Current Journal of Applied Science and Technology

39(30): 61-69, 2020; Article no.CJAST.55422
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Analysis of Heavy Metals Concentrations in Food Spices from Some Markets in Port Harcourt Meteropolis, Rivers State, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author AAO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors TFM managed the analyses of the study. Author AAO managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2020/v39i3030971
Editor(s):
(1) Ming-Chih Shih, Chinese Culture University, Taiwan.
Reviewers:
(1) Ahmed Eid Alprol, National Institute for Oceanography & Fisheries, Egypt.
(2) Kaywood Elijah Leizou, Niger Delta University, Nigeria.
(3) Mini K D, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/55422

Original Research Article

Received 15 January 2020
Accepted 20 March 2020
Published 02 October 2020

ABSTRACT

This study analysed the levels of some heavy metals like copper (Cu), cadmium (Cd), chromium(Cr), nickel (Ni) and lead (Pb) present in selected food spices widely used in Port Harcourt, Rivers State, Nigeria. The Atomic Absorption Spectroscopy (AAS) and wet digestion was used for analysis. The results revealed different concentrations of heavy metals in the food spices analysed. The mean and standard deviation of heavy metals across the samples revealed that copper had the highest concentration in tomatoes (15.45±5.09 mg/Kg), curry (10.30±2.03 mg/Kg), garlic (8.65±2.08 mg/Kg), onions (6.50±2.52 mg/Kg) and uda (6.15±3.75 mg/Kg) respectively. Chromium was only detected in curry (2.75±1.00 mg/Kg), pepper (0.65±0.02 mg/Kg) and salt (0.05±0.00 mg/kg). The detected level of nickel was high in tomatoes (6.90±4.89 mg/Kg), curry (4.09±1.90 mg/Kg), salt (6.15±3.70 mg/Kg) and onions (3.09±2.10 mg/Kg). Lead occurred more in

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uda (3.08±2.87 mg/Kg), tomatoes (3.80±1.28 mg/Kg), curry (2.86±1.34 mg/Kg) and salt (2.60±0.76 mg/Kg) respectively. Cadmium was not detected in any of the food spices, while in chilles spice no heavy metals was detected. The daily intake limit was calculated and compared with minimum risk level (MRL) values. The concentrations of lead in some of the food spices were much larger than those of MRL values. The regular consumption of the spices can lead to accumulation of these toxic heavy metals in human beings.

Keywords: Food Spices; heavy metals; Atomic Absorption Spectroscopy (AAS); Nigeria.

1. INTRODUCTION

Since ancient times, spices have always been used in folk medicine and food flavouring. According to Shahidi and Hossain [1] a lot of phytochemicals are found in spices. Some of these spices and the associated phytochemicals include: piperine (black pepper), sabinene (curry leaf), capsaicin (capsicum),), linalool (coriander), cinnamaldehyde (cinnamon), eugenol (clove limonene (dill seed),), allicin (garlic), gingerol (ginger), safranal (saffron), and curcumin (turmeric), thymol (ajowan and thyme), estragole (fennel seed, anethole (aniseed). Spices contain antioxidants that have anti-inflammatory, anti-cancer and anti-mutagenic properties. Spices also contain some essential oils with strong antimicrobial activity against fungi, yeasts, bacteria and the synthesis of microbial toxins.

When inhaled or ingested, Cadmium can cause severe irritation of the pulmonary and gastrointestinal track in humans. The intake of high concentrations of cadmium is usually accompanied with such symptoms as abdominal pain, burning sensation, nausea, vomiting, salivation, muscle cramps, vertigo, shock, loss of consciousness and convulsions within 15 to 30 min [2].

Chromium (Cr (VI)) equally induces negative health effects in human beings. The evidence of Cr (VI)-induced human toxicity includes respiratory cancers in workers occupationally exposed to Cr (VI)-containing compounds [3], DNA strand breaks in peripheral lymphocytes and lipid peroxidation products in urine observed in chromium-exposed workers [4]. There is also the Lead-induced toxicity and apoptosis in human cancer cells involves series of cellular and molecular mechanisms such as oxidative stress and the induction of death of cells [5], transcriptional activation of stress genes and DNA damage [6].

