausea, vomiting and reversible hepatic impairment. This chemical is potentially unsafe to consume as there is no antidote for xylene [59].

The chemical compound carbon tetrachloride was not detected in the waterleaf samples in the four locations studied. The FEPA permissible limits for carbon tetrachloride is 0.03 µg/kg. Similarly, carbon tetrachloride was not found in the fluted pumpkin samples. According to ATSDR [14] oral exposure to carbon tetrachloride include headache, weakness, lethargy, nausea and vomiting; while exposure to higher levels can lead to liver and kidney damage.

The concentrations of the chemical compound glycol in the waterleaf samples showed that all the locations had some levels of the chemical, except, Ohafia (0.00±0.00 µg/kg). The FEPA permissible limits for gylcol is 0.02 µg/kg. All the values for glycol fell above the acceptable standards. Isuikwuato had the highest values of glycol in the waterleaf samples (2.32±0.00 µg/kg) while, Umuahia South had the lowest (1.37±0.00 µg/kg). Subsequently, glycol was found in all the fluted pumpkin samples except Aba South (0.00±0.00 µg/kg). All the values for glycol in the fluted pumpkin samples exceeded the permissible limits. Ohafia had the highest values of glycol in the fluted pumpkin samples (1.56±0.00 µg/kg) while, Umuahia South had the least (0.96±0.00 µg/kg). The high levels of glycol investigated might be a reflection of severe pollution of soil possibly the release of wastes (solid and liquid) from hairdressing salon activities and consequently taken up by the plants growing in such regions. According to Aruba, Jason & Thomas [8] ingestion of glycol in contaminated foods can cause severe complications such as kidney failure, permanent nerve damage and in some cases, death.

In Table 6, the chemical compound alkylolamides was not detected in the waterleaf samples in the four locations studied except, in Ohafia (7.48±0.00 µg/kg). The FEPA permissible limits for alkylolamides is 0.01µg/kg. The values in Ohafia location was much higher than the acceptable limits. In the same vein, the concentrations of alkylolamides in the fluted pumpkin samples showed that the chemical compound was not found in the four locations, except Ohafia (8.86±0.00 µg/kg). The above value also exceeded the FEPA permissible limits. Ingestion of alkylolamides through contaminated foods or vegetables can cause burns to the oesophagus and stomach as well as gastrointestinal distress including disruption of the human endocrine system [30].

The chemical compound naphthalene in the waterleaf samples showed that Aba South and Ohafia locations recorded no values for naphthalene. However, Umuahia South and Isuikwuato were observed to have concentrations of naphthalene higher than the FEPA permissible limits of 0.01 µg/kg. Isuikwuato had the highest values of naphthalene in waterleaf samples (1.12±0.00 µg/kg). Whereas, Umuahia South had the least (0.17±0.00 µg/kg). Furthermore, the concentrations of naphthalene in the fluted pumpkin samples showed that all the locations had some levels of naphthalene which were above the FEPA permissible limits, except Ohafia that recorded zero naphthalene concentrations (0.00±0.00 µg/kg). Aba South had the highest values of naphthalene in fluted pumpkin samples (1.83±0.00 µg/kg) while, Isuikwuato had the lowest (0.56±0.00 µg/kg). Uchechi, Chuka and Matthew [65] documented high levels of naphthalene in waterleaf (*Talinum* *triangulare*) and Fluted pumpkin (*Telfairia occidentalis*). According to ATSDR [14] ingestion of naphthalene from contaminated food or food materials can destroy or change the mechanisms of red blood cells making them incapable of carrying oxygen; which can eventually lead to organ damage.

The chemical component fluoranthene was not detected in the waterleaf samples in the four locations studied. The FEPA permissible limits for fluoranthene is 0.01 µg/kg. In the same vein, fluoranthene was not detected in the fluted pumpkin samples in all the locations studied.

The chemical compound 1-2 benzathracene in the waterleaf samples showed that Aba South and Umuahia South had no compositions of 1-2 benzathracene. But, Ohafia and Isuikwuato were observed to have some components of 1-2 benzathracene. The FEPA permissible limits for 1-2 benzathracene is 0.02 µg/kg. Isuikwuato had the highest values of 1-2 benzathracene in waterleaf samples (0.03±0.00 µg/kg). Whereas, Ohafia had the lowest (0.01±0.00 µg/kg). These showed that Isuikwuato fell above the permissible limits; while Ohafia was within the safe limits. In addition, the concentrations of 1-2 benzathracene in the fluted pumpkin samples showed that Aba South and Umuahia South had no compositions of the chemical compound. However, 1-2 benzathracene was found in both Ohafia and Isuikwuato respectively. Ohafia had the highest concentrations of 1-2 benzathracene in fluted pumpkin samples (0.75±0.00 µg/kg) while, Isuikwuato had the least (0.02±0.00 µg/kg). Ohafia exceeded the safe limits for 1-2 benzathracene; but, Isuikwuato was within the acceptable standards. According to USEPA [66] direct evidence of acute toxicity resulting from oral exposure of humans to 1-2 benzathracene is unavailable.

