World Journal of Advanced Research and Reviews, 2020, 06(03), 275–288

World Journal of Advanced Research and Reviews

e-ISSN: 2581-9615, Cross Ref DOI: 10.30574/wjarr

Journal homepage: https://www.wjarr.com

(RESEARCH ARTICLE)

Variations in the levels, source, cancer and non-cancer risks of trace metals in the local and exotic fruits

Ebong Godwin Asukwo *, Etuk Helen Solomon, Dan Emmanuel Udo and Ekpo Keziah James

Department of Chemistry, Faculty of Science University of Uyo, P. M. B 1017 Uyo Akwa Ibom State, Nigeria.

Publication history: Received on 20 June 2020; revised on 26 June 2020; accepted on 27 June 2020

Article DOI: https://doi.org/10.30574/wjarr.2020.6.3.0224

Abstract

Local and exotic fruits are generally consumed for their high nutritive values however, they also contain high quantities of harmful substances including trace metals. This work investigated the variations in the levels of Cd, Cu, Fe, Ni, Pb, and Zn in the local *Citurs sinensis*, *Persea americana*, *Citrus paradise*, *Malus domestica*, and *Citurs limon* are their exotic counterparts. The cancer and non-cancer health risks related to the consumption of both the local and exotic fruits were also examined. The results obtained revealed higher levels of all the metals in the local fruits than in their exotic counterparts however; the mean values of the metals were within their recommended limits by FAO/WHO. Multivariate analysis indicated anthropogenic factor as the major source of trace metals in the studied fruits. The average daily intake rates of the metals were generally lower than their provisional tolerable daily intake limits by FAO/WHO. The study showed that the consumers of local fruits were more vulnerable to health hazard than those consuming the exotic ones. Results for the cancer risk and total cancer risk were generally within the acceptable range of 10^{-6} – 10^{-4} by USEPA. Though, the consumers of the locally sourced fruits were more exposed to carcinogens.

Keywords: Fruits; Carcinogens; cancer and non-cancer risks; Multivariate analysis.

1. Introduction

The persistent contamination of our environments has significant negative impact on the quality of our foods. Contaminants in foods including metals affect both the nutritive value and the consumers health negatively [1, 2]. Fruits are used for nutritive values and as cure for different ailments hence, insufficient consumption could result in serious human health problems and death [3, 4]. Fruits are good sources of vitamins, protein, essential elements and minerals to the human system however, they also accumulate high levels of toxic substances including trace metals from the environment [5, 6]. Trace metals such as Mn, Fe, Ni, Cu, Zn, and Cr at their normal limits are necessary for normal activities in organisms [7, 8]. Nevertheless, Pb, Cd, Hg, As, and Ag are not beneficial to any living cell including human rather they are toxic even at a very low concentration [9, 10]. The essential metals are also toxic at concentrations higher than what is required by the organism [11, 12]. Reports have shown that trace metals (both the essential and toxic ones) in fruits are mostly from agrochemicals, wastewater, aerial deposition, vehicular emissions, and methods of processing them [13, 14, 15, 16]. It has also been reported that plants have the potential of absorbing high level of metals from a contaminated environment [17, 18, 19]. Thus, the intensive use of agrochemicals for the cultivation of fruits globally has impacted negatively on their quality. In the developing Countries such as Nigeria, untreated wastewater is usually used for the irrigation and it may result in the accumulation of trace metals in the edible plants [20, 21].

Trace metals including the essential ones can cause harmful effects to the human system [22, 23, 24, 25]. In Akwa Ibom State, both the local and exotic fruits are widely consumed mainly for their nutritive values though, their trace metals content are rarely examined. Consequently, the metal loads of these fruits have not been established and the associated health consequences remain unabated. Invariably, the consumers might be ingesting toxic substances into the body as fruits thus; some of the ailments today could be imported alongside the foreign fruits. The variations in trace metals

* Corresponding author: Ebong Godwin Asukwo

loads between the locally sourced fruits and their exotic counterparts were investigated in this study. The non-cancer and cancer risks associated with the consumption of these fruits were also examined. The source and the relationships of these metals in the studied fruits were identified using the multivariate analysis. It is hoped that the results of this study shall create awareness on the negative impact associated with the consumption of fruits harvested from a contaminated environment which hitherto was unavailable in the study area. The results shall also serve as a deciding factor for the consumers to rely either on the locally sourced fruits or their exotic counterparts. The negative impact of some agrochemicals on the quality of soil and fruits cultivated there has also been identified.

2. Material and methods

2.1. Sample collection and preparation

Five local fruits and their exotic counterparts namely: *Citrus sinensis* (orange), *Persea americana* (Pear), *Citrus paradise* (grape), *Malus domestica* (apple), and *Citurs limon* (lemon) were bought from supermarkets and Akpan Andem Market both in Uyo Metropolis Akwa Ibom State, Nigeria. Akwa Ibom State is located in the Niger Delta Area of Nigeria and lies between latitudes $4^0\ 32'$ and $5^0\ 33'$ North and longitudes $7^0\ 25'$ and $8^0\ 25'$ East. These fruits were carefully washed with tap water first followed by deionized water to clear them of all contaminants adsorbed on the exocarp. The fruits were cut into pieces and oven dried for 48 h at 100°C. The dried samples were pulverized with porcelain mortar and pestle to a fine powder and sieved with a 1 mm sieve. The samples were properly labeled and stored in dry plastic containers for digestion and analysis.

2.2. Digestion of samples and metal analysis

1 g of the dried sample was digested with a mixture of HNO_3 and $HClO_4$ in a ratio of 5:1 until the solution was transparent in nature [8, 26]. The solution was filtered, poured into a 25 ml flask and stored for metal analysis. An Agilent 710 Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) was used for the determination of Cd, Cu, Fe, Ni, Pb, and Zn.

2.3. Health Risk Assessment

The possible health risks of trace metals associated with the consumption of the studied local and exotic fruits were evaluated using daily intake rate of the metals [27], hazard quotient (HQ) [28], and hazard index (HI) [29].

Determination of daily Intake of Trace Metals (DIM) in the studied local and exotic fruits was computed using equation (1).

$$DIM = \frac{\text{Cmetal x Dfruit intake}}{\text{Bw average}} \text{--} (1)$$

Where Cmetal represents the concentration ($mgkg^{-1}$) of trace metal in the studied fruits; Dfruit intake is the daily intake rate of the studied fruits which in this study 300 g/kg/day was used [30]; Bw average stands for the average body weight of a Nigerian which according to WHO [30] is 62 kg.

2.3.1. Determination of a non-carcinogenic risk index described as hazard quotient (HQ) was calculated using equation (2).

$$HQ = \frac{\text{DIM}}{\text{RfD}} \text{--} (2)$$

Where DIM signifies the daily intake rates of the trace metals via the consumption of the studied fruits and RfD stands for the oral reference dose of the metals. The RfD values for Cd, Cu, Fe, Ni, Pb, and Zn are 0.001, 0.04, 0.7, 0.02, 0.004, and 0.3 mg/kg/day, respectively [31].

2.3.2. Determination of hazard index (HI)

Hazard index (HI) is the sum of all the hazard quotients (HQs) for the entire trace metals, it was estimated using equation (3).

$$\text{HI} = \Sigma HQ = HQCd + HQCu + HQFe + HQNi + HQPb + HQZn \text{---} (3)$$

Where HI represents hazard index and HQ is the hazard quotient of the trace metals. According to Cao *et al*. [32] when the value of HI is less than 1, the consumers of the studied fruits are safe but when HI is equal to or more than 1, then the consumers are at risk.

