**Public Health Implications of Toxic Heavy Metals: Lead (Pb) and Cadmium (Cd) in Common Street Vended Foods Consumed in Bayelsa State, Nigeria.**

**ABSTRACT**

**Aim:** Over the years, Street Vended Food (SVFs) had gained prominence because they are ready-to-eat and very affordable. As such, they serve as a convenient source of processed foods with dissimilar options. However, the safety and security of SVFs is so alarming due to environmental contaminants, unhygienic practice of some vendors as well as the vending site. Therefore, the aim of this study is to evaluate the levels of Lead and Cadmium in some Street Vended Foods from Yenagoa, Amassoma and Ogbia communities in Bayelsa State, Nigeria and analyze its health implications via oral ingestion to the general public.

**Study Design:** This study involves sample collection, preparation, digestion and Atomic Absorption Spectrophotometer, FAAS; and it was carried out in the Central Research Laboratory, Department of Chemical Sciences, Faculty of Science, Niger Delta University, between March 2024- May 2024.

**Methodology:** The concentrations (mg/kg dry weight basis) of Pb and Cd from the digested biomass of the SVFs were analyzed with FAAS.

**Results:** The concentrations of Pb in the 15 SVFs studied were all higher that threshold limits of Joint Food and Agricultural Organization/ World Health Organization (FAO/WHO) and Codex Alimentarius Commission but, Cd concentrations were below their standard limits. Analysis of variance shows significant differences (p = 0.01 and 0.02) in the levels of Pb and Cd across the three communities among the SVFs. The human health risk exposure assessment indicates no carcinogenic risk at the moment. However, the carcinogenic risk assessment revealed that most of the SVFs samples exceeded the threshold values of 10E-04– 10E-06. Therefore, daily/regular consumption of Street Vended Foods should be discouraged.

**Keywords:** Public Health Implication, Toxic Heavy Metals, Lead, Cadmium, Street Vended Foods, Bayelsa State.

**INTRODUCTION:**

Over the years, street vended foods (SVFs) had gained prominence because they are readily accessible, very cheap and affordable and ready to eat which serve as convenient source of cooked/processed foods with dissimilar options (Mazi et al., 2023; Oyet and Samuel, 2020; Ekhator et al., 2017 and Mohammed et al., 2016). In facts, literature search revealed that over two (2) billions of people across the globe consume SVFs daily (MWOVE et al., 2023; Fuste-Forne, 2021; FAO, 2017). This has led to proliferation and economic boom in SVFs Sector as large proportion of both rural and urban populations now depends on street vended foods (SVFs) for their daily nutritional needs for adequate diet (Adeosun et al.,2022; Ajeji, 2023 and Imathiu, 2017). However, the safety and security of SVFs is so alarming and questionable due to environmental contaminants such as heavy metals. Studies had shown that most SVFs are often prepared, processed and sold in unhealthy (unhygienic) environment and thus are easily exposed to contaminants such as heavy metals, bacteria, dust etc. (Letuku,2023; Ekhator et al., 2017, Sequzin and Sanlier, 2016, Nurudeen et al., 2014 and Rane, 2011). These contaminants have been linked to foodborne diseases such as Cholera, diarrhea, food poisoning, stomach ache, renal disorder, major organ damages and cardiovascular diseases (Letuka, 2023; Rakha, 2022; Okojie and Isah 2019 and Imathiu, 2017).

In Bayelsa State, the consumption of SVFs is wide spread due to its benefits such as its affordability and ready- to- eat by both the low, middle and high-class citizens. This has resulted in in economic boom in street food sectors within the state and has become unregulated. Often, most vending stalls are located close or near roadside, dumpsite or wastebin which may stand the risk of contamination. Therefore, the contamination of SVFs by contaminants such as heavy metals are inevitable.

Generally, the contamination of heavy metals in SVFs often stemmed from different factors such as; vending site (located on the road with high vehicular emission and wasted disposal site) and construction site, vendors unsafe and unhealthy hygienic practice during food preparation and poor packaging materials, and leaching of metals from cooking utensils especially metals utensils (Letuka et al., 2023; Ankar-Brewoo et al., 2020; Ikpome et al., 2009).As such, various studies had confirmed an elevated concentrations of heavy metals in SVFs (Mazi et al., 2023; Letuka et al.,2023; Ajegi et al., 2023; Oyet et al., 2020; Mohammed et al., 2020; Ekhator et al.,2017; Adeyeye, 2017; etc.).In addition, a study carried out by Ikpome et al., (2009) revealed that samples of SVFs obtained from busy road side and uncovered after preparation had high levels of heavy metals compared to the samples obtained in a healthy environment and good hygienic practices. Heavy metals when present in elevated concentrations pose public health risk especially when consumed through food (Jomovaa et al., 2022). This is because heavy metals are non-biodegradable, but rather persist and bioaccumulate within tissues and organs and causes health hazards such as gastrointestinal disease, anemia, cardiovascular diseases, neurological disorder etc. (Markmanuel et al., 2023,2020, Hazrat et al.,2021).

However, literature search shows no comprehensive data on the concentrations of heavy metals in SVFs from Bayelsa State and the health risk posed via consumption, Therefore, the aim of this study is to investigate the concentrations of Lead (Pb) and Cadmium (Cd) in street vended foods (SVFs) obtained from Bayelsa State, Nigeria.