Alkaloids, glycosides, saponins, organic acids, and phenolic compounds are the commonest chemical compounds found in spices [7]. Spices are play significant role in flavor enrichment, improvement of digestion and providing antioxidants properties to human health [8]. Srinivasan [9] and Yanishlieva [10] reported that rosemary, nutmeg, oregano, ginger, thyme, and sage possess some phenolics that function as effective antioxidants. The presence of these phenolic compounds is responsible for the reduction of protein, lipid, and enzymatic oxidation and increase in the shelf life of foods. The phenolics play vital roles in the prevention or retardation of off-flavor and the development of rancidity in foods [11]. Phenolic compounds from spices serve as a rich source of natural antioxidants that can be incorporated into foods to prevent the appearance of oxidation derived changes.

Phytochemicals derived from spices are not only important in food but are also used in food packaging to increase the quality of food products and their shelf life. The incorporation of antioxidants compounds into packaging materials improves the quality of food by preventing the occurrence of oxidation. The practice of use of synthetic antioxidants such as butylated hydroxylanisole (BHA), butylated hydroxyltoluene (BHT), and tertiary butylhydroquinone (THBQ)) is been discouraged of their harmful effect to human health [12] are important and the latter is a current trend in the food packaging sector according to Silva-Weiss [13], the current trend in the food packaging industries favours the use of natural antioxidants like phenolics and polyphenolics and those isolated from essential oils in spices. Some spice extracts have demonstrated inhibitory activity against pathogenic organisms and can be useful in the control of foodborne pathogens [14].

Many of the phenolic compounds are lipophilic, which enhances their antimicrobial activities. This is because lipophilic components are responsible for inflicting structural and functional damage to microorganisms by disrupting the osmotic balance of the cell and membrane permeability [15].

There have been increased interests in studying the heavy metals contamination of spices in recent years. This is because some of the metals like cobalt, copper, chromium, manganese, nickel and zinc when present in small quantities are essential for cellular metabolism and growth, but if the concentrations exceeds the systems threshold levels, they become harmful to the organism [16]. The toxicity of heavy metals occurs when the metal combines and forms complexes with proteins, in a reaction involving carboxylic acid (-COOH), amine (-NH_2), and thiol (-SH) functional groups. The proteins become biologically modified, and so, loses its ability to function properly leading to the death of affected cells [17]. The main aim of this study is to evaluate the concentrations of heavy metals in some food spices sold in major markets in Port Harcourt city, Rivers State, Nigeria.

2. EXPERIMENTAL METHOD

2.1 Study Area

Rumuokoro Town and Port Harcourt City Local Government Area, Rivers State was used for the study. It is a cosmopolitan Town with people from different ethnic and cultural background living together. The local government is bounded by Okrika LGA to the South, Eleme LGA to the east and Degema LGA to the West. The area also houses many industries which could lead to release of heavy metals into the atmosphere.

2.2 Collection of Sample

The spices used in this study includes; Garlic, Uda, Salt, Ginger, Pepper, Thyme, Chilles, Curry, Tomatoes, Onions. The spices were bought from different retailers at the open market in Rumuokoro Town, Port Harcourt City, Rivers State, Nigeria. All the spices were purchased between 9.00am and 11.00am in July, 2019.

2.3 Treatment of Samples

The samples were washed with distilled water and placed in clean trays to drain off the water. 10 to 50 g of the samples was weighed into quartz crucibles, dried at 105°C for 24 hours and later ashed in the muffle furnace at 400°C. The samples used are classified in Table 1.

2.4 Sample Digestion

2 g each of the sample was weighed out into 12 mL solution of aqua regia HNO_3/ HCl (1:3) on a hot plate and digested for 3 hours at 110°C until the brown fumes disappeared. The heating process continued until the fumes turned white. Then, 20 ml distilled water was added and heated again the solution appeared colourless. The colourless solution was allowed to cool and filtered into a 100 ml standard conical flask with Whatman No. 42 filter paper. The volume was increased to 100 ml by adding distilled water as described by Alinnor [18] and Iyaka [19]. Using the Atomic Absorption Spectrophotometer (AAS), the concentrations of the heavy metals in the all samples was analyse.