2.3.3. Determination of cancer risk (CR) index

Cancer risk denotes the probability of a consumer developing cancer over a lifetime due the exposure to trace metals (potential carcinogens) via the consumption of the studied fruits. The cancer risk (CR) associated with the exposure to Cd, Ni, and Pb through the consumption of the studied fruits over lifetime was calculated using equation (4).

$$CR = CSF \ x \ DIM \quad (4)$$

Where CSF signifies the cancer slope factor and DIM is the daily intake rates of the trace metals. According to USEPA [33] the values of CSF are 0.38, 1.7, and 0.0085 mg/kg/day for Cd, Ni, and Pb, respectively. There were no data for the computation of CR for Cu, Fe, and Zn. The acceptable range of predicted lifetime risk for carcinogens by USEPA [34] is 10−4 (risk of developing cancer is 1 in 10,000) to 10−6 (risk of developing cancer over a lifetime is 1 in 1,000,000).

2.3.4. Determination of total cancer risk (TCR)

The probability of a consumer developing cancer when exposed to several trace metals (carcinogens) via the consumption of a particular fruit was adopted, and the sum of the different trace metals increasing risk was computed using equation (5).

$$\text{Total cancer risk} = \Sigma \, CR \quad (5)$$

Where CR denotes the cancer risk.

2.4. Statistical analysis

The data obtained in this study were treated for the mean and standard deviation using IBM SPSS Statistics 20. The principal component analysis (PCA) was done by calculating the data with Varimax Factor analysis. The cluster analysis (CA) of metals determined was done by categorizing the results in Hierarchical Cluster Dendrogram plots with IBM SPSS Statistics 20.

3. Results and discussion

Table 1 Level of Trace metals in Local fruits and Exotic fruits

		Cd	Cu	Fe	Ni	Pb	Zn
Citrus	Local	0.023	0.021	0.300	0.015	0.005	0.963
sinensis	Exotic	0.032	0.030	0.221	0.005	0.002	1.248
Persea	Local	0.056	0.035	0.218	0.023	0.002	1.633
americana	Exotic	0.041	0.029	0.249	0.007	0.001	1.405
Citrus	Local	0.026	0.040	0.257	0.020	0.004	1.817
paradise	Exotic	0.038	0.019	0.189	0.010	0.003	1.742
Malus	Local	0.091	0.017	0.193	0.017	0.003	0.952
domestica	Exotic	0.084	0.037	0.186	0.006	0.002	1.059
Citrus limon	Local	0.086	0.039	0.292	0.064	0.003	1.748
	Exotic	0.075	0.019	0.323	0.008	0.005	0.893
Min		0.023	0.017	0.186	0.005	0.001	0.893
Max		0.091	0.040	0.323	0.064	0.005	1.817
SD		0.025	0.009	0.047	0.017	0.001	0.350
Mean		0.055	0.029	0.243	0.018	0.003	1.346
MRL		0.10	2.00	0.30	0.20	0.05	5.00

Min = Minimum; Max = Maximum; SD = Standard deviation; MRL = Maximum recommended limit by FAO/WHO [35].

3.1. Trace metals in the studied fruits

Cadmium (Cd) in the studied fruits varied between 0.023 and 0.091 mgkg^{-1} in the local *Citrus sinensis* and *Malus domestica,* respectively. This range is higher than 0.001 – 0.006 mgkg^{-1} obtained by Sobukola *et al*. [36] but lower than 0.01 to 0.362 mgkg^{-1} reported by Elbagermi *et al*. [23]. The results revealed higher levels of Cd in the local fruits than in their exotic counterparts except in *Citrus sinensis* and *Citrus paradise.* This could be attributed to the class and quantity of agrochemicals used by local farmers [16, 37]. The method of processing and handling of the local fruits could also elevate their levels of trace metals [14, 38]. The mean value of Cd (0.055±0.025 mgkg^{-1}) is lower than the 0.10 mgkg^{-1} recommended limit in fruits by FAO/WHO [35]. Consequently, the consumption of the studied fruits might not result in health problems associated with Cd toxicity. However, as a toxic element to both plants and animals its presence in our environment should be controlled to forestall serious problems along the food chain as reported by Divrikli *et al*. [1].

Copper (Cu) is an essential element for plants and animals but at higher concentrations it could be harmful [39]. Levels of Cu ranged from 0.017 mgkg^{-1} in local *Malus domestica* to 0.040mgkg^{-1}in local *Citrus paradise*, respectively. This range is lower than 0.04 – 0.22 mgkg^{-1} and 2.4 – 25.0 mg kg^{-l} obtained by Ezeonyejiaku and Obiakor [40] and Aydinalp and Marinova [41], respectively. The concentrations of Cu were generally higher in the local than in the exotic fruits except for *Citrus sinensis* and *Malus domestica.* This could be attributed to the variations in anthropogenic factors between the local and foreign environments as opined by [42]. The mean value of Cu (0.029 ± 0.009 mgkg^{-1}) obtained is lower than 2.00 mgkg^{-1} recommended limit by FAO/WHO [35]. Hence, the consumers of the studied fruits may not experience Cu toxicity and its attendants´ health problems.

The levels of iron (Fe) in the studied fruits varied between 0.186 mgkg^{-1} in exotic *Malus domestica* and 0.323 mgkg^{-1} in exotic *Citrus limon.* This range is lower than 1.10 – 36.0 μg/g and 2.50 – 5.60 mgkg^{-1} reported by Mehari *et al*. [43] and Yami *et al*. [44], respectively. Fe is essential for all living organisms and its deficiency is harmful to both plants and animals [45, 46]. The levels of Fe were higher in all the local fruits than in the exotic ones except for *Persea americana* and *Citrus limon*. This could be attributed to the variations in the soil properties and anthropogenic factor [47, 48]. The mean value of Fe (0.243±0.047 mgkg^{-1}) is lower than 0.300 mgkg^{-1} recommended by FAO/WHO [35] for fruits. Consequently, all the studied fruits were suitable for consumption except exotic *Citrus limon* which had Fe concentration higher than the recommended limit.

Nickel (Ni) in the studied fruits ranged from 0.005 mgkg^{-1} in exotic *Citrus sinensis* to 0.064 mgkg^{-1} in the local *Citrus limon*. This range is consistent with 0.001 - 0.061 mgkg^{-1} obtained by Sobukola *et al.* [36] but lower than 0.000 – 0.400 mgkg^{-1} and 0.000 – 0.475 mgkg^{-1} reported by Guerra *et al.* [49] and Omoyajowo *et al*. [50], respectively. The levels of Ni were generally higher in the local than in the exotic fruits. This could be the consequence of disparity in both the natural and anthropogenic factors [14, 48]. The average Ni level obtained (0.018±0.017 mgkg^{-1}) is much lower than 0.20 mgkg^{-1} recommended limit for fruits by FAO/WHO [35]. The high standard deviation reported is an indication that, more of the values were far from the mean [51].