**2.0. MATERIALS AND METHODS**

**2.1. Study Area**

Bayelsa State is characterized by a unique riverine and estuarine settling and as such, most communities are surrounded by water making road inaccessible. The state lies in the heaviest rainfall area in Nigeria with heavy rain forest and a short dry season (ranging from November to April). The major occupations of state indigenes are fishing, farming, palm wine tapping and trading. Geographically, the state is located within the latitude 4 Â ° 23” South and Longitude 5 Â ° 22” West and 6 Â ° 45” East. Bayelsa State is bounded by River State in the East, Delta State in the North and Atlantic Ocean in the Southern and Western Regions. Bayelsa State is made up of Eight (8) Local Government Namely; Brass, Ekeremor, Kolokuma/Opokuma, Nembe, Sagbama, Southern Ijaw and Yenagoa. Yenagoa is the capital city of Bayelsa State. The total landmass of the state is approximately 21110 5q Km with three quarter of this landmass covered by water with moderate low land stretching from Ekeremor to Nembe – Brass. (Markmanuel et al., 2019; Overview of Bayelsa State, 2023). Bayelsa State is one of the largest oils producing state in Nigeria, having significant crude oil and natural gas reserves. As such, the state attracts major oil and gas industries which serves as the backbone of the state’s economy, also, contributing massively to Nigeria’s overall economy especially in the exports of oil and gas. Due to the massive oil and gas exploration and exploitation by oil companies and illegal refiners of the crude oil (locally known as kpo fire) by indigenes, the state is constantly impacted by climate change and environmental degradation especially oil spillage and carbon emission (THISDAYLIVE, 2023). These and many more activities within the state undoubtfully have released heavy metals into the streets of Bayelsa State.



**Figure 1. Map showing the Study Area and Sampling Points.**

**2.2. SAMPLE COLLECTION PROCEDURE AND PREPARATION.**

Street Vended Foods (SVFs) were collected from three different communities in three Local Government Areas of Bayelsa State namely; Yenagoa city (the capital city of Bayelsa State in Yenagoa Local Government Areas, Amassoma town in Sothern Ijaw Local Government Area and Ogbia town in Ogbia Local Government Area) respectively. The sampling location selection was based on high increase in population, industrial activities as well as an increase in anthropogenic activities.

SVFs samples consisting of Akara, Puff-puff, Fried beef, Fried fish, Fried chicken, cooked beans, Jollof rice, Moi-moi, Agidi, Fufu, Meatpie, Madiga, Roasted plantain, Roasted yam and Suya (a total of fifteen, 15 SVFs samples) were purchased from vendors in the three different communities across three Local Government Areas in Bayelsa State. They were carefully wrapped in an aluminum foil and placed in an ice cooled cooler to avoid bacterial and microbial activities. All samples were transported to the laboratory of Chemical Sciences, Faculty of Science, Niger Delta University at 4° C prior for further analysis. Note, the choices of SVFs samples were carefully selected to reflect the highly and commonly consumed street foods in Bayelsa State.

All SVFs sample were properly wrapped and labeled accordingly and oven dried at 105° C to a constant weight. The oven dried samples were grinded with Laboratory mortar and pestle and sieved into a uniform particle size.

**2.3. SVFs DIGESTION AND FAAS DETERMINATION.**

Approximately one gram (1 g) of each SVFs biomass was weighed into separate 250 mL beakers,15 mL of Aqua ragia solution containing 3:1 v/v of conc. HNO3 and HCl was added and predigested for 1 hour at room temperature. Thereafter, 5 mL of Aqua ragia solution and 2 mL of HClO4 were also added across the mixtures and the solution were placed on hot plate in a fume cupboard and allowed to boil off to near dryness. After which, clear solutions were obtained and the digests were cooled, diluted with 25 mL distilled water and filtered into 100 mL flask and distilled water was added to make up the mark (Markmanuel et al., 2023;).

The concentrations of Pb and Cd were determined with Thermo Elemental Atomic Absorption Spectrophotometer, FAAS-S4- 71096 model. All analysis were carried out in triplicates and chemicals were of analytical grade. Plastic and glass bottles were soaked with 10 % HNO3 and washed thoroughly with distilled water and sun-dried before analysis.

 **Human Health Risk Exposure Assessment**.

The exposure pathways to the heavy metals (Pb and Cd) in the studied SVFs by the public (residence in Bayelsa State) were determined by adopting the United State Environmental Protection Agency, USEPA models which had been proven successfully by many researchers. (Markmanuel and Ebuete 2025; Markmanuel et al., 2023; 2022; 2020a and 2020b); Ekhator et al., 2017; USEPA, 2017, 2016, 2011,2005). These include;

**2.3.1.** The Estimated Daily Intake, EDIm (mg/kg- bw/day)

$$......... 1$$

 $EDI$m$(mg/kg - bw/day) = CM$SVFs $× DI$SVFs

$ABW$a

Where CMSVFs is the concentration (mg/kg) of the metals in the SVFs DISVFs is the Daily Intake of SVFs (0.30 mg/kg – bw/day/person) and ABWa is the Average Body Weight (kg) of adults in the study area (70kg).

**2.3.2.** Chronic Daily Intake, CDIm (mg/kg-bw/day)

$$........ 2$$

 $CDI$m = $EDI$m $× EF × ED$

$× 10$-3 $Type equation here.$…..$Type equation here.$

$$AET$$

Where; EDIm is Estimated Daily Intake of the metals; EF is the Exposure Frequency (365 days/years); ED is the Exposure Duration 70years (adults); AET is the Average Exposure Time (EF $×$ ED) = 365 days/years $×$ 70 years for adults); 10-3 is the conversion factor unit.

