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Assessment of Heavy Metals Concentration in the Juice Extracts of Orange Fruits Sold Along Roadsides in Effurun and Warri Metropolis

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Abstract

Heavy metals contamination in the environment is a great concern in environmental studies. This is based on the fact that heavy metals can mobilize from the environment to the human body system, bioaccumulate and pose adverse impacts on human health. This study aimed at assessing the concentration of heavy metals such as Zn, Fe, Mn, Cu, Cd, Cr, Ni and Pb in the juice extracts of orange fruits (Citrus sinensis) sold along roadsides in Effurun and Warri metropolis. A comparative design was adopted in this study. Therefore, samples of orange fruits were obtained from roadside vendors in both Effurun and Warri metropolis. Orange fruits from standing orange trees were also collected along with the surround soil to deduce the source of heavy metals contamination in vended orange fruits within the study areas. The Flame Atomic Absorption Spectrometry technique was used to determine the metals concentration. Human health risk assessment indices for carcinogenic and non-carcinogenic risk assessment were used to analyse the level of heavy metals concentration in the fruit juices with Rtotal ranging from 2.42E-06 to 5.5E-05 and HI ranging from 1.72E-02 to 8.2E-04. Pearson's correlation coefficient was used to analyse the relationship between the heavy metals concentration in the standing orange fruits and their surrounding soil. Positive correlations ranging from 7.26E-01 - 9.87E-01 were found out. It is therefore, deduced from this findings that the contamination of heavy metals in the orange fruits sold along roadsides in Effurun and Warri metropolis were from the farm soil from which they were harvested.

Keywords: Assessment; heavy metals; juice extracts; orange fruits

Introduction

Orange fruit *(Citrus sinensis)* is an edible juicy fruit with great nutritional values. It is commonly sold in cities and villages among other fruits such as water melon, garden egg, banana, coconut, groundnut, etc. Orange fruit is a known natural source of vitamin-C (ascorbic acid) essential in human diet among other nutritional contents and benefits. Due to its sweet taste and flavour, it is consumed by both children and adults. According to [5, 18], fruit juices present a vital source of minerals and vitamins. Orange juice in particular has many beneficial health effects and is rich in vitamin C for the human body. It contains antioxidant and anti-inflammatory properties and thus possesses anti-diabetic effects and also increases the clearance of uric acid in the human body system. According to [14], orange fruits contain essential elements as well as toxic elements. The toxic elements in oranges are As, Cd, Pb, Al, U, and B, while the essential elements are Se, Cu, Ni, Co, Li, P, Sr, Mg, Cr, Mn, Fe, V, K, Na, and Ca. The latter are important for human health, while toxic elements are undesirable and/or harmful in excessive amounts, they buttressed.

Structurally, orange is an evergreen flowering tree generally growing to 9–15 m in height with a tap root system having several lateral branches and deep tap roots capable of absorbing water and nutrients from a depth of 3-6 feet in the ground [13]. This makes it easily adaptable to nutrient uptake within a wide range of the rhizosphere. It also has the ability to withstand a wide range of weather conditions and geological factors such as heavy rainfall, flooding and erosion and is thus grown in many tropical and subtropical regions in areas approximately located between latitudes of 35° north and 35° south [34].

Though, there are visible orange trees within Effurun and Warri, commercial orange fruits are mostly imported from other states and are marketed by traders along roadsides within the metropolis. Undoubtedly, the nature of the soil at which these oranges were cultivated, the method of cultivation, nitrification and preservation are unknown to members of the public and Effurun and Warri in particular. According to [10], oranges exposure to metals contamination may be as a result of cultivation in contaminated soil and polluted water. Orange contamination by heavy metals poses non-carcinogenic health risk as well as carcinogenic health risks to the public.

The discovery of oil in Nigeria led to great economic and industrial development, which in turn caused environmental pollution and metals contamination. Recent studies show that presently, the drinking water (including surface waters, underground waters and rainwater) [8, 15, 22], agricultural land [19, 29, 35] and air quality [6, 30, 38] have been affected adversely due to the numerous incidences of oil spillage from oil exploration and exploitation; and emission of gas from industrial activities and vehicles. Environmental pollution has thus become a great concern over the years due to its debilitating impacts on human health and the environment.

Heavy metals bioaccumulation in human beings is a gradual process, which may occur through ingestion of contaminated food sources, inhalation of contaminated air and/or having a thermal (body or skin) contacts with the contaminated sources [39]. Research review shows traces of heavy metals in plants tissues, which are the primary producers in the ecosystem through which animals including humans depend upon for food. Some studies show higher concentration of metals in food sources than regulatory standards while in some cases they are within or below recommended limits.

The accumulation of heavy metals in the biosphere and in living organisms and its corresponding impact on human health has become a global concern which has drawn the attention of many researchers, owing to their toxicity, longevity in the atmosphere, and ability to accumulate in the human body via bioaccumulation [24]. The accumulation of heavy metals and metalloids such as arsenic (As), mercury (Hg), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), selenium (Se) and zinc (Zn) in soils and plants poses many risks to human and ecosystem health [23]. According to the world health data report, in Nigeria, most of the highest-ranked causes of Death and Disability-adjusted Life Years (DALYs) are related to environmental risk factors [32]. On this note, efforts have been made by different researchers to determine the ecological and human health impact of specific heavy metals exposure in various matrices. In the same vein, world agencies such as USEPA and WHO/FAO have gone far to highlight the limit of specific heavy metals and other contaminates in food sources such as drinking water, fish, meat, and food crops. This is primarily to set a bench mark for contaminants moderations in various matrices above which control measure is required to prevent their ecological or human health impacts.

Remediation and prevention are well known measures to bring the concentration of contaminants in environmental media such as water, soil, air and food sources under international regulatory standards such as USEPA and FAO/WHO. Preventive measures are highly required due to the limited standard health facilities in our localities, which are not easily assessable and/or highly costly for the average citizen to afford. Therefore, the chances of survival are always lower for the “common man” thus leading to improper management and higher mortality rate caused by these diseases. Assessment of the quality of fruits is necessary to ensure proper monitoring of fruits consumed within a specific area and creating public awareness goes a long way in checkmating the occurrence of disease from heavy metals contamination. Surprisingly, this is limited in our local environment especially on orange fruits in Effurun and Warri metropolis, with a projected population of 1,378,864people in 2025 [26]. It is the concern of the health of the society that necessitated this study since food security is one of the great tools for public health safety. Therefore, the aim of this study is to assess the heavy metals concentration in orange fruits sold in Effurun and Warri metropolis.

Methodology

Materials and Sample Collection

This study employed a comparative approach which utilized various materials and equipment for sample collection, sample preparation and laboratory sample analysis (data collection). The study was carried out in Effurun and Warri metropolis, located within 5°30'47"N 5°43'00"E and 5°34'59"N 5°48'26"E. Effurun and Warri are two commercial cities where the local government secretariats of Uvwie Local Government Area and Warri-South Local Government Area are located respectively in Delta State, Nigeria. These local government areas share a common boundary with no clear distinction using physical description thus Google Earth was used to identify the boundary. There are various points at which the two cities are interconnected with roads. These roads include Warri-Effurun Road at 5°31'39"N 5°46'23"E, Airport road at 5°32'29"N 5°45'44"E, Link Road at 5°33'37"N 5°44'36"E, and NPA Express Road at 5°34'00"N 5°43'50"E. Due to these interconnections, there is free movement of people across the boundary without any form of obstruction. The map of the area of the study is shown in figure 2.1.