The level of lead (Pb) in the studied fruits varied between 0.001 mgkg^{-1} in exotic *Persea americana* and 0.005 mgkg^{-1} in local *Citrus sinensis* and exotic *Citrus limon*. The obtained levels of Pb is lower than 0.01 to 0.87 mgkg^{-1} and 1.69-5.80 mgkg^{-1} reported by Radwan and Salama [52] and Ihesinachi and Eresiya [53], respectively. Nevertheless, the range reported in this study is higher than the below detectable limit (BDL) obtained in all the fruits analyzed by Yami *et al*. [44]. The overall results revealed higher levels of Pb in the local than in the exotic fruits except for *Citrus limon*. This could be attributed to the impact of inorganic fertilizers and aerial depositions [13, 54]. The mean value of Pb recorded (0.003±0.001 mgkg^{-1}) is lower than 0.05 mgkg^{-1} recommended limit in fruits by FAO/WHO [35]. Thus, the consumption of these fruits might not cause serious health problems associated with Pb toxicity however; as a toxic element its availability should be drastically reduced to avoid bioaccumulation along the food chain.

The concentrations of zinc (Zn) in the studied fruits ranged from 0.893 mgkg^{-1} in exotic *Citrus limon* to 1.817 mgkg^{-1} in local *Citrus paradise.* The reported range is higher than 0.039 - 0.082 mgkg-^{1} reported by Sobukola *et al*. [36] but, lower than 6.31 – 49.3 mgkg^{-1} obtained by Alzahrani *et al.* [6]. Higher concentrations of Zn were reported in the local *Persea americana, Citrus paradise,* and *Citrus limon* than in the exotic ones while the reverse was the case in *Citrus sinensis* and *Malus domestica*. This variation could be attributed to both the natural and anthropogenic factors. Zn is an essential element for all living organisms including human but, it could be toxic at a higher concentration [55, 56]. The mean value of Zn obtained (1.346±0.350 mgkg^{-1}) is below 2.00 mgkg^{-1} limit by FAO/WHO [35]. Hence, the levels of Zn in all the studied fruits might not pose serious health challenge to the consumers. Among the metals determined in the studied fruits, Zn had the highest concentration as also observed by Radwan and Salama [52].

The results obtained also indicated that although there were variations in the level of these metals between the local and exotic fruits. The concentrations of the metals determined followed a similar order Zn > Fe > Cd > Cu > Ni > Pb.

Table 2 DIM of trace metals in the local and exotic fruits

	Local fruits				
	Citrus sinensis	***Persea americana***	***Citrus paradise***	***Malus domestica***	***Citrus limon***
Cd	1.1E-04	3.0E-04	1.3E-04	4.4E-04	4.2E-04
Cu	1.0E-04	2.0E-04	1.9E-04	8.0E-05	1.9E-04
Fe	1.0E-03	1.0E-03	1.2E-03	9.0E-04	1.4E-03
Ni	7.0E-05	1.0E-04	9.7E-05	8.0E-05	3.1E-04
Pb	2.0E-05	9.0E-06	1.9E-05	2.0E-05	1.5E-04
Zn	5.0E-03	8.0E-03	8.8E-03	4.6E-03	8.4E-03
Exotic fruits					
Cd	2.0E-04	1.9E-04	2.0E-04	4.0E-04	3.6E-04
Cu	2.0E-04	2.0E-04	9.0E-05	2.0E-04	9.0E-05
Fe	1.0E-03	1.2E-03	9.0E-04	9.0E-04	1.5E-03
Ni	2.0E-05	3.4E-05	4.8E-05	2.0E-05	3.8E-05
Pb	9.0E-06	4.8E-06	1.4E-05	9.0E-06	2.0E-05
Zn	6.0E-03	6.8E-03	8.0E-03	5.0E-03	4.0E-03

3.2. Daily intake of trace metals via the consumption of local and exotic fruits

The mean DIM values for Cd are 2.80E-04 and 2.7E-04 mg for the local and exotic fruits, respectively. These values represent 28 and 27% of the RfD value of 0.001 mg per day for a 62 kg adult for local and exotic fruits, respectively [57]. The daily intake of Cd via the local and exotic fruits as shown in Table 2 are lower than the provisional tolerable daily intake of 0.06 mg by FAO/WHO [58]. Thus, the consumption of these fruits might not pose any health risk related to Cd toxicity. However, the consumers of the local fruits are more vulnerable to Cd toxicity. *Malus domestica* contributed the greatest Cd intake via the consumption of both the local and exotic fruits accounting for 31 and 30%, respectively of the DIM.

The average DIM values for Cu are 1.52E-04 and 1.56E-04 mg for the local and exotic fruits, respectively. The mean DIM value in the local fruits represents 0.38% while that of exotic accounted for 0.39% of the RfD value of 0.04 mg for a 62 kg adult [57]. Thus, the consumers of the exotic fruits are more exposed to Cu than those consuming their local counterparts. The values obtained for DIM in Table 2 through the consumption of both classes of fruits are lower than the recommended PTDI of 3.0 mg by FAO/WHO [58]. Consequently, the consumers of these fruits are free of risk associated with Cu toxicity however, could be deficient of this essential element. *Persea americana* is the greatest route through which the consumers of these fruits are exposed to Cu with 26% each of the total DIM.

The daily intake rates of Fe varied as follows: 9.0E-04 – 1.4E-03 mg and 1.1E-03 and 9.0E-03 mg for the local and exotic fruits, respectively (Table 2). The mean DIM values for Fe via the consumption of the local and exotic fruits is 1.10E-03 mg each. This represents 0.16% each of the RfD value of 0.7 mg per day for a 62 kg adult [58]. Consequently, the consumers of both the studied local and exotic fruits will have the same level of exposure to Fe. The values obtained for DIM via the consumption of both classes of fruits are lower than 0.70 mg per day for a 62 kg adult by WHO [58]. Hence, the consumers may not be exposed to high level of Fe and its attendants´ health problems. The DIM values for both categories of the studied fruits are also lower than the stipulated PTDI limit of 48 mg by FAO/WHO [59]. This also confirms the deficient nature of the much-needed Fe in these fruits thus, the consumers should complement from other sources. Amongst the studied fruits, *Citrus limon* contributed highest level of Fe to the total DIM with 26 and 27% for the local and exotic fruits, respectively.

The mean DIM values for Ni in the studied local and exotic fruits are 1.31E-04 and 3.20E-05 mg, respectively. Based on the results in Table 2, the consumers of the studied local fruits are more exposed to Ni than the consumer of the exotic ones. These mean values represent 0.66 and 0.16% of the RfD value of 0.1 mg per day for a 62 kg adult [58]. The values of DIM for Ni in Table 2 vary from 7.0E-05 to 3.1E-04 mg and 2.0E-05 to 4.8E-05 mg for the local and exotic fruits, correspondingly. These values are less than 0.02 mg per day for a 62 kg adult recommended by WHO [58]. Hence, the consumers of both classes of the studied fruits might not be exposed to Ni toxicity though there are other routes of exposure to metal toxicity. The values obtained are also lower than the recommended PTDI range of 0.1 – 0.3 mg by FAO/WHO [59]. Thus, the consumers might not be at risk as far as Ni is concerned. *Citus limon* was the highest contributor of Ni in the local fruits with 47% while *Citrus paradise* contributed the highest in the exotic fruits with 30% to the total DIM.