**2.3.3.** Target Hazard Index (THQm)

 $(THQ$m) $= CDI$m $.........$3

$RfD$m

Where; CDI is the Chronic Daily Intake for each metal and RfDm is the Oral Reference Dose for each metal (Pb = 0.004; Cd = 0.001) respectively.

**2.3.4.** Hazard Index (HI) = $∑$THQm for all the metals.

 $HI = THQpb + THQCd$

Where; HI is the summation of the hazard indices of all the studied heavy metals.

**2.3.5.** Lifetime Cancer Risk; LTCR.

$LTCR = CDI$m$........ 4$

$CSFO$m

Where; CDIm is the Chronic Daily Intake for each studied metal and CSFOm is the Cancer Slop Factor Oral (mg/kg- bw/day/person) for each studied metal (pb = 0.009; Cd=0.38).

**2.3.6.** Cumulative Lifetime Cancer Risk, CLTCR

CLTCR = $∑$LTCR = CLTCRpb + CLTCRCd

**Toxicity Limits:**

The toxicity limits and the acceptable threshold values for carcinogenic substances are 10E04$-$ 10E-06 (that is one person in ten thousand to one person in a million population). While, the upper toxicity factor for non-carcinogenic substance is 1 (that HI $\leq $ 1). Note, when HI is $>$ 1 it implies that the exposed population is at risk (USEPA, 2013).

**3.0. Results and Discussion.**

**3.1. Concentrations (mg/kg) of some Lead (Pb) and Cadmium (Cd) in Street Vended Foods in Bayelsa State.**

The mean concentrations and standard deviation (mean $\pm $ SD) of the toxic heavy metals; Pb and Cd in some Street Vended Foods SVFs, fried food (akara, puff-puff, fried beef, fried fish and fried chicken); cooked food (beans, jollof rice, moi-moi, agidi and fufu); baked food (meatpie and madiga) and roasted food (plantain, yam and suya), obtained from three different communities in three Local Government Areas of Bayelsa State are presented in table 1.

**Table 1. Mean Concentrations (mg/kg) of Pb and Cd in some common Street Vended Foods from Bayelsa State.**

|  |  |  |  |
| --- | --- | --- | --- |
| **LOCATION** | **SAMPLE** | **Pb** | **Cd** |
|   **YENAGOA TOWN** |  **Fried Food** | Akara | 0.234$ \pm 0.001$ | 0.009$ \pm 0.013$ |
| Puff-puff | 0.230$ \pm $0.001 | 0.003$ \pm $ 0.002 |
| Fried Beef | 0.112$ \pm $0.002 | 0.035$ \pm 0.003$ |
| Fried Fish | 0.115$ \pm $0.003 | 0.022$ \pm 0.002$ |
| Fried Chicken | 0.116$ \pm $0.005 | 0.031$ \pm 0.001$ |
| **Cooked Food** | Beans | 0.194$ \pm 0.005$ | 0.019$ \pm 0.002$ |
| Jollof Rice | 0.204$ \pm 0.005$ | 0.017$ \pm 0.002$ |
| Moi-moi | 0.196$ \pm 0.005$ | 0.020$ \pm 0.002$ |
| Agidi | 0.149$ \pm 0.001$ | 0.030$ \pm 0.001$ |
| Fufu | 0.184$ \pm 0.003$ | 0.023$ \pm 0.001$ |
| **Baked Food** | Meat Pie | 0.228$ \pm 0.002$ | 0.011$ \pm 0.002$ |
| Madiga | 0.193$ \pm 0.003$ | 0.013$ \pm 0.002$ |
| **Roasted Food** | Plantain | 0.263 $\pm 0.003$ | 0.020$ \pm 0.001$ |
| Yam | 0.133$ \pm 0.004$ | 0.023$ \pm 0.002$ |
| Suya | 0.149$ \pm 0.001$ | 0.021$ \pm 0.002$ |
| **AMASSOMA TOWN** | **Fried Food** | Akara | BDL | 0.015$ \pm 0.002$ |
| Puff-puff | 0.239$ \pm 0.003$ | 0.029$ \pm 0.001$ |
| Fried Beef | 0.005$ \pm 0.001$ | 0.033$ \pm 0.004$ |
| Fried Fish | 0.015$ \pm 0.002$ | 0.034$ \pm 0.003$ |
| Fried Chicken | 0.046$ \pm 0.001$ | 0.035 $\pm 0.002$ |
| **Cooked Food** | Beans | 0.153$ \pm 0.003$ | 0.014$ \pm 0.001$ |
| Jollof rice | 0.209$ \pm 0.008$ | 0.020$ \pm 0.001$ |
| Moi-moi | BDL | 0.012$ \pm 0.001$ |
| Agidi | 0.225$ \pm 0.001$ | 0.014$ \pm 0.003$ |
| Fufu | 0.092$ \pm 0.006$ | 0.011$ \pm 0.003$ |
| **Baked Food** | Meatpie | 0.223$ \pm 0.002$ | 0.021$ \pm 0.002$ |
| Madiga | 0.225$ \pm 0.003$ | 0.017$ \pm 0.001$ |
| **Roasted Food** | Plantain | 0.215$ \pm 0.005$ | 0.019$ \pm 0.002$ |
| Yam | 0.114$ \pm 0.001$ | 0.018$ \pm 0.001$ |
| Suya | 0.101$ \pm 0.001$ | 0.031$ \pm 0.003$ |
| **OGBIA TOWN** | **Fried Food** | Akara | 0.250$ \pm 0.001$ | 0.015$ \pm 0.003$ |
| Puff-puff | 0.239$ \pm 0.001$ | 0.030$ \pm 0.002$ |
| Fried Beef | 0.104$ \pm 0.002$ | 0.034$ \pm 0.003$ |
| Fried Fish | 0.122$ \pm 0.003$ | 0.023$ \pm 0.002$ |
| Fried Chicken | 0.139$ \pm 0.002$ | 0.019$ \pm 0.001$ |
| **Cooked Food** | Beans | 0.167$ \pm 0.002$ | 0.012$ \pm 0.002$ |
| Jollof Rice | 0.185$ \pm 0.001$ | 0.014$ \pm 0.002$ |
| Moi-moi | 0.209$ \pm 0.001$ | 0.012$ \pm 0.003$ |
| Agidi | 0.220 $\pm 0.001$ | 0.010$ \pm 0.001$ |
| Fufu | 0.158$ \pm 0.002$ | 0.021$ \pm 0.002$ |
| **Baked Food** | Meat pie | 0.241$ \pm 0.002$ | 0.002$ \pm 0.001$ |
| Madiga | 0.196$ \pm 0.005$ | 0.010$ \pm 0.003$ |
| **Roasted Food** | Plantain | 0.149$ \pm 0.001$ | 0.019$ \pm 0.001$ |
| Yam | 0.077 $\pm 0.002$ | 0.028$ \pm 0.001$ |
| Suya | 0.078$ \pm 0.005$ | 0.044$ \pm 0.001$ |