During sample collection, orange fruits were purchased from orange vendors in twenty [20] different locations along roadsides in Effurun and Warri metropolis. Orange samples from standing orange trees were also plucked in ten [10] different locations within Effurun and Warri metropolis. These were separated into pre-labelled polyethene bags. Again, soil samples were collected around the standing orange trees within Effurun and Warri metropolis. Soil samples were collected with matchet from the surface down to a depth of 30cm. This was done randomly within a radius of 1-5m from the orange tree.

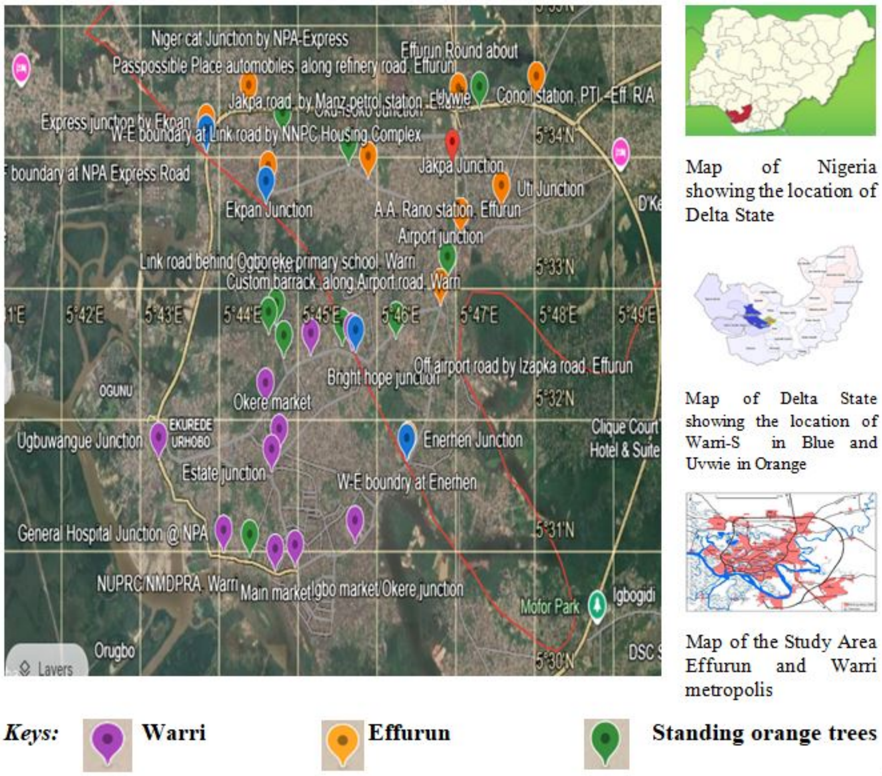

Figure 2.1: Map of the Study Area (Effurun and Warri metropolis) showing the location where vended orange samples were collected. Modelled from Google Earth at Camera 19km with 1:3000m scale

Orange Sample Preparation

The orange samples collected from each orange vendor were first washed with tap water and rinsed twice with distilled water, allowed to dry and peeled with knife to remove the epicarps while the mesocarps were further removed by hand peeling to expose the juicy endocarps. The endocarps were then cut open with knife, after which the seeds were removed with the knife. Then, the juicy endocarps were blended with electric blender and sieved into a container: a method adopted from [21]. The juice was further filtered gently using a muslin bag to obtain a clearer juice [27] into pre-labelled plastic container and stored in a refrigerator at 0^0C overnight.

In the laboratory, the samples were processed for easy sample analyses and data collection by Flame Atomic Absorption Spectrometry (FAAS) analyses for heavy metals. The orange juices were thus prepared in triplicates by "Dry-Ashing" method adapted from [28] using nitric acid (HNO_3) with minimal modification. 5ml from each orange sample were measured in triplicates by location into porcelain crucibles and evaporated on hot plate till dryness. The samples were then ashed in Muffle furnace (Searchtech Instruments, SX-5-12 model, USA) at a temperature of 550ºC for about 8 hours. The samples were then cooled in a desiccator after which 5ml of 65% nitric acid (HNO_3) was added, ensuring that all the ash came into contact with the acid and the with the use of hot plate the resultant solution was heated until the ash were completely dissolved. This was allowed to cool and diluted with 10ml of 0.1mol.L^{-1} nitric acid and filtered into 50ml volumetric flask and topped with distilled water to the mark.

Soil Sample Preparation

The soil samples collected from each location of standing orange tree were sun-dried in flat dishes. Large stones were hand-picked and the rest of the soil was pounded using clean and dry mortar and pestle (3). The soil samples were further grinded into finer powders on white tiles and smooth bottle. The fine powdered soils were then sieved using a 0.5mm sieve into pre-labelled polyethene bags and stored in a refrigerator at 0^0C overnight before taken to the laboratory for further preparation for Flame Atomic Absorption Spectrometry (FAAS) analysis.

In the laboratory, wet digestion was applied for the soil samples using Aqua-regia in ratio of 1:3 for HNO_3 and HCl by volume adapted from [25]. 1g of the finely grinded soil samples by location were digested in triplicates slowly with 20ml of freshly prepared aqua-regia (1:3) by volume of HNO_3 and HCl on a hot plate in a fume cupboard. After evaporation, HCl was added to the mixture and again evaporated until white fume appeared, indicating the complete digestion of the soil samples. The solution of the digested soil samples were filtered through Whatman No. 1 filter paper and diluted to a final volume of 50ml with distilled water in a volumetric flask.

Method of Data Collection

During data collection from the various matrixes i.e. juice extracts of orange fruits and soil samples, the absorbance levels of the various analytes were read using Atomic Absorption Spectrophotometer (Varian SpectrAA, 600 model, U.S.A.) with acetylene gas and air compressor while the metal concentrations were derived using calibration curves. The instrument is made of four major parts: the hollowed cathode lamp which produces the unique wavelength of the metal; nebulizer supplied with acetylene gas which mixes the sample, fuel and oxidant into fine aerosol and introduce them into the flame for atomization; monochromator which isolates the specific wavelength from the light source and removing scattered lights thereby introducing a narrow spectral line to the detector (photomultiplier tube). The detector on its part detects the amount of photons of the light exiting the monochromator and converts them to an electric signal which the read-out device i.e. monitor reads as total absorbance.

