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Research Article
Heavy Metal Contamination of Selected Foods from the Oil Producing State of Akwa Ibom in Southern Nigeria

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Abstract

Background and Objective: Heavy metals represent an important category of bio-toxic substances that are encountered under various environmental and occupational circumstances. The toxicity of these metals is in part due to their tendency to accumulate in biological tissues, a process known as bioaccumulation that can result from exposure to metals in foods of plant and animal origin. In this study, a survey was carried out to assess the awareness of residents of eight communities in the Akwa Ibom state in Nigeria about heavy metal contamination. **Materials and Methods:** Standard methods were used to analyse the amounts of the most dominant heavy metals in seven varieties of foods procured from selected farms in these communities as well as microbial contamination of these food samples. Questionnaires were administered for the survey studies. Data generated from the analysis were subjected to one-way analysis of variance and accepted at the 0.05 probability level. **Results:** All of the survey respondents were between 31 and 60 years-old and 55.1% were male. The awareness of heavy metal contamination, particularly of arsenic and lead (22.5 and 28.8%, respectively), was high. There was no fecal contamination detected in foods sampled from main urban areas. Lead, mercury and copper accumulation was most pronounced in food samples from communities located in riverine areas that are subjected to oil exploration and exploitation. There were also high amounts of heavy metal accumulation in samples from communities having a strong agriculture and commercial presence. The heavy metal content and microbial load of the various food samples varied significantly ($p<0.05$) among the eight communities. **Conclusion:** Microbial contamination of the foods surveyed was more common in agrarian and fishing communities than in urban areas.

Key words: Anthropogenic factors, bio-accumulation, bio-toxic substances, heavy metals, Nigeria, permissible limit

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Concern about the quality of food and food items for human consumption has been increasing and has prompted multiple studies that focused on the nature and composition of food. These studies also considered how environmental and anthropogenic factors, industrialization and industrial activities and waste control and management as well as several other factors affect food quality.

According to Al-Jassir *et al*[1], mercury and lead are often referred to as "heavy metals", a term which, when strictly applied, describes metals having a density >5 mg cm^{-1}. However, used collectively, "heavy metals" can also refer to arsenic, cadmium, chromium, copper, lead, nickel, molybdenum, vanadium and zinc as well as to aluminum, cobalt, strontium and different rare metals[2]. Heavy metals like cadmium, copper, lead, chromium and mercury are common environmental pollutants, particularly in areas that have high evolutionary pressure[3]. The presence of these heavy metals in the atmosphere, soil and water, even in trace amounts, can be lethal to any or all organisms; hence, bio-accumulation within the food chain is particularly dangerous to human health[3]. Once present in high concentrations within the body, heavy metals tend to bio-accumulate and become harmful to health.

As human activities increase, particularly those involving the use of modern technologies, pollution and contamination of the human food chain has become inevitable[3]. The increasing use of metals in commerce and daily living, with its attending health hazards arising from bio-toxic metal pollution, have taken on serious dimensions. One aspect of heavy metal pollution concerns exhaust emissions into the environment, including those from the increasing number of vehicles and industrialization worldwide. Meanwhile, other challenges accompany the presence of heavy metals and their deposition, especially in the oil-producing areas such as the Akwa Ibom state in Nigeria. These challenges emanate from activities associated with exploration for oil and the exploitation of crude oil. The presence of pipelines in regions involved in the production and transportation of both crude and refined oil products is also a serious challenge for control of heavy metal pollution. Edokpolor *et al*.[4] reported that crude oil contains heavy metals such as iron, nickel, cobalt, copper and vanadium. Spillage of crude oil can contribute to heavy metal contamination of the soil, atmosphere and water in areas affected by oil spills.

The objectives of this study were to: (1) Conduct a survey study on the level of awareness of the presence of heavy metals in some foods in the Akwa Ibom state of Southern Nigeria, (2) Identify the most dominant heavy metals and their concentrations in foods from eight communities in the Akwa Ibom state and (3) Evaluate the microbial status of selected foods from the eight communities.