The average values of daily intake rates of Pb are 4.36E-05 and 1.14E-05 mg for the local and exotic fruits, correspondingly. Consequently, the consumers of the studied local fruits are more exposed to Pb than the consumers of their exotic counterparts. The mean DIM values of Pb in the local and exotic fruits represent 1.1 and 0.29% of the RfD value of 0.004 mg per day for a 62 kg adult [58]. The values of DIM for Pb varied from 9.0E-06 to 1.5E-04 mg in the local fruits and 4.8E-06 to 2.0E-05 mg in the exotic fruits. These values are lower than 0.004 mg per day for an adult by WHO [58]. Hence, these fruits are safe for human consumption with respect to Pb but, as a highly toxic metal bioaccumulation should avoided. The values of DIM reported for Pb are less than the recommended PTDI value of 0.214 mg as well [59]. This affirms the safe nature of the studied fruits for human consumption. The highest contributors of Pb was *Citrus limon* for both the local and exotic fruits with 69 and 35%, respectively of the total DIM.

The mean values recorded for the daily intake of Zn via the consumption of local and exotic fruits are 6.96E-03 and 5.96E-03 mg, respectively. Accordingly, the consumers of the studied exotic fruits are less exposed to Zn than the consumers of their local species. The average DIM values of Zn in the exotic and local fruits contributed 1.99 and 2.32% of the RfD value of 0.3 mg per day for a 62 kg adult [58]. The range of DIM for Zn ranged from 4.60E-03 to 8.80E-03 mg for local fruits and 4.0E-03 to 8.0E-03 mg for the exotic ones (Table 2). These values are less than 0.3 mg per day recommended for a 62 kg adult by WHO [58]. Consequently, these fruits are deficient of this essential element and should be complemented from other sources of food. These values are also lower than 60 mg the recommended PTDI value by FAO/WHO [58]. Hence, these fruits might not serve as a good source of Zn for the consumers although, the consumers of the local fruits are better off. The major source of Zn to the consumers in this study was *Citrus paradise* for both the local and exotic fruits contributing 24 and 13%, respectively to the total DIM obtained.

The daily intake rates of trace metals followed the order Zn > Fe > Cd > Cu > Ni > Pb for the local fruits and Zn > Pb > Fe > Cd > Cu > Ni for the exotic fruits, respectively. Thus, both the local and exotic fruits exposed the consumers more to Zn than other metals.

Table 3 THQs and HI of trace metals in the local and exotic fruits

	HQs for local fruits				
	Citrus sinensis	***Persea americana***	***Citrus paradise***	***Malus domestica***	***Citrus limon***
Cd	1.1E-01	0.2.7E-01	1.3E-01	4.4E-01	4.2E-01
Cu	3.0E-03	4.0E-03	4.0E-03	2.0E-03	5.0E-03
Fe	2.0E-03	1.0E-03	1.0E-03	1.0E-03	2.0E-03
Ni	3.0E-03	6.0E-03	5.0E-03	4.0E-03	2.0E-03
Pb	6.0E-03	2.0E-03	5.0E-03	3.6E-03	3.6E-03
Zn	1.2E-02	2.7E-02	2.9E-02	1.5E-02	2.8E-02
HI	0.14	0.31	0.17	0.47	0.46
			HQs for exotic fruits		
Cd	1.5E-01	2.0E-01	1.8E-01	4.1E-01	3.6E-01
Cu	4.0E-04	3.5E-03	3.0E-03	5.0E-3	2.0E-03
Fe	1.5E-03	1.7E-03	1.3E-03	1.3E-03	2.0E-03
Ni	1.2E-03	1.6E-03	2.4E-03	1.6E-03	1.9E-03
Pb	2.0E-03	1.2E-03	4.0E-03	3.0E-03	6.0E-03
Zn	2.0E-02	2.2E-02	2.9E-02	1.8E-02	1.4E-02
HI	0.18	0.23	0.22	0.44	0.39

3.3. Hazard quotient (HQ)

Hazard quotient is an index related to a long-term exposure to these metal contaminants through the consumption of the studied fruits. According to Wang *et al*. [59] it is not used to quantify the risk involved but it specifies the degree of concern. The HQ values for the trace metals determined in the studied fruits are shown in Table 3. The HQ values of Cd ranged from 0.11 to 0.44 and 0.15 to 0.41 in the local and exotic fruits, respectively. The highest HQ values of the local and exotic fruits were obtained in *Malus domestica*. Thus, the consumption of *Malus domestica* from both the local and foreign sources might expose the consumers to Cd toxicity over time [60].

The HQ values for Cu in the local and exotic fruits ranged as follows: 2.0E-03 – 5.0E-03 and 4.0E-04 – 5.0E-03, respectively. The fruits with highest HQ values of Cu in the local and exotic fruits were *Citrus limon and Malus domestica,* respectively. Cu is an essential element hence, more of it might be required by the consumers as its deficiency in the human system could also result in serious health problems [61]. However, the bioaccumulation of Cu in fruits should be controlled to avoid damage to the liver and kidney of the consumers [62].

The HQ values of Fe in both the local and exotic fruits varied from 1.0E-03 to 2.0E-03 and 1.3E-03 to 2.0E-03, respectively. The highest HQ value of Fe in the local fruits was obtained in *Citrus sinensis* and *Citrus limon* while *Citrus limon* had the highest HQ value of Fe among the exotic fruits. As an essential element with HQ values less than 1, there might be no tendency for Fe toxicity and the related problems in the consumers. Although, the low and excessive levels of Fe in fruits have their related health problems [63, 64].

Ranges of 2.0E-03 – 6.0E-03 and 1.2E-03 – 2.4E-03 were obtained for the HQ values of Ni in the local and exotic fruits, respectively. The highest HQ value of Ni in the local fruits was obtained in *Persea americana* whereas, *Citrus paradise* had the highest HQ value of Ni in the exotic fruits. Accordingly, the consumers of the local *Persea americana* and exotic *Citrus paradise* might be exposed to health problems associated with Ni toxicity over time [65].

The values of hazard quotient for Pb in the local and exotic fruits ranged from 2.0E-03 to 6.0E-03 and 1.2E-03 to 6.0E-03, correspondingly. The highest HQ values of Pb in the local and exotic fruits were obtained in *Citrus sinensis* and *Citrus limon,* respectively. Pb is not an essential element hence, a prolonged consumption of these fruits might pose serious health risk to the consumers as reported by Guerra *et al*. [49].

The HQ values of Zn in the local and exotic fruits varied from 1.2E-02 to 2.9E-02 and 1.4E-02 to 2.9E-02, respectively. The highest HQ values for Zn in both the local and exotic fruits were obtained in *Citrus paradise.* Thus, the consumption of these fruits might expose the consumers to the required level of Zn in the human body but its toxicity should be avoided to forestall health challenges reported by Roohani *et al*. [66].

Generally, the HQ values for the metals were lower than 1 consequently, these fruits may not pose any non-cancer risk to the consumers. Although, the HQ value of the metals is directly proportional to the potential human health risk [67, 68].

3.4. Hazard index (HI) associated with the exposure to trace metals

In assessing the human health risk associated with all the trace metals determined in the studied fruits, the idea of total hazard index (HI) was introduced. When an HI value is less than 1, it shows that consumption of the studied fruits might not result in non-carcinogenic risk. However, when the HI value is equal to or higher than 1, there is likelihood that serious health problems may occur [32, 49]. The HI values of the studied local and toxic fruits are indicated in Table 3. The HI values of the trace metals in local fruits ranged from 0.14 in *Citrus sinensis* to 0.47 in *Malus domestica*. Whereas, the HI values of the metals in the exotic fruits varied between 0.18 in *Citrus sinensis* and 0.44 in *Malus domestica*. The HI values of the local and exotic fruits followed the order *M. domestica* > *C. limon* > *P. americana* > *C. paradise* > *C. sinensis.* The general values of HI for all the fruits were below 1 hence, the consumption of these fruits may not pose any non-carcinogenic risk. Though, the consumers of the local fruits could be more susceptible to non-carcinogen risks than those consuming their exotic counterparts.