Table 1shows the mean concentrations (mg/kg) of Pb and Cd in the various Street Vended Foods in three communities in the three different Local Government Areas in Bayelsa State. The concentrations (mg/kg dry weight basis) for Pb ranged from 0.105-0.263 mg/kg in Yenagoa; 0.005 - 0.239 mg/kg in Amassoma; and 0.077- 0.241mg/kg in Ogbia. The highest concentration of Pb was recorded in roasted plantain (0.263$ \pm $0.003 mg/kg) from Yenagoa city, while, the lowest mean concentration was recorded in fried beef (0.005$ \pm $0.001 mg/kg) from Amassoma town, while, Pb was below detection limit (BDL). Generally, the concentrations of Pb in the fried, cooked, baked and roasted foods in each food samples from the three communities were evenly distributed. The mean concentrations of Pb in the SVFs from the three communities were subjected to two-way analysis of variance (ANOVA) without replication and the results indicate significant difference (p = 0.02 and p = 0.01) of Pb levels across the three communities and the SVFs, suggesting variability of Pb level between the three communities and the SVFs. This observed difference could be attributed to the exposure of each food sample to Pb, (especially vehicular emission from lead exhaust pipe) the vending site as well as the unhygienic practices of vendors during food preparation. The concentrations of Pb from this study is similar to the mean values reported by Oyet and Samuel (2020) which ranged from 0.01- 0.18 mg/kg. However, Mohammed et al., reported a higher value of Pb in akara and puff-puff. Also, Mwove et al., 2023 reported higher values of Pb between 0.271-1.891 mg/kg respectively. The concentrations of Pb from this study is higher than the Maximum Recommended Limits (MRL) of 0.1mg/kg set by Joint FAO/WHO (2021) and Codex Alimentarius Commission (2019) for food standard values. The high percentage of Pb from this study is a major source of public concern considering the high rate of daily consumption/ exposure to SVFs. Again, Pb is a very toxic metal and has no known biochemical role in the living system rather, it is very toxic even at low concentration. It damages major organs such as liver, lung, brain, kidney and death may occur if not properly handled (Hazrat et al., 2019).

Cd concentrations ranged from 0.003-0.035 mg/kg in Yenagoa; 0.011-0.035 mg/kg in Amassoma; and 0.002-0.044 mg/kg in Ogbia. The highest concentration of Cd was found in suya (0.044$\pm $0.001 mg/kg) from Ogbia town while, the lowest concentration was also found in meat pie (0.002$\pm $0.001 mg/kg) from Ogbia town respectively. Notably, the concentrations of Cd in animal-based food samples such as fried beef, chicken, fish and roasted suya were similar and higher than other food samples in all the three communities. This is attributed to the high bio accumulative properties of Cd in animals. Analysis of Variance (ANOVA) pointed out significant difference (p = 0.02) in the level of Cd across the three communities. Also, Ekhator et al., (2017) reported similar trends where Cd concentrations were not detected in most of the studied Street Vended Food samples except meat-based products. Mohammed et al., (2016) Oyet and Samuel (2020) and Kingsley et al., also reported similar values of Cd in some road side snacks and roasted foods from Ilorin and Lagos State, (Nigeria). The mean concentrations of Cd from this study were higher that the values reported by Mwove et al., 2023; but lower than the reported values of 1.30$ \pm $0.03 mg/kg – 6.90$ \pm 0.00$ mg/kg by Ajegi et al., (2023); and 0.001 – 1.000 mg/kg in shawarma, fruit chaat and dahi baray by Hassan et al., (2022). The concentration of Cd from this study is lower than the `recommended limits of FAO/WHO (2021) and Codex Alimentarius commission (2019) which were 0.05 mg/kg and 0.10 mg/kg respectively. Although, the levels of Cd reported from this study is lower than standard recommended limits, its trace level in food is a source of concern considering the fact that Cd had no known biochemical role in living system but causes toxicity even at low concentration (Letuka et al.,2023; Mwove et al., 2023).