2.5 Calculation of Pollution Index in Trace Metal

The ratio of heavy metal concentration in any given material to that of the Standard of Federal Environmental Protection Agency (FEPA) of Nigeria, United States Environmental Protection Agency (USEPA) or the World Health Organisation is usually calculated as the Pollution index (PI) [20]. The PI value of <1 indicates that the material is not contaminated, whereas PI value of >1 reveals heavy metal contamination or pollution. Accordingly, Chukwuma [21] stated that a critical stage is reached when the value of PI = 1, and makes the material very important for environmental monitoring.

Pollution Index can be is expressed mathematically as:

$$PI = Cplant / C_{USEPA/WHO\text{-}standard} \qquad (i)$$

Where:

PI = pollution index of each heavy metal;
Cplant = heavy concentration of the metal in the material;

$C_{USEPA}/_{WHO\text{-}standard}$ = value of the regulatory limit of the heavy metal by USEPA; [22].

2.6 Estimated Daily Intake (EDI) (mg/kg/day) of Heavy Metals in Food Spices

The amount of daily heavy metals intake is dependent on the concentration of heavy metal in a given food and the quantity of food consumption daily. In addition, the body weight of humans can influence the tolerance of contaminants. The EDI was calculated based on the following formula [23].

$$EDI = \frac{C \times D}{BW}$$

Where:

C = concentration of heavy metal (mg/kg) in spices,
D = daily intake of food (kg /person)
BW = average body weight (kg/person).

For this study, an average daily consumption of 10 g of spices was assumed and an average body weight of 60 kg for an adult was considered to be. This method was adopted because spices are widely consumed as a major part of the diet.

3. RESULTS

The results obtained from analysis of some heavy metals in the food spices are presented in the Tables and Figs. below:

Table 1. List of spices, common and scientific names, nature in the market and parts used

Spice	English name	Scientific name	Parts used	Local name	Nature
Garlic	Garlic	*Alium Sativum*	Bulb	-	Raw
Uda	-	-	Seed	Uda	Raw
Salt	Common salt	*Sodium Chloride*	Granules	Ara	Processed
Ginger	Ginger	*Zingiber Afficinale*	Rhizomes	-	Raw
Pepper	Pepper	*Capsicum Frutescens*	Fruit	Ose	Raw
Thyme	Thyme	-	-	Thyme	Processed
Chilles	Long Pepper	*Capsicum Annum*	Fruit	Pepper	Raw
Curry	Curry	-	Leave	Curry	Raw
Tomatoes	Tomatoes	*Solanum Lycos.*	Fruit	Tomato	Raw
Onions	Onions	*Alium Cepa*	Bulb	Ayo	Raw

Table 2. Mean ± std concentration in mg/Kg of heavy metals in food spices from Rumuokoro market

Heavy Metals	Copper (Cu)	Cadmium(Cd)	Chromiun(Cr)	Nickel (Ni)	Lead (Pb)
Garlic	8.65±2.08	Nil	Nil	2.03±1.55	2.07±1.07
Uda	6.15±3.75	Nil	Nil	0.15±0.21	3.08±2.87
Salt	2.35±0.76	Nil	0.06±0.00	6.15±3.70	2.60±0.76
Ginger	2.95±1.42	Nil	Nil	ND	1.50±0.05
Pepper	3.10±2.05	Nil	0.60±0.02	3.50±2.41	0.88±0.05
Thyme	3.40±0.63	Nil	Nil	2.01±0.43	1.27±1.02
Chilles	ND	Nil	Nil	ND	ND
Curry	10.30±2.03	Nil	2.70±1.00	4.09±1.90	2.86±1.34
Tomatoes	15.45±5.09	Nil	Nil	6.90±4.89	3.80±1.28
Onions	6.50±2.52	Nil	Nil	3.09±2.10	0.55±0.04
MPL(WHO)	50	0.3		50	10