The concentrations of propanol in the waterleaf samples studied showed that the chemical compound was not found in Aba South and Umuahia South locations. However, Ohafia and Isuikwuato showed some compositions of propanol. The FEPA permissible limits for propanol is 0.02 µg/kg. Ohafia (0.03±0.00 µg/kg) was above the permissible limits. Whereas, Isuikwuato (0.02±0.00 µg/kg) was within the range of permissible limits. Moreover, concentrations of propanol in the fluted pumpkin samples showed that Aba South, Umuahia South and Isuikwuato had no compositions of propanol. It was observed that only Ohafia recorded some levels of propanol (0.03±0.00 µg/kg) in the fluted pumpkin which also exceeded the permissible limits. According to Michael [47] ingestion of propanol through contaminated food can lead to ataxia, slurred speech, dysarthria and confusion; and in severe cases respiratory depression, coma and death has been reported.

The chemical compound propane as seen in the waterleaf samples (Table 6) showed that Aba South and Ohafia had similar values of propane. But, there was no detection of propane in Umuahia South and Isuikwuato respectively. The FEPA permissible limits for propane is 0.01µg/kg. Aba South (0.03±0.00 µg/kg) and Ohafia (0.03±0.00 µg/kg) both exceeded the permissible limits for propane. In addition, the concentrations of propane in the fluted pumpkin samples showed that all the locations (Ohafia, Umuahia South & Isuikwuato) recorded some levels of propane except, Aba South. Ohafia had the highest concentrations of propane in fluted pumpkin samples (0.03±0.00 µg/kg). Whereas, Umuahia South and Isuikwuato had the least (0.01±0.00 µg/kg). Again, Ohafia fell above the permissible limits. But, Umuahia South and Isuikwuato were within the range of acceptable limit. Oral exposure to propane has been associated with symptoms such as nausea, and vomiting, collapse, convulsions, coma and death including permanent damage of the brain and heart as well as the nervous system at high concentrations [21].

In Table 7, the chemical compound dimethyl ether was not detected in the waterleaf samples in the four locations studied. The FEPA permissible limits for dimethyl ether is 0.01 µg/kg. Similarly, dimethyl ether was also not detected in the fluted pumpkin samples in all the locations.

The chemical component hydantoin was not detected in the waterleaf samples in the four locations. The FEPA permissible limits for hydantoin is 0.01 µg/kg. In the same vein, hydantoin was not found in the fluted pumpkin samples in the various locations (Aba South, Umuahia South, Ohafia & Isuikwuato) studied as shown in Table 7.

In Table 7, the last chemical compound shown was isopropyl alcohol. This was not found in the waterleaf samples in the four locations studied. The FEPA permissible limits for isopropyl alcohol in vegetables is 0.01µg/kg. Similarly, isopropyl alcohol was also not detected in the fluted pumpkin samples in all the locations (Aba South, 0.00±0.00 µg/kg; Umuahia South, 0.00±0.00 µg/kg; Ohafia, 0.00±0.00 ug/kg & Isuikwuato, 0.00±0.00 µg/kg).

Conclusion

The presence of heavy metals and accumulation of PAHs in the leafy vegetables is a serious Environmental Health concern in the study areas; since waterleaf and fluted pumpkin are consumed daily. From the results of this study, it is evident that hairdressing salon activities impacted the soil where such edible plants were planted. The study has demonstrated that hairdressing salon contamination can lead to gradual heavy metal and PAHs build-up in vegetables growing in such soils as high levels of metals including PAHs were found in waterleaf and fluted pumpkin harvested around hairdressing salon facilities. Moreover, there were recorded nutrient loss of calcium, magnesium, zinc and iron in the studied vegetables suggesting that these apart from being potential hazards to humans and the food chain are also shown to be nutrient deficient. There is therefore urgent need for monitoring and adequate management of hairdressing salon activities to preserve the integrity of ecosystem.

Conflicts of Interest

The authors declare no conflicts of interest.

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