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# An Assessment of the Environmental and Health Impact of Heavy Metals in Soil and Vegetables around Second Cemetery, Benin City, Edo State

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**Abstract**
*Heavy metals contamination of soil and edible parts of plants and vegetables is currently a challenging environmental issue. An attempt was made in this study to determine the accumulated amount of tin (Sn), antimony (Sb), molybdenum (Mo), zinc (Zn), copper (Cu), iron (Fe) and nickel (Ni) in soil, mango leaves, sweet potato leaves, citrus leaves and bitter leaf collected around second cemetery in Benin City. Plant leaves and soil were randomly collected and taken to the laboratory for preliminary preparation. The samples were air dried, pulverized and digested and the concentration of metals in the samples was determined using SKYRAY EDXRF type EDX3600B. Using standard equations, risk indication measures such as the health risk index and daily intake of heavy metals were assessed. The findings indicate that daily metal intakes were greater than oral reference values, and children were identified as having a higher health risk.*

***Keywords:*** *Transfer factor, Daily metal intake, Health risk index, Target hazard quotient*

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## 1. Introduction

Globally, a difficult environmental problem is heavy metal contamination of soil and edible plant and vegetable parts (Gupta et al., 2022a). It is dangerous for human health as well as soil and plant life when heavy metals are present in soils in hazardous amounts. Since soil is a critical resource for life and needs proper protection from excessive heavy metal build-up, attention to heavy metals polluted agricultural soils is extremely important (Muhammad et al., 2021). Finding out how many heavy metals are present in the food that is served to the public has gained more and more attention. However, the relationship between their concentration in bio-available form and the overall concentration of the metal is not always linear (Nkwunonwo et al., 2020). The ecosystem's quality is changed as heavy metals enter it as a result of anthropogenic activities (Ashraf et al., 2021). Chronic heavy metal deposition in the human liver, kidney, and bones may develop from long-term exposure to high levels of heavy metals through contaminated food, leading to kidney, cardiovascular, neurological, and bone problems. The aim of this study is to determine the concentration of selected heavy metals in soil, vegetables and plant leaves collected around second cemetery in Benin City, in order to determine the health risk, they pose to consumers.

## 2. Materials and methods

### 2.1 Description of study area

Benin City, the capital of Edo State, serves as the focal point for this research. Positioned as a nodal town, it stands as one of the largest cities in Nigeria. Situated between latitude 6°20′17″ N and longitude 5°37′32″ E, the city resides in the southern part of the country, boasting an elevation of 88 meters above sea level. The climatic conditions in Benin City are characterized by two distinct seasons: the wet season, spanning from March to October, and the dry season, lasting from October to March. As of the 2006 national census, the city was home to a population of 1.15 million individuals. Predominantly inhabited by the Bini-speaking people of Edo ethnic nationality, the city projects a population of 2.136 million by the year 2024, based on the National Population Commission's growth rate of 3.5% per annum for urban centres. Within the city, three primary public cemeteries are present, namely 1st cemetery, 2nd cemetery, and 3rd cemetery. Figure 1 provides a 3D-study area map depicting the spatial arrangement of these cemeteries. For this research, the second cemetery was used as the study area.