MATERIALS AND METHODS

Sample collection: Fresh and mature cassava (*Manihot esculenta*) cultivars, cowpea (*Vigna unguiculata* L.), spinach (*Spinacia oleracea*), fish (*Cynoglossus senegalensis*), crab (*Callinectes pallidus*), maize (*Zea mays*) and pineapple (*Ananas comosus*) were procured from selected farms in eight communities (Uyo, Ikot Abasi, Ikono, Etinan, Ikot Ekpene, Esit Eket, Mkpati Etin and Oron) located in the Akwa Ibom state in southern Nigeria. Animal samples (fish and crab) were carefully packed on ice in clean polyethylene bags. The ice was used to conserve and reduce tissue decay and to maintain moist conditions during transport. Fresh crop samples were kept in a cooler and transferred to the laboratory where they were refrigerated at 4°C until analysis. For the survey study, questionnaires were administered to a total of 160 respondents, comprising 20 adult males and 20 adult females from each of the eight communities. The survey evaluated the respondents' awareness of the presence of heavy metals and which metals predominated in seven varieties of foods consumed in each of the eight communities of the oil-producing southern state of Akwa Ibom of Nigeria. Survey data were compared with test results on the various foods analysed for this study.

Extraction and analysis of heavy metals in selected foods (dry basis): Frozen samples of each of animal food product were thawed. The fish were dissected to remove muscle and liver tissue for analysis. Body parts of the crabs were also taken for analysis. Oven-dried samples (1 g) were pulverized into a fine powder for digestion. The cassava, cowpea, maize, pineapple, fish, crab and spinach samples were removed from the refrigerator and placed on a clean laboratory working bench where they were allowed to reach room temperature. The piliferous layers of cassava tubers were carefully removed, sliced into uniform thickness (4 mm) and oven-dried at 55°C to a constant weight. The dried samples together with other selected samples were ground into a powder and labelled. A total of 1g of each ground sample was weighed and placed into a 100 mL beaker. Concentrated nitric acid (5 mL) and 2 mL perchloric acid were added to the beaker, which was heated in a fume hood until the sample was nearly completely dry. The dried samples were reconstituted in 10 mL deionised water with stirring and the solution was filtered with Whatman filter paper No. 42. Blank samples were prepared using the same procedure with deionised water substitute for cassava and other samples. The filtrate of each sample was aspirated into an AAS flame along with standard solution.

Determination of microbial quality of the samples (wet basis): Determination of total viable count (TVC) as well as mould and coliform counts were performed using methods described by Prescott *et al.*[5].

Data analysis and experimental design: Data (triplicate measurement of values) generated from the analysis were subjected to one way analysis of variance (ANOVA) at a 0.05 probability level. Duncan's new multiple range test (DNMRT) was used to compare treatment means using the statistical product for service solution (SPSS) version 23.0.

RESULTS AND DISCUSSION

Survey of awareness of the presence of heavy metals in food and food materials in selected communities in Akwa Ibom state: A survey involving 160 subjects was conducted to gauge the level of awareness of the presence of heavy metals in food and food materials in eight communities in Akwa Ibom state (Table 1). Respondents aged 30-40 years-old predominated in the study population and 42% possessed post-graduate certificates in various disciplines. About 59% of the respondents sourced their foods from various open markets that would be expected to have a higher likelihood of having microbial contamination. Interestingly, around 71% of the participants were already aware of what heavy metals are; this result is consistent with the high literacy rate of the respondents associated with the high percentage of subjects who had post-graduate degrees. The highest level of awareness was for lead (28.8%) and awareness of cadmium and aluminum as heavy metals was lowest (3.80%). In general, the level of awareness of the presence of heavy metal in food had a linear relationship to the educational qualifications of the respondents.