**3.2. Human Health Risk Exposure Assessment.**

The human health risk exposure assessment was estimated to ascertain the risk associated with the oral ingestion of Street Vended Foods (Akara, Puff-puff, fried beef, fried fish, fried chicken, cooked beans, jollof rice, moi-moi, agidi, fufu, meatpie, madiga, roasted plantain, roasted yam and suya meat) contaminated with Pb and Cd from Bayelsa State. The calculated results are presented in table 2 and 3 as shown below.

**Table 2: Estimated Daily Intake, EDI and Chronic Daily Intake, CDI (mg/kg-bw/day/person) of Pb and Cd in some Street Vended Foods from Bayelsa State.**

|  |  |  |  |
| --- | --- | --- | --- |
| **LOCATION** | **SAMPLE** | **EDI** | **CDI** |
|  |  |  | **Pb** | **Cd** | **Pb** | **Cd** |
| **YENAGOA TOWN** | **Fried Food** | Akara | 1.1E-03 | 3.7E-05 | 1.0E-06 | 3.9E-08 |
| Puff-Puff | 9.9E-04 | 2.0E-05 | 9.9E-07 | 2.0E-08 |
| Fried beef | 4.8E-04 | 1.5E-04 | 4.8E-07 | 1.5E-07 |
| Fried fish | 4.5E-04 | 9.4E-05 | 4.5E-07 | 9.4E-08 |
| Fried chicken | 4.5E-04 | 1.3E-04 | 4.5E-07 | 1.3E-07 |
| **Cooked Food** | **Beans** | 8.3E-04 | 8.3E-05 | 8.3E-07 | 8.3E-08 |
| **Jollof rice** | 8.7E-04 | 7.3E-05 | 8.7E-07 | 7.3E-08 |
| **Moi-moi** | 8.4E-04 | 8.4E-05 | 8.4E-07 | 8.4E-08 |
| **Agidi** | 6.4E-04 | 1.3E-04 | 6.4E-07 | 1.3E-07 |
| **Fufu** | 7.9E-04 | 1.0E-04 | 7.9E-07 | 1.0E-07 |
| **Baked Food** | **Meatpie** | 9.8E-04 | 4.9E-05 | 9.8E-07 | 4.9E-08 |
| **Madiga** | 8.3E-04 | 5.4E-05 | 8.3E-07 | 5.4E-08 |
| **Roasted Food** | **Plantain** | 1.1E-03 | 8.7E-05 | 1.1E-06 | 8.7E-08 |
| **Yam** | 5.7E-04 | 9.7E-05 | 5.7E-07 | 9.7E-08 |
| **Suya** | 6.4E-04 | 8.9E-05 | 6.4E-07 | 8.9E-08 |
| **AMASSOMA TOWN** | **Fried Food** | **Akara** | BDL | 6.6E-04 | BDL | 6.6E-08 |
| **Puff-puff** | 1.0E-03 | 1.3E-04 | 1.0E-06 | 1.3E-07 |
| **Fried beef** | 2.3E-05 | 1.4E-04 | 2.3E-08 | 1.4E-07 |
| **Fried fish** | 6.4E-05 | 1.5E-04 | 6.4E-08 | 1.5E-07 |
| **Fried chicken** | 2.0E-04 | 1.5E-04 | 2.0E-07 | 1.5E-07 |
| **Cooked Food** | **Beans** | 6.5E-04 | 6.1E-05 | 6.5E-07 | 6.1E-08 |
| **Jollof rice** | 8.9E-04 | 8.6E-05 | 8.9E-07 | 8.6E-08 |
| **Moi-moi** | BDL | 4.6E-05 | BDL | 4.6E-08 |
| **Agidi** | 9.6E-04 | 5.9E-05 | 9.6E-07 | 5.9E-08 |
| **Fufu** | 3.9E-04 | 4.9E-05 | 3.9E-07 | 4.9E-08 |
| **Baked Food** | **Meatpie** | 9.6E-04 | 9.1E-05 | 9.6E-07 | 9.1E-08 |
| **Madiga** | 9.6E-04 | 7.1E-05 | 9.6E-07 | 7.1E-08 |
| **Roasted Food** | **Plantain** | 9.2E-04 | 8.3E-05 | 9.2E-07 | 8.3E-08 |
| **Yam** | 4.9E-04 | 7.9E-05 | 4.9E-07 | 7.9E-08 |
| **Suya** | 4.3E-04 | 1.3E-04 | 4.3E-07 | 1.3E-07 |
| **OGBIA TOWN** | **Fried Food** | **Akara** | 1.1E-03 | 6.4E-05 | 1.1E-06 | 6.4E-08 |
| **Puff-puff** | 1.0E-03 | 1.2E-04 | 1.0E-06 | 1.3E-07 |
| **Fried beef** | 4.4E-04 | 1.4E-04 | 4.4E-07 | 1.4E-07 |
| **Fried fish** | 5.2E-04 | 9.7E-05 | 5.2E-07 | 9.7E-08 |
| **Fried chicken** | 5.9E-04 | 8.3E-03 | 5.9E-07 | 8.3E-08 |
| **Cooked Food** | **Beans** | 7.2E-04 | 5.3E-05 | 7.2E-07 | 5.3E-08 |
| **Jollof rice** | 7.9E-04 | 6.0E-05 | 7.9E-07 | 6.0E-08 |
| **Moi-moi** | 9.0E-04 | 5.3E-05 | 9.0E-07 | 5.3E-08 |
| **Agidi** | 9.4E-04 | 4.1E-05 | 9.4E-07 | 4.1E-08 |
| **Fufu** | 6.8E-04 | 8.9E-05 | 6.8E-07 | 8.9E-08 |
| **Baked Food** | **Meat pie** | 1.0E-03 | 8.6E-05 | 1.0E-06 | 8.6E-08 |
| **Madiga** | 8.4E-04 | 4.4E-05 | 8.4E-07 | 4.4E-08 |
| **Roasted Food** | **Plantain** | 6.4E-04 | 8.3E-05 | 6.4E-07 | 8.3E-08 |
| **Yam** | 3.3E-04 | 1.2E-04 | 3.3E-07 | 1.2E-07 |
| **Suya** | 3.3E-04 | 1.9E-04 | 3.4E-07 | 1.9E-07 |