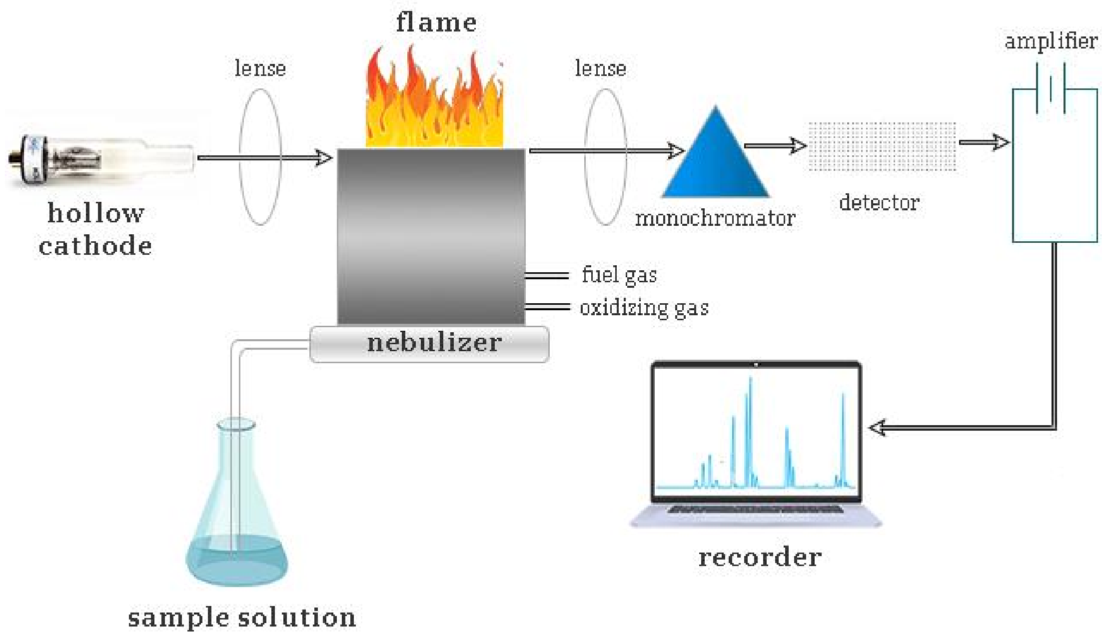

Figure 2.2: Instrumentation of Flame Atomic Absorption Spectroscopy

The instrument was first calibrated with metal standards of different concentrations. Working calibration standard solutions were prepared using pure grade metal solution purchased from Accustandards Inc. U.S.A. The recovery test of the total analytical procedures was also carried out for each metal analysed in the selected samples by spiking samples with aliquots of metal standards and reanalyzed using FAAS. Acceptable recoveries of 95.6%, 89.0%, 92.5%, 97.2%, 95.1%, 94.1%, 94.8% and 87.7% were obtained for Zn, Fe, Mn, Cu, Cd, Cr, Ni, and Pb respectively.

$$R = \frac{Cs - c}{s} x\ 100\%$$

Where,

R = Percentage recover

S = Concentration equivalent of analyte added to the sample

Cs = Metal content of the spiked sample

C = Metal content of non-spiked sample

Method of Data Analyses

The instruments for data analyses in this study include descriptive statistical tools such as range, mean and standard deviation. These were used to describe the level of heavy metals concentration in the juice extracts of orange fruits and the soil samples in each study site, between Effurun and Warri metropolis and published work of related matrixes and analytes.

Furthermore, the Pearson's correlation coefficient was used to analyse the relationship between the concentration of heavy metals between the soil samples and the orange juice samples in each site of standing orange trees. Correlation coefficient is an inferential statistical tool used to analyse the relationship between two variables: an independent (x) variable and a dependent (y) variable. In this study, the concentration of heavy metals in the standing orange fruits is the dependent variable while the heavy metals concentration in the soil is the independent variable. The use of correlation coefficient in this was basically to deduce probable sources of metal contaminations in the orange fruits sold along roadsides.

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

Where,

r = Correlation coefficient

= Metal concentration of soil

= Mean concentration of metals in soil

= Metal concentration of metal in orange fruit juice

= Mean concentration of metals in orange fruit juice

Finally, human health risk assessment indices were used to analyses the metal concentration over a lifetime exposure. Thus, carcinogenic risk assessment and non-carcinogenic risk assessment indices were used for this analysis and the outcome characterized in relation to regulatory bodies. The cancer risk was assessed as the cumulative cancer risk (R_{total}) after determining the target cancer risk (TRC) i.e. lifetime average daily dose (LADD) of the carcinogens which are cadmium (Cd), chromium (Cr), nickel (Ni) and lead (Pb) in this study: a method adapted from Abbasi et al. (1, 31, 2 and 16).

$$TCR = \frac{Cb \times 1 \times 10^{-3} \times CPS \times \times EFr \times EDtot}{BWa \times ATc}$$

$$R_{total} = \sum TCR$$

Where:

TRC = Target cancer risk

Cb = Concentration of heavy metals in mg/kg

I= Average daily consumption through ingestion pathways (kg/person/day)

CPS = Carcinogens potency slope oral ((µg/g/day))

Efr = Exposure frequency (days/year)

EDtot= Total exposure duration (years)

BWa = Average body weight (kg)

ATc = Averaging time carcinogens (day)

Rtotal = Cumulative or total cancer risk

The non-carcinogenic risk assessment of the heavy metals in the juice extracts of oranges was determined using the Estimated Dose Intake (EDI), Target Hazard Quotient (THQ) and the Target Hazard Index (HI) adapted from (1, 31, 2 and 16). The estimated dose intake is a term used to describe the average daily dose of metals consumption due to exposure to various pathways. The target hazard quotient (THQ) is a term used to describe health risks of a single metal while the risk of exposure to two or more metals is described as hazard index (HI) term.

$$THQ = \frac{C \times I \times 10^{-3} \times EFr \times EDtot}{RfD \times Bw \times ATn} \qquad HI = \sum_{i}^{n} THQ$$

Where:

THQ = Target hazard quotient

C = Concentration of heavy metal in mg/kg

I = Average daily consumption through ingestion pathways (kg/person/day)

Efr = Exposure frequency (days/year)

EDtot = Total exposure duration (years)

RfD = Reference dose in (µg/g/day)

BWa = Average body weight (kg)

ATc = Averaging time carcinogens (day)

HI = Target hazard index

Results and Discussion

Heavy Metals Concentration in Juice Extracts of Orange Fruits

The concentration of heavy metals in the juice extracts of oranges sold along roadsides in Effurun (table 3.1) and Warri (table 3.2) metropolis are presented and discussed in this section. The level of concentration of each heavy metal is further discussed comparatively.

