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# Heavy Metals Contamination and Human Health Risk Asssessment Via Consumption of Medicinal Plants from Amassoma Community, Bayelsa State of Nigeria

**Ebimobowei Assayomo [a*], Solomon Brepi Patrick [a], Ruth Angobrakumor Ajimmy [b], Eyidenghabofa David Odikeme [c] and Ahiakwo Bright Ogbo [d]**

[a] *Department of Biological Sciences, Faculty of Science, Niger Delta University Wilberforce Island, P.O Box 071, Bayelsa State, Nigeria.*
[b] *Department of Marine Environment and Pollution Control, Nigeria Maritime University Okerenkoko, Nigeria.*
[c] *Department of Community Health, Bayelsa State College of Health Technology, School of Public Health, Otuogidi Ogbia Town, Nigeria.*
[d] *Department of Biochemistry, University of Port Harcourt, East West Road, P.M.B 5323 Port Harcourt. Rivers State, Nigeria.*

***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

**Aims:** Man-made activities such as excessive oil exploration, automobile emissions, gas flaring and agricultural activities tend to elevate the concentrations of heavy metals in the surrounding. Heavy metals have the tendency to accumulate in plant roots, which may result to heavy metal contamination.

**Objectives:** This study aimed at evaluating the concentration of heavy metals such as Lead (Pb), Cadmium (Cd), Nickel and Zinc (Zn) in Pawpaw fruits, seeds, leaf and Scent leaf from Amosoma community in Bayelsa State, Nigeria. The concentrations of these metals were used to assess the human health risk melted to the consumers of the vegetables and fruits.

**Corresponding author: E-mail: assaebiconfam@gmail.com;*

**Materials and Methods:** Sixteen different vegetables and fruit samples comprising of Pawpaw and Scent leaves were digested and analyzed for heavy metals using Flame Atomic Absorption Spectrophotometer (F-AAS).
**Results:** The result of the present study reviewed that Pb, Cd, Ni, and Zn ranged from 1.090 ± 0.01 - 5.990 ± 0.06; 0.213 ± 0.03 - 1.317 ± 0.02; 2.810 ± 0.04 - 4.767 ± 0.09; and 0.793 ± 0.01 -5.303 ± 0.02 mg/kg, respectively. The concentrations of Pb, Cd, and Ni in some of the analyzed pawpaw and scent leaf samples exceeded the permissible limit as recommended by WHO/FAO, EC/CODEX and NAFDAC respectively. The concentrations of Zn were below the permissible limit as recommended by WHO/FAO. The Estimated Daily Intake (EDI) of Pb and Cd exceeded the oral reference dose (RfDo) however; Ni and Zn fall within the oral RfDo. The Target Hazard Quotient (THQ) and Hazard Index (HI) values of Pb, Cd, Ni and Zn were less than 1. The Carcinogenic Risk (CR) of Cd and Ni exceeded the range of permissible predicted lifetime risks for carcinogens as recommended by US EPA, meanwhile, the carcinogenic risk of Pb was within the permissible predicted lifetime risks as recommended by USEPA.
**Conclusion:** The result from the present study indicate that the fruits and leaves from pawpaw and scent leaf may be contaminated with Pb, Cd, and Ni and the exposed population may be at risk of developing cancer due to carcinogenic ingestion of Cd and Ni over time.

*Keywords: Carcinogenic risk; estimated daily intake; fruits; heavy metals; pawpaw; risk assessment; scent leaf; target hazard quotient.*

## 1. INTRODUCTION

Recently, Traditional medicine has been used in treating various illnesses, as the use of scientific medications have proven nearly impossible because of poverty. Most times, traditional medicines are obtained from plants which over the years have been proven to solve various health issues. These plants have the tendency to be the cure for many illnesses. This is evident as the World Health Organization (WHO) estimates, that nearly 70–80% of the world population still primarily relies on nonconventional medications, mostly derived from plants [1,2]. The scent leaf plant is a plant eaten by the Amassoma indigenes as vegetable and it is nutritionally important as a seasoning partly because of its aromatic flavor. Phytochemical evaluation of this plant has revealed its rich contents to include alkaloids, flavonoids, tannins, phytates and oligosaccharides. This could be the reason that they are seen as a cure for various ailments [3]. Heavy metal has long biological half-live, they are non biodegradable and the pollution that emanates from heavy metals are usually persistent and irreversible [4]. Heavy metal pollution degrades the quality of the soil, atmosphere, water bodies, and food crops and also threatens the health and well-being of animals and human beings by way of the food chain [5,6,4]. In residential and industrial areas, gradual and consistent accumulation of heavy metals in the surrounding soils result to the absorption and accumulation of these metals by plants via the roots and these absorbed metals tend to disperse to the leaves and fruits which directly threaten the well-being of exposed inhabitants via the consumption of these medicinal plants and fruits [7,8,9]. Vegetables and fruits from medicinal plants such as pawpaw and scent leaf are an important part of the human diet because they contain carbohydrates, proteins, vitamins, minerals as well as trace elements. Heavy metals pollution can result to health dangers to a given exposed population, especially when their concentrations are above the very low permissible limits [10]. Therefore, heavy metals must be controlled in food sources in order to assure public health safety [11]. Excessive amount of heavy metals in food cause a number of diseases, especially cardiovascular, renal, neurological, and bone diseases [12]. Heavy metals could reach food chain through various biochemical processes and ultimately biomagnified in various trophic levels and eventually threaten the health of humans [13].

