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Appraisal of Heavy Metals in Some Fruits Sold in Effurun Market

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Abstract

Background: Heavy metal contamination of edible food has become rampant in our society and this has led to increase in the occurrence of terminal diseases in the society. Fruits are cultivated, harvested and sold without cooking thereby protecting the nutrients in them. Contamination of fruits by heavy metals have been reported in some parts of Nigeria.

Aim: Hence, this study aims to appraise the heavy metals in some fruits sold in Effurun market.

Methods: Five edible fruits of Orange (*Citrus sinensis*), Watermelon (*Citrullus lanatus*), Cucumber (*Cucumis sativus*), Pineapple (*Ananas comosus*) and Banana (*Musa sapientum*) were digested and evaluated for the presence of heavy metals using atomic absorption spectrophotometer (AAS).

Results: The study revealed varying concentrations of heavy metals among the fruit samples. Copper, Chromium and Cadmium showed relatively higher concentrations compared to the permissible limits in all the fruits evaluated, while nickel was higher in *C. sativus* and remain within permissible limits in other fruits. Cobalt, manganese, zinc and lead were all within the permissible limits established by the World Health Organization and Food and Agriculture Organization for all the fruits examined.

Conclusion: The differences in metal concentrations may be attributed to environmental exposure, transportation, storage conditions, and contamination from agricultural inputs. Although some fruits remained within acceptable safety limits, continuous consumption of contaminated fruits may predispose consumers to bioaccumulation and associated health risks such as nephrotoxicity, hepatotoxicity, neurological disorders, and carcinogenic effects. Regular monitoring of heavy metal contamination in fruits sold in local markets is essential to safeguard public health. Implementation of stricter environmental regulations, improved agricultural practices, and periodic food safety surveillance are recommended to minimize heavy metal exposure through fruit consumption.

Keywords: Heavy metals; Effurun; fruits; contamination; environmental pollutants.

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Introduction

Fruits are consumed for nourishment and nutrients such as carbohydrates, proteins, vitamins, electrolytes, minerals, and trace elements (Sobukola et al., 2010). However, the methods of cultivation, processing and marketing have drawn the attention of public health practitioners due to the resurgence of terminal diseases such as cancer, renal failure, cardiac arrest, liver dysfunction as a result of fruits contamination by heavy metals. Fruits can be contaminated either from the soil or from the atmosphere due to the presence of industrial pollutants. Previous authors have observed that toxic metals are common in foods, drinking water and air (Jaishankar et al., 2014; Singh et al., 2007). The contamination of fruits with heavy metals from the soil and atmosphere has raised a lot of questions in the public health domain (Yusuf et al., 2003). Heavy metals are metals which can affect the environment and living organisms with a specific density of greater that 5 grams/centimeter cubes (>5 g/cm^3) (Järup, 2003). Divrikli et al. (Divrikli et al., 2013) observed that some of these heavy metals are toxic and deleterious to health even at minute concentrations. However, there are some heavy metals that are important to human health as well as plants well-being. Some diseases such as gastrointestinal cancer have been linked to consumption/ingestion of fruits with high concentrations of heavy metals such as Ar, Cu, Cd, and Pb (Türkdoğan et al., 2003). Evidence has also shown that other sources such as waste incineration, industrial processes, and vehicular traffic can emit heavy metals into the atmosphere (Czarnek et al., 2015). It has been observed that the direct route of exposure to heavy metals by humans is through consumption or ingestion of contaminated fruits (Sajjad et al., 2009; Tsafe et al., 2012). For good yield as a result of organic manure, abandoned waste dumpsites have been used to cultivate fruits crops. Amash and Aly (Amash & Aly, 2019) in their study observed that bioaccumulation of environmental pollutants in contaminated soil can enter the plants. In an earlier study, Benson and Ebong (Benson & Ebong, 2005), observed that fruits are capable of accumulating high levels of heavy metals from polluted soils through translocation. Heavy metals are known to be persistent and non-biodegradable (Khadeeja et al., 2013), which might be transported from soil to ground waters or taken up by crops. There has been an increase rate of terminal disease in recent times. These increased have been attributed to food and pollutants present in our environment. Therefore, we sought to evaluate the presence of heavy metals in some fruits that are sold in Effurun market, in Uvwie, Local Government area of Delta State and to advise on their public health implications.