Table 4 Cancer risk and total cancer risk of the trace metals in the local and exotic fruits

			Local fruits		
	Citrus sinensis	***Persea americana***	***Citrus paradise***	***Malus domestica***	***Citrus limon***
Cd	4.18E-05	1.14E-04	4.94E-05	1.67E-04	1.60E-04
Cu	-	-	-	-	-
Fe	-	-	-	-	-
Ni	1.19E-04	1.70E-04	1.65E-04	1.36E-04	5.27E-04
Pb	1.70E-06	7.65E-07	1.62E-07	1.70E-07	1.28E-07
Zn	-	-	-	-	-
ΣCR	1.63E-04	2.85E-04	2.15E-04	3.03E-04	6.87E-04
			Exotic fruits		
Cd	7.60E-05	7.22E-05	7.60E-05	1.52E-04	1.37E-04
Cu	-	-	-	-	-
Fe	-	-	-	-	-
Ni	3.40E-05	5.78E-05	8.16E-05	3.40E-05	6.46E-05
Pb	7.65E-08	4.08E-08	1.19E-07	7.65E-08	1.70E-07
Zn	-	-	-	-	-
ΣCR	1.10E-04	1.30E-04	1.58E-04	1.86E-04	2.02E-04

3.5. The Cancer Risk (CR)

In this study, Cd, Ni, and Pb were of special concern due to their high carcinogenic risk [69]. The acceptable range of predicted lifetime risk for carcinogens by USEPA [34] is 10^{-6} (1 in 1,000,000) to 10^{-4} (1 in 10,000). Substances with risk factor below 10^{-6} may be ignored for further consideration as a substance of concern. The results obtained for the cancer risk (CR) of these metals via consumption of the studied fruits are shown in Table 4. The predictable lifetime risk to cancer because of Cd intake via the consumption of the local and exotic fruits varied from 4.18E-05 to 1.67E-04 and 7.22E-05 to 1.52E-04, respectively. These values are within the safe range of lifetime risk to cancer [34]. However, the cancer risk associated with the consumption of the local fruits are higher. The cancer risk values for Ni through the consumption of local and exotic fruits ranged from 1.19E-04 to 5.27E-04 and 3.40E-05 to 8.16E-05, respectively. Based on USEPA [34] recommendations, these values are within the permissible range by USEPA [34] though, higher cancer risk values were recorded for Ni via the consumers of the local fruits. The cancer risk due to Pb intake through the consumption of the local and exotic fruits varied from 1.28E-07 to 1.70E-06 and 4.08E-08 to 1.70E-07, correspondingly. These values are below the acceptable range and should be ignored except for *Citrus sinensis* with a value of 1.70E-06. Although, the CR values obtained may not pose any cancer risk to the consumers, the local fruits might have exposed the consumers to a higher degree of risk than the exotic ones. In other words, the studied exotic fruits would have been much safer than their local counterparts. There were insufficient data for the carcinogenic potentials of Cu, Fe, and Zn for the computation of their cancer risk in this study [33].

3.6. Total Cancer Risk (TCR)

The results for the total cancer risk in Table 4 indicate a range of 1.63E-04 - 6.87E-04 for the local fruits and 1.10E-04 – 2.02E-04 for the exotic fruits, respectively. These values are within the threshold range by USEPA [34]. Thus, the consumption of both the local and exotic fruits may not expose the consumers to cancer risk. Nevertheless, the probability of exposure to cancer risk is higher in the consumers of local fruits than in the consumers of the exotic ones.

Table 5 Total Variance Explained for trace metals in the studied local and exotic fruits

Component	Local fruits								
	Initial Eigen values			**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	2.69	44.86	44.86	2.69	44.86	44.86	2.36	39.34	39.34
2	2.16	35.92	80.79	2.16	35.92	80.79	1.91	31.81	71.15
3	1.05	17.54	98.32	1.05	17.54	98.32	1.63	27.18	98.32
	Exotic fruits								
1	2.67	44.45	44.45	2.67	44.45	44.45	2.55	42.55	42.55
2	2.35	39.10	83.55	2.35	39.10	83.55	2.46	41.00	83.55

Extraction Method: Principal Component Analysis

Table 6 Matrix of the major principal component

	Local fruits			**Exotic fruits**	
	Component			**Component**	
	1	2	3	1	2
Cd	0.329	-0.801	0.485	0.390	-0.707
Cu	0.882	0.358	-0.302	-0.767	-0.625
Fe	0.144	0.864	0.462	0.777	-0.268
Ni	0.808	0.038	0.588	0.526	0.736
Pb	-0.568	0.759	0.213	0.947	-0.030
Zn	0.899	0.248	-0.349	-0.386	0.917

3.7. Results of Multivariate Analysis

The Principal component analysis (PCA) was employed to identify the factors responsible for the accumulation of trace metals in the studied local and exotic fruits and their relationships [70, 71]. The values extracted from the PCA are presented in Table 5. The Table indicates three major factors with Eigen values > 1 with 98.32% of the total variance for the local fruits. Factor 1 contributed 44.86% of the total variance with significant positive loadings on Cu, Zn, and a strong negative loading on Pb (Table 6). This represents the negative impact of agrochemicals on the quality of the studied local fruits [72, 73]. Factor 2 contributed 35.92% of the total variance with strong positive loadings on Fe, Pb but strong negative loading on Cd. This is the negative impact of natural factor and inorganic fertilizers on the quality of the local fruits as reported by Benson *et al*. [37] and Ebong *et al.* [74]. Factor 3 contributed 17.54% of the total variance with a significant positive loading on Ni and a moderate positive loading on Cd. This represents the impact of industrial wastes on the quality of the local fruits [75]. For the exotic fruits, PCA revealed two main factors with Eigen values greater than one with strong 83.55% of the total variance (Table 5). Factor one contributed 44.45% of the total variance with strong positive loadings on Fe, Ni, and Pb but a significant negative loading on Cu (Table 6). This denotes the negative impact of both the natural and anthropogenic factors on the metal load of exotic fruits [74]. Factor 2 contributed 39.10% of the total variance with significant negative loadings on Cd and Cu but strong positive loadings on Ni and Zn (Table 6). This represents the negative effects of organic wastes on the quality of the exotic fruits [16, 76]. This study has revealed the different sources of trace metals in the studied local and exotic fruits. The sources of trace metals in the local fruits were more than in the exotic ones. This might have resulted in the higher values of most of the metals reported in the local fruits.

