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Health Risk Assessment of Heavy Metals in Citrus Varieties from Selected Orchards in Benue State, Nigeria

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Abstract

Contamination of fruits by heavy metals has serious health implication on consumers especially when their concentrations are above the permissible limits set by regulatory bodies. This study assesses the health risk of heavy metals in three orange varieties using the following parameters: Estimated Daily Intake (EDI), Target Hazard Quotient (THQ) and Hazard Index (HI). The result showed that the EDI for Pb and Hg are below the RfD values of 0.0003 and 0.001 mg/kg/ day, which is evidence that no risk involved in consuming the oranges. The THQ < 1 is an indication that no carcinogenic health effects of ingestion of heavy metals associated with the consumption of the orange fruits by both Male and Female. The HI < 1 means that the population has no potential cancer risk arising from the consumption of these oranges associated with the heavy metals studied from the consumption of oranges from Benue State.

Keywords: heavy metals, Estimated Daily Intake, Target Hazard Quotient and Hazard Index

Introduction

Agricultural activities constantly expose man to different toxic substances such as heavy metals and chemical (pesticides, herbicides and fertilizers) contamination of foodstuffs [1]. Some common heavy metals present in environmental are Cu, Ni, Cr, Pb, Cd, Hg, Fe and As [2]. The occurrence of these heavy metals in the environment is a major threat to plant, animal and human life due to their bioaccumulation ability and toxicity [3].

Suspended heavy metals in particulates emitted from automobiles are deposited on road and plant surfaces. During rainfall, these metals dissolve and are washed off the roadway with the dust into drainages with many being absorbed by plants. The silt from these drainages during de-silting ends up in refuse dumps or carried to farmlands by flood [4]. The heavy metals' environmental pollution and associated health effects are among the leading cause of health concerns all over the world. For instance, bioaccumulation of Pb in the human body to certain concentration may interfere with the functioning of mitochondria, thereby impairing respiration and also causes constipation, swelling of the brain, paralysis and even death [5]. Heavy metals are natural constituents of the earth's crust and they persistently contaminate the environment, they are non-degradable and may make their way into the human body through plant produce, air, and water and have the tendency to bioaccumulate over a period of time [6]. Heavy metals may be released into the environment by natural and anthropogenic processes. Anthropogenic processes may include agricultural activities like use of pesticide and herbicide, contaminated irrigation water, municipal waste used for fertilization and even mineral fertilizer containing traces of heavy metals [7]. Also direct waste disposal on farmland, mining activities, use of lead as anti-knock in petrol, traffic emissions, cigarette smoking, metallurgy and smelting, aerosol cans, sewage discharge, and building materials [8]. The atmosphere can be loaded with heavy metals through the breakdown of applied waste materials, which gradually release the heavy metals in them. Lead accumulation on Nigerian soil is a result of long-term cultivation and use of different types of fertilizers and pesticides [9]. The accumulation in plant tissues depend upon temperature, moisture, organic matter, pH, and nutrient availability [10]. It also depends on plant species, while the efficiency of plants in absorbing metals is determined by either plant uptake or soil to plant transfer factors of the metals [11]. Elevated lead in soils is known to decrease soil productivity, while at very low concentrations, may inhibit some vital plant processes, like photosynthesis, mitosis, metabolism and water absorption, leading to symptoms of toxicity which is justified in dark green leaves, wilting of older leaves, stunted foliage, and brown short roots [12].

Fruits are part of the daily diet in almost every household in Nigeria and contained vitamins and minerals. They are made chiefly of cellulose, hemi-cellulose and pectin, which give them their texture and firmness [13]. Consumer perception of vegetables is subjective as they consider dark green and big leaves as characteristics of good quality. However, the external morphology of vegetables cannot guarantee wholesomeness because heavy metals rank high amongst the major contaminants of leafy vegetables [14]. Heavy metals become toxic when they are not metabolized by the body and accumulate in the soft tissues [15]. The general signs and symptoms associated with lead and mercury poisoning include gastrointestinal disorders, diarrhoea, stomatitis, tremor, hemoglobinuria, ataxia, paralysis, vomiting, and convulsion, depression, and pneumonia when vapours and fumes are inhaled [16]. The determination and risk analysis of heavy metals in food stuffs is an important part of nutritional and toxicological analyses because industrial and agricultural activities can spike concentration of toxicants like heavy metals in the environment that affect both plant and animals [17].