**Table 3: THQ, HI Indices, LTCR and CLTCR of Pb and Cd in the Street Vended Foods from Bayelsa State.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **LOCATION** | **SAMPLE** | **THQ** | **HI** | **LTCR** | **CLTCR** |
| **YENAGOA TOWN** | **Fried Food** |  | **Pb** | **Cd** | $$∑THQ$$ | **Pb** | **Cd** | $$∑LTCR$$ |
| Akara | 2.5E-04 | 3.9E-05 | 2.89E-04 | 1.1E-04 | 1.0E-07 | 1.10E-04 |
| Puff-puff | 2.5E-04 | 2.0E-05 | 2.70E-04 | 1.1E-04 | 5.3E-07 | 1.11E-04 |
| Fried beef | 1.2E-04 | 1.5E-04 | 2.70E-04 | 5.4E-05 | 4.0E-07 | 5.44E-05 |
| Fried fish | 1.1E-04 | 9.4E-05 | 2.04E-04 | 5.0E-05 | 2.5E-07 | 5.03E-05 |
| Fried chicken | 1.1E-04 | 1.3E-04 | 2.40E-04 | 5.0E-05 | 3.5E-07 | 5.04E-05 |
| **Cooked Food** | Beans | 2.1E-04 | 8.3E-05 | 2.93E-04 | 9.2E-05 | 2.2E-07 | 9.22E-05 |
| Jollof rice | 2.2.E-04 | 7.3E-05 | 7.30E-05 | 9.7E-05 | 1.9E-07 | 9.72E-05 |
| Moi-moi | 2.1E-04 | 8.4E-05 | 2.94E-04 | 9.3E-05 | 2.2E-07 | 9.32E-05 |
| Agidi | 1.6E-04 | 1.3E-04 | 2.90E-04 | 7.1E-05 | 3.4E-07 | 7.13E-05 |
| Fufu | 2.0E-04 | 1.0E-04 | 3.00E-04 | 8.8E-05 | 2.6E-07 | 8.83E-05 |
| **Baked Food** | Meatpie | 3.4E-04 | 4.9E-05 | 3.89E-04 | 1.1E-04 | 1.3E-07 | 1.10E-04 |
| Madiga | 2.1E-04 | 5.4E-05 | 2.64E-04 | 9.2E-05 | 1.4E-07 | 9.21E-05 |
| **Roasted Food** | Plantain | 2.8E-04 | 8.7E-05 | 3.67E-04 | 1.3E-04 | 2.3E-07 | 1.30E-04 |
| Yam | 1.4E-04 | 9.7E-05 | 2.37E-04 | 6.3E-05 | 2.6E-07 | 6.33E-05 |
| Suya | 1.6E-04 | 8.9E-05 | 2.49E-04 | 7.1E-05 | 2.3E-07 | 7.12E-05 |
| **AMASSOMA TOWN** |  | Akara | BDL | 6.6E-05 | 6.60E-05 | BDL | 1.7E-07 | 1.70E-07 |
| Puff-puff | 2.6E-04 | 1.3E-04 | 3.90E-04 | 1.1E-04 | 3.3E-07 | 1.10E-04 |
| Fried beef | 5.7E-06 | 1.4E-04 | 1.46E-04 | 2.5E-06 | 3.7E-07 | 2.87E-06 |
| **Fried Food** | Fried fish | 1.6E-05 | 1.5E-04 | 1.66E-04 | 7.1E-06 | 3.8E-07 | 7.48E-06 |
| Fried chicken | 4.9E-05 | 1.5E-04 | 1.99E-04 | 2.2E-05 | 3.9E-07 | 2.24E-05 |
| **Cooked Food** | Beans | 1.6E-04 | 6.1E-05 | 2.21E-04 | 7.3E-05 | 1.6E-07 | 7.32E-05 |
| Jollof rice | 2.2E-04 | 8.6E-05 | 3.06E-04 | 9.9E-05 | 2.3E-07 | 9.92E-05 |
| Moi-moi | BDL | 4.6E-05 | 4.60E-05 | BDL | 1.2E-07 | 1.20E-07 |
| Agidi | 2.4E-04 | 5.9E-05 | 2.99E-04 | 1.1E-04 | 1.5E-07 | 1.10E-04 |
| Fufu | 9.8E-05 | 4.9E-05 | 1.47E-04 | 4.4E-05 | 1.3E-07 | 4.41E-05 |
| **Baked Food** | Meatpie | 2.4E-04 | 9.1E-05 | 3.31E-04 | 1.1E-04 | 2.4E-07 | 1.10E-04 |
| Madiga | 2.4E-04 | 7.1E-05 | 3.11E-04 | 1.1E-04 | 1.9E-07 | 1.10E-04 |
| **Roasted Food** | Plantain | 2.3E-04 | 8.3E-05 | 3.13E-04 | 1.0E-04 | 2.2E-07 | 1.00E-04 |
| Yam | 1.2E-04 | 7.9E-05 | 1.99E-04 | 5.4E-05 | 2.1E-07 | 5.42E-05 |
| Suya | 1.1E-04 | 1.3E-04 | 2.40E-04 | 4.8E-05 | 3.5E-07 | 4.84E-05 |
| **OGBIA TOWN** | **Fried Food** | Akara | 2.7E-04 | 6.4E-05 | 3.34E-04 | 1.2E-04 | 1.7E-07 | 1.20E-04 |
| Puff-puff | 2.6E-04 | 1.3E-04 | 3.90E-04 | 1.1E-04 | 3.3E-07 | 1.10E-04 |
| Fried beef | 1.1E-04 | 1.4E-04 | 2.50E-04 | 4.9E-05 | 3.8E-07 | 4.94E-05 |
| Fried fish | 1.3E-04 | 9.7E-05 | 2.27E-04 | 5.8E-05 | 2.6E-07 | 5.83E-05 |
| Fried chicken | 1.4E-04 | 8.3E-05 | 2.23E-04 | 6.6E-05 | 2.2E-07 | 6.62E-05 |
| **Cooked Food** | Beans | 1.8E-04 | 5.3E-05 | 2.33E-04 | 8.0E-05 | 1.4E-07 | 8.01E-05 |
| Jollof rice | 2.0E-04 | 6.0E-05 | 2.60E-04 | 8.8E-05 | 1.6E-07 | 8.82E-05 |
| Moi-moi | 2.2E-04 | 5.3E-05 | 2.73E-04 | 10.0E-05 | 1.4E-07 | 1.00E-04 |
| Agidi | 2.4E-04 | 4.1E-05 | 2.81E-04 | 1.0E-04 | 1.1E-07 | 1.00E-04 |
| Fufu | 1.7E-04 | 8.9E-05 | 2.59E-04 | 7.5E-05 | 2.3E-07 | 7.52E-05 |
| **Baked Food** | Meatpie | 2.6E-04 | 8.6E-05 | 3.46E-04 | 1.1E-04 | 2.3E-07 | 1.10E-04 |
| Madiga | 2.1E-04 | 4.4E-05 | 2.54E-04 | 9.3E-05 | 1.2E-07 | 9.31E-05 |
| **Roasted Food** | Plantain | 1.6E-04 | 8.3E-05 | 2.43E-04 | 7.1E-05 | 2.2E-07 | 7.12E-05 |
| Yam | 8.3E-05 | 1.2E-04 | 2.03E-04 | 3.7E-05 | 3.1E-07 | 3.73E-05 |
| Suya | 8.4E-05 | 1.9E-04 | 2.74E-04 | 3.7E-05 | 5.0E-07 | 3.75E-05 |