Materials and Methods

Study Area

This study was conducted in Effurun the headquarter of Uvwie local government area of Delta State. Effurun is a twin city to Warri and both has been regarded as the commercial nerve centre of Delta State. It has a large market popularly known as Effurun market which house all shade of traders within the city and environ. It is located on 5°31′N 5°45′E. The market is located along the busy Effurun-Sapele road, about 5 km from the Warri refinery and petrochemical company.

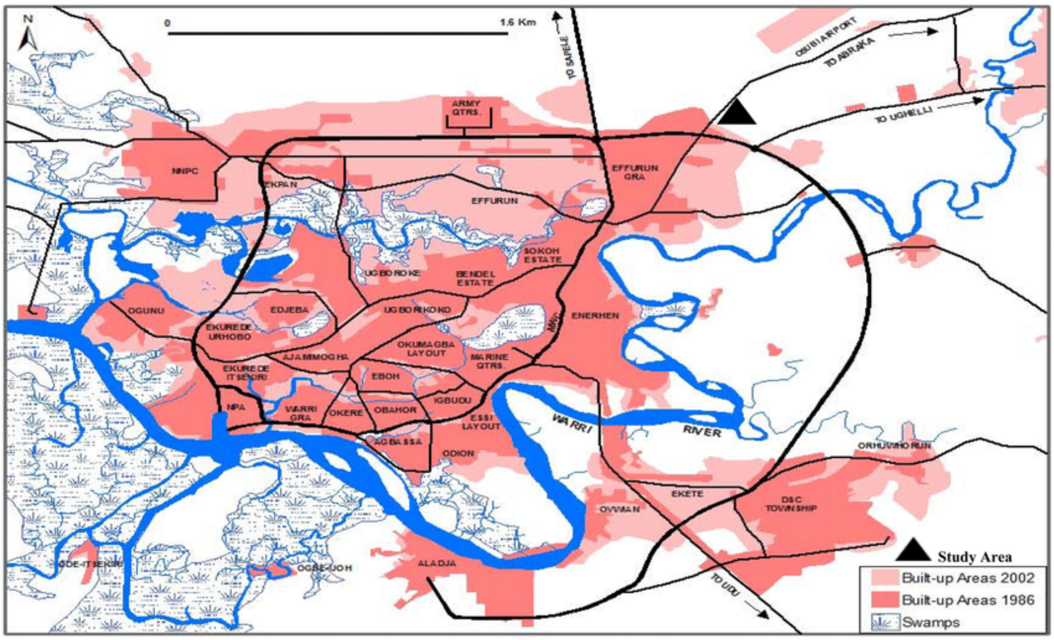

Figure 1: Map of Effurun metropolis showing the study area.