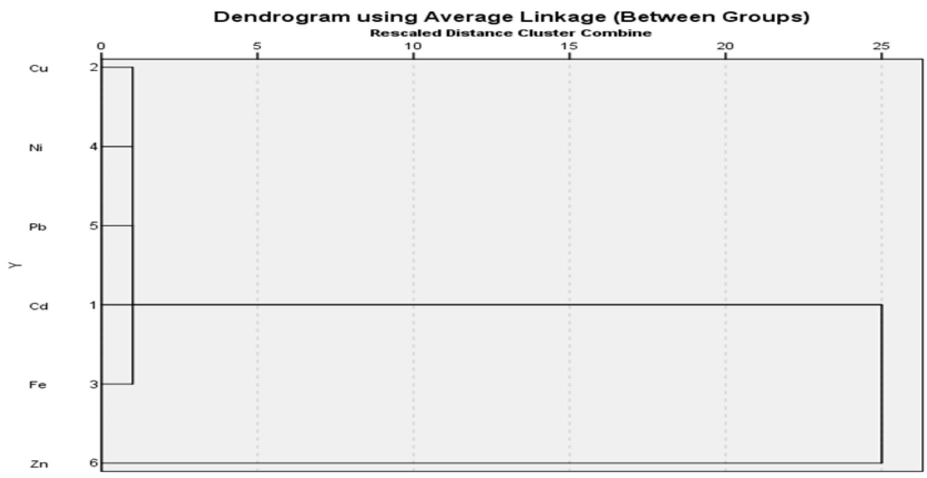

Figure 1 Hierarchical clusters formed among trace metals studied in the local fruits

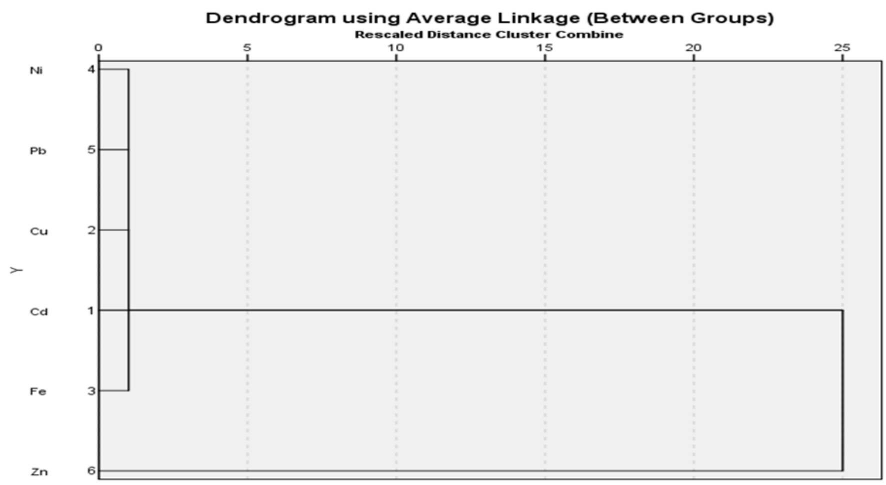

Figure 2 Hierarchical clusters formed among trace metals studied in the exotic fruits

The pair-wise affiliations between trace metals in the studied local and exotic fruits are demonstrated by Hierarchical cluster analysis (HCA) in figures 1 and 2, respectively. Both figures show two main clusters: (i) one linking all the trace metals together except Zn, and (ii) the one linking only Zn. This is an indication of a mutual source and similarities among trace metals in the first cluster [77]. Cluster two might have indicated a separate major source of Zn in the studied fruits from the other trace metals. The results of the HCA have also shown that irrespective of the source of the contaminants, their properties remain the same.

4. Conclusion

The study revealed the variations in the levels of Cd, Cu, Fe, Ni, Pb, and Zn between the local and exotic fruits. It has also indicated the consequences of agrochemicals including organic and inorganic manures on the quality of the fruits cultivated. The cancer and non-cancer risks related to the consumption of these fruits have also been identified. The difference in the degree of exposure to carcinogens through the consumption of the locally sourced fruits and the exotic ones has also been indicated. The multivariate analysis employed in the study was able to identify the factors responsible for the accumulation of these trace metals in the studied fruits and it was mainly anthropogenic. The study reported higher levels of most of the metals in the locally sourced fruits than in the exotic ones. It also revealed that the consumers of local fruits are more susceptible to metal toxicity and its attendants´ health problems than those consuming exotic fruits. Consequently, the extensive use of inorganic fertilizers and untreated organic wastes on farmlands should be controlled to avoid metal accumulation and the allied problems.

Compliance with ethical standards

Acknowledgments

We wish to sincerely appreciate the efforts of the Technical Staff of the Department of Chemistry, University of Uyo, Uyo.

Disclosure of conflict of interest

There is no conflict of interest.

References

[1] Divrikli U, Horzum N, Soylak M and Elci L. (2006). Trace heavy metal contents of some spices and herbal plants from western Anatolia, Turkey. International Journal of Food Science and Technology, 41, 712-716.

[2] Manzoor J, Sharma M and Wani KA. (2018). Heavy metals in vegetables and their impact on the nutrient quality of vegetables: A review. Journal of Plant Nutrition, 41(13), 1744 – 1763.

[3] WHO. (2012). World Health Organization Evaluation of certain food additives and contaminants (41st Report of the Joint FAO/WHO Expert Committee on Food Additives). World Health Organization Technical Report Series No. 837.

[4] Mausi G, Simiyu G and Lutta S. (2014). Assessment of Selected Heavy Metal Concentrations in Selected Fresh Fruits in Eldoret Town, Kenya. J. Environ. Earth Sci., 4(3), 1-8.

[5] Sobukola OP, Awonorin SO, Idowu MA and Bamiro FO. (2008). Chemical and physical hazard profile of 'robo' processing – a street vended melon snack. Inter. J. Food Sci. Technol., 43(2), 237-242.

[6] Alzahrani HR, Kumakli H and Ampiah E. (2017). Determination of macro, essential trace elements, toxic heavy metal concentrations, crude oil extracts and ash composition from Saudi Arabian fruits and vegetables having medicinal values. *Arabian Journal of Chemistry*, 10(7), 906-913.

[7] Prashanth L, Kattapagari KK, Chitturi RT, Baddam VR and Prasad LK. (2015). "A review on role of essential trace elements in health and disease," Journal of NTR University of Health Sciences, 4, 75–85.

[8] Ikechukwu UR, Okpashi VE, Oluomachi UN, Paulinus NC, Obiageli NF and Precious O. (2019). Evaluation of heavy metals in selected fruits in Umuahia market, Nigeria: Associating toxicity to effect for improved metal risk assessment. *Journal of Applied Biology & Biotechnology*, 7(04), 39 - 45.

[9] Rahim M, Ullah I, Khan A and Haris MRHM. (2016). "Health risk from heavy metals via consumption of foodcrops in the vicinity of District Shangla," *Journal of the Chemical Society of Pakistan*, 38(1), 177–185.

[10] Ali H, Khan E and Ilahi I. (2019). Environmental Chemistry and Ecotoxicology of Hazardous Heavy Metals: Environmental Persistence, Toxicity, and Bioaccumulation. Journal of Chemistry, 1 - 14.

[11] Khan S, Aijun I, Zhang S, Hu Q and Zhu YG. (2008). Accumulation of polycyclic aromatic hydrocarbons and heavy metals in lettuce grown in the soils contaminated with long-term wastewater irrigation. *J. Hazard Material*, 152(2), 506 - 515.

[12] Kooner RB, Mahajan VC and Dhillon WS. (2014). Heavy Metal Contamination in Vegetables, Fruits, Soil and Water-A Critical Review. International Journal of Agriculture, Environment & Biotechnology, 7(3), 603-612.