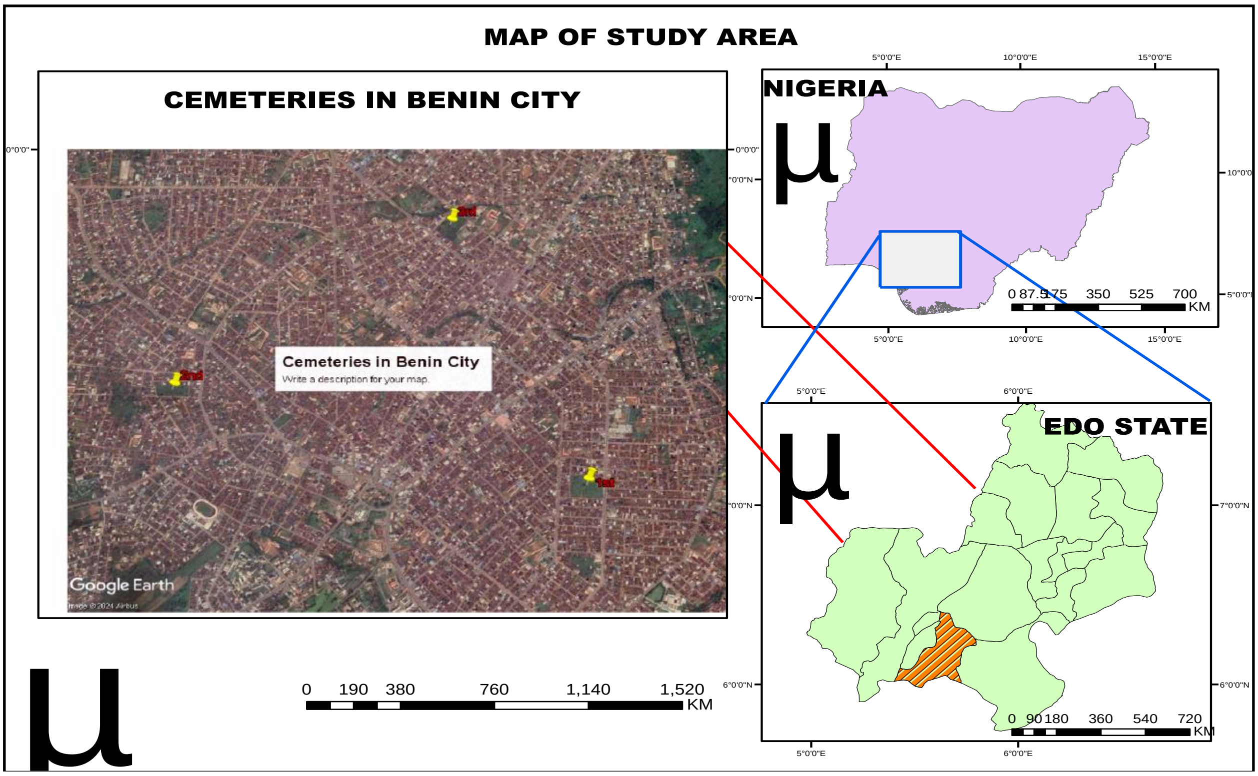


**Fig. 1:** Study area map showing the three cemeteries

## 2.2 Sample collection and analysis

Eight (8) samples of soil were randomly collected around second cemetery in order to determine the level of heavy metal concentration. In addition, plant leaves comprising Bitter leaf (Vernonia amygdalina), sweet potato leaves (Ipomoea batatas), orange leaves (Citrus sinensis) and mango leaves (Mangifera indica) were collected from around the cemetery and transported to University of Benin Civil engineering laboratory for sample preparation. The plant leaves were washed with distilled water to remove any traces of dirt, and the soil samples were air-dried, powdered, and sieved (Rehman et al., 2017). The washed leaves were separated, air-dried and further dried in oven for 72 h at 65 °C to attain constant weight. The dried leaves were pulverized, sieved, digested and analysed for heavy metals using SKYRAY EDXRF model EDX3600B.

## 2.3 Health risk assessment

### 2.3.1 Transfer factor (TF)

The transfer factor of heavy metals from soils to vegetables was assessed by computing the ratio of the concentration of each heavy metal in vegetables and the concentration of corresponding heavy metals in the soil. The equation proposed by Zhou et al. (2016) was employed as follows:

$$TF = \frac{Conc_{plants}}{Conc_{soil}} \qquad (1)$$

where $Conc_{plants}$ is the concentration of heavy metals in plant on dry weight (dw) basis (mg/kg dw), and $Conc_{soil}$ is the concentration of heavy metals (mg/kg dw) in soil. TF>1 suggests less movement of heavy metals from soil to vegetables while TF<1 suggest high movement.

### 2.3.2 Daily intake of metal (DIM)

The daily intake of metals (DIM) was developed to approximate the average daily metal loading into the body system of a consumer with a given body weight. The DIM was determined using the equation proposed by Fonge et al. (2021) as follows:

$$DIM = \frac{C_m * C_f * D_{vi}}{B_{aw}} \qquad (2)$$

where DIM denotes the daily intake of metals (mg/person/day), $C_m$ signifies heavy metals content in vegetables, $D_{vi}$, is the daily vegetable intake (g/person/ day), $B_{aw}$ is the average body weight (kg) and $C_f$ is the conversion factor of vegetables from fresh to dry weight (Edogbo et al., 2020). *C*f value of 0.085 used by Edogbo et al., (2020) was adopted in this study while the $D_{vi}$ and $B_{aw}$ values used are 205 g/person/day and 70kg for adults and 150 g/person/day and 20kg for children.

### 2.3.3 Health risk index

The health risk index (HRI) which defines the risk that metal poses to human health was determined using Equation (3) (Fonge et al., 2021).

$$HRI = \frac{DIM}{RfD} \quad (3)$$

where DIM is the daily metal intake in (mg/person/day), RfD represents reference oral dose which was taken as: 0.02mg/kg/day for Nickel, 0.005mg/kg/day for Molybdenum, 0.0004mg/kg/day for Antimony, 0.04mg/kg/day for copper, 0.0003mg/kg/day for tin, 0.0003mg/kg/day for Arsenic, 0.7mg/kg/day for Iron, 0.02mg/kg/day for cobalt and 0.3mg/kg/day for zinc (USEPA, 2021).