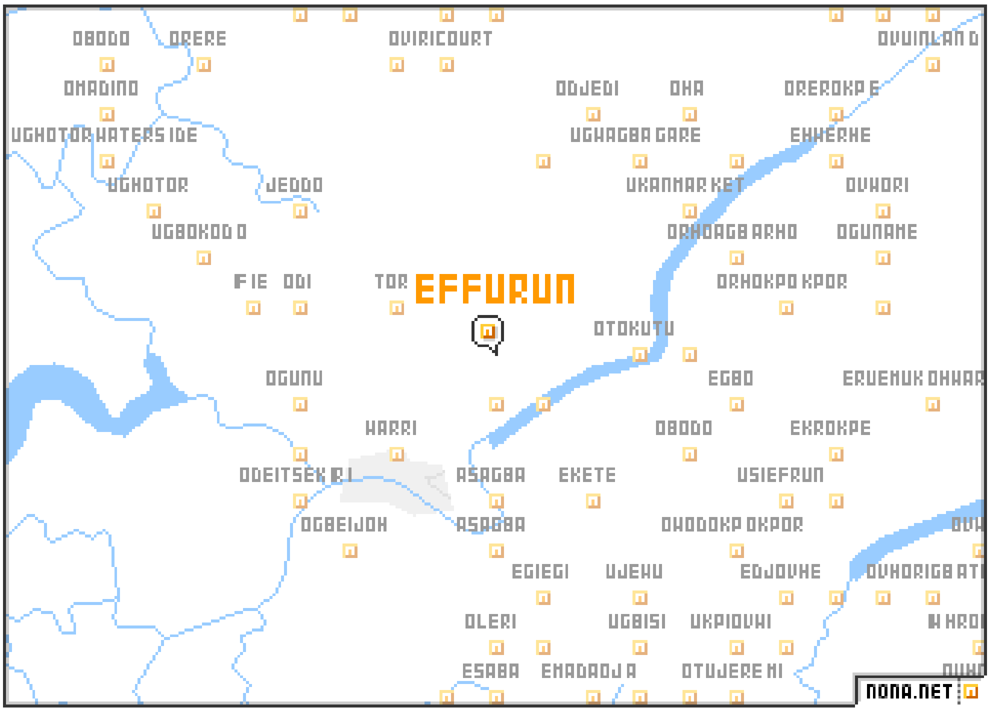

Figure 2: Map of Effurun and its environs.

Types of Samples

Three sets of five edible fruits of Orange (*Citrus sinensis*), Watermelon (*Citrullus lanatus*), Cucumber (*Cucumis sativus*), Pineapple (*Ananas comosus*) and Banana (*Musa sapientum*), were used in this study.

Collection of Fruit Samples

The fruits were bought from different spots in Effurun market in Uvwie, Delta State, Nigeria. Effurun market is a centralized modern market in Uvwie.

Preparation of Fruit Samples

The different sets of fruits samples from different spots in the market were washed thoroughly using tap water and then distilled water to remove pollutants which may be adsorbed. They were pooled together and cut into pieces, then dried in hot air oven for 48 hours. The dried samples were pulverized to a fine powder and sieved with a 1 mm mesh. Each fruit sample was labeled (F1–F5). They were stored in a dry plastic container.

Digestion of Fruits Samples

A 5:1 ratio solution of HNO_3 and $HClO_4$ was prepared. 0.5 g of the dried sample was weighed into a beaker and the 5:1 solution of HNO_3 and $HClO_4$ was added until a transparent solution was obtained to digest the samples (Food and Agriculture Organization/World Health Organization, 2001). The transparent solution was filtered and made up to 25 ml with distilled water. The samples were analysed for heavy metals with atomic absorption spectrophotometer (AAS) (Model: GBC Avanta PM A6600) according to the method described by American Public Health Association. All samples were run in triplicates and the mean taken as the concentration of the heavy metal present to ensure quality data.

Determination of Daily Intake of Heavy Metals (DIM)

The DIM of the heavy metals was calculated using the equation below according to Ali et al. (Ali et al., 2018).

$$\text{DIM} = \frac{C_{\text{metal}} \times D_{\text{fruit intake}}}{BW_{\text{average}}}$$

Where: C_{metal} is the metal concentration in fruits in mg/kg; $D_{\text{fruit intake}}$ is the daily intake of fruit which is 300 g/person/day; and BW_{average} is the average body weight of a Nigerian which is 62 kg (WHO, 2018).[1]

[1] The "WHO, 2018" citation (body weight statistics for Nigeria) was not accompanied by a corresponding entry in the submitted reference list, so it could not be linked to a full bibliographic record. Flagged for the authors to resolve.