This study assessed the heavy metals contamination and potential human health risk that may be posed to the populace of Amasoma community in Bayelsa State of Nigeria via the consumption of medicinal plants and fruits from pawpaw and scent leaf.

## 2. MATERIALS AND METHODS

### 2.1 Sample Area

Amassoma community in Southern Ijaw Local Government Area, Bayelsa State of Nigeria was selected for sampling. Sampling was done at random from three different locations within Amassoma metropolis. These locations were selected at random to centralize the sample stations within the community (Sample location) as shown in Figure 1. Geographically, sample area has land mass of 2682 km$^2$ and a population of 319413 at the 2006 census. The people are predominant farmers, fishermen, business men and civil servants.

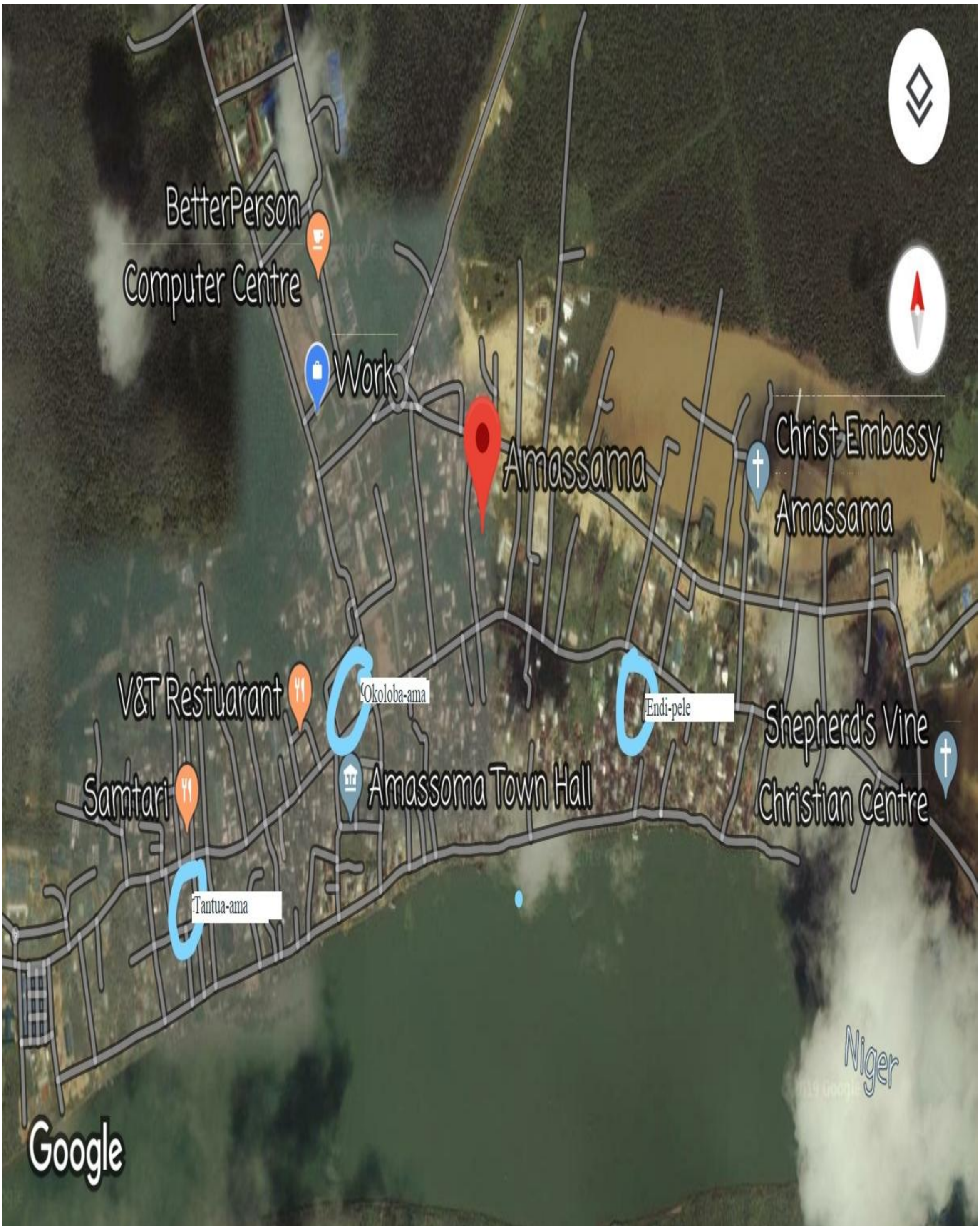


**Fig. 1. Study Area Map (Amassoma Community), Showing sampling sites**

## 2.2 Sample Collection and Preparation

Fresh samples each of the four selected leaves and fruits from pawpaw and scent leaf were collected randomly from different farms in Amasoma community in Bayelsa State. The samples were properly tagged according to the various locations in polythene bags and taken to the Herbarium of Plant Science and Biotechnology Department, University of Port Harcourt for identification, and subsequently taken to the laboratory for heavy metal analyses.