### 2.3.4 Target hazard quotient (THQ)

The target hazard quotient (THQ) calculates the total non-cancerous risks associated with consuming contaminated vegetables on a regular basis. THQ <1 suggests no non-carcinogenic risks. While THQ >1 suggests possibility of substantial health hazards (Zhou et al., 2016). THQ was determined by using the equation proposed by Haque et al., (2021).

$$THQ = \frac{C * VIR * EF * ED * 0.001}{BW * AT * RfD} \quad (4)$$

where C is heavy metals content in vegetables (mg/kg dw), VIR is the vegetable ingestion rate (150 g/person/day and 205 g/person/day for children and adults, respectively), EF and ED refer to the exposure frequency and exposure duration which were assumed as 365 days/year and 70 years respectively. BW is average body weights (20kg and 70kg for children and adults respectively), AT represents the average time of exposure for non-carcinogenic health risk taken as (ED × 365) days and RfD represents reference oral dose.

### 2.3.4 Total target hazard quotient (TTHQ)

The sum total of all the target hazard quotient is the total target hazard quotient (TTHQ) and was determined using Equation (5)

$$TTHQ = \sum_{i=1}^{n} (THQ) \quad (5)$$

TTHQ > 1 suggest that ingestion of metals through vegetables will likely result to adverse health effects (Zhou et al., 2016; Edogbo et al., 2020).

## 3. Results and discussion

Summary result of the heavy metal analysis of soil samples and plant leaves from second cemetery is presented in Table 1. From the heavy metal analysis results, it was observed that nine (9) out of the twenty-seven (27) metals analyzed possess appreciable concentration when compared to their concentration in the control sample and they include: Aluminium (Al), Silicon (Si), Iron (Fe), Nickel (Ni), Copper (Cu), Zinc (Zn), Molybdenum (Mo), Tin (Sn) and Antimony (Sb).

The calculated target hazard quotient (THQ) and total target hazard quotient (TTHQ) is presented in Table 2. From the result of Table 2, it was observed that the THQ and TTHQ of tin and antimony were greater than 1 and suggests that the continuous consumption of plants and vegetables around cemetery is likely to result to adverse health effect caused by tin and antimony. The result also shows that for bitter leaf, the TTHQ for children is 287 compared to that of adult which is 112 an indication that children who consumed the plants and vegetables around cemetery are more at health risk than adults.

The calculated daily intake of metals (DIM) and health risk index (HRI) is presented in Tables 3 and 4. When compared to the reference oral dose of 0.02mg/kg/day for Nickel, 0.005mg/kg/day for Molybdenum, 0.0004mg/kg/day for Antimony, 0.04mg/kg/day for copper, 0.0003mg/kg/day for tin, 0.0003mg/kg/day for Arsenic, 0.7mg/kg/day for Iron, 0.02mg/kg/day for cobalt and 0.3mg/kg/day for zinc (USEPA, 2021), it was observed that the calculated daily intake of heavy metals is higher than the reference oral dose as observed in Table 5. More also, the health risk index calculated for childreen were higher than those for adult as observed in Table 4 showing that children are at greater health risk arising from the intake of these vegetables than adult. The estimated transfer factor of heavy metals from soil to vegetables is presented in Figures 2 to 8. With TF>1, it was concluded that the soil around second cemetery is polluted with lead and antimony including nickel and copper which were present in sweet potato and bitter leaf.

**Table 1:** Summary result of heavy metals in soil and vegetables around second cemetery

| Samples | Index | Sn | Sb | Mo | Zn | Cu | Fe | Ni |
|---|---|---|---|---|---|---|---|---|
| Soil | Mean±SD | 6.520±0.872 | 6.023±0.620 | 0.298±0.140 | 0.776±1.174 | 0.303±0.100 | 5.374±2.969 | 0.165±0.032 |
| | Range | 5.453-7.643 | 5.238-6.785 | 0.113-0.484 | 0.250-3.601 | 0.118-0.395 | 2.860-11.32 | 0.180-0.200 |
| Mango Leaves | Mean±SD | 7.023±0.497 | 6.104±0.184 | 0.255±0.189 | 0.276±0.017 | 0.731±0.469 | 2.303±1.579 | 0.163±0.021 |
| | Range | 6.672-7.375 | 5.974-6.235 | 0.121-0.389 | 0.264-0.288 | 0.400-1.063 | 1.187-3.419 | 0.148-0.178 |
| Sweet Potato Leaves | Mean±SD | 6.741±0.246 | 6.024±0.460 | 0.099±0.036 | 0.224±0.015 | 0.357±0.047 | 3.358±4.353 | 0.190±0.030 |
| | Range | 6.567-6.915 | 5.698-6.349 | 0.074-0.125 | 0.213-0.235 | 0.324-0.391 | 0.280-6.436 | 0.169-0.211 |
| Citrus Leaves | Mean±SD | 6.646±0.263 | 5.637±0.290 | 0.266±0.172 | 0.239±0.019 | 0.342±0.056 | 5.745±7.633 | 0.160±0.014 |
| | Range | 6.461-6.833 | 5.433-5.842 | 0.145-0.388 | 0.226-0.252 | 0.302-0.382 | 0.348-11.14 | 1.150-1.170 |
| Bitter Leaf | Mean±SD | 6.487±0.623 | 5.777±0.366 | 0.234±0.019 | 0.221±0.004 | 0.309±0.026 | 5.411±7.267 | 0.173±0.008 |
| | Range | 6.047-6.928 | 5.518-6.036 | 0.221-0.248 | 0.218-0.223 | 0.291-0.328 | 0.273-10.55 | 0.168-0.178 |