Assessment of heavy metal contamination in selected food samples: Heavy metal concentrations were determined for selected food products (fish, crabs, cowpea, pineapple,

Table 1: Awareness level of heavy metal contamination of foods across socio-demographic characteristics

Characteristic	Awareness level	No.	Percentage
Sex	**1.39±0.55**		
Male		88	55.00
Female		72	45.00
Age	**1.57±0.84**		
≥30<40		81	50.60
≥40<50		49	30.60
≥50<60		20	12.50
≥60		10	6.30
Educational qualifications	**2.99±1.08**		
Below diploma (high school)		15	9.37
Diploma and above		33	20.60
HND and above		45	28.10
Post graduate		67	41.90
Employment Status	**1.33±0.92**		
Yes		106	66.30
No		48	30.00
Uncertain		6	3.75
***Respondent's sources of foods:**	**1.8±0.73**		
Road side stand		45	28.10
Open market		94	58.80
Supermarket		13	8.10
From own farm		4	2.50
Awareness of particular heavy metals in food	**2.74±2.76**		
Arsenic		36	22.50
Cadmium		6	3.80
Lead		46	28.80
Cobalt	ND		
Chromium		3	1.90
Mercury		9	5.60
Nickel	ND		
Iron		15	9.40
Aluminum		6	3.80
Others, Please state		1	0.60

*Respondents can choose more than one source of food, ND: Not detected

Table 2: The dominant heavy metals in selected food samples from the selected eight communities

	Community							
	Uyo	Ikot Abasi	Ikono	Etinam	Ikot Ekpene	Esit Eket	Mkpati Etim	Oron
Food Sample	copper	Cadmium	Mercury	Tin	Lead	Cobalt	Chromium	Nickel
Fish	255.80 ± 1.06^{a}	13.70 ± 0.02^{c}	0.29 ± 0.02^{f}	496.80 ± 1.59^{c}	0.44 ± 0.04^{c}	0.37 ± 0.01^{b}	0.16 ± 0.08^{a}	13.20 ± 0.04^{c}
Crab	248.93 ± 0.40^{b}	3.47 ± 0.03^{d}	0.25 ± 0.04^{f}	72.27 ± 0.45^{e}	0.46 ± 0.08^{d}	0.31 ± 0.02^{b}	116.97 ± 0.15^{g}	0.59 ± 0.02^{b}
Maize	83.37 ± 0.40^{d}	53.44 ± 0.34^{e}	0.49 ± 0.03^{e}	53.44 ± 0.34^{g}	0.68 ± 0.18^{b}	53.34 ± 0.45^{a}	0.88 ± 0.03^{a}	0.08 ± 0.01^{d}
Cassava	230.37 ± 0.25^{c}	57.50 ± 0.02^{b}	0.49 ± 0.03^{e}	508.17 ± 0.47^{a}	0.54 ± 0.24^{e}	16.02 ± 0.02^{b}	0.14 ± 0.01^{de}	0.14 ± 0.01^{de}
Spinach	45.38 ± 0.03^{f}	49.20 ± 0.26^{e}	1.12 ± 0.05^{b}	354.36 ± 0.32^{d}	0.48 ± 0.03^{b}	0.20 ± 0.02^{b}	0.74 ± 0.04^{b}	0.74 ± 0.04^{b}
Pineapple	47.20 ± 0.26^{e}	16.02 ± 0.02^{b}	0.81 ± 0.02^{c}	70.20 ± 0.36^{f}	0.47 ± 0.05^{a}	0.27 ± 0.03^{b}	$0.15d\pm0.01^{e}$	$0.15d\pm0.01^{e}$
Cowpea	0.26 ± 0.04^{b}	50.21 ± 020^{a}	0.74 ± 0.49^{d}	504.22 ± 0.36^{b}	0.25 ± 0.22^{a}	0.17 ± 0.03^{b}	0.55 ± 0.03^{b}	0.66 ± 0.04^{a}

Values are means±standard deviation of triplicate determinations. Means with different superscripts in the same column are significantly ($p<0.05$) different

spinach, maize and cassava) from eight communities in the Akwa Ibom state in which the survey was conducted (Table 2). The lead content of samples from Ikot Ekpene ranged from 0.21-0.68 mg kg^{-1}. Maize had the highest value of lead at 0.68 mg kg^{-1} while cowpea had the lowest value of 0.21 mg kg^{-1}. Lead was also present in fish (0.44 mg kg^{-1}), cassava (0.54 mg kg^{-1}), spinach (0.48 mg kg^{-1}) and cowpea (0.25 mg kg^{-1}). There was no significant ($p>0.05$) difference in the concentration of lead among fish, cassava and spinach, or between cowpea and pineapple. However, there was a significant ($p<0.05$) difference in the concentration of nickel among the food samples. In Ikot abasi, the nickel concentration of the food samples ranged from 3.47-57.50 mg kg^{-1}. Cobalt dominated in fish from Esit Eket, a community that has various oil wells. Meanwhile, copper levels were high in fish from Uyo, the state capital. Cadmium was found in cassava from Etinan and chromium was present in samples from Ikono. There was no significant ($p>0.05$) difference in heavy metal concentrations between spinach and pineapple samples.