This study aims at evaluating the potential health risks associated with Pb and Hg through consumption of oranges (Washington, Ibadan Sweet and Valencia) from selected orchards in Benue State, Nigeria, using some health risk assessment parameters such as: Estimate Daily Intake (EDI), Target Hazard Quotients (THQs) and Hazard Index (HI).

Materials and Methods

Study area

The citrus fruits were collected from orchards located in seven (7) Local Government Areas of Benue State and the geographical coordinates are; 7°47´E and 10°0´E longitude, 6°25´N and 8°8´N latitude with an area of 34,059 km^2.

Sample collection

The citrus fruits varieties (Washington, Ibadan Sweet and Valencia) with average weights of 235 ± 15, 147 ± 12 and 129 ± 18 depending on the season were collected from seven (7) Local Government Areas of Benue State because they are the major producers of citrus fruits. Three orchards were selected from three (3) council wards of each Local Government Area where the citrus fruit samples were taken and bulked based on varieties to a total of twenty one (21) composite samples for analysis.

Laboratory Procedures for Digestion of Pb and Hg

The citrus fruits were washed with tap water and then with distilled water after which the juice was squeezed manually into separate beakers. About 200 mL of juice were obtained from each sample. The juice was filtered with 0.5 mm mesh, mixed thoroughly and 1.0 mL of the sample was measured and put into a beaker and 10 mL of a mixture of nitric acid (65 % v/v HNO_3) and perchloric acid ($HClO_4$) in the ratio (4:1) was added to each sample and heated on a hot plate in a fume chamber at a temperature between 150 and 250°C until all the fumes were given off. Then the digest were allowed to cool and acidified with 10 mL of 1:1 mixture of 32 % v/v HCl: H_2O, filtered and transferred to a 100 mL volumetric flask and made up to mark with deionized water [18]. The digested samples were transferred into plastic bottles and the content analyzed for lead using Atomic Absorption Spectrophotometer (AAS). Similarly, 1.0 mL of the homogenized orange sample was measured into 100 mL volumetric digestion flask and a mixture of 2 mL H_2O, 4 mL HNO_3– $HClO_4$ (1:1) and 10 mL H_2SO_4 were added. The mixture was then heated at a temperature between 150 and 250°C until the solution was clear. The sample solution was then cooled, filtered with 0.5 mm mesh and transferred to a 100 mL volumetric flask and made up to mark with deionized water and the contents analyzed for mercury using Cold Vapour Atomic Absorption Spectrophotometer (CV-AAS).

Heavy metal health risk assessment

The health risks associated with the ingestion of heavy metals from the consumption of three orange varieties (Washinghton, Ibadan Sweet and Valencia) were assessed based on the following indices: Estimated Daily Intake (EDI) of heavy metals, Target Hazard Quotient (THQ) and Hazard Index (HI)) in men and female respectively

Estimated Daily Intake (EDI)

$$EDI = \frac{E_f \times E_d \times F_{ir} \times C_m \times C_f}{B_w \times T_a} \times 0.001 \quad (1)$$

where; E_f is exposure frequency (365 days/year); E_d is exposure period: for men 60 years, women 64 years [19], which is equivalent to the average life span; F_{ir} is average vegetable consumption (240 g/person/day), as defined by the World Health Report [20] for low fruit and vegetable intake. C_m is metal concentration (mg/kg dry weight); C_f is concentration conversion factor for fresh vegetable weight to dry weight (0.085) [21]; Bw is body weight (85.9 kg for men, 74 kg for women); and Ta is average exposure period (Ed × 365 days/year), and 0.001 is the unit conversion factor

Target Hazard Quotient (THQ)