Table 3.1: Concentration (mg/kg) of Heavy metals in orange fruits sold along roadsides in Effurun

Heavy metals	EFF 001	EFF 002	EFF 003	EFF 004	EFF 005	EFF 006	EFF 007	EFF 008	EFF 009	EFF 010	Min	Max	Mean
Zn	12.070	2.206	1.570	4.403	8.950	1.676	12.050	12.300	6.098	9.913	1.570	12.300	7.124
Fe	13.480	6.811	4.489	5.588	3.844	4.566	4.933	79.460	7.563	21.270	3.844	79.460	15.200
Mn	0.790	0.655	0.087	1.040	0.385	0.626	1.108	1.541	1.281	0.694	0.087	1.541	0.821
Cu	0.453	0.992	0.241	2.640	0.597	1.676	3.719	1.869	2.948	1.185	0.241	3.719	1.632
Cd	0.626	0.067	0.019	0.125	0.000	0.106	0.164	0.067	0.000	0.039	0.000	0.626	0.121
Cr	0.877	0.260	0.019	0.000	0.048	0.000	0.000	0.000	0.000	0.039	0.000	0.877	0.124
Ni	0.771	1.204	0.212	1.098	0.780	1.195	0.472	1.975	1.146	2.004	0.212	2.004	1.086
Pb	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 3.2: Concentration (mg/kg) of Heavy metals in orange fruits sold along roadsides in Warri

Heavy metals	WAR 001	WAR 002	WAR 003	WAR 004	WAR 005	WAR 006	WAR 007	WAR 008	WAR 009	WAR 010	Min	Max	Mean
Zn	3.064	10.337	7.659	5.915	3.526	4.653	2.669	2.457	5.453	6.301	2.457	10.337	5.203
Fe	4.489	6.667	10.501	5.241	8.449	9.528	9.489	12.418	10.135	5.477	4.489	12.418	8.239
Mn	1.050	1.599	1.079	1.060	1.301	1.830	2.620	2.447	2.466	0.800	0.8	2.62	1.625
Cu	1.339	1.946	1.994	2.447	7.909	6.946	4.094	5.636	5.819	2.303	1.339	7.909	4.043
Cd	0.096	0.193	0.116	0.212	0.048	0.279	0.000	0.125	0.096	0.096	0	0.279	0.126
Cr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0	0	0.000
Ni	1.435	1.965	1.657	1.792	0.356	3.227	1.532	0.578	1.118	2.331	0.356	3.227	1.599
Pb	0.135	0.000	0.000	0.067	0.019	0.000	0.000	0.000	0.000	0.255	0	0.255	0.048

Concentrations of Zinc (Zn) in Orange Fruit Juice Extracts

In Effurun, the minimum and maximum concentrations of zinc (Zn) were found in EFF003 and EFF008 having 1.570mg/kg and 12.300mg/kg respectively while the average concentration was found to be 7.124mg/kg. In Warri, the minimum and maximum concentrations of Zn were found in WAR008 and WAR002 having 2.457mg/kg and 10.337mg/kg respectively while the average concentration was found to be 5.203mg/kg. This implies that the average concentration of Zn in the juice extracts of oranges in Effurun (7.124mg/kg) is higher than that of the average concentration of Zn in the juice extracts of oranges in Warri (5.203mg/kg). The average concentration of Zn in the juice extracts of the oranges in both Effurun and Warri metropolis are far less than the permissible limit (99.40mg/kg) recommended by FAO/WHO [21, 12].

Concentrations of Iron (Fe) in Orange Fruit Juice Extracts

In Effurun, the minimum and maximum concentrations of Iron (Fe) were found in EFF005 and EFF008 having 3.844mg/kg and 79.460mg/kg respectively while the average concentration was found to be 15.200mg/kg. In Warri, the minimum and maximum concentrations of Fe were found in WAR001 and WAR008 having 4.489mg/kg and 12.418mg/kg respectively while the average concentration was found to be 8.239mg/kg. This implies that the average concentration of Fe in the juice extracts of oranges in Effurun (15.200mg/kg) is higher than that of the average concentration of Fe in the juice extracts of oranges in Warri (8.239mg/kg). The average concentration of Fe in the juice extracts of the oranges in both Effurun and Warri metropolis are higher than the permissible limit (0.80mg/kg) recommended by FAO/WHO [41].

Concentrations of Manganese (Mn) in Orange Fruit Juice Extracts

In Effurun, the minimum and maximum concentrations of manganese (Mn) were found in EFF003 and EFF008 having 0.087mg/kg and 1.541mg/kg respectively while the average concentration was found to be 0.821 mg/kg. In Warri, the minimum and maximum concentration of Mn were found in WAR010 and WAR007 having 0.800mg/kg and 2.620mg/kg respectively while the average concentration was found to be 1.625mg/kg. This implies that the average concentration of Mn in the juice extracts of oranges in Effurun (0.821mg/kg) is less than that of the average concentration of Mn in the juice extracts of oranges in Warri (1.625mg/kg). The average concentration of Mn in the juice extracts of the oranges in both Effurun and Warri metropolis are slightly higher than 0.30mg/kg which is the permissible limit recommended by FAO/WHO [21].

Concentrations of Copper (Cu) in Orange Fruit Juice Extracts

In Effurun, the minimum and maximum concentrations of copper (Cu) were found in

EFF003 and EFF007 having 0.241mg/kg and 3.719mg/kg respectively while the average concentration was found to be 1.632mg/kg. In Warri, the minimum and maximum concentrations of Cu were found in WAR001 and WAR005 having 1.339mg/kg and 7.909mg/kg respectively while the average concentration was found to be 4.043mg/kg. This implies that the average concentration of Cu in the juice extracts of oranges in Effurun (1.632mg/kg) is less than that of the average concentration of Cu in the juice extracts of oranges in Warri (4.043mg/kg). The average concentration of Cu in the juice extracts of the oranges in both Effurun and Warri metropolis are higher than the permissible limit (0.50mg/kg) recommended by FAO/WHO [21].

Concentrations of Cadmium (Cd) in Orange Fruit Juice Extracts

In Effurun, the minimum concentrations of cadmium (Cd) were found in EFF005 and EFF009 where nothing was detected while the maximum concentration was detected in EFF001 with a concentration of 0.626mg/kg. The average concentration was found to be 0.121mg/kg. In Warri, the minimum and maximum concentrations of Cd were found in WAR007 and WAR006 having 0.00mg/kg and 0.279mg/kg respectively while the average concentration was found to be 0.126 mg/kg. This implies that the average concentration of Cd in the juice extracts of oranges in Effurun (0.121mg/kg) is less than that of the average concentration of Cd in the juice extracts of oranges in Warri (0.126mg/kg). The average concentration of Cd in the juice extracts of the oranges in both Effurun and Warri metropolis are slightly above the permissible limit (0.10mg/kg) recommended by FAO/WHO [21].

Concentrations of Chromium (Cr) in Orange Fruit Juice Extracts

In Effurun, the minimum concentrations of chromium (Cr) were found in EFF004, EFF006, EFF007, EFF008 and EFF009 where nothing was detected while the maximum concentration was detected in EFF001 with a concentration of 0.877mg/kg. The average concentration was found to be 0.124mg/kg. Thus, the average concentration of Cr in the juice extracts of oranges in Effurun (0.124mg/kg) a bit higher than the permissible limit (0.10mg/kg) recommended by FAO/WHO (21). In Warri, Cr was not detected in any of the samples.

Concentrations of Nickel (Ni) in Orange Fruit Juice Extracts

In Effurun, the minimum and maximum concentrations of nickel (Ni) were found in EFF003 and EFF010 having 0.212mg/kg and 2.004mg/kg respectively while the average concentration was found to be 1.086mg/kg. In Warri, the minimum and maximum concentration of Ni were found in WAR005 and WAR006 having 0.356mg/kg and 3.227mg/kg respectively while the average concentration was found to be 1.599mg/kg. This implies that the average concentration of Ni in the juice extracts of oranges in Effurun (1.086mg/kg) is less than that of the average concentration of Ni in the juice extracts of oranges in Warri (1.599mg/kg). The average concentration of Ni in the juice extracts of the oranges in both Effurun and Warri metropolis are slightly above the permissible limit (0.14mg/kg) recommended by FAO/WHO [21].