Mercury levels in fish samples from all the sites were above the permissible limit of 0.5 mg kg^{-1}, as recommended by WHO[6]. There was a significant accumulation of heavy metals in most of the oil-producing and agro-based communities in which farming, fishing and oil exploration and trading are the main occupation of the inhabitants. Overall, the variance in heavy metal concentrations in samples from among the sampled communities appears to be positively affected by the occupation of the inhabitants of test sites. This result is consistent with earlier reports[7,8] showing that uptake and bioaccumulation of heavy metals are influenced by occupation. These studies also showed that multiple other factors such as climate, atmospheric conditions, soil concentrations of heavy metals and the nature of the soil, as well as the degree of maturity of the materials at the time of harvest can contribute to heavy metal contamination of foods for human consumption. Long-term use of well water, either treated or untreated, is another factor involved in elevated levels of heavy metals[9-11]. Aspects of agricultural practices such as use of sewage sludge and manures, fertilizers, pesticides, pH and organic matter are implicated in the heavy metal levels in food materials[11]. Therefore, the observed levels and variations in the heavy metal contents of samples observed in this study are likely associated with a combination of the above mentioned factors. The different environmental aspects and locations of the survey sites in oil-producing communities could also likely account for the observed differences.

Assessment of microbial contamination of selected food commodities: Tests of the microbial content in selected food samples including total viable count as well as coliform and mold counts, showed that the microbial population was highest in maize from Esit Eket (6.7×10^{6} CFU g^{-1}) and Etinan (6.3×10^{6} CFU g^{-1}), which both have agricultural and oil activity, whereas the lowest total viable count was in maize from the commercial city of Uyo (1.2×10^{5} CFU g^{-1}; Table 3). Furthermore, the coliform population was high in cowpea and fish farming communities of Etinan (1.3×10^{3}CFU g^{-1}) and Ikot Abasi (3.3×10^{2} CFU g^{-1}), respectively. Mold growth was not detected in most of the foods from non-coastal areas like Uyo and Ikot Ekpene. These results indicate that rural communities engaged in persistent farming and fishing may lack essential health and sanitation infrastructure. It can be inferred that farmers and fishermen resort to open defecation into the sea, rivers and any available water body, as well as on farms. These habits ultimately contributed to the high microbial load in foods collected from rural sites.

There was no fecal contamination in foods sampled from urban areas such as Uyo. This result supports those of Belay[2], who suggested that micro-organisms present in agricultural produce directly reflect the sanitary quality of cultivation processes, environment and water for irrigation, as well as harvest time and methods. Types or means of produce transport and storage environment in addition to processing techniques also play major roles in the likelihood of fecal contamination. The microbial load of most of the food samples was high, which supports that open defecation is still a health concern in rural communities in the Akwa Ibom state of Nigeria.

Table 3: Microbial status (CFU g^{-1}) of selected food samples from the eight communities surveyed