## 2.3 Sample Preparation

Leafy vegetable and fruit samples of pawpaw and scent leaf were thoroughly washed with tap water to remove dust particles, soil, unicellular algae etc. The edible parts of the samples were further washed with distilled water and finally with deionized water. The washed leaves and fruits were dried with blotting paper followed by filter paper at room temperature to remove surface water. They were immediately kept in desiccators to avoid further evaporation of moisture from the materials. After that, they were chopped into small pieces and oven dried at 55 ± 1 oC. They were crushed into fine powder using a porcelain mortar and pestle. The resulting powder was kept in air tight polythene packet at room temperature before being taken to the laboratory for digestion and metals analyses [13].

## 2.4 Digestion and Metal Analysis

5 g of each samples was measured into a clean dried beaker (100 mL), 2 mL of acidic mixture of $H_2SO_4$, $HNO_3$, and $HClO_4$ in ratio 40:40:20, was then added to the sample for digestion. The samples were allowed to be evenly distributed in the acid by stirring with a glass rod; the beaker was then placed on the digestion block in a fume cupboard for 2 hours at temperature 150°C for digestion. The digested samples were then filtered into a 25 mL volumetric flask and made to mark with deionized water. The digested samples were kept at 4°C prior to analysis. A Solar thermo elemental Flame Atomic Absorption Spectrophotometer (Flame-AAS) with model number, S4 71096 was used for lead (Pb), cadmium (Cd), nickel (Ni), and Zinc (Zn) analysis [14]. The AAS method was carried out by installing a hollow cathode lamp for the desired metal. The wavelength dial was set as specified by the analytical methodology. Slit width was set according to the suggested setting of the manufacturer. The instrument was turned on, the hollow cathode lamp current was applied as suggested by the manufacturer, and the instrument was allowed to warm up until energy sources were stabilized, for about 10 to 20 minutes. The current was readjusted after warm-up. The wavelength dial was also adjusted until optimum energy gain was obtained. The lamp was aligned in accordance with the instructions of the manufacturer. A suitable burner head was installed, and its position was adjusted. A 10cm, single-slot burner head was recommended for air-acetylene flames. Air was turned on, and the flow rate was adjusted according to the instructions of the manufacturer to give maximum sensitivity for the measured metal. Acetylene was turned on and flow rate was adjusted to the specified value. The flame was ignited and allowed to stabilize for few minutes. The blank sample was aspirated and the instrument was zeroed. A standard solution was aspirated and aspiration rate of nebulizer was adjusted to obtain maximum sensitivity. The burner was adjusted both vertically and horizontally to obtain maximum response. The blank was aspirated again and the instrument was zeroed. The standard was aspirated with a concentration near the middle of the linear range and the absorbance was recorded. The instrument was then ready to operate. After analysis was finished, the flame was extinguished by turning off acetylene first and then air.

## 2.5 Heavy Metal Health Risk Assessment

The potential health risks of heavy metal consumption through medicinal plants (pawpaw and scent leaf) were assessed based on the estimated daily intake of metals (EDI) [15], the target hazard quotient (THQ) [16], Hazard index (HI) [17] and the Incremental Lifetime Cancer Risk (ILCR) [18]. The estimated daily intake of metals (EDI) was carried out to ascertain the daily metal ingestion into the body system of both the adult and children body weight of the exposed populace. This will give an insight on the relative phyto-availability of the studied metals.

## 2.6 Estimated Daily Intake (EDI)

$$\text{EDI} = \text{EDI} = \frac{C_{metal} \times D_{food\ Intake}}{\text{BWaverage}}$$

Where $C_{metal}$ is concentration of heavy metals in leaves and fruits of pawpaw and scent leaf in mg/kg

$D_{food\ intake}$ is the daily average consumption of leaves and fruits of pawpaw and scent leaf in kg/person in the study area.

BWaverage is body weight in kg/person (60kg for adult and 24kg for children) [19].

## 2.7 Non-carcinogenic Health Effect

### 2.7.1 Target hazard quotient (THQ)

Non-carcinogenic risk estimation of heavy metals consumption was determined using THQ values [16] (Storelli *et al*., 2008). Target Hazard Quotient values were calculated using the following formula below [16].

$$THQ = \frac{EFR \times ED \times FIR \times C}{BW \times ATn}$$

Where EFR is exposure frequency in 156 days per year
ED is the exposure duration (56 years, equivalent to the average lifetime of the Nigerian population)
FIR is average daily consumption in kg/person/day
C is concentration of metal in leaves and fruits samples in mg/kg
RfDo is reference dose in mg/kg/day [20].
ATn is average exposure time for non–carcinogens in days (156 x 56).
The following reference doses were used (Pb = 0.0035 mg/kg; Cd; = 0.001 mg/kg; Ni=0.02 mg/kg; Zn = 0.3 mg/kg) [21].