The target hazard quotient (THQ) values were calculated to evaluate non carcinogenic human health risks from the consumption of heavy metal-contaminated orange varieties. It was determined as the proportion of average daily metal consumption to an oral reference dose of each metal [22] as expressed by equation below.

$$THQ = \frac{EDI}{RfD} \quad (2)$$

Where EDI represents the population's average daily metal consumption in mg/kg/day body weight and RfD is the oral reference dosage (mg/kg/day) values for the metals analyzed. The RfD values of Pb and Hg are 0.0003 and 0.001 mg/kg/day, respectively [23]. When the THQ < 1, it is usually assumed to be secure for the risk of non-carcinogenic effects; if THQ > 1, it is assumed that there is a greater likelihood of non-carcinogenic effects as the value rises [24].

Hazard Index

The hazard index (HI) for the overall human risk is calculated as the sum of all THQs estimated for specific heavy metals.

$$HI = \sum_{n=1}^{i} THQ_{n;}\ i = 1, 2, 3, 4 \ldots\ldots n \quad (3)$$

Where HI is the sum of various metals, there is no probable health impact if HI < 1 but HI > 1, it is an indication that the possibility of an adverse health effect occurring.

Statistical Analysis

Statistical package for Statistical Analysis System (SAS Version 2017) was employed to determine if there is any correlation in the concentrations of lead between soil and citrus varieties.

Results and Discussion

Orange fruits can accumulate heavy metals from the soil they are grown on and also from the chemical treatment for healthy growth and increase yield. The level of heavy metals and their health risk on consumers especially in adults (men and women) in orange varieties (Washington, Ibadan sweet and Valencia) in selected orchards in some major orange producing Local Government Areas in Benue State were examined as presented in Tables 1-6.

Table 1: Concentrations of Heavy Metals in Wahington Orange with EDI (mgkg^{-1}day^{-1}), THQ and HI Values

MEN							
LGA	Pb (mgkg^{-1})	EDI	THQ	Hg (mgkg^{-1})	EDI	THQ	HI
Katsana-Ala	6.58	8.77E-06	2.92E-02	6.35E-03	8.47E-09	8.47E-06	2.92E-02
Konshisha	1.58	2.11E-06	7.03E-03	7.70E-04	1.03E-09	1.03E-06	7.03E-03
Kwande	1.75	2.33E-06	7.77E-03	2.20E-3	2.93E-09	2.93E-06	7.77E-03
Logo	1.23	1.64E-06	5.47E-03	2.88E-03	3.84E-09	3.84E-06	5.47E-03
Ukum	ND	ND	ND	ND	ND	ND	ND
Ushongo	0.316	4.21E-07	1.40E-03	7.70E-04	1.03E-09	1.03E-06	1.40E-03
Vandeikya	0.919	1.23E-06	4.10E-03	2.13E-03	2.84E-09	2.84E-06	4.10E-03

Table 2: Concentrations of Heavy Metals in Ibadan Sweet Orange with EDI (mgkg^{-1}day^{-1}), THQ and HI Values

	MEN						
LGA	Pb (mgkg^{-1})	EDI	THQ	Hg (mgkg^{-1})	EDI	THQ	HI
Katsana-Ala	3.48	4.64E-06	1.55E-02	6.53E-03	8.71E-09	8.71 E-06	1.55E-02
Konshisha	0.158	2.11E-07	7.03E-04	7.70E-04	1.03 E-09	1.03 E-06	7.04E-04
Kwande	1.40	1.87E-06	6.23E-03	2.30E-03	3.07 E-09	3.07 E-06	6.23E-03
Logo	1.02	1.36E-06	4.53E-03	1.84E-03	2.45 E-09	2.45 E-06	4.53E-03
Ukum	1.67	2.23E-06	7.43E-03	3.92E-03	5.23 E-09	5.23 E-06	7.44E-03
Ushongo	ND	ND	ND	5.78E-04	7.71 E-09	7.71 E-06	7.71E-06
Vandeikya	0.158	2.11E-07	7.03E-04	1.80E-03	2.40 E-09	2.40 E-06	7.05E-04