**Table 2:** Total target health quotient (TTHQ)) of heavy metals around second cemetery

| Heavy Metals | Mango Leaves | | Potato Leaves | | Citrus Leaves | | Bitter Leaf | |
|---|---|---|---|---|---|---|---|---|
| | Adult | Children | Adult | Children | Adult | Children | Adult | Children |
| **Sn** | 71.9931 | 184.373 | 67.5065 | 172.883 | 66.699 | 170.815 | 67.627 | 173.19 |
| **Sb** | 45.6484 | 116.904 | 46.4823 | 119.04 | 42.772 | 109.538 | 44.195 | 113.183 |
| **Mo** | 0.2278 | 0.5835 | 0.073 | 0.1871 | 0.2271 | 0.5816 | 0.1452 | 0.3719 |
| **Zn** | 0.0028 | 0.0072 | 0.0023 | 0.0059 | 0.0025 | 0.0063 | 0.0022 | 0.0056 |
| **Cu** | 0.0778 | 0.1994 | 0.0286 | 0.0732 | 0.028 | 0.0716 | 0.024 | 0.0614 |
| **Fe** | 0.0143 | 0.0366 | 0.0269 | 0.069 | 0.0466 | 0.1194 | 0.0441 | 0.113 |
| **Ni** | 0.0261 | 0.0669 | 0.0309 | 0.0792 | 0.0248 | 0.0636 | 0.0262 | 0.067 |
| **TTHQ** | **117.99** | **302.17** | **114.15** | **292.34** | **66.70** | **281.20** | **112.06** | **286.99** |

**Table 3:** Daily metal intake (DIM) of heavy metals around second cemetery

| Heavy Metals | Mango Leaves | | Potato Leaves | | Citrus Leaves | | Bitter Leaf | |
|---|---|---|---|---|---|---|---|---|
| | Adult | Children | Adult | Children | Adult | Children | Adult | Children |
| Sn | 1.8358 | 4.7015 | 1.7214 | 4.4085 | 1.7008 | 4.3558 | 1.7245 | 4.4163 |
| Sb | 1.552 | 3.9747 | 1.5804 | 4.0474 | 1.4542 | 3.7243 | 1.5026 | 3.8482 |
| Mo | 0.0968 | 0.248 | 0.031 | 0.0795 | 0.0965 | 0.2472 | 0.0617 | 0.158 |
| Zn | 0.0717 | 0.1836 | 0.0584 | 0.1496 | 0.0628 | 0.1607 | 0.0556 | 0.1424 |
| Cu | 0.2647 | 0.6779 | 0.0972 | 0.2489 | 0.095 | 0.2434 | 0.0815 | 0.2088 |
| Fe | 0.8512 | 2.1799 | 1.6022 | 4.1031 | 2.7736 | 7.1032 | 2.6261 | 6.7255 |
| Ni | 0.0444 | 0.1137 | 0.0525 | 0.1346 | 0.0422 | 0.1081 | 0.0445 | 0.1139 |

**Table 4:** Health risk index (HRI) of heavy metals around second cemetery

| Heavy Metals | Mango Leaves | | Potato Leaves | | Citrus Leaves | | Bitter Leaf | |
|---|---|---|---|---|---|---|---|---|
| | Adult | Children | Adult | Children | Adult | Children | Adult | Children |
| Sn | 6119.41 | 15671.7 | 5738.05 | 14695 | 5669.43 | 14519.3 | 5748.26 | 14721.2 |
| Sb | 3880.11 | 9936.87 | 3950.99 | 10118.4 | 3635.6 | 9310.69 | 3756.58 | 9620.51 |
| Mo | 19.3666 | 49.5975 | 6.2083 | 15.8993 | 19.3019 | 49.4318 | 12.3419 | 31.6073 |
| Zn | 0.239 | 0.612 | 0.1947 | 0.4987 | 0.2092 | 0.5357 | 0.1853 | 0.4745 |
| Cu | 6.6171 | 16.9463 | 2.4302 | 6.2236 | 2.376 | 6.0849 | 2.0381 | 5.2195 |
| Fe | 1.216 | 3.1141 | 2.2888 | 5.8616 | 3.9623 | 10.1475 | 3.7516 | 9.6079 |
| Ni | 2.2192 | 5.6833 | 2.6274 | 6.7288 | 2.1109 | 5.406 | 2.2242 | 5.6961 |