Determination of Non-Carcinogenic Risk (CR) Index

The non-CR assessment is to estimate the potential health risks of pollutants using the target hazard quotient (THQ). The THQ values were calculated using the standard assumption for an integrated risk analysis in line with the USEPA (United States Environmental Protection Agency, 2010) recommendation in the equation below.

$$\text{THQ} = \frac{\text{DIM}}{\text{RfD}}$$

Where: DIM is the DIMs (mg/kg/person); Reference dose (RfD) is the oral reference dose (mg/kg/-day). According to USEPA (United States Environmental Protection Agency, 2010), RfDs for Cu, Ni, Co, Cr, Cd, Mn, Zn, and Pb are 0.04, 0.02, 0.03, 0.003, 0.001, 0.014, 0.3, and 0.004 mg/kg/day, respectively. Note, if THQ value is $\geq$1, there is a potential health risk. However, if THQ is $<$1, the exposed population is unlikely to experience any adverse health hazard and safe for human consumption, but interventions and protective measurements should be taken (Wang et al., 2005).

Determination of Hazard Index (HI)

Hazard index is the sum of the target hazard quotient (THQ) for all the heavy metals that estimate the risk to human health through more than one heavy metal. It is calculated according to the formula below by Gezahegn et al. (Gezahegn et al., 2017).

$$\begin{aligned}\text{HI} = \sum \text{THQ} = \text{THQ}_{Cu} + \text{THQ}_{Ni} + \text{THQ}_{Co} \\ + \text{THQ}_{Cr} + \text{THQ}_{Cd} + \text{THQ}_{Mn} \\ + \text{THQ}_{Zn} + \text{THQ}_{Pb}\end{aligned}$$

Where: HI = Hazard Index; THQ = Target HQ.

HQ for the locals (consumers) through the consumption of contaminated fruits were analyzed by finding the ratio of DIM to the oral RfD (for each metal). If the value of HQ is $<$1, then the exposed local population (consumers) is said to be safe; if HQ is $\geq$1, it is considered unsafe for human health.

Determination of CR Index

CR indicates an incremental probability of an individual to developing cancer over a lifetime due to exposure to a potential carcinogen. Cancer risk over a lifetime exposure to Ni, Cr, Cd, and Pb was obtained by the equation below using cancer slope factor (CSF).

$$\text{CR} = \text{CSF} \times \text{EDI}$$

Where: CSF is the oral carcinogenic slope factor of 0.0085, 0.38, 0.5, and 1.7 (mg/kg/day) for Pb, Cd, Cr, and Ni, respectively, according to USEPA (United States Environmental Protection Agency, 2010). EDI is the estimated DIM. Acceptable risk levels for carcinogens range from 10^{-4} (risk of developing cancer over a human lifetime is 1 in 10,000) to 10^{-6} (risk of developing cancer over a human lifetime is 1 in 1,000,000).

Determination of Total CR

The cumulative cancer risk due to exposure to multiple sources of carcinogenic heavy metals through consumption of a particular type of fruit was assumed, and the sum of the individual heavy metal increment risk was calculated using the following equation by Mwegoha and Kihampa (Mwegoha & Kihampa, 2010).

$$\text{Total cancer risk} = \sum \text{CR}$$

Where: CR is the cancer risk.

Statistical Analysis

The data were analyzed using statistical package for social sciences version 25 to obtain mean $\pm$ standard error of the mean and compared with the permissible limits of the metal. Results are expressed in means $\pm$ standard errors of means.

Results

The study shows higher concentration of copper, chromium and cadmium in all the fruits when compared with the permissible limits. Nickel was observed to be higher in *C. sativus* only but cobalt, manganese, zinc and lead are within permissible limits for all the fruits evaluated as shown in Tables 1 and 2 below.