Table 3: Concentrations of Heavy Metals in Valencia Orange with EDI (mgkg^{-1}day^{-1}), THQ and HI Values

	MEN						
LGA	Pb (mgkg^{-1})	EDI	THQ	Hg (mgkg^{-1})	EDI	THQ	HI
Katsana-Ala	2.57	3.43E-06	1.14E-02	5.22E-03	7.66E-09	7.66E-06	1.14E-02
Konshisha	0.158	2.11E-07	7.03E-04	7.70E-04	1.03 E-09	1.03 E-06	7.04E-04
Kwande	0.158	2.11E-07	7.03E-04	7.70E-04	1.03 E-09	1.03 E-06	7.04E-04
Logo	1.43	1.91E-06	6.37E-03	3.38E-03	4.51 E-09	4.51 E-06	6.37E-03
Ukum	3.73	4.97E-06	1.66E-02	7.70E-04	1.03 E-09	1.03 E-06	1.66E-02
Ushongo	0.158	2.11E-07	7.03E-04	7.70E-04	1.03 E-09	1.03 E-06	7.04E-04
Vandeikya	0.158	2.11E-07	7.03E-04	1.71E-03	2.28 E-09	2.28 E-06	7.05E-04

Table 4: Concentrations of Heavy Metals in Washington Orange with EDI (mgkg^{-1}day^{-1}), THQ and HI Values

Women							
LGA	Pb (mgkg^{-1})	EDI	THQ	Hg (mgkg^{-1})	EDI	THQ	HI
Katsana-Ala	6.58	1.81E-06	6.03E-03	6.35E-03	1.75E-09	1.75E-06	6.03E-03
Konshisha	1.58	4.36E-07	1.45E-03	7.70E-04	2.12 E-10	2.12 E-07	1.45E-03
Kwande	1.75	4.82E-07	1.61E-03	2.20E-3	6.06 E-10	6.06 E-07	1.61E-03
Logo	1.23	3.39E-07	1.13E-03	2.88E-03	7.94 E-10	7.94 E-07	1.13E-03

Ukum	ND	ND	ND	ND	ND	ND	ND
Ushongo	0.316	8.71E-08	2.90E-04	7.70E-04	2.12E-10	2.12E-07	2.90E-04
Vandeikya	0.919	2.53E-07	8.43E-04	2.13E-03	5.87E-10	5.87E-07	8.44E-04

Table 5: Concentrations of Heavy Metals in Ibadan Sweet Orange with EDI (mgkg^{-1}day^{-1}), THQ and HI Values

Women							
LGA	Pb (mgkg^{-1})	EDI	THQ	Hg (mgkg^{-1})	EDI	THQ	HI
Katsana-Ala	3.48	9.55E-07	3.20E-03	6.53E-03	1.80E-09	1.80E-06	3.20E-03
Konshisha	0.158	4.36E-08	1.45E-04	7.70E-04	2.12E-10	2.12E-07	1.45E-04
Kwande	1.40	3.86E-07	1.29E-03	2.30E-03	6.34E-10	6.34E-07	1.29E-03
Logo	1.02	2.81E-07	9.37E-04	1.84E-03	5.07E-10	5.07E-07	9.38E-04
Ukum	1.67	4.60E-07	1.53E-03	3.92E-03	1.08E-09	1.08E-06	1.53E-03
Ushongo	ND	ND	ND	5.78E-04	1.59E-10	1.59E-07	1.59E-07
Vandeikya	0.158	4.36E-08	1.45E-04	1.80E-03	4.96E-10	4.96E-07	1.45E-04

Table 6: Concentrations of Heavy Metals in Valencia Orange with EDI (mgkg^{-1}day^{-1}), THQ and HI Values