Concentrations of Lead (Pb) in Orange Fruit Juice Extracts

Lead (Pb) was not detected in any of the samples in Effurun. In Warri, Pb was detected in four samples with WAR010 having the maximum concentration with 0.255mg/kg. The average concentration in the Warri samples was found to be 0.048mg/kg which is below the permissible limit (0.1mg/kg) recommended by FOA/WHO [41].

Human Health Risk Assessment

The human health risk assessment (HHRA) implies the assessment of potential health risk of humans due to the exposure to stressors over a life time. In this study the HHRA of the heavy metal contamination of the orange juice extracts was determined using Carcinogenic Risk Assessment Indices (CRAI) and Non-carcinogenic Risk Assessment Indices (NcRAI).

Carcinogenic Risk Assessment

Cancer is a deadly disease that affects both adults and children in Nigeria and abroad. According to [37], cancer affect all ages ranging from 1-98years. In Nigeria and other African countries, high cases of mortality due to cancer are contributed to the unprepared nature of most health systems, the high cost of treatment, the absence of healthcare providers in remote villages and towns, and the lack of access to timely and high-quality diagnosis and treatment [33]. Therefore, the carcinogenic risk assessment was conducted on both adults and children to determine the potential risk of exposure to the various carcinogens through consumption of contaminated orange fruits with the observed concentrations in Effurun (table 3.3 & 3.4) and Warri metropolis (table 3.5 & 3.6).

Table 3.3: Lifetime Average Daily Dose (LADD) and Total Cancer Risk (Rtotal) for Children in Effurun

Carcinogens	EFF001	EFF002	EFF003	EFF004	EFF005	EFF006	EFF007	EFF008	EFF009	EFF010
Cd	3.81E-05	4.08E-06	0.00000118	7.61E-06	0	6.46E-06	9.99E-06	4.08E-06	0	2.38E-06
Cr	4.24E-06	1.26E-06	9.3E-08	0	2.32E-07	0	0	0	0	1.89E-07
Ni	1.27E-05	0.0000198	0.00000348	0.000018	0.0000128	0.0000196	7.76E-06	0.0000325	0.0000188	0.0000329
Pb	0	0	0	0	0	0	0	0	0	0

Ttotal	0.000055	0.0000251	0.00000475	0.0000257	0.0000131	0.0000261	0.0000177	0.0000365	0.0000188	0.0000355

Table 3.4: Lifetime Average Daily Dose (LADD) and Total Cancer Risk (Rtotal) for Adult in Effurun

Carcinogens	EFF001	EFF002	EFF003	EFF004	EFF005	EFF006	EFF007	EFF008	EFF009	EFF010
Cd	0.0000194	2.08E-06	5.99E-07	3.88E-06	0	3.29E-06	5.09E-06	2.08E-06	0	1.21E-06
Cr	2.16E-06	6.41E-07	4.76E-08	0	1.18E-07	0	0	0	0	9.61E-08
Ni	6.46E-06	1.01E-05	1.78E-06	0.0000092	0.00000654	0.00001	3.95E-06	0.0000165	9.61E-06	0.0000168
Pb	0	0	0	0	0	0	0	0	0	0
Rtotal	0.0000281	1.28E-05	2.42E-06	0.0000131	0.00000665	1.33E-05	9.05E-06	0.0000186	9.61E-06	0.0000181

In Effurun, the cumulative cancer risk (R_{total}) of children exposure to heavy metals contamination through consumption of oranges in Eff001 is 5.5E-05, Eff002 is 2.51E-05, Eff003 is 4.75E-06, Eff004 is 2.57E-05, Eff005 is 1.31E-05, Eff006 is 2.61E-05, Eff007 is 1.77E-05, Eff008 is 3.65E-05, Eff009 is 1.88E-05 while Eff010 is 3.55E-05. To the adults, the cumulative cancer risk due to exposure to heavy metals contamination through consumption of oranges in Eff001 is 2.81E-05, Eff002 is 1.28E-05, Eff003 is 2.42E-06, Eff004 is 1.31E-05, Eff005 is 6.65E-06, Eff006 is 1.33E-05, Eff007 is 9.05E-06, Eff008 is 1.86E-05, Eff009 is 9.61E-06 while Eff010 is 1.81E-05.

According to the USEPA (2006), the acceptable range of R_{total} of carcinogenic risk assessment is between 1×10^{-4} to 1×10^{-6}, R_{total} greater than 1×10^{-4} is considered unacceptable and R_{total} less than 1×10^{-6} is said to be insignificant i.e. not likely to pose any significant health risk. This implies that all the R_{total} of heavy metals in the juice extracts of oranges estimated for children in Effurun are within the acceptable limit having a minimum R_{total} of 4.75E-06 in Eff003 and maximum R_{total} of 5.5E-05 in Eff001. Similarly, all the R_{total} of heavy metals in the juice extracts of oranges estimated for adult in Effurun are within the acceptable limit having a minimum R_{total} of 2.42E-06 in Eff003 and maximum R_{total} of 2.81E-05 in Eff001.

Table 3.5: Lifetime Average Daily Dose (LADD) and Total Cancer Risk (TCR) for Children in Warri

Carcinogens	WAR001	WAR002	WAR003	WAR004	WAR005	WAR006	WAR007	WAR008	WAR009	WAR010
Cd	5.85E-06	1.18E-05	7.06E-06	0.0000129	0.00000292	0.000017	0	7.61E-06	5.85E-06	5.85E-06
Cr	0	0	0	0	0	0	0	0	0	0
Ni	0.0000236	3.23E-05	0.0000272	0.0000294	0.00000585	0.000053	0.0000252	0.0000095	0.0000184	0.0000383
Pb	1.1E-08	0	0	6E-09	2E-09	0	0	0	0	2.1E-08
Rtotal	0.0000294	0.000044	0.0000343	0.0000424	0.00000878	0.00007	0.0000252	0.0000171	0.0000242	0.0000442

In comparison, the minimum and maximum R_{total} for both children and adults in Effurun were found in Eff003 and Eff001 respectively. The R_{total} for both children and adults are all within the acceptable limit as prescribed by USEPA i.e. between 1×10^{-4} to 1×10^{-6}. The implication is that there is likelihood of people developing cancer over a lifetime due to exposure to heavy metals through consumption of contaminated oranges as observed in Effurun. The R_{total} for children is greater than that of the R_{total} for adults in each of the locations in Effurun. This implies that the children are at greater risk of developing cancer than adults due to exposure to heavy metals through consumption of contaminated oranges.