**3.2.1. Non-Carcinogenic Health Risk Assessment.**

The non-carcinogenic models employed in this study were; the EDI (mg/kg- bw/day/person), CDI (mg/kg – bw/day/person), THQ and HI. The EDI and CDI expresses the maximum amount of a toxicant a person can be exposed to per day without any health hazard in future; THQ is a dimension less quantity that defines chronic exposure which its values are relative measure between contaminants and their oral reference dose (RfD), and the HI defines the interactive/combined hazard of contaminants or toxicants in a given matrix. Table 2 and 3 shows the experimental calculated results for EDI, CDI THQ and HI.

The EDI and CDI values of Pb in the SVFs ranged from 4.5E – 04 – 1.1E-03 and 4.5E-04 – 1.0E-04 (mg/kg-bw/day/person) in Yenagoa; 2.3E-05 –1.0E-03 and 2.3E-08– 1.0E-06 (mg/kg-bw/day/person) in Ogbia. EDI values of Pb from this study were either within or below the Provisional Tolerable Intake (PTDI) of Pb set by Council of Europe (CoE, 2013) and FAO/WHO (2011), which were 3.6E-04 and 3.0E-04 (mg/kg-bw/day/person). Again, these values were all lower than the EDI and CDI to Upper Intake Level (UL) of 2.4E-01 set by USEPA (2013).The EDI and CDI for Cd ranged from 2.0E-05– 1.0E-04 and 2.0E-08– 1.0E-07 (mg/kg-bw/day/person) in Yenagoa; 4.6E-05– 1.5E-04 and 2.0E-08– 1.0E-07 (mg/kg-bw/day/person) in Amassoma; 4.1E-05– 1.9E-04 and 4.1E-08– 1.9E-07 (mg/kg-bw/day/person) in Ogbia. The EDI and CDI values for the different SVFs obtained from this study were all lower the PTDI limits of 3.6E-04 mg/kg-bw/day/person set by CoE (2013) and FAO/WHO (2011), and 6.4E-02 mg/kg-bw/day/person set by USEPA (2013). The EDI and CDI values of Pb and Cd obtained from this study were lower than the reported range values of 8.6E-05– 2.6E-03 mg/kg-bw/day/person (adults); and 2.7E-03– 9.5E-03 mg/kg-bw/day/person (children); and 8.6E-05– 7.7E-04 mg/kg-bw/day (adults), 2.7E-04– 2.4E-03 (children) in some street and homemade foods (Kingsley et al.,2023). However, Ekhator et al., (2023) reported similar EDI values for Pb and Cd in some street vented foods consumed in Mid-West Nigeria which were; 4.0E-05– 6.9E-03 and 7.2E-05– 1.1E-02 (mg/kg-bw/day/person) in children and adults; and 1.3E-06– 4.5E-06 and 2.2E-06– 9.9E-06 (mg/kg-bw/day/person) person in adults and children respectively. Again, ANOVA results revealed a significant difference (p = 0.02) in the EDI and CDI values of Pb and Cd in the SVFs across the three communities.