### 2.7.2 Calculation of hazard index

Hazard index was calculated as the sum of hazard quotients (HQs). Since different pollutants can cause similar adverse health effects, it is often appropriate to combine HQs associated with different substances. HI = ΣTHQ (THQ1+THQ2+THQ3………. THQn).

### 2.7.3 Carcinogenic risk (CR)

Incremental lifetime cancer risk (ILCR) is the lifetime probability of an individual developing any type of cancer due to carcinogenic daily exposure to a contaminant over a life time [22]. The ILCR is obtained using the Cancer Slope Factor (CSF) which evaluates the probability of an individual developing cancer from oral exposure to contaminant levels over a period of a lifetime of 1 mg/kg BW/day and is contaminant specific [23]. Therefore, ILCR value in vegetable evaluates the probability of an individual developing cancer from oral exposure to contaminant levels over a period of a lifetime [24]. Ingestion cancer slope factors are expressed in units of (mg/kg/day).

The cancer risk was calculated using the equation below;

Carcinogenic risk = EDI × CSFing

Where: EDI is the estimated daily intake of each heavy metal (mg/kg/day)
CSFing is ingestion cancer slope factor (mg/kg/day) (Pb = 0.0085, Cd = 0.38, Ni = 0.91) [25]. USEPA [26] states that $10^{-6}$ (1 in 1,000,000) to $10^{-4}$ (1 in 10,000) represent a range of permissible predicted lifetime risks for carcinogens. Chemical for which the risk factor falls below $10^{-6}$ may be eliminated from further consideration as a chemical of concern.

## 3. RESULTS AND DISCUSSION

### 3.1 Concentrations of Heavy Metals in Medicinal Plants (Pawpaw fruits and Scent leaf)

The results showed that the concentration of Pb, Cd, Ni, and Zn in edible portions of leaves and fruits was shown in Table 1. The concentration of Pb, Cd, Ni, and Zn ranged from 1.090 ± 0.01 - 5.990 ± 0.06, 0.213 ± 0.03 - 1.317 ± 0.02, 2.810 ± 0.04 - 4.767 ± 0.09, and 0.793 ± 0.01 -5.303 ± 0.02 mg/kg, respectively. The concentrations of heavy metals in all the analyzed leaves and fruit samples were in the order of Pb > Zn > Ni > Cd. The highest level of Pb was recorded in pawpaw fruit (5.990 ± 0.06 mg/kg) from site 1, meanwhile the lowest was seen in pawpaw leaf (1.090 ± 0.01 mg/kg) from site 2. The highest level of Cd was observed in pawpaw fruit (1.317 ± 0.02 mg/kg) from site 1. However, pawpaw seed (0.213 ± 0.03 mg/kg) from site 3 recorded the lowest value of Cd. The highest concentration of Ni was seen in pawpaw seed (4.767 ± 0.09 mg/kg) from site 3, meanwhile, scent leaf from site 4 (2.810 ± 0.04 mg/kg) recorded the lowest level of Ni. The highest concentration of Zn was recorded in pawpaw seed (5.303 ± 0.02 mg/kg) from site 3, meanwhile, the lowest concentration of Zn was seen in scent leaf from site 4 (0.793 ± 0.01 mg/kg).

**Table 1. Heavy Metals Concentration in Edible Fruits and Vegetables**

| Sample | Pb | Cd | Ni | Zn |
|---|---|---|---|---|
| Site 1 Pawpaw Fruit | 5.990 ± 0.06 | 1.317 ± 0.02 | 3.763 ± 0.07 | 2.517 ± 0.02 |
| Site 2 Pawpaw Leaf | 1.090 ± 0.01 | 0.963 ± 0.01 | 3.470 ± 0.04 | 2.530 ± 0.04 |
| Site 3 Pawpaw Seed | 3.716 ± 0.04 | 0.213 ± 0.03 | 4.767 ± 0.09 | 5.303 ± 0.02 |
| Site 4 Scent Leaf | 1.097 ± 0.01 | 0.587 ± 0.01 | 2.810 ± 0.04 | 0.793 ± 0.01 |
| **FAO/WHO** | 2.0 | 1.0 | | 50 |
| **EU** | 0.3 | 0.2 | | |
| **NAFDAC** | | | 2.7 | |

### 3.2 Estimated Daily Intake (EDI) of Heavy Metals in Adult populace via Consumption of Medicinal Plants (Pawpaw fruits and Scent Leaf)

The EDI of Pb, Cd, Ni, and Zn in edible portions of leaves and fruits in adult populace was shown in Table 2. The EDI of Pb, Cd, Ni, and Zn in adult populace ranged between 0.004 - 0.020, 0.001 - 0.004, 0.009 - 0.016, and 0.003 - 0.018 mg/kg, respectively. The highest EDI value of Pb was recorded in pawpaw seed (0.012 mg/kg) from site 3, meanwhile the lowest was seen in pawpaw leaf and scent leaf (0.004 mg/kg) from site 2 and 4. The highest EDI value of Cd was observed in pawpaw fruit (0.004 mg/kg) from site 1. However, pawpaw seed (0.001 mg/kg) from site 3 recorded the lowest EDI value of Cd. The highest EDI value of Ni was seen in pawpaw seed (0.016 mg/kg) from site 3, meanwhile, scent leaf from site 4 (0.009 mg/kg) recorded the lowest EDI value of Ni. The highest EDI value of Zn was recorded in pawpaw seed (0.018 mg/kg) from site 3, meanwhile, the lowest EDI value of Zn was seen in scent leaf from site 4 (0.003 mg/kg).