Table 3.6: Lifetime Average Daily Dose (LADD) and Total Cancer Risk (TCR) for Adult in Warri

Carcinogens	WAR001	WAR002	WAR003	WAR004	WAR005	WAR006	WAR007	WAR008	WAR009	WAR010
Cd	2.98E-06	5.99E-06	0.0000036	6.58E-06	0.00000149	8.66E-06	0	0.00000388	0.00000298	2.98E-06
Cr	0	0	0	0	0	0	0	0	0	0
Ni	0.000012	0.0000165	0.0000139	0.000015	0.00000298	0.000027	0.0000128	0.00000484	0.00000937	0.0000195
Pb	5.66E-09	0	0	2.81E-09	7.96E-10	0	0	0	0	1.07E-08
Rtotal	0.000015	0.0000225	0.0000175	0.0000216	0.00000447	0.0000357	0.0000128	0.00000872	0.0000123	0.0000225

In Warri, the cumulative cancer risk of children exposure to heavy metals contamination through consumption of oranges in War001 is 2.94E-05, War002 is 4.4E-05, War003 is 3.43E-05, War004 is 4.24E-05, War005 is 8.78E-06, War006 is 7E-05, War007 is 2.52E-05, War008 is 1.71E-05, War009 is 2.42E-05, while War010 is 4.42E-05. To the adults, the cumulative cancer risk due to exposure to heavy metals contamination through consumption of oranges in WAR001 is 1.50E-05, WAR002 is 2.25E-05, WAR003 is 1.75E-05, WAR004 is 2.16E-05, WAR005 is 4.47E-06, WAR006 is 3.57E-05, WAR007 is 1.28E-05, WAR008 is 8.72E-06, WAR009 is 1.23E-05 while WAR010 is 2.25E-05.

This implies all the R_{total} of heavy metals in the juice extracts of oranges estimated for children in Warri are within the acceptable limit having a minimum R_{total} of 8.78E-06 in WAR005 and maximum R_{Total} of 7E-05 in WAR006. Similarly, to the adults, the R_{total} of heavy metals in the juice extracts of oranges estimated for adult in Warri are within the acceptable limits having a minimum R_{total} of 4.47E-06 in War005 and maximum R_{total} of 3.57E-05 in WAR006.

In comparison, the minimum and maximum R_{total} for both children and adults in Warri were found in WAR005 and WAR006 respectively. The R_{total} for both children and adults are all within the acceptable limit as prescribed by USEPA i.e. between 1 x 10^{-4} to 1x 10^{-6}. The implication is that there is likelihood of people developing cancer over a lifetime due to exposure to heavy metals through consumption of contaminated oranges as observed in Warri. The R_{total} for children is greater than that of the R_{total} for adults in each of the locations in Warri as in Effurun. This implies that the children are more likely to develop cancer than adults due to exposure to heavy metals through consumption of contaminated oranges.

Contrary to (2), in both adults and children, the calculated cancer risk (CR) values of Pb were found to be 0.0005378 and 0.018824 respectively for citrus nectar a value more than the prescribed limit by USEPA i.e. 1 x 10^{-4} to 1x 10^{-6}. Similarly, Yaradua1et al (2019), reported the cumulative cancer risk (ΣILCR>10^{-3}) in all the studied pepper fruits reaching the moderate risk limit in adults, while in children it is above the moderate risk limit (>10^{-2}).

Non-carcinogenic Risk Assessment

Apart from cancer, there are other chronic diseases that are traced to metal contamination. These include mental illness, heart-diseases, respiratory disorder etc. The non-carcinogenic health risk assessment is used to determine any potential adverse health effect other than cancer that may result from metal exposure over a lifetime. The non-carcinogenic risk assessment of the heavy metals in the juice extracts of oranges was determined using the Estimated Dose Intake (EDI), Target Hazard Quotient (THQ) and the Target Hazard Index (HI) adapted from [1, 2, 16, 31]. The estimated dose intake is the average daily dose of consumption of the metals due to exposure to various pathways such as ingestion, inhalation and dermal contact. The target hazard quotient (THQ) is a term used to describe health risks of a single metal while the risk of exposure to two or more metals are described as hazard index (HI) term. In this section, effort is made to analyse the potential non-carcinogenic health risk of both children and children due to exposure to heavy metals through consumption of contaminated oranges in Effurun (table 3.7 & 3.8) and Warri Metropolis (table 3.9 & 3.10).

The target hazard index of heavy metal exposure to children in EFF001 is 0.01719, EFF002 is 0.00549, EFF003 is 0.001199, EFF004 is 0.005582, EFF005 is 0.0026, EFF006 is 0.004853, EFF007 is 0.005831, EFF008 is 0.010254, EFF009 is 0.004072 while EFF010 is 0.006593. The minimum and maximum HI was found in EFF003 with 0.001199 and EFF001 with 0.01719 respectively. For adults, the target hazard index of heavy metal exposure in EFF001 is 0.00548, EFF002 is 0.00175, EFF003 is 0.000382, EFF004 is 0.001779, EFF005 is 0.000828, EFF006 is 0.001546, EFF007 is 0.001858, EFF008 is 0.003267, EFF009 is 0.001297 while EFF010 is 0.002101. The minimum and maximum HI were found in EFF003 with 0.000382 and EFF001 with 0.00548 respectively. According to the USEPA HI < 1 is acceptable (unlikely to experience adverse health effects) while HI>1 is unacceptable (adverse health effects may occur). This implies that adverse health effects may not result in adults from consumption of orange fruits with the observed metal contaminations in Effurun as the HI estimated in all the various locations are less than 1.

Table 3.7: Target Hazard Quotient and Hazard Index (HI) Children in Effurun

Metals	EFF001	EFF002	EFF003	EFF004	EFF005	EFF006	EFF007	EFF008	EFF009	EFF010
Zn	0.00062	0.00011	0.000081	0.000227	0.000461	0.0000864	0.000621	0.000634	0.000314	0.000511
Fe	0.0007	0.00035	0.000231	0.000288	0.000198	0.000235	0.000254	0.004097	0.00039	0.001097
Mn	0.0000873	0.0000724	0.00000958	0.000115	0.0000425	0.0000692	0.000122	0.00017	0.000142	0.0000767
Cu	0.00018	0.00038	0.0000931	0.001021	0.000231	0.000648	0.001438	0.000723	0.00114	0.000458
Cd	0.00968	0.00104	0.000299	0.001933	0	0.001639	0.002537	0.001036	0	0.000603
Cr	0.00452	0.00134	0.0000995	0	0.000247	0	0	0	0	0.000201
Ni	0.0014	0.00219	0.000386	0.001998	0.001419	0.002174	0.000859	0.003594	0.002086	0.003646
Pb	0	0	0	0	0	0	0	0	0	0
HI	0.01719	0.00549	0.001199	0.005582	0.0026	0.004853	0.005831	0.010254	0.004072	0.006593

Table 3.8: Target Hazard Quotient and Hazard Index (HI) for Adults in Effurun

Metals	EFF001	EFF002	EFF003	EFF004	EFF005	EFF006	EFF007	EFF008	EFF009	EFF010
Zn	0.000198	0.0000362	0.0000258	0.0000723	0.000147	0.0000275	0.000198	0.000202	0.0001	0.000163
Fe	0.000221	0.000112	0.0000738	0.0000918	0.0000632	0.000075	0.000081	0.001305	0.000124	0.000349
Mn	0.0000278	0.0000231	0.00000305	0.0000366	0.0000136	0.000022	0.000039	0.0000542	0.0000451	0.0000244
Cu	0.0000558	0.000122	0.0000297	0.000325	0.0000736	0.000207	0.000458	0.00023	0.000363	0.000146
Cd	0.003085	0.00033	0.0000951	0.000616	0	0.000522	0.000808	0.00033	0	0.000192
Cr	0.001441	0.000427	0.0000317	0	0.0000789	0	0	0	0	0.0000641
Ni	0.000447	0.000698	0.000123	0.000637	0.000452	0.000693	0.000274	0.001145	0.000665	0.001162
Pb	0	0	0	0	0	0	0	0	0	0
HI	0.005476	0.001749	0.000382	0.001779	0.000828	0.001546	0.001858	0.003267	0.001297	0.002101