	Community							
Sample	Uyo	Ikot Abasi	Ikono	Etinan	Ikot Ekpene	Esit Eket	Mkpati Etim	Oron
Total viable count (CFU g^{-1})								
Fish	2.5×10^{6}	2.3×10^{6}	2.4×10^{6}	2.5×10^{5}	2.1×10^{5}	1.8×10^{5}	2.0×10^{5}	1.7×10^{5}
Crab	2.9×10^{5}	2.7×10^{6}	2.8×10^{6}	6.3×10^{6}	2.5×10^{5}	1.7×10^{5}	2.3×10^{5}	2.2×10^{5}
Maize	8.4×10^{5}	6.2×10^{5}	7.2×10^{6}	1.8×10^{5}	6.2×10^{4}	4.2×10^{4}	6.7×10^{6}	5.2×10^{4}
Cassava	2.3×10^{6}	1.6×10^{6}	1.8×10^{6}	2.3×10^{5}	1.3×10^{5}	6.3×10^{4}	1.6×10^{5}	1.2×10^{5}
Spinach	1.3×10^{6}	1.2×10^{6}	1.0×10^{6}	1.4×10^{6}	5.2×10^{4}	3.4×10^{4}	1.3×10^{5}	6.1×10^{4}
Pineapple	1.0×10^{6}	9.4×10^{5}	9.2×10^{5}	1.0×10^{5}	4.3×10^{4}	3.1×10^{4}	7.3×10^{4}	4.2×10^{5}
Cowpea	2.6×10^{6}	2.5×10^{6}	2.6×10^{6}	2.6×10^{5}	2.3×10^{5}	2.0×10^{5}	2.8×10^{5}	2.6×10^{5}
Coliform (CFU g^{-1})								
Fish	9.5×10^{2}	1.0×10^{3}	8.1×10^{2}	9.4×10^{2}	4.2×10^{2}	2.2×10^{2}	1.8×10^{2}	1.0×10^{2}
Crab	4.4×10^{2}	3.3×10^{2}	1.0×10^{3}	1.0×10^{3}	5.1×10^{2}	2.3×10^{2}	2.2×10^{2}	1.3×10^{2}
Maize	4.0×10^{1}	8.0×10^{1}	6.0×10^{1}	6.0×10^{1}	Nil	Nil	1.0×10^{1}	1.0×10^{1}
Cassava	1.3×10^{3}	1.2×10^{3}	5.3×10^{2}	3.4×10^{2}	1.6×10^{2}	1.2×10^{2}	4.0×10^{1}	3.0×10^{1}
Spinach	1.4×10^{2}	3.7×10^{2}	1.2×10^{2}	1.1×10^{1}	1.0×10^{1}	1.0×10^{1}	2.0×10^{1}	1.0×10^{1}
Pineapple	3.2×10^{2}	1.3×10^{2}	2.0×10^{1}	1.0×10^{1}	1.0×10^{1}	Nil	2.0×10^{1}	1.0×10^{1}
Cowpea	1.8×10^{3}	1.5×10^{3}	1.2×10^{3}	1.1×10^{3}	6.2×10^{2}	3.2×10^{2}	2.4×10^{2}	1.2×10^{2}
Mold growth (CFU g^{-1})								
Fish	2.0×10^{1}	Nil	1.0×10^{2}	2.0×10^{1}	4.0×10^{1}	2.0×101	2.0×10^{1}	1.0×10^{1}
Crab	1.1×10^{2}	1.3×10^{2}	2.1×10^{2}	1.7×10^{2}	7.0×10^{1}	2.0×10^{1}	3.0×10^{1}	1.0×10^{1}
Maize	2.0×10^{1}	3.0×10^{1}	1.0×10^{1}	2.0×10^{1}	Nil	Nil	Nil	Nil
Cassava	Nil	1.0×10^{1}	Nil	4.0×10^{1}	1.0×10^{1}	Nil	1.0×10^{1}	Nil
Spinach	3.0×10^{1}	5.0×10^{1}	2.0×10^{1}	Nil	Nil	Nil	Nil	Nil
Pineapple	Nil	1.0×10	Nil	Nil	Nil	Nil	Nil	Nil
Cowpea	1.5×10^{2}	1.0×10^{2}	1.2×10^{2}	6.0×10^{1}	6.0×10^{1}	1.1×10^{2}	1.1×10^{2}	6.0×10^{1}

CONCLUSION

The results of the present study showed that a significant percentage of residents of Akwa Ibom communities were aware of the existence and presence of heavy metals. There were also clear indications and an appreciable awareness of the knowledge and effect of heavy metals present in foods, particularly lead and mercury, on human health. Microbial contamination of the foods surveyed was more common in agrarian and fishing communities than in urban areas. Fecal contamination of staple and aquatic foods was also more common in rural communities that lack disposal systems for human waste.

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