Table 1: Mean ± SD of Heavy Metals in Fruits Sold at Effurun Market with Their Permissible Limits

Fruits	Cu (ppm)	Ni (ppm)	Co (ppm)	Cr (ppm)	Cd (ppm)	Mn (ppm)	Zn (ppm)	Pb (ppm)
Permissible limits	0.010	0.020	2.00	0.003	0.001	0.300	2.00	0.010
C. sinensis	0.120±0.043	0.001±0.000	0.020±0.001	0.064±0.001	0.032±0.000	0.023±0.001	0.02±0.000	0.001±0.000
C. lanatus	0.100±0.000	0.005±0.000	0.010±0.001	0.010±0.001	0.025±0.001	0.030±0.001	0.10±0.000	0.001±0.000
C. sativus	0.079±0.002	0.025±0.001	0.020±0.001	0.050±0.001	0.032±0.002	0.065±0.001	1.00±0.001	0.001±0.000
A. comosus	0.100±0.001	0.014±0.002	0.020±0.002	0.121±0.001	0.034±0.002	0.067±0.001	0.10±0.001	0.001±0.000
M. sapientum	0.101±0.000	0.001±0.001	0.010±0.000	0.125±0.002	0.023±0.001	0.075±0.002	0.11±0.001	0.002±0.001

Permissible limits according to WHO/FAO (Food and Agriculture Organization/World Health Organization, 2001). *Key*: Cu=Copper, Ni=Nickel, Co=Cobalt, Cr=Chromium, Cd=Cadmium, Mn=Manganese, Zn=Zinc, Pb=Lead.

Table 2: Daily Intake of Metals (DIM) in Each of the Fruit Sold in Effurun Market (mg/person/day)

Fruits	Cu	Ni	Co	Cr	Cd	Mn	Zn	Pb
C. sinensis	5.81E-04	4.84E-06	9.68E-05	3.10E-04	1.55E-04	1.11E-04	9.68E-05	4.84E-06
C. lanatus	4.84E-04	2.42E-05	4.84E-05	4.84E-05	1.21E-04	1.45E-04	4.84E-04	4.84E-06
C. sativus	3.82E-04	1.21E-04	9.68E-05	2.42E-04	1.55E-04	3.15E-04	4.84E-03	4.84E-06
A. comosus	4.84E-04	6.77E-05	9.68E-05	5.85E-04	1.65E-04	3.24E-04	4.84E-04	4.84E-06
M. sapientum	4.89E-04	4.84E-06	4.84E-05	6.05E-04	1.11E-04	3.63E-04	5.32E-04	9.68E-06
RfDs	0.0400	0.0200	0.0430	0.1500	0.0010	0.0140	0.0300	0.0040

RfDs = Oral Reference Dose. *Key*: Cu=Copper, Ni=Nickel, Co=Cobalt, Cr=Chromium, Cd=Cadmium, Mn=Manganese, Zn=Zinc, Pb=Lead, DIM=Daily Intake of Heavy Metals.

Table 3: Target Hazard Quotient (THQ) of Each Metal in the Fruit Sold in Effurun Market

Fruits	Cu	Ni	Co	Cr	Cd	Mn	Zn	Pb
C. sinensis	0.014525	0.000242	0.003226	0.103226	0.154839	0.007949	0.000323	0.001210
C. lanatus	0.012100	0.001210	0.001613	0.016129	0.120968	0.010369	0.001613	0.001210
C. sativus	0.009550	0.006048	0.003226	0.080645	0.154839	0.022465	0.016129	0.001210
A. comosus	0.012100	0.003387	0.003226	0.195161	0.164516	0.023157	0.001613	0.001210
M. sapientum	0.012225	0.000242	0.001613	0.201613	0.111290	0.025922	0.001774	0.002419

Table 4: Hazard Index (HI) of Each Fruit Sold in Effurun Market

Fruits	Hazard Risk Index
C. sinensis	0.28554
C. lanatus	0.165212
C. sativus	0.294112
A. comosus	0.40437
M. sapientum	0.357098