In comparison, the HI of children is higher than that of adults in all the sample locations. The minimum and maximum HI for both children and adults are found in EFF003 and EFF001 respectively. HI in both children and adults are within the acceptable limit of less than 1.00 implying no risk of development of adverse health effect on children and adults due to exposure to orange fruit with the observed concentrations. This is similar to the work of (2) with HI <1 and thus concluded safe in consumption of citrus juice or nectar if not exceeded the observed metal concentrations. Other related reports include (1) in processed fruit's products, (4) on rice stalk and the grains. On the contratry, HI>1 was estimated by [36] in fruit jams.

In Warri, the target hazard index of heavy metal exposure to children in WAR001 is 0.00564, WAR002 is 0.00837, WAR003 is 0.006636, WAR004 is 0.008437, WAR005 is 0.005283, WAR006 is 0.013806, WAR007 is 0.005287, WAR008 is 0.0062, WAR009 is 0.006845 while WAR010 is 0.008298. The minimum and maximum HI was found in WAR005 with 0.005283 and WAR006 with 0.013806 respectively. For adults, the target hazard index of heavy metal exposure in WAR001 is 0.0018, WAR002 is 0.00267, WAR003 is 0.002115, WAR004 is 0.002689, WAR005 is 0.001683, WAR006 is 0.004399, WAR007 is 0.001685, WAR008 is 0.001976, WAR009 is 0.002181 while WAR010 is 0.002644. The minimum and maximum HI were found in WAR005 with 0.001683 and WAR006 with 0.004399 respectively.

Table 3.9: Target Hazard Quotient and Hazard Index (HI) for Children in Warri

Metals	WAR001	WAR002	WAR003	WAR004	WAR005	WAR006	WAR007	WAR008	WAR009	WAR010
Zn	0.0002	0.0005	0.0004	0.0003	0.0002	0.0002	0.0001	0.0001	0.0003	0.0003
Fe	0.0002	0.0003	0.0005	0.0003	0.0004	0.0005	0.0005	0.0006	0.0005	0.0003
Mn	0.0001	0.0002	0.0001	0.0001	0.0001	0.0002	0.0003	0.0003	0.0003	0.0000884
Cu	0.0005	0.0008	0.0008	0.0009	0.0031	0.003	0.002	0.002	0.002	0.0009
Cd	0.001	0.003	0.002	0.003	0.0007	0.004	0	0.002	0.001	0.0015
Cr	0	0	0	0	0	0	0	0	0	0
Ni	0.003	0.004	0.003	0.003	0.0006	0.006	0.003	0.001	0.002	0.0042
Pb	0.0005	0	0	0.0003	0.0000735	0	0	0	0	0.001
HI	0.006	0.008	0.007	0.008	0.0053	0.014	0.005	0.006	0.007	0.0083

Table 3.10: Target Hazard Quotient and Hazard Index (HI) for Adults in Warri

Metals	WAR001	WAR002	WAR003	WAR004	WAR005	WAR006	WAR007	WAR008	WAR009	WAR010
Zn	0.0000503	0.00017	0.00013	0.0000972	0.0000579	0.0000764	0.0000438	0.0000404	0.0000896	0.0001
Fe	0.0000737	0.00011	0.00017	0.0000861	0.00014	0.00016	0.00016	0.000204	0.00017	0.00009
Mn	0.000037	0.0000563	0.000038	0.0000373	0.0000458	0.0000644	0.0000922	0.0000861	0.0000868	0.0000282
Cu	0.00017	0.00024	0.00025	0.0003	0.00098	0.00086	0.0005	0.000694	0.00072	0.0003
Cd	0.00047	0.00095	0.00057	0.00105	0.00024	0.00138	0	0.000616	0.00047	0.0005
Cr	0	0	0	0	0	0	0	0	0	0
Ni	0.00083	0.00114	0.00096	0.00104	0.00021	0.00187	0.00089	0.000335	0.00065	0.0014
Pb	0.00017	0	0	0.0000826	0.0000234	0	0	0	0	0.0003
HI	0.0018	0.00267	0.00212	0.00269	0.00168	0.0044	0.00169	0.001976	0.00218	0.0026

According to the USEPA HI < 1 is acceptable (unlikely to experience adverse health effects) while HI>1 is unacceptable (adverse health effects may occur). This implies that adverse health effects may not result in children from consumption of orange fruits with the observed metal contaminations in Warri as the HI estimated in all the various locations are less than 1.

In comparison, the HI of children is higher than that of adults in all the sample locations. The minimum and maximum HI for both children and adults are found in WAR005 and WAR006 respectively. HI in both children and adults are within the acceptable limit of less than 1 implying no risk of development of adverse health effect on children and adults du e to exposure to orange fruit with the observed concentrations. This is similar to the work of (2) with HI <1 and thus concluded safe in consumption of citrus juice or nectar if not exceeded the observed metal concentrations. Other related reports include (1) in processed fruit's products, (4) on rice stalk and the grains. On the contratry, HI>1 was estimated by [36] in fruit jams.

With special emphasis to metals toxicity and organ dysfunction, lead has deblitatiting effects on all organs but has the greatest influence on the kidneys. Acute lead nephropathy causes proximal tubular dysfunction, which invariably leads to glomerulonephritis and renal failure as a whole [24]. Chronic exposure to lead is toxic to the liver cells, which may cause depletion of glycogen in the liver and cellular infiltration, which according to [17] can result in chronic liver cirrhosis. Nevertheless, lead was not found in any of the orange samples in Effurun and the average concentration of lead in the orange samples in Warri was found to be 0.048mg/kg which is below the permissible limit (0.1mg/kg) recommended by FOA/WHO [41]. Cadmium has adverse effect on the renal cortex of the kidney and the liver [9]. Acute exposure to cadmium causes a variety of hepatic dysfunctions. Cadmium also changes the cellular redox balance, which causes oxidative stress and hepatocellular damage and liver failure [40]. In this study, the average concentration of Cadmium in the juice extracts of the oranges in Effurun (0.121mg/kg) as well as the average concentration of cadmium in Warri metropolis (0.126mg/kg) are slightly above 0.10mg/kg which is the permissible limit recommended by FAO/WHO [21] and thus need some attentions.

Correlation coefficient between heavy metals concentrations in standing orange fruits and their surrounding soil metal concentrations

The Pearson's correlation coefficient was used in this study. The analysis of the concentration of heavy metals in orange fruits and their surrounding soil show very high positive correlations in all the ten [10] sites using Pearson's correlation coefficient (table 3.11). This implies that the concentration of heavy metals in the standing orange fruits is due to increase in heavy metals concentration in the soil.