**Table 5:** Comparison of RfD with calculated DIM

| Heavy Metals | Mango Leaves | | |
|---|---|---|---|
| | Adult | Children | RfD |
| Sn | 1.8358 | 4.7015 | 0.0003 |
| Sb | 1.552 | 3.9747 | 0.0004 |
| Mo | 0.0968 | 0.248 | 0.005 |
| Zn | 0.0717 | 0.1836 | 0.3 |
| Cu | 0.2647 | 0.6779 | 0.04 |
| Fe | 0.8512 | 2.1799 | 0.7 |
| Ni | 0.0444 | 0.1137 | 0.02 |

| Heavy Metals | Potato Leaves | | |
|---|---|---|---|
| | Adult | Children | RfD |
| Sn | 1.7214 | 4.4085 | 0.0003 |
| Sb | 1.5804 | 4.0474 | 0.0004 |
| Mo | 0.031 | 0.0795 | 0.005 |
| Zn | 0.0584 | 0.1496 | 0.3 |
| Cu | 0.0972 | 0.2489 | 0.04 |
| Fe | 1.6022 | 4.1031 | 0.7 |
| Ni | 0.0525 | 0.1346 | 0.02 |

| Heavy Metals | Citrus Leaves | | |
|---|---|---|---|
| | Adult | Children | RfD |
| Sn | 1.7008 | 4.3558 | 0.0003 |
| Sb | 1.4542 | 3.7243 | 0.0004 |
| Mo | 0.0965 | 0.2472 | 0.005 |
| Zn | 0.0628 | 0.1607 | 0.3 |
| Cu | 0.095 | 0.2434 | 0.04 |
| Fe | 2.7736 | 7.1032 | 0.7 |
| Ni | 0.0422 | 0.1081 | 0.02 |

| Heavy Metals | Bitter Leaf | | |
|---|---|---|---|
| | Adult | Children | RfD |
| Sn | 1.7245 | 4.4163 | 0.0003 |
| Sb | 1.5026 | 3.8482 | 0.0004 |
| Mo | 0.0617 | 0.158 | 0.005 |
| Zn | 0.0556 | 0.1424 | 0.3 |
| Cu | 0.0815 | 0.2088 | 0.04 |
| Fe | 2.6261 | 6.7255 | 0.7 |
| Ni | 0.0445 | 0.1139 | 0.02 |