Women							
LGA	Pb (mgkg^{-1})	EDI	THQ	Hg (mgkg^{-1})	EDI	THQ	HI
Katsina-Ala	2.57	7.08E-07	2.36E-03	5.22E-03	1.44E-09	1.44E-06	2.36E-03
Konshisha	0.158	4.36E-08	1.45E-04	7.70E-04	2.12E-10	2.12E-07	1.45E-04
Kwande	0.158	4.36E-08	1.45E-04	7.70E-04	2.12E-10	2.12E-07	1.45E-04
Logo	1.43	3.9E-07	1.31E-03	3.38E-03	9.23E-10	9.23E-07	1.31E-03
Ukum	3.73	1.03E-06	3.43E-03	7.70E-04	2.12E-10	2.12E-07	3.43E-03
Ushongo	0.158	4.36E-08	1.45E-04	7.70E-04	2.12E-10	2.12E-07	1.45E-04
Vandeikya	0.158	4.36E-08	1.45E-04	1.71E-03	4.71E-10	4.71E-07	1.45E-04

Discussion

Estimated Daily Intake (EDI)

The dietary exposure approach to vegetable consumption is a valid method for examining a population's diet regarding nutrient, bioactive component, and contaminant intake levels, providing critical information regarding potential nutritional deficiencies or food contamination exposure [25]. Because of the increasing awareness of the connection between diet and human health, people are eating more fruits in recent time. Food safety and sustainability have become critical issues due to the rapid cultivation and use of fruits by human beings [26]. The concentrations Pb and Hg in each orange variety and their respective consumption rates were used to calculate the EDI. The results of men and women are presented in tables 1- 6 above. The EDI values as for Pb and Hg in the orange varieties in men ranged Pb: Washington (4.21E-07 – 2.33E-06); Ibadan sweet (2.11E-07-4.64E-06) and Valencia (2.11E-07 – 4.97E-06); Hg; Washington (1.03E-09 – 8.47E-09); Ibadan sweet (1.03E-09 – 8.71E-09) and Valencia (1.03E-09 – 7.66E-09) and in women in the range; Pb: Washington (8.71E-08 – 1.81E-06); Ibadan sweet (4.36E-08-4.60E-07) and Valencia (4.36E-08 – 7.08E-07); Hg: Washington (2.12E-10 – 1.75E-09); Ibadan sweet (1.59E-10-1.80E-09) and Valencia (2.12E-10-1.44E-09). The EDI values in men for Pb in washington was higher in Katsina-Ala (8.77E-6) and lower in Ushongo (4.21E-07), for Hg it was higher in Katsina-Ala (8.47E-09) and lower in Konshisha and Ushongo (1.03E-09) respectively. In Ibadan Sweet Kastina- Ala recorded the highest value of EDI for Pb (4.64E-06) and the lowest values were recorded in Konshisha and Kwande (2.11E-07) respectively, for Hg, the highest EDI value was also recorded in Katsina-Ala (8.71E-09) and the lowest in Konshisha (1.03E-09). In valencia, the EDI values for Pb were higher in Ukum (4.97E-06) and lower in Konshisha, Kwande, Ushongo and Vandeikya (2.11E-07) respectively, for Hg, Katsina-Ala recorded the highest value (7.66E-09) and Konshisha, Kwande, Ukum and Ushongo recorded the lowest (1.03E-09) respectively. The EDI values in women for Pb in washington was higher in Katsina-Ala (1.81E-06) and lower in Ushongo (8.71E-08), for Hg it was higher in Katsina-Ala (1.75E-09) and lower in Konshisha and Ushongo (2.12E-10) respectively. In Ibadan Sweet, Kastina- Ala recorded the highest value of EDI for Pb (9.55E-07) and the lowest values were recorded in Konshisha and Vandeikya (4.36E-08) respectively, for Hg, the highest EDI value was also recorded in Katsina-Ala (1.80E-09) and the lowest in Ushongo (1.59E-07). In valencia, the EDI values for Pb were higher in Katsina-Ala (7.08E-07) and lower in Konshisha, Kwande, Ukum and Ushongo (4.36E-08) respectively, for Hg, Katsina-Ala recorded the highest value (1.44E-09) and Konshisha, Kwande, Ukum and Ushongo recorded the lowest (2.12E-10) respectively. The estimated daily intake of Pb (mgkg^{-1}day^{-1}) for adults by consumption of vegetables irrigated with waste water from an Urban Market in Zaria, Nigeria is in the range: 0.02-0.50 mgkg^{-1}day^{-1} in cabbage, onions, bitter leaf, jute mallow, spinach, tomato and lettuce respectively [27]. The EDI of Pb was assessed from consumption of fruits and vegetables cultivated in selected farms around Kaduna Metropolis, Nigeria from three different sites in cucumber, cabbage, garden egg, paw paw and banana in the range: 0.02-0.06 $mgkg^{-1}day^{-1}$ [28]. The EDI of Pb was reported from consuming potatoes, tomatoes, onions, cabbages, carrots, beetroots and lettuce from selected Markets in Bahir Dar town, Northwest Ethopia [29]. The orders of EDI (Men) of Pb and Hg in the orange varieties were: Washington > Valencia > Ibadan sweet and Valencia > Washington > Ibadan sweet respectively, in Women the orders of EDI for Pb and Hg in the orange varieties are: Washington > Valencia > Ibadan sweet and Ibadan sweet > Washington > Valencia respectively, with the highest value recorded in men and could be that men consume more oranges than women.