[13] Mirecki N, Agič R, Šunić L, Milenković L and Ilić ZS. (2015). Transfer factor as indicator of heavy metals content in plants. *Fresenius Environmental Bulletin*, 24, 4212 - 4219.

[14] Hezbullah M, Sultana S, Chakraborty SR and Patwary MI. (2016). Heavy metal contamination of food in a developing country like Bangladesh: An emerging threat to food safety. *Journal of Toxicology and Environmental Health Sciences*, 8(1), 1-5.

[15] Onuoha SC. (2017). Assessment of Metal Contamination in Aquaculture Fish Ponds South Eastern, Nigeria. *World Applied Sciences Journal*, 35 (1), 124-127.

[16] Orisakwe OE, Oladipo OO, Ajaezi GC and Udowelle NA. (2017). Horizontal and Vertical Distribution of Heavy Metals in Farm Produce and Livestock around Lead-Contaminated Goldmine in Dareta and Abare, Zamfara State, Northern Nigeria. *Journal of Environmental and Public Health,* 1 – 12.

[17] Khairiah T, Zalifah MK, Yin YH and Aminah A. (2004). The uptake of heavy metals by fruit type vegetables

[18] Kumar B, Smita K and Flores LC. (2017). Plant mediated detoxification of mercury and lead. *Arabian Journal of Chemistry*, 10, S2335 – S2342.

[19] Sulaiman FR and Hamzah HA. (2018). Heavy metals accumulation in suburban roadside plants of a tropical area (Jengka, Malaysia). *Ecological Processes*, 7(28), 1 -11.

[20] Zia MS and Khan MJ. (2008). Waste water use in agriculture and heavy metal pollution in soil plant system. *Journal-Chemical Society of Pakistan,* 30(3), 424-430.

[21] Khalid S, Shahid M, Bibi I, Sarwar T, Shah A and Niazi N. (2018). A review of environmental contamination and health risk assessment of wastewater use for crop irrigation with a focus on low- and high-income countries. *International Journal of Environmental Research and Public Health*, 15(5), 895.

[22] Pasha Q, Malik SA, Shaheen N and Shah MH. (2010). Comparison of Trace Elements in the scalp Hair of Malignant and Benign Breast Lesions Versus Healthy Women. *Biol Trace Elem Res.,* 134(2), 16073.

[23] Elbagermi MA, Edwards HGM and Alajtal AI. (2012). Monitoring of heavy metal content in fruits and vegetables collected from production and market sites in the Misurata area of Libya. Analytical Chemistry, 1-5.

[24] Neal AP and Guilarte TR. (2012). Mechanisms of heavy metal neurotoxicity: Lead and manganese. *J Drug Metab Toxicol*, S5, 1-13.

[25] Ogunkunle AT, Bello OS and Ojofeitimi OS. (2014). Determination of heavy metal contamination of street-vended fruits and vegetables in Lagos state, Nigeria. *Inter. Food Res. J.,* 21(5), 1725-1730.

[26] FAO/WHO. (2001). Codex Alimentarius Commission. Food additives and contaminants. Joint FAO/WHO Food Standards Program 2001; ALINORM 01/12A:1-289. Guiyang, PR China. *Bull Environ Contam Toxicol*., 80(5), 465–468.

[27] Adedokun AH, Njoku KL, Akinola MO, Adesuyi AA and Jolaoso AO. (2016). Potential Human Health Risk Assessment of Heavy Metals Intake via Consumption of some Leafy Vegetables obtained from Four Market in Lagos Metropolis, Nigeria. J. Appl. Sci. Environ. Manage, 20(3), 530 – 539.

[28] Storelli MM. (2008). Potential human health risks from metals (Hg, Cd, and Pb) and polychlorinated biphenyls (PCBs) via seafood consumption: Estimation of target hazard quotients (THQs) and toxic equivalents (TEQs). *Food Chemistry and Toxicology,* 46, 2782–2788.

[29] Jan FA, Ishaq M, Khan S, Ihsanullah I, Ahmad I and Shakirullah M. (2010). A comparative study of human health risks via consumption of food crops grown on wastewater irrigated soil (Peshawar) and relatively clean water irrigated soil (lower Dir). *Journal of Hazard Materials*, 179, 612–621.

[30] WHO. (2018). World Health Organization *"Obesity and overweight*".

[31] USEPA. (2010). Integrated risk information system (I R I S). United States Environmental Protection.

[32] Cao S, Duan X, Zhao X, Wang B, Ma J, Fan D, Sun C, He B, Wei F and Jiang G. (2015). Health risk assessment of various metal(loid)s via multiple exposure pathways on children living near a typical lead-acid battery plant, China. *Environ. Pollut.,* 200, 16 –23.

[33] USEPA (2020). USEPA Regional Screening Level (RSLs): User's Guide - Generic Tables.

[34] USEPA (2011). United States Environmental Protection Agency, *Exposure Factors Handbook: 2011 Edition*, EPA/600/R-090/052F.

[35] WHO/FAO. (2011). Joint report, Food standard programs Codex committee on contaminants in foods (CF/5 INF/1). Fifth Session, Rome, 64 - 89.

[36] Sobukola OP, Adeniran OM, Odedairo AA and Kajihausa OE. (2010). Heavy metal levels of some fruits and leafy vegetables from selected markets in Lagos, Nigeria. *Afr. J. Food Sci*, 4(2), 389-393.

[37] Benson NU, Anake WU and Etesin UM. (2014). Trace Metals Levels in Inorganic Fertilizers Commercially Available in Nigeria. *Journal of Scientific Research & Reports,* 3(4), 610 - 620.

[38] Morgan JN. (1999). Effects of Processing on Heavy Metal Content of Foods. Impact of Processing on Food Security, 195 -211.

[39] Bost M, Houdart S, Oberli M, Kalonji E, Huneau JF and Margaritis I. (2016). Dietary copper and human health: current evidence and unresolved issues. *J Trace Elem Med Biol*., 35, 107–115.

[40] Ezeonyejiaku CD and Obiakor MO. (2017). A Market Basket Survey of Horticultural Fruits for Arsenic and Trace Metal Contamination in Southeast Nigeria and Potential Health Risk Implications. Journal of Health & Pollution, 7(15), 40 – 50.

[41] Aydinalp C and Marinova S. (2012). Concentration of Cu and Zn in some fruits and vegetables grown in north western Turkey. Bulgarian Journal of Agricultural Science, 18 (5), 749-751.

[42] Itanna F. (2002). Metals in leafy vegetables grown in Addis Ababa and toxicology implications. Ethiopian J. Health Develop, 16, 295–302.

[43] Mehari TF, Greene L, Duncan AL and Fakayode SO. (2015). Trace and Macro Elements Concentrations in Selected Fresh Fruits, Vegetables, Herbs, and Processed Foods in North Carolina, USA. *Journal of Environmental Protection*, 6, 573 – 583.

[44] Yami SG, Chandravanshi BS, Wondimu T and Abuye C. (2016). Assessment of selected nutrients and toxic metals in fruits, soils and irrigation waters of Awara Melka and Nura Era farms, Ethiopia. *SpringerPlus*, 5, 734 -747.

[45] Alvarez-Fernandez A, Paniagua P, Abadia J and Abadia A. (2003). Effects of Fe Deficiency Chlorosis onYield and Fruit Quality in Peach (Prunus Persica L. Batsch). *J. Agric Food Chem*., 51(19), 5738 - 5744.