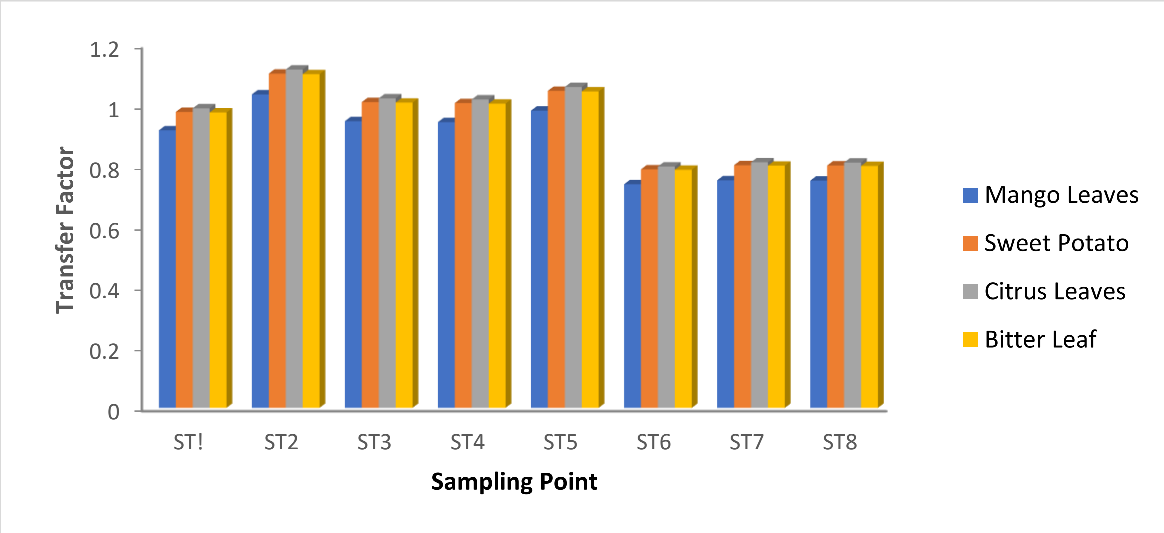


**Fig. 2:** Transfer factor of Tin from soil to vegetables

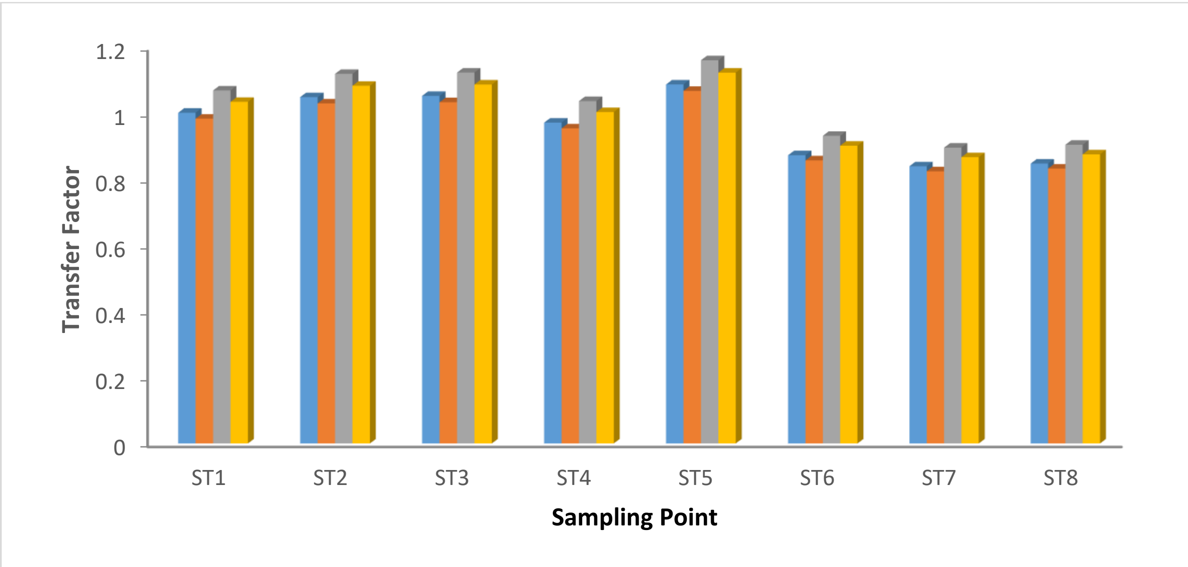


**Fig. 3:** Transfer factor of Antimony from soil to vegetables

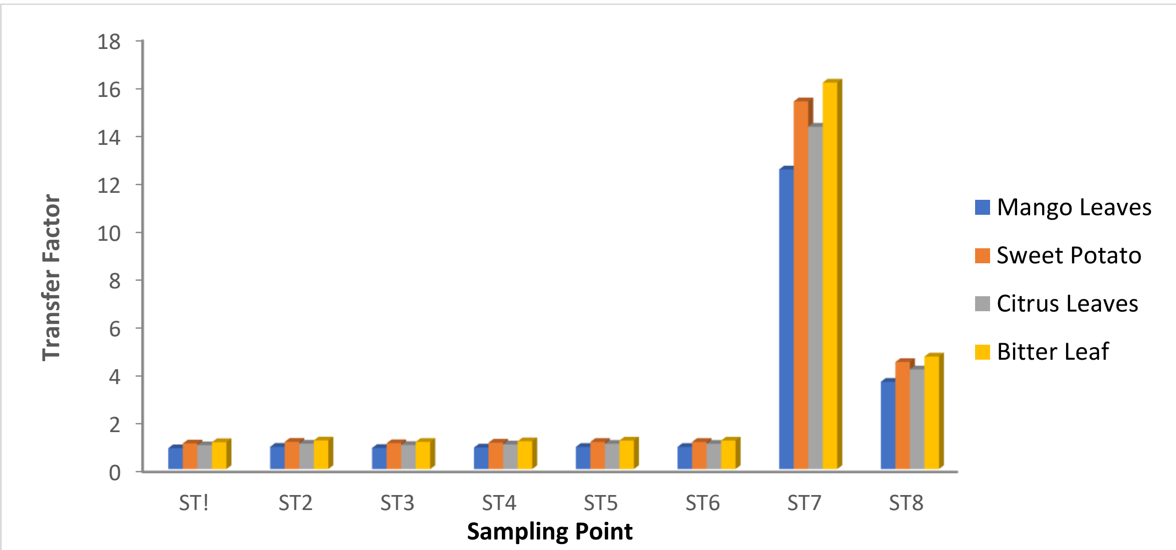


**Fig. 4:** Transfer factor of Zinc from soil to vegetables

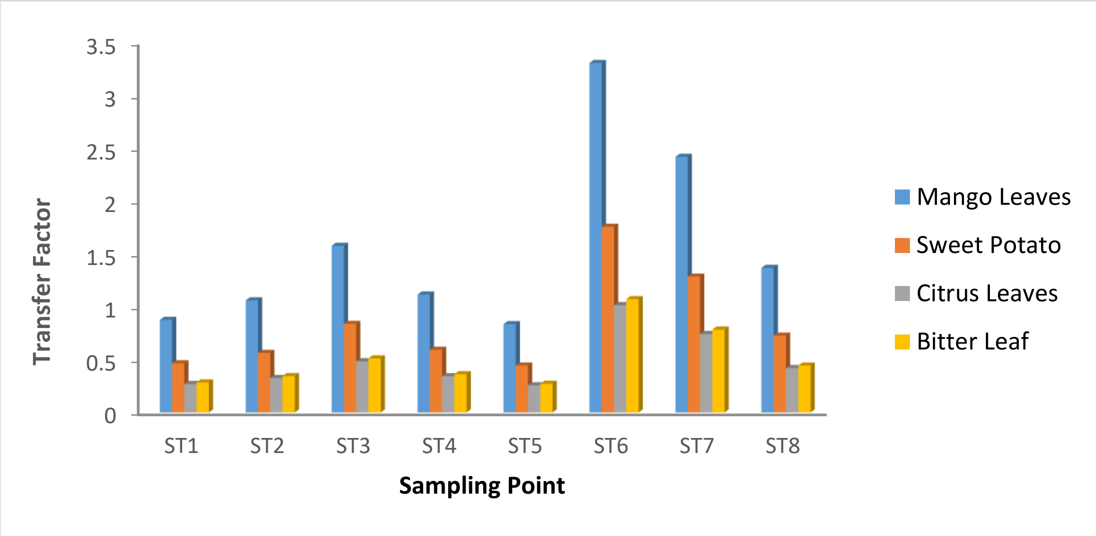


**Fig. 5:** Transfer factor of Iron from soil to vegetables

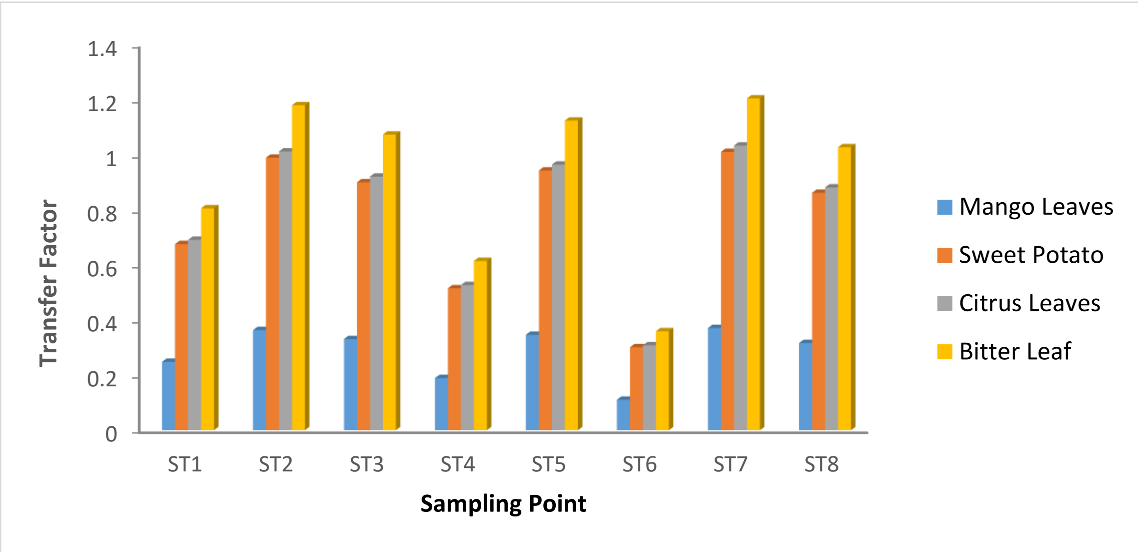


**Fig. 6:** Transfer factor of Copper from soil to vegetables

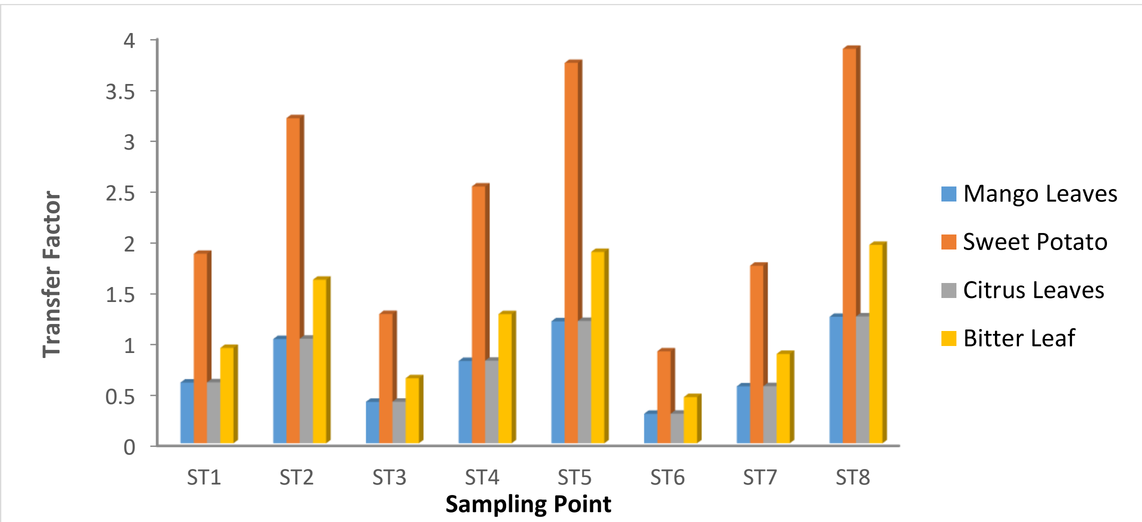


**Fig. 7:** Transfer factor of Molybdenum from soil to vegetables

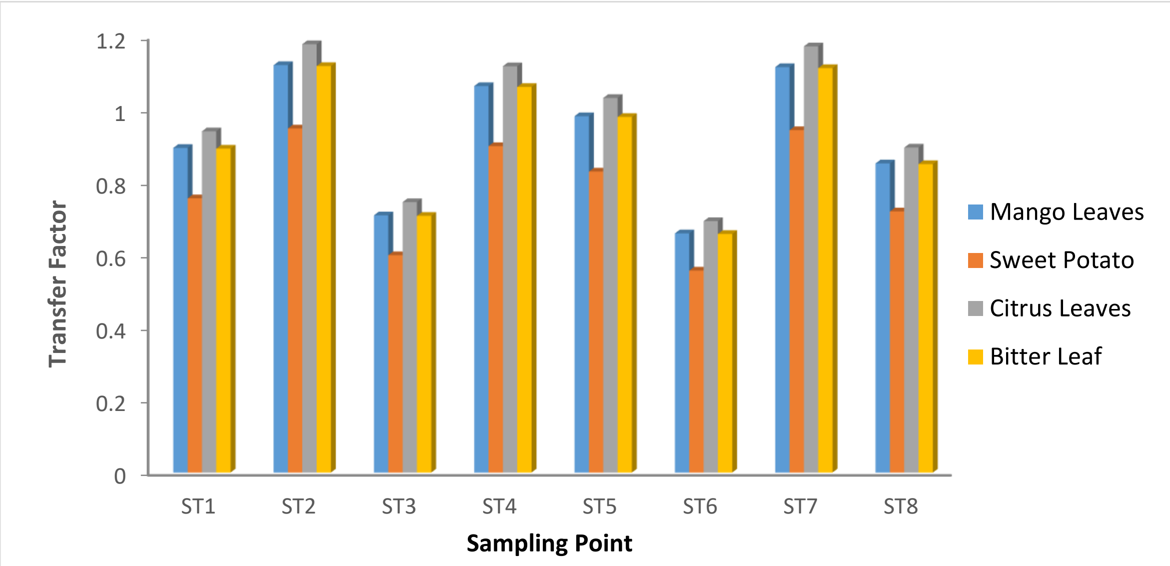