The Target Hazard Quotient (THQ) of Pb and Cd are presented in table 3. The THQ values for Pb ranged from 1.1E-04– 3.4E-04 in Yenagoa city, 5.6E-05 – 2.6E-04 in Amassoma town and 8.3E-05 – 2.7E-04 in Ogbia town.The highest THQ values were found in meat pie (3.4E-04) from Yenagoa while, the lowest THQ value of Pb was recorded in fried beef from Amassoma. THQ values for Cd ranged from 2.0E-05– 1.5E-04 in Yenagoa, 4.6E-05– 1.5E-04 in Amassoma; and 4.1E-05– 1.9E-04 in Ogbia; with suya from Ogbia recording the highest (1.9E-04) and puff-puff from Yenagoa recording the lowest (2.0E-05). The hazard indices for both Pb and Cd in the studied SVFs from Bayelsa State were all below the maximum tolerable limits of 1[HI<1] Indicating no health hazard at the moment. Also, the THQ values for both Pb and Cd were lower than their oral reference doze (RfD) which were 4.0E-03 and 1.0E-03 respectively. The THQ and HI values from this study were lower than the reported values of Ekhator et al., (2017) but, similar to the reported values of Kingsley et al., 2023.Therefore, the experimental calculated values for THQ and HI indicate that the exposed populations (Bayelsa Residents) are unlikely to experience non-carcinogenic risk hazard at the moment.

**3.2.2. Carcinogenic Health Risk Assessment.**

The carcinogenic health risk assessment was evaluated as the incremental probability of an individual developing cancer over a life time of 70 years (the assured lifetime). In this study, the carcinogenic health risk was expressed as Life Time Cancer Risk (LTCR) and it is a measure of chronic daily exposure to the cancer slope factor oral (mg/kg-bw/day/person) of the contaminants (Pb and Cd). Table 3 shows the Life Time Cancer Risk (LTCR) and the Cumulative Life Time Cancer Risk (CLTCR) Pb and Cd for the exposed populations (Bayelsa Residents) via ingestion of SVFs. The LTCR values of Pb in Akara, Puff-puff, meat pie and roasted plantain from Yenagoa city, Puff-puff, agidi, meat pie, madiga and roasted plantain from Amassoma; and akara, puff-puff, agidi and meat pie from Ogbia were within the limits value of 1.0E-04 (one in ten thousand) but lower than the limits of 1.0E-06 (one in a million) set by USEPA (2017), Moi-moi from Amassoma was below detection limit (BDL), but, all other SVFs from this study were higher than the threshold values (1.0E-04– 1.0E-06) respectively. The combine or cumulative life time cancer risk of Pb in akara, puff-puff, meat pie and roasted plantain (Yenagoa), akara, puff-puff, moimoi, agidi, meat pie and madiga (Amassoma) and akara, puff-puff, moi-moi, agidi and meat pie (Ogbia) were also within the safe limit of 1.0E-04 while, all other SVFs from this study were higher than the threshold value of 1.0E-04– 1.0E-06 respectively. Generally, the LTCR and CLTCR values of Pb in akara, puff-puff, meat pie in all the three local Government Areas were within threshold values. The high LTCR and CLTCR values obtained from most of the SVFs is a major source of concern considering the toxicity of Pb and Cd in animal studies and the fact that these metals have no known biochemical roles in living system rather they elicit different toxicity even at low levels (Hazrat et al., 2019).

**CONCLUSION**

This study has unveiled the levels of Pb and Cd in some SVFs in three Local Government Areas of Bayelsa State. The concentrations of Pb in the various SVFs were all higher than the threshold limits of FAO/WHO, (2021) and Codex Alimentarius Commission (2019). But, the concentrations of Cd were below the recommended threshold limits of FAO/WHO, (2021) and codex Alimentarius commission (2019). Analysis of variance shows significant difference (p = 0.01 and 0.02) in the levels of Pb and Cd across the three communities among the SVFs. The human health risk exposure assessment indicate that the EDI, CDI THQ and HI (non-carcinogenic risk) were all within the safe limits at the moment. However, the carcinogenic risk assessment (LTCR and CLTCR values) for most of the studied SVFs exceeded their recommended threshold values, while, some were within the set limits. Therefore, regular /or daily consumption of street vended foods should be discouraged so as to avert health hazard in future.

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