### 3.3 Estimated Daily Intake (EDI) of Heavy Metals in Children populace via Consumption of Medicinal Plants (Pawpaw fruits and Scent Leaf)

The EDI of Pb, Cd, Ni, and Zn in edible portions of leaves and fruits in children populace was shown in Table 3. The EDI of Pb, Cd, Ni, and Zn in children populace ranged between 0.009 - 0.050, 0.002 - 0.011, 0.023 - 0.040, and 0.007 - 0.044 mg/kg, respectively. The highest EDI value of Pb was recorded in pawpaw fruit (0.050 mg/kg) from site 1, meanwhile the lowest was seen in pawpaw leaf and scent leaf (0.009 mg/kg) from site 2 and 4. The highest EDI value of Cd was observed in pawpaw fruit (0.011 mg/kg) from site 1. However, pawpaw seed (0.002 mg/kg) from site 3 recorded the lowest EDI value of Cd. The highest EDI value of Ni was seen in pawpaw fruit (0.031 mg/kg) from site 1, meanwhile, scent leaf from site 4 (0.023 mg/kg) recorded the lowest EDI value of Ni. The highest EDI value of Zn was recorded in pawpaw seed (0.044 mg/kg) from site 3, meanwhile, the lowest EDI value of Zn was seen in scent leaf from site 4 (0.007 mg/kg).

### 3.4 Target Hazard Quotient (THQ) of Heavy Metals in Adult populace via Consumption of Medicinal Plants (Pawpaw fruits and Scent Leaf)

The THQ of Pb, Cd, Ni, and Zn in edible portions of leaves and fruits in adult populace was shown in Table 4. The THQ of Pb, Cd, Ni, and Zn in adult populace ranged from 1.9E-05 - 1.0E-04, 1.1E-06 - 6.6E-06, 2.8E-04 - 4.8E-04 and 1.2E-03 - 8.0E-03, respectively. The highest THQ value of Pb was recorded in pawpaw fruit (1.0E-04) from site 1, meanwhile the lowest was seen in pawpaw leaf and scent leaf (1.9E-05) from site 2 and 4. The highest THQ value of Cd was observed in pawpaw fruit (6.6E-06) from site 1. However, pawpaw seed (1.1E-06) from site 3 recorded the lowest THQ value of Cd. The highest THQ value of Ni was seen in pawpaw seed (4.8E-04) from site 3, meanwhile, scent leaf from site 4 (2.8E-04) recorded the lowest THQ value of Ni. The highest THQ value of Zn was recorded in pawpaw seed (5.9E-01) from site 3, meanwhile, the lowest THQ value of Zn was seen in scent leaf from site 4 (1.0E-01).

**Table 2. Estimated Daily Intake (EDI) of Heavy Metals in Adult Population via Consumption of Fruits and Vegetables**

| Sample | Pb | Cd | Ni | Zn |
|---|---|---|---|---|
| Site 1 Pawpaw Fruit | 0.020 | 0.004 | 0.013 | 0.008 |
| Site 2 Pawpaw Leaf | 0.004 | 0.003 | 0.012 | 0.008 |
| Site 3 Pawpaw Seed | 0.012 | 0.001 | 0.016 | 0.018 |
| Site 4 Scent Leaf | 0.004 | 0.002 | 0.009 | 0.003 |
| **RfDo** | 0.0035 | 5.0E-4 | 0.02 | 0.3 |

*RfDo: Reference Dose [21]*

**Table 3. Estimated Daily Intake (EDI) of Heavy Metals in Children Population via Consumption of Fruits and Vegetables**

| Sample | Pb | Cd | Ni | Zn |
|---|---|---|---|---|
| Site 1 Pawpaw Fruit | 0.050 | 0.011 | 0.031 | 0.021 |
| Site 2 Pawpaw Leaf | 0.009 | 0.008 | 0.029 | 0.021 |
| Site 3 Pawpaw Seed | 0.031 | 0.002 | 0.040 | 0.044 |
| Site 4 Scent Leaf | 0.009 | 0.005 | 0.023 | 0.007 |
| **RfDo** | 0.0035 | 5.0E-4 | 0.02 | 0.3 |

*RfDo: Reference Dose [21]*

**Table 4. Target Hazard Quotient (THQ) of Heavy Metals in Adult Population via Consumption of Fruits and Vegetables**

| Sample | Pb | Cd | Ni | Zn | HI |
|---|---|---|---|---|---|
| Site 1 Pawpaw Fruit | 1.0E-04 | 6.6E-06 | 3.8E-04 | 3.8E-03 | 3.0E-01 |
| Site 2 Pawpaw Leaf | 1.9E-05 | 4.8E-06 | 3.5E-04 | 3.8E-03 | 2.9E-01 |
| Site 3 Pawpaw Seed | 6.5E-05 | 1.1E-06 | 4.8E-04 | 8.0E-03 | 5.9E-01 |
| Site 4 Scent Leaf | 1.9E-05 | 2.9E-06 | 2.8E-04 | 1.2E-03 | 1.0E-01 |
| **Reference Value** | 1 | 1 | 1 | 1 | 1 |

The result of the Hazard Index (HI) in adult population from the various locations is shown in Tables 4. The HI of the analyzed metals ranged from 1.0E-01 - 5.9E-01. The highest HI value in adult population was recorded in pawpaw seed (5.9E-01) from site 3 whereas the lowest HI value was recorded in scent leaf (1.0E-01) from site 4.