Target Hazard Quotient (THQ)

The THQ is used to estimate the health risk of ingestion of heavy metals associated with the consumption of orange fruits by both male and female from the studied orchards as presented in tables 1-6 above. The THQ, which is the ratio of a pollutant's calculated dosage to a reference dose level, is being used to assess the health risks of adult populations from contaminated orange fruit varieties. If THQ > 1, the exposed population is expected to be affected. In this study, the THQ of Hg and Pb calculated were far below unity which is an indication that no carcinogenic effect. The THQ values for Pb and Hg in the orange varieties in men is in the range; Pb: Washington (1.40E-03 – 2.92E-02); Ibadan sweet (7.03E-04 – 1.55E-02) and Valencia (7.03E-04 – 1.14E-02); Hg; Washington (1.03E-06 – 8.47E-06); Ibadan sweet (1.03E-06 – 8.71E-06) and Valencia (1.03E-06 – 7.66E-06) and in women in the range; Pb: Washington (1.13E-03 – 8.43E-04); Ibadan sweet (1.45E-04 – 3.53E-03) and Valencia (1.45E-04 – 3.43E-03) while Hg: Washington (2.12E-07 – 1.75E-06); Ibadan sweet (2.12E-07 – 1.08E-06) and Valencia (2.12E-07 – 1.14E-06) respectively. The THQ values in men for Pb in washington was higher in Katsina-Ala (2.92E-02) and lower in Ushongo (1.40E-03), for Hg it was higher in Katsina-Ala (8.47E-06) and lower in Konshisha and Ushongo (1.03E-06) respectively. In Ibadan Sweet Kastina- Ala recorded the highest value of THQ for Pb (1.55E-02) and the lowest values were recorded in Konshisha and Vandeiky (7.03E-04) respectively, for Hg, the highest THQ value was also recorded in Katsina-Ala (8.71E-06) and the lowest in Konshisha (1.03E-06). In valencia, the THQ values for Pb were higher in Ukum (1.66E-02) and lower in Konshisha, Kwande, Ushongo and Vandeikya (7.03E-04) respectively, for Hg, Katsina-Ala recorded the highest value (7.66E-06) and Konshisha, Kwande, Ukum and Ushongo recorded the lowest (1.03E-06) respectively. The THQ values in women for Pb in washington was higher in Katsina-Ala (6.03E-03) and lower in Ushongo (2.90E-04), for Hg it was higher in Katsina-Ala (1.75E-06) and lower in Konshisha and Ushongo (2.12E-07) respectively. In Ibadan Sweet Kastina-Ala recorded the highest value of THQ for Pb (3.20E-03) and the lowest values were recorded in Konshisha and Vandeikya (1.45E-04) respectively, for Hg, the highest THQ value was also recorded in Katsina-Ala (1.80E-06) and the lowest in Konshisha (2.12E-07). In valencia, the THQ values for Pb were higher in Katsina-Ala (2.36E-03) and lower in Konshisha, Kwande, Ushongo and Vandeikya (1.45E-04) respectively, for Hg, Katsina-Ala recorded the highest value (1.44E-06) and Konshisha, Kwande, Ukum and Ushongo recorded the lowest (2.12E-07) respectively. The THQ values of Pb in some adults consuming vegetables irrigated with wastewater from an Urban Market in Zaria, Nigeria was reported in the range: 1- 28 [27]. THQ of Pb in some selected vegetables Marketed in Dutsin-Ma, Katsina State, Nigeria was reported in the range: 7.29E-05 – 4.98E-03 [30]. THQ of Pb in fruits cultivated in Kaduna State, Nigeria was reported in the range: 0.07 – 0.16 [28]. The orders of THQ (Men) of Pb and Hg in the orange varieties are: Washington > Valencia > Ibadan sweet and Ibadan sweet > Washington > Valencia, in Women, the orders of THQ for Pb and Hg in the orange varieties are: Washington > Valencia > Ibadan sweet and Ibadan sweet > Washington > Valencia. The reason may not be different as stated above.