Table 5: Cancer Risk Index (CR) of Each Metal Present in the Fruit

Fruits	**Ni (ppm)**	**Cr (ppm)**	**Cd (ppm)**	**Pb (ppm)**	**TCR**
C. sinensis	8.23E-06	1.55E-04	5.88E-05	4.11E-08	2.22E-04
C. lanatus	4.11E-05	2.42E-05	4.60E-05	4.11E-08	1.11E-04
C. sativus	2.06E-04	1.21E-04	5.88E-05	4.11E-08	3.86E-04
A. comosus	1.15E-04	2.93E-04	6.25E-05	4.11E-08	4.71E-04
M. sapientum	8.23E-06	3.02E-04	4.23E-05	8.23E-08	3.53E-04

Table 6: Total Cancer Risk (TCR) of Each Fruit Sold in Effurun Market

Fruits	**TCR**
C. sinensis	2.22E-04
C. lanatus	1.11E-04
C. sativus	3.86E-04
A. comosus	4.71E-04
M. sapientum	3.53E-04

Discussion

The evaluation of heavy metals in fruits sold in Effurun Market provides critical insight into environmental contamination, food safety, and potential public health risks. Heavy metals such as lead (Pb), cadmium (Cd), copper (Cu), manganese (Mn), zinc (Zn), chromium (Cr), cobalt (Co) and nickel (Ni) are of particular concern due to their persistence, bioaccumulation, and toxicity even at low concentrations. The occurrence of terminal disease has become so common among the populace in recent time in Nigeria. This may be attributed to contaminated food we eat on a daily basis because toxic metals are commonly present in foods, drinking water and air (Jaishankar et al., 2014; Singh et al., 2007). Fruits are consumed for their minerals and other nutrients; however, these fruits are contaminated either from the farm or at the market place where they are sold. This study observed that the level of copper in all the fruits exceed the permissible values of 0.010$\pm$0.000 ppm recommended. This is in accordance with earlier report by Ikechukwu et al.[2] Although copper is an essential element used in pigmentation by the body (Sobukola et al., 2010), its high concentrations is toxic in the body (Oyasowo et al., 2021). However, the level of nickel was higher in *C. sativus* but within the permissible limits for other fruits. This is in line with earlier observation by Oladele and Aladesanmi (Oladele & Aladesanmi, 2020) and Oyasowo et al. (Oyasowo et al., 2021). Patrick-Iwuanyanwu and Chioma (Patrick-Iwuanyanwu & Chioma, 2017) opined that high concentrations of nickel in the human body can lead to systemic reactions. The level of cobalt was observed to be within the permissible limits in all the fruits evaluated. This is in tandem with earlier report of Uroko et al. (Uroko et al., 2019). Chromium was observed to exceed the permissible limits in all the fruits. This is in accordance with earlier observation by Gowd et al. (Gowd et al., 2010). Cr is an essential mineral in fruits that enhance metabolism of nutrients by impacting on insulin. But, increases in Cr (beyond the permissible limits) may interfere with physiological processes which may damage the liver and kidney (Vupputuri et al., 2003). The level of cadmium was observed to exceed the permissible limit in all the fruits examined. This is in tandem with previous observation by FAO/WHO (Food and Agriculture Organization/World Health Organization, 2001). However, cadmium is said to be accumulated from soil by fruit

[2] The "Ikechukwu et al., 2019" citation was not accompanied by a corresponding entry in the submitted reference list, so it could not be linked to a full bibliographic record. Flagged for the authors to resolve.

much more efficiently than any other heavy metal (Adewole & Uchegbu, 2010). Bioaccumulation of cadmium in the human body results in skeletal muscle damage, renal dysfunction as well as reproductive deficiencies (Kumar & Sharma, 2019). Manganese, zinc and lead were observed to be within the permissible limits for all the fruits in this study. This is in a variance with earlier observation by Oyasowo and colleagues (Oyasowo et al., 2021). Zinc is needed for metabolic processes as well as in the neutralization of cadmium toxicity but its elevation results in disruption of physiological processes in the body (Elbagermi et al., 2012).