### 3.5 Target Hazard Quotient (THQ) of Heavy Metals in Children populace via Consumption of Medicinal Plants (Pawpaw fruits and Scent Leaf)

The THQ of Pb, Cd, Ni, and Zn in edible portions of leaves and fruits in children populace was shown in Table 5. The THQ of Pb, Cd, Ni, and Zn in children populace ranged from 7.6E-07 - 4.2E-06, 4.3E-08 - 2.6E-07, 1.1E-05 - 1.9E-05 and 4.8E-05 - 3.2E-04, respectively. The highest THQ value of Pb was recorded in pawpaw fruit (4.2E-06) from site 1, meanwhile the lowest was seen in scent leaf (7.7E-07) from site 4. The highest THQ value of Cd was observed in pawpaw fruit (2.6E-07) from site 1. However, pawpaw seed (4.3E-08) from site 3 recorded the lowest THQ value of Cd. The highest THQ value of Ni was seen in pawpaw seed (1.9E-05) from site 3, meanwhile, scent leaf from site 4 (1.1E-05) recorded the lowest THQ value of Ni. The highest THQ value of Zn was recorded in pawpaw seed (3.2E-04) from site 3, meanwhile, the lowest THQ value of Zn was seen in scent leaf from site 4 (4.8E-05).

The result of the Hazard Index (HI) in children population from the various locations is shown in Tables 5. The HI of the analyzed metals ranged from 6.0E-05 - 3.4E-04. The highest HI value in children population was recorded in pawpaw seed (3.4E-04) from site 3 whereas the lowest HI value was recorded in scent leaf (6.0E-05) from site 4.

**Table 5. Target Hazard Quotient (THQ) of Heavy Metals in Children Population via Consumption of Fruits and Vegetables**

| Sample | Pb | Cd | Ni | Zn | TCR |
|---|---|---|---|---|---|
| Site 1 Pawpaw Fruit | 4.2E-06 | 2.6E-07 | 1.5E-05 | 1.5E-04 | 1.7E-04 |
| Site 2 Pawpaw Leaf | 7.6E-07 | 1.9E-07 | 1.4E-05 | 1.5E-04 | 1.7E-04 |
| Site 3 Pawpaw Seed | 2.6E-06 | 4.3E-08 | 1.9E-05 | 3.2E-04 | 3.4E-04 |
| Site 4 Scent Leaf | 7.7E-07 | 1.2E-07 | 1.1E-05 | 4.8E-05 | 6.0E-05 |
| **Reference Value** | 1 | 1 | 1 | 1 | 1 |

### 3.6 Carcinogenic Risk (CR) of Heavy Metals in Adult populace via Consumption of Medicinal Plants (Pawpaw fruits and Scent Leaf)

The CR of Pb, Cd, and Ni in edible portions of leaves and fruits in adult populace was shown in Table 6. The CR of Pb, Cd, and Ni in adult populace ranged from 3.1E-05 - 1.7E-04, 2.7E-04 - 1.7E-03, and 8.5E-03 - 1.4E-02, respectively. The highest CR value of Pb was recorded in pawpaw fruit (1.7E-04) from site 1, meanwhile the lowest was seen in pawpaw leaf and scent leaf (3.1E-05) from sites 2 and 4. The highest CR value of Cd was observed in pawpaw fruit (1.7E-03) from site 1. However, pawpaw seed (2.7E-04) from site 3 recorded the lowest CR value of Cd. The highest CR value of Ni was seen in pawpaw seed (1.4E-02) from site 3, meanwhile, scent leaf from site 4 (8.5E-03) recorded the lowest CR value of Ni.

The result of the Carcinogenic Risk (CR) in adult population from the various locations is shown in Tables 6. The CR of the analyzed metals ranged from 9.3E-03 - 1.5E-02. The highest CR value in adult population was recorded in pawpaw seed (1.5E-02) from site 3 whereas the lowest CR value was recorded in scent leaf (9.3E-03) from site 4.

### 3.7 Carcinogenic Risk (CR) of Heavy Metals in Children populace via Consumption of Medicinal Plants (Pawpaw fruits and Scent Leaf)

The CR of Pb, Cd, and Ni in edible portions of leaves and fruits in children populace was shown in Table 7. The CR of Pb, Cd, and Ni in children populace ranged from 7.7E-05 - 4.2E-04, 6.7E-04 - 4.2E-03, and 2.3E-02 - 3.6E-02, respectively. The highest CR value of Pb was recorded in pawpaw fruit (4.2E-04) from site 1, meanwhile the lowest was seen in pawpaw leaf (7.7E-05) from sites 2. The highest CR value of Cd was observed in pawpaw fruit (4.2E-03) from site 1. However, pawpaw seed (6.7E-04) from site 3 recorded the lowest CR value of Cd. The highest CR value of Ni was seen in pawpaw seed (3.6E-02) from site 3, meanwhile, scent leaf from site 4 (2.3E-02) recorded the lowest CR value of Ni.