Hazard Index (HI)

The HI, indicates the effects of all elements and is used to assess their health risks. Tables 1-6 above show the HI of the studied area due to consumption of orange fruits for both men and women. For men, the HI values are in the range: Washington (1.40E-03 - 2.92E-02); Ibadan sweet (7.71E-06 - 1.55E-02) and Valencia (7.05E-04 - 1.14E-02) while for women, the values are in the range: Washington (2.90E-04 - 6.03E-03); Ibadan sweet (1.45E-04 - 3.20E-03) and Valencia (1.45E-04 - 2.36E-03). The highest value of HI in men in washington was recorded in Katsina- Ala (2.92E-02) and lowest in Ushongo (1.40E-03), in Ibadan sweet, the highest value was recorded in Katsina-Ala (1.55E-02) and in Valencia the highest value is recorded in Ukum (1.14E-02) and the lowest in Konshisha, Kwande, Ushongo and Vandeikya (7.05E-04) respectively. The HI for Pb, Fe, Cu, Zn and Cd in fruits from Kaduna State, Nigeria was reported in range: 1.32 – 3.86 [28]. HI values of some vegetable irrigated with wastewater from Urban Market in Zaria, Nigeria were calculated and reported in the range: 10 – 51 [27]. HI values associated with the consumption of vegetables Marketed in Bahir Dar Town, Northwest Ethiopia was reported in the range: 3.66E-01 – 9.68E-01 [29]. The orders of HI in Men is Washington > Valencia > Ibadan sweet and in women it is in the order: Washington > Valencia > Ibadan sweet respectively were the same. The reason could be attributed to consumption rate being the same or different since variation is similar.

Conclusion

Studies conducted revealed that plants can accumulate heavy metals from the soil and also from agricultural activities such as chemical application (insecticides, herbicides and fertilizers). The level of heavy metals and their health risk on consumers especially in Men and Women in three orange varieties (Washington, Ibadan Sweet and Valencia) in some selected orchards in seven (7) Local Government Areas in Benue State indicates that the EDI for Pb and Hg were below the RfD values in the orange varieties which is evidence that no risk is associated with the consumption of these oranges. The THQ values calculated from consumption of orange varieties associated with heavy metals is less than 1, an indication that consumers are safe from non-carcinogenic effects. The HI values calculated in both Men and Women adults' consumers of these orange varieties were less than 1, implying that the population has no potential cancer risk arising from the consumption of these oranges studied but interestingly, the EDI, THQ and the HI values were higher in Men than Female revealing that men consume more oranges than the female because they are always working on the orchards. Therefore, we solicit that constant studies on these metals and many more are carried out on oranges to monitor the heavy metal contamination due to their bioaccumulation tendencies.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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