Table 3.11: Pearson's Correlation coefficient between concentration of heavy metals in standing orange fruits and their surrounding soil

Site	Calculated values	Table value at 5% level of significance	Decision
Site001	0.97003	0.738	Acceptable
Site002	0.976092	0.738	Acceptable
Site003	0.735551	0.738	Not-acceptable
Site004	0.898166	0.738	Acceptable
Site005	0.853404	0.738	Acceptable
Site006	0.796141	0.738	Acceptable
Site007	0.884655	0.738	Acceptable
Site008	0.948236	0.738	Acceptable
Site009	0.726461	0.738	Not-acceptable
Site010	0.986705	0.738	acceptable

The strongest correlation was found in Site010 with a correlation coefficient of 0.986705 while the weakest correlation coefficient was found in site009 with a correlation coefficient of 0.726461. In comparison, positive correlation was determined in the work of [7] on soil and tomatoes with a perfect correlation of 1.00.

According to the principle of decision making, the correlation coefficient should be accepted if the calculated value is greater than the table value at a specific level of significant. In this study, the calculated value of Site001 (0.97003), Site002 (0.976092), Site004 (0.898166), Site005 (0.853404), Site006 (0.796141), Site007 (0.884655), Site008 (0.948236) and Site010 (0.986705) are greater than the table values of 0.738 at 95% level of significant. Therefore, the correlation coefficient is accepted and agrees with the fact that the concentration of heavy metals in the orange fruits is a consequence of the increase in concentration of heavy metals in the soil. Nevertheless, in Site003 (0.735551) and Site009 (0.726461), the calculated values are less than the table value of 0.738 at 95% level of significant. Therefore, the correlation coefficient is not accepted and disagrees with the fact that the increase in concentration of heavy metals in the orange fruit is a caused totally by the increase in the concentration of heavy metals in the soil. Thereby, suggesting other contributing factors which may include stomatal and lenticular deposit, absorption and circulation. Heavy metals from the atmosphere can deposit and settle on the surfaces of leafy vegetables and subsequently be absorbed into their tissues [11]. Possible reasons for the non-significant correlations in Site003 and Site009 may be that the orange plantations are located in close proximity with sources of air pollution which may include a road with busy traffic, factories, filling station, artisanal refineries and even refinery with gas flaring.

Summary and Conclusion

In this study, all the samples were collected within Effurun and Warri metropolis. Orange fruits were collected from vendors along the roadsides in twenty [20] different locations. These were juiced and analysed using the Flame Atomic Absorption Spectrophotometer for heavy metals concentration. The heavy metals analysed are Zn, Fe, Mn, Cu, Cd, Cr, Ni and Pb. Orange fruits from standing orange trees were also sampled along with the surrounding soil randomly within a radius range of 1-5m. These were also prepared and analysed using Flame Atomic Absorption Spectrophotometer for heavy metals concentrations. From the analyses of the data, this study shows that there are some levels of heavy metals contamination in the juice extracts of oranges sold in Effurun and Warri metropolis. Some observed metal concentrations exceed the recommended concentrations by USEPA and therefore implies that they may lead to health issues over time if oranges with such metal concentrations are continuously imported to the metropolis. For instance, the average concentration of Fe in the juice extracts of the oranges in both Effurun and Warri metropolis are higher than the permissible limit (0.80mg/kg) recommended by FAO/WHO [41]. Similarly, the average concentration of Mn in the juice extracts of the oranges in both Effurun and Warri metropolis are slightly higher than 0.30mg/kg which is the permissible limit recommended by FAO/WHO [21]. Also, the average concentration of Cu in the juice extracts of the oranges in both Effurun and Warri metropolis are higher than the permissible limit (0.50mg/kg) recommended by FAO/WHO [21]. Again, the average concentration of Cd in the juice extracts of the oranges in both Effurun and Warri metropolis are slightly above the permissible limit (0.10mg/kg) recommended by FAO/WHO (21). Furthermore, the average concentration of Ni in the juice extracts of the oranges in both Effurun and Warri metropolis are slightly above the permissible limit (0.14mg/kg) recommended by FAO/WHO [21]. The exceedances of the metal concentration above the recommended limit may be that the soil on which the orange tree were cultivated are contaminated. These may be seepage from waste dump site, mechanic workshops, factories and industrial effluents, etc, It may also be as result of atmospheric deposit due to location close to a road with busy traffic, factories, filling station, artisanal refineries and even refinery with gas flaring.

Risk assessment indices for carcinogenic and non-carcinogenic risk assessment were used to analyse the observed metals concentrations in both children and adults in Effurun and Warri metropolis. It was found out from these analyses that the total cancer risk (R_{total}) on children in Effurun ranged from (5.5E-05 - 4.75E-06). In adults, it ranged from 2.81E-05- 2.42E-06. In Warri, the total cancer risk (R_{total}) estimated on children ranged from 7E-05 - 8.78E-06 while in adults it ranged from 3.57E-05-4.47E-06. In all, the estimated cumulative cancer risk for both children and adult in Effurun and Warri are within the recommended range postulated by USEPA. The total cancer risk (R_{total}) estimated on children was higher than that of the adults per sample location. This is similar in both Effurun and Warri samples. In terms of non-carcinogenic risk assessment, the Hazard Index (HI) estimated on children in Effurun ranged from 1.72E-02 - 1.2E-03 while in adults, it ranged from 5.476E-03 - 3.82E-04. In Warri, the hazard index (HI) estimated on children ranged from 1.38E-02-5.28E-03 while in adults it ranged from 4.4E-03 - 1.68E-03. The estimated hazard index in all the samples for children and adults were lower than one (<1), which is within the recommended limit proposed by USEPA. Nevertheless, the HI estimated on children in all the samples were greater than that of the HI estimated on adults. The implication of the analyses of risk assessment, it shows that consumption of orange fruits sold along roadside in Effurun and Warri may not pose adverse health risk to children as well as adults provided the concentrations of heavy metals do not exceed the observed concentrations in this study.

The observed heavy metals concentration between the standing orange trees and their surrounding soils were analysed using Pearson's correlation coefficient. The analyses of the observed heavy metals concentrations of standing orange fruits and the surrounding soils, using Pearson's correlation coefficient, shows strong and positive correlations in all locations ranging 0.986705-0.726461. This implies that the strongest correlation between metals concentration in the soil and orange fruit juice is 0.986705 while the weakest correlation coefficient was found to be 0.726461. This implies that the metal contamination in the juice extracts of the orange fruits is caused by the heavy metals contamination of the soil. This can also be used to deduce that the metals contamination of the orange fruits sold along roadsides in Effurun and Warri metropolis is also from the soil from which they were harvested.

Heavy metals such as Zn, Fe, Mn and Cu which contribute to human health in diet at minimal quantities are found in all orange samples including the ones obtained from the standing orange trees. This implies that consuming the orange fruits in Effurun and Warri metropolis is a good source of obtaining animal nutrients to correct mineral deficiencies in adults and children. Nevertheless, some of these metals were found with a concentration higher than the recommended limit in some locations. Therefore, there is need for attention and further studies to monitor the concentration of heavy metals in orange fruits and other food source at regular intervals to ensure that the level of heavy metals contamination is within the regulatory standard recommended by FAO/WHO and USEPA.

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