**Table 6. Carcinogenic Risk (CR) of Heavy Metals in Adult Population via Consumption of Fruits and Vegetables**

| Sample | Pb | Cd | Ni | Zn | HI |
|---|---|---|---|---|---|
| Site 1 Pawpaw Fruit | 1.7E-04 | 1.7E-03 | 1.1E-02 | - | 1.3E-02 |
| Site 2 Pawpaw Leaf | 3.1E-05 | 1.2E-03 | 1.1E-02 | - | 1.2E-02 |
| Site 3 Pawpaw Seed | 1.1E-04 | 2.7E-04 | 1.4E-02 | - | 1.5E-02 |
| Site 4 Scent Leaf | 3.1E-05 | 7.4E-04 | 8.5E-03 | - | 9.3E-03 |
| **Reference Value** | $10^{-6} – 10^{-4}$ | $10^{-6} – 10^{-4}$ | $10^{-6} – 10^{-4}$ | - | $10^{-6} – 10^{-4}$ |

**Table 7. Carcinogenic Risk (CR) of Heavy Metals in Children Population via Consumption of Fruits and Vegetables**

| Sample | Pb | Cd | Ni | Zn | HI |
|---|---|---|---|---|---|
| Site 1 Pawpaw Fruit | 4.2E-04 | 4.2E-03 | 2.9E-02 | - | 3.3E-02 |
| Site 2 Pawpaw Leaf | 7.7E-05 | 3.0E-03 | 2.6E-02 | - | 2.9E-02 |
| Site 3 Pawpaw Seed | 2.6E-04 | 6.7E-04 | 3.6E-02 | - | 3.7E-02 |
| Site 4 Scent Leaf | 7.8E-05 | 1.9E-03 | 2.3E-02 | - | 2.5E-02 |
| **Reference Value** | $10^{-6} – 10^{-4}$ | $10^{-6} – 10^{-4}$ | $10^{-6} – 10^{-4}$ | - | $10^{-6} – 10^{-4}$ |

The result of the Carcinogenic Risk (CR) in children population from the various locations is shown in Tables 7. The CR of the analyzed metals ranged from 2.5E-02 - 3.7E-02. The highest CR value in children population was recorded in pawpaw seed (3.7E-02) from site 3 whereas the lowest CR value was recorded in scent leaf (2.5E-02) from site 4.

## 4. DISCUSSION

This research has shown the contamination profile of leaves and fruits from medicinal plants commonly consumed from selected locations in Amasoma community in Bayelsa State of Nigeria and the possible public health implications.

The concentration of Pb in pawpaw fruit and pawpaw seed from sites 1 and 3 respectively exceeded the 2.0 mg/kg permissible limit recommended by FAO/WHO [27]. This is an indication that the pawpaw fruit and seed obtained from sites 1 and 3 may be contaminated as a result of high concentration of Pb which may result to health risk to the exposed population. However, pawpaw leaf and scent leaf from sites 2 and 4 respectively were below the safe limit recommended by FAO/WHO [27] which simply indicates that there may not be contamination of the pawpaw leaf and scent leaf from sites 2 and 4 respectively as a result of Pb. The results obtained from this present study were contrary to the report of Adusei-Mensah *et al*. [28] which recorded lower concentrations of Pb in medicinal plants. This high concentration of Pb in the analyzed medicinal plants may be as a result of pollutants in irrigation water, farm soil contaminated by crude oil from oil exploration and also pollution from the highways traffic [29]. Furthermore, high concentration of Pb could be due to increase in mobile metal fraction of Pb and high level of oil exploration [30] with higher metal fraction, uptake and accumulation of metal in vegetable increase.

Lead is known to induce reduced cognitive development and intellectual performance in children and cardiovascular disease and increased blood pressure in adults [31]. Generally, Pb contaminations occur in vegetables grown in contaminated soils, through air deposition, sewage sludge/waste water application or oil exploration [29]. In human body, Pb causes neurological, hematological and physiological disorders [32]. Lead influences the nervous system, slowing down nervous response. This influences learning abilities and behavior [33].