[46] Rout GR and Sahoo S. (2015). Role of iron in plant growth and metabolism. *Reviews in Agricultural Science*, 3, 1 - 24.

[47] Rieuwerts JS, Thornton I, Farago ME and Ashmore MR. (1998). Factors influencing metal bioavailability in soils: preliminary investigations for the development of a critical loads approach for metals, Chemical Speciation & Bioavailability, 10(2), 61-75.

[48] Nouri J, Khorasani N, Lorestani B, Karami M, Hassani AH and Yousefi N. (2013). Accumulation of heavy metals in soil and uptake by plant species with phytoremediation potential. *Environmental Earth Sciences*, 59(2), 315-323.

[49] Guerra F, Trevizam AR, Muraoka T, Marcante NC and Canniatti-Brazaca SG. (2012). Heavy metals invegetables and potential risk for human health. *Science and Agriculture*, 69, 54–60.

[50] Omoyajowo KO, Njoku KL, Babalola OO and Adenekan OA. (2017). Nutritional composition and heavy metal content of selected fruits in Nigeria. Journal of Agriculture and Environment for International Development – JAEID, 111(1), 123-139.

[51] Rumsey DJ. (2002). Discussion: Statistical literacy: Implications for teaching, research, and practice. International Statistical Review, 70(1), 32-36.

[52] Radwan MA and Salama AK. (2006). Market basket survey for some heavy metals in Egyptian fruits and vegetables. Food and Chemical Toxicology, 44 (8), 1273 – 1278.

[53] Ihesinachi K and Eresiya D. (2014). Evaluation of heavy metals in orange, pineapple, avocado pear and pawpaw from a farm in Kaani, Bori, Rivers State Nigeria. International Research Journal of Public and Environmental Health,1(4), 87-94.

[54] Rahman MM, Azirun SM and Boyce AN. (2013). Enhanced Accumulation of Copper and Lead in Amaranth (Amaranthus paniculatus), Indian Mustard (Brassica juncea) and Sunflower (Helianthus annuus). *PLoS ONE*, 8(5), e62941.

[55] Plum LM, Rink L and Haase H. (2010). The Essential Toxin: Impact of Zinc on Human Health. International Journal of Environmental Research and Public Health, 7(4), 1342–1365.

[56] Sharma A, Patni B, Shankhdhar D and Shankhdhar SC. (2013). Zinc – An Indispensable Micronutrient. Physiol Mol Plants, 19(1), 11–20.

[57] World Health Organization. (WHO). (2010). *Quantifying Environmental Health Impacts.* World Health Organization, Geneva.

[58] FAO/WHO. (1999). Joint Expert Committee on Food Additives, "Summary and Conclusions", in proceedings of the 53rd Meeting of Joint FAO/WHO Expert Committee on Food Additives, In: 53rd meeting, Rome, Italy.

[59] Wang X, Sato T and Baoshan X. (2005). Health risk of heavy metals to the general public of Tianjin, China via consumption of vegetables and fish. *Sci Total Environ*., 350, 28-37.

[60] World Health Organization. (WHO). (2004). *Evaluation of certain food additives and Contaminants*. In: Sixty-First Report of the Joint FAO/WHO Expert Committee on Food Additives. WHO, Geneva, Switzerland. (WHO Technical Series, 922).

[61] Goldhaber SB. (2003). Trace element risk assessment: essentially vs. toxicity. *Regul Toxicol Pharmacol.,* 38, 232–242.

[62] Adewole MB and Uchegbu LU. (2010). Properties of soils and plants uptake within the vicinity of selected automobile workshops in Ile-Ife, Southwestern Nigeria. Ethiop J Environ Stud Manage, 3, 23-28.

[63] Tuzen M. (2003). Determination of heavy metals in soil, mushrooms and plant samples by AAS. *Microchem J.,* 74, 289–297.

[64] Bagdatlioglu N, Nergiz C and Ergonul PG. (2010). Heavy metal levels in leafy vegetables and some selected fruits. *Journal of Consumer Protection and Food Safety*, 5, 421– 428.

[65] Arias VO, Som LV, Rodríguez VQ, Romero RG, Muñoz N, Alarcón MN and Vique CC. (2015). Nickel in food and influencing factors in its levels, intake, bioavailability and toxicity: a review. *CyTA – Journal of Food,* 13(1), 87–101.

[66] Roohani N, Hurrell R, Kelishadi R and Schulin R. (2013). Zinc and its importance for human health: An integrative review. *Journal of Research in Medical Science*, 18(2), 144 – 157.

[67] Man YB, Sun XL, Zhao YG, Lopez BN, Chung SS and Wu SC. (2010). Health risk assessment of abandoned agricultural soils based on heavy metal contents in Hong Kong, the world's most populated city. *Environment International***,** 36(6), 570-576.

[68] Li Z, Zhang D, Wei Y, Luo L and Dai T. (2014). Risk assessment of trace elements is cultured from freshwater fishes from Jiangxi Provence, China. Environ Monit Assess., 186, 2185 - 2194.

[69] IARC. (International Agency for Research on Cancer). (2011). IARC (International Agency for Research on Cancer) Agents Classified by the IARC Monographs, 1-102.

[70] Yang P, Yang M, Mao R and Shao H. (2014). Multivariate-Statistical Assessment of Heavy Metals for Agricultural Soils in Northern China. *The Scientific World J.*, 1 – 7.

[71] Paladino O, Moranda A and Sevedsalehi M. (2017). A Method for Identifying Pollution Sources of Heavy Metals and PAH for a Risk-Based Management of a Mediterranean Harbour. *Scientifica (Cairo),* 1-9.

[72] Sumner ME. (2000). "Beneficial use of effluents, wastes, and biosolids," *Communications in Soil Science and Plant Analysis*, 31(11–14), 1701–1715.

[73] Azeez JO, Hassan OA and Egunjobi PO. (2011). Soil Contamination at Dumpsites: Implication of Soil HeavyMetals Distribution in Municipal Solid Waste Disposal System: A Case Study of Abeokuta, Southwestern Nigeria. *Soil and Sediment Contamination: An International Journal*, 20(4), 370 - 386.

[74] Ebong GA, Ettesam ES and Dan EU. (2020). Impact of Abattoir Wastes on Trace Metal Accumulation, Speciation, and Human Health–Related Problems in Soils Within Southern Nigeria. *Air, Soil, and Water* Research, 13, 1-14.

[75] Wu YF, Liu CQ and Tu CL. (2008). Atmospheric deposition of metals in TSP of Guiyang, PR China. *Bull Environ Contam Toxicol*., 80(5), 465–468.

[76] Olabanji IO, Oluyemi EA and Obianjuwa EI. (2015). Nondestructive analysis of dumpsite soil and vegetable for elemental composition. *Journal of Environmental Chemistry and Ecotoxicology,* 7(1), 1-10.

[77] Yang Z, Lu W, Long Y, Bao X and Yang Q. (2011). Assessment of heavy metals contamination in urban topsoil from Changchun City, China. *J. Geochemical Explor,* 108, 27-38.

How to cite this article

Ebong GA, Etuk HS, Dan EU and Ekpo KJ. (2020). Variations in the levels, source, cancer and non-cancer risks of trace metals in the local and exotic fruits. World Journal of Advanced Research and Reviews, 6(3), 275-288.