**Fig. 8:** Transfer factor of Nickel from soil to vegetables

## 4. Conclusion

Estimated DIM and THQ values were higher than the permissible limits, particularly for tin and antimony, indicating that cemetery operations constitute a major contributor to the current level of heavy metals in the research area. For mango leaves, the estimated total target hazard quotient ($TTHQ_{Sn}$) for children is 184.373 while for adult, a value of 71.993 was obtained. For potato leaves, the estimated ($TTHQ_{Sn}$) for children is 172.883 while for adult, a value of 67.5065 was obtained. For citrus leaves, the estimated ($TTHQ_{Sn}$) for children is 170.815 while for adult, a value of 66.699 was obtained. For bitter leaf, the estimated ($TTHQ_{Sn}$) for children is 173.19 while for adult, a value of 67.627 was obtained. In addition, the daily metal intake ($DIM_{Sn}$) in mango leaves was estimated as 4.7015mg/person/day for children and 1.8358mg/person/day for adult while the ($DIM_{Sn}$) in potato leaves was estimated as 4.4085mg/person/day for children and 1.7214mg/person/day for adult. For bitter leaf, the estimated ($DIM_{Sn}$) is 4.4163mg/person/day for children and 1.7245mg/person/day for adult. The soil and vegetable harvests of the research region should therefore be closely monitored on a regular basis to prevent further accumulation, which could pose serious non-carcinogenic health concerns to people who consume these veggies in the near future.


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