The concentration of Cd in the analyzed samples were above the 0.2 mg/kg permissible limit as recommended by European Union [34], however, all the samples analyzed in this current study were below the safe recommended limit by FAO/WHO [27] except Pawpaw Fruit from site 1 which exceeded both permissible limits by FAO/WHO and EU [27;34]. This is an indication that pawpaw fruit from site 1 may be contaminated as a result of high concentration of Cd which may eventually result to health risk to the exposed population. The result of the present study corroborated with the report of Adedokun *et al*. [35] who reported similar low value of Cd in leafy vegetables cultivated along road sides in Lagos State. Low level of cadmium may be attributed to low or no use of phosphate fertilizers by the farmers on the planted vegetables. The result of the current study disagreed with the report of Adusei-Mensah *et al*. [28] which recorded lower concentrations of Cd in medicinal plants. The higher level of cadmium in this study may be due to high use of phosphate fertilizers by the farmers in the study area which tend to elevate the gradual accumulation of cadmium in the soil. Cadmium is a heavy metal with high toxicity and it is a non-essential element in foods and natural waters and it accumulates principally in the kidney and liver [36;33]. Accumulation of Cd in human body leads to certain disorder including cardiovascular diseases, liver and nervous system diseases [36;33]. The most common sources of Cd in plants and vegetables are sewage sludge application, deposition from fossil fuel combustion, phosphate fertilizers etc. [33]. Cadmium accumulates especially in the kidney leading to dysfunction of the kidney with increased secretion of proteins in urine (proteinuria) and other effects [37].

The concentration of Ni in the analyzed samples in this present study exceeded the permissible limit of 2.7 mg/kg recommended by NAFDAC. This indicates that the analyzed medicinal plant samples were contaminated as a result of high concentration of Ni which may result to health risk to the exposed populace when they consumed the medicinal plants. The result of this study is contrary to the report of Adedokun *et al*. [35] who reported lower concentration of Ni in leafy vegetables cultivated along road side in Lagos State of Nigeria. This high level of Ni in this study may be as a result of excessive oil exploration and illegal bunkering activities in the study area. Inhaled Ni carbonyl, a carcinogenic gas that results from the action of nickel with heated carbon monoxide from cigarette smoke, car exhaust, and some industrial wastes is very toxic and Ni allergy can also cause systematic reactions [38].

The concentration of Zn in all the analyzed medicinal plants were below the 50 mg/kg permissible limit recommended by FAO/WHO [27], this showed that the analyzed samples may not be contaminated as a result of Zn. The concentration of Zn in this study corroborated with the report of Adusei-Mensah *et al*. [28] in the research heavy metal content and health risk assessment of commonly patronized herbal medicinal preparations from the Kumasi metropolis of Ghana. The result of this study showed that the concentrations of Zn were contrary to those reported by Nkpaa *et al*. [39] who reported higher Zn concentration. Zinc is an important trace component that results in delayed development, loss of taste, dermatitis, alopecia, hypogonadism and reduced fertility [40].

The Estimated Daily Intake (EDI) of Pb, Ni, and Zn in the adult and children populace from this study were below the oral reference dose (RfDo) as recommended by USEPA-IRIS [21]. This is an indication that the populace may not be in danger of developing health risk as a result of the ingestion of Pb, Ni, and Zn. However, the EDI of Cd in all the analyzed medicinal plant samples exceeded the recommended oral reference dose (RfDo) recommended by USEPA-IRIS [21], which may indicate that the exposed populace may be at health risk due to the gradual ingestion of Cd into the body system as they gradually consume the medicinal plants.

The Target Hazard Quotient (THQ) of Pb, Cd, Ni, and Zn in the adult and children populace from this present study were less than 1. This is an indication that the exposed population may not be in danger of developing non carcinogenic risk. This is because THQ $< 1$ show that there may not be health danger, however, THQ $> 1$ indicate health risk. Furthermore, the Hazard Index of the analyzed metals in the present study were less than 1, an indication that there may not be non carcinogenic health risk posed to the populace as a result of the ingestion of the metals into the body system via the consumption of the medicinal plants.

The Carcinogenic Risk (CR) of Pb in the adult and children populace from the present study in the analyzed samples were within the range of permissible predicted lifetime risks for carcinogens as suggested by USEPA [26], which indicate that the populace may not be at risk of developing cancer over time as a result of the carcinogenic ingestion of Pb via the consumption of the medicinal plants. However, the CR of Cd and Ni in the adult and children populace in all the analyzed samples from this study were above the range of permissible predicted lifetime risks for carcinogens as suggested by USEPA [26], which indicate that the populace may be at risk of developing cancer over time as a result of the carcinogenic ingestion of Cd and Ni via the consumption of the medicinal plants.

## 5. CONCLUSION

This study has shown the level of contamination of medicinal plants by selected heavy metals (Pb, Cd, Ni, and Zn) and the health risk that may emanate from these heavy metals contamination when the medicinal plants are consumed by the populace. From the results obtained from this study, the concentrations of Pb, Cd, and Ni were higher than the recommended permissible limits which indicate that there may be contamination of the medicinal plants by these metals, however, the concentration of Zn in the analyzed samples were below the recommended permissible limit which shows that there may not be contamination of the medicinal plants as a result of Zn. The EDI of Pb and Cd in adult and children populace exceeded the recommended oral reference dose which is an indication that the populace may be at health risk as a result of Pb and Cd contamination. Furthermore, the THQ and HI in the adult and children populace were less than 1 which is an indication that there may not be non carcinogenic health risk posed to the exposed populace. The CR of Cd and Ni in the adult and children populace exceeded the permissible predicted range for carcinogen as recommended by USEPA which indicate that the populace may be at risk of developing cancer as a result of carcinogenic ingestion of Cd and Ni.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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