Contamination of food items in Effurun Market can be attributed to both anthropogenic such as industrial discharge, refining activities, heavy traffic emission that emit heavy metals into the atmosphere as well as natural sources (Czarnek et al., 2015). Effurun's proximity to industrial hubs in Delta State increases the likelihood of environmental contamination. Additionally, poor handling, storage, and display practices in open markets may contribute to contamination via dust and airborne particulates. In Effurun Market, such contamination may be influenced by proximity to industrial activities, oil exploration, vehicular emissions, and improper waste disposal, all of which are characteristic of the Niger Delta region. Natural sources, such as weathering of mineral-rich soils, may also contribute to baseline levels of certain metals like chromium and nickel. However, anthropogenic contributions are often the dominant factor in elevated concentrations.

The accumulation of heavy metals in fruits is a pointer to health risk to consumers especially where consumption rates are high (Díez et al., 2009), hence the estimation of daily intake of metals (DIM) or tolerable intake is very vital as marker of safety levels of intake of heavy metals. The DIM of copper and chromium in all the fruits in this study is below the tolerable intake limits of 4.0E-02 and 1.50E-01 respectively (Nguta, 2010). This is in tandem with Uroko et al. (Uroko et al., 2019). Adewole and Uchegbu (Adewole & Uchegbu, 2010) observed that slight increase of copper and chromium leads to alteration of physiological processes that can results in kidney and liver damage. The daily intake of nickel, cobalt and cadmium are below the tolerable limits of 2.0E-02, 4.3E-02 and 1.0E-02 respectively. This is in agreement with earlier study by Uroko et al. (Uroko et al., 2019). Likewise, the DIM of manganese, zinc and lead are below the tolerable limits 1.4E-02, 3.0E-02 and 4.0E-03 respectively of these metals.

Target health quotient (THQ) is the measure of contaminants in fruits but not necessarily the measure of health risk. However, value $\geq$1 is considered red flag for human health risk. This study observed a THQ of $<$1 in all the fruits examined. This is in tandem with earlier report by Uroko et al. (Uroko et al., 2019). This therefore, implies that they are safe for human consumption.

Cancer risk index is the probability of an individual to contact cancer over a period of 70 years. The cancer risk index of all the fruits is less than 10^{-4}. The highest cancer risk for cadmium (Cd) was observed in *A. comosus*, followed by *C. sativus*, *C. sinensis*, then *C. lanatus* and finally *M. sapientum* (*A. comosus* $>$ *C. sativus*, *C. sinensis* $>$ *C. lanatus* $>$ *M. sapientum*), while for lead (Pb) it is *M. sapientum* that has the greatest cancer risk index compared to other fruits.

The total cancer risk as shown in Table 6 has all the fruits total cancer risk less than 10^{-4}. It was observed that all the fruits had its cancer risk below 10^{-6} – Incremental life cancer risk [ILCR] $<10^{-6}$. It can therefore be inferred that the fruits are safe for consumption because the total cancer risk associated with them is minimal.

Conclusion

This study highlights the urgent need for public health interventions, including routine screening of food products, environmental monitoring, and public awareness campaigns. Policies aimed at reducing industrial emissions, improving waste management, and regulating agricultural practices are essential to mitigate contamination. The appraisal of heavy metals in food items sold in Effurun Market reveals a potential public health concern due to environmental contamination and unsafe agricultural and market practices. Continuous monitoring, stricter regulatory enforcement, and public health education are essential to reduce exposure and safeguard consumer health.

The limitations of this study include using single-centre design as well as relatively small sample size, and the absence of longitudinal follow-up to know the source of contamination, which restrict causal interpretation.

Declarations

Conflict of Interest

None.

Funding

None.

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