MPL = Maximum Permissible Limit, Nil = Non detected, STD = Standard deviation

Table 3. Pollution index (PI) of the heavy metals in the food spices

Metal	Cu	Cd	Cr	Ni	Pb
Garlic	0.173	-	-	0.041	0.207
Uda	0.123	-	-	0.003	0.308
Salt	0.047	-	-	0.123	0.260
Ginger	0.059	-	-	-	0.150
Pepper	0.062	-	-	0.070	0.089
Thyme	0.068	-	-	-	-
Chilles	-	-	-	-	-
Curry	0.206	-	-	0.082	0.286
Tomatoes	0.309	-	-	0.138	0.380
Onions	0.130	-	-	0.062	0.056

Table 4. Estimated daily intake of food spices in mg/Kg/day

Spices	Cu	Cd	Cr	Ni	Pb
Garlic	1.44E-3	-	-	3.38E-4	3.45E-4
Uda	1.03E-3	-	-	2.50E-5	5.13E-4
Salt	3.92E-4	-	8.05E-6	1.02E-3	4.31E-4
Ginger	4.92E-4	-	-	-	2.50E-4
Pepper	5.17E-4	-	1.08E-4	5.83E-4	1.48E-4
Thyme	5.67E-4	-	-	3.35E-4	2.12E-4
Chilles	-	-	-	-	-
Curry	1.72E-3	-	4.58E-4	6.82E-4	4.77E-4
Tomatoes	2.58E-3	-	-	1.15E-3	1.33E-4
Onions	1.08E-3	-	-	5.15E-4	9.33E-5
MRL (ASTDR)	10E-3			50E-4	2E-4

Table 5. Effect of estimated daily intake of food spices in mg/Kg/day

Spices	Cu	Cd	Cr	Ni	Pb
Garlic	Nil	Nil	Nil	Nil	Acute
Uda	Nil	Nil	Nil	Nil	Acute
Salt	Nil	Nil	Nil	Nil	Acute
Ginger	Nil	Nil	Nil	Nil	Acute
Pepper	Nil	Nil	Nil	Nil	Nil
Thyme	Nil	Nil	Nil	Nil	Acute
Chilles	Nil	Nil	Nil	Nil	Nil
Curry	Nil	Nil	Nil	Nil	Acute
Tomatoes	Nil	Nil	Nil	Nil	Nil
Onions	Nil	Nil	Nil	Nil	Nil
MRL (ASTDR)	0.01	0.0002		0.005	0.0002

4. DISCUSSION

Heavy metals such as arsenic cadmium, chromium, lead, and mercury are naturally occurring, but human activities are responsible for their environmental contamination. These group of heavy metals have been found to be systemic toxicants that cause serious health problems in human beings, including cardiovascular diseases, developmental abnormalities, neurologic and neurobehavioral disorders, diabetes, hearing loss, hematologic and immunologic disorders, and different kinds of cancer. The major mode of exposure is through ingestion, inhalation and skin contact [24].

The mean concentrations of heavy metals in the various spices examined in this study showed that copper had a range of 2.35±0.76 to 15.45±5.09 mg/Kg for all the spices studied. Tomatoes had the highest concentration of copper with 15.45±5.09 mg/Kg. High concentrations of copper metal were also detected in curry (10.30±2.03 mg/Kg), garlic (8.65±2.08 mg/Kg), onions (6.50±2.52 mg/Kg) and Uda (6.15±3.75 mg/Kg). While those with lower mean concentration includes; thyme (3.40±0.63 mg/Kg), pepper (3.10±2.05 mg/Kg), ginger (2.95±1.42 mg/Kg) and salt (2.35±0.76 mg/Kg). Although, slightly high concentrations were detected in the spices, the values fell far below the World Health Organisation permissible limit of 50 mg/Kg. Umar and Salihu [25] detected lower heavy metals concentrations in analysis of spices analysed sold in Abuja, Nigeria. The need for constant evaluation is necessary to prevent further due to bioaccumulation. Cadmium could not be detected by the analytical instrument.

The mean concentration of chromium was low, it ranged from 0.05±0.00 to 2.70±1.00 mg/Kg. It was only detected in three spice samples which were curry (2.70±1.00 mg/Kg), pepper (0.60±0.02 mg/Kg) and salts (0.06±0.00 mg/Kg). Previous study by [26] in Pakistan detected Chromium in the range of 115 to 368 mg/kg in commercial spices. It should be noted that he accumulation of chromium in edible plants may be hazardous to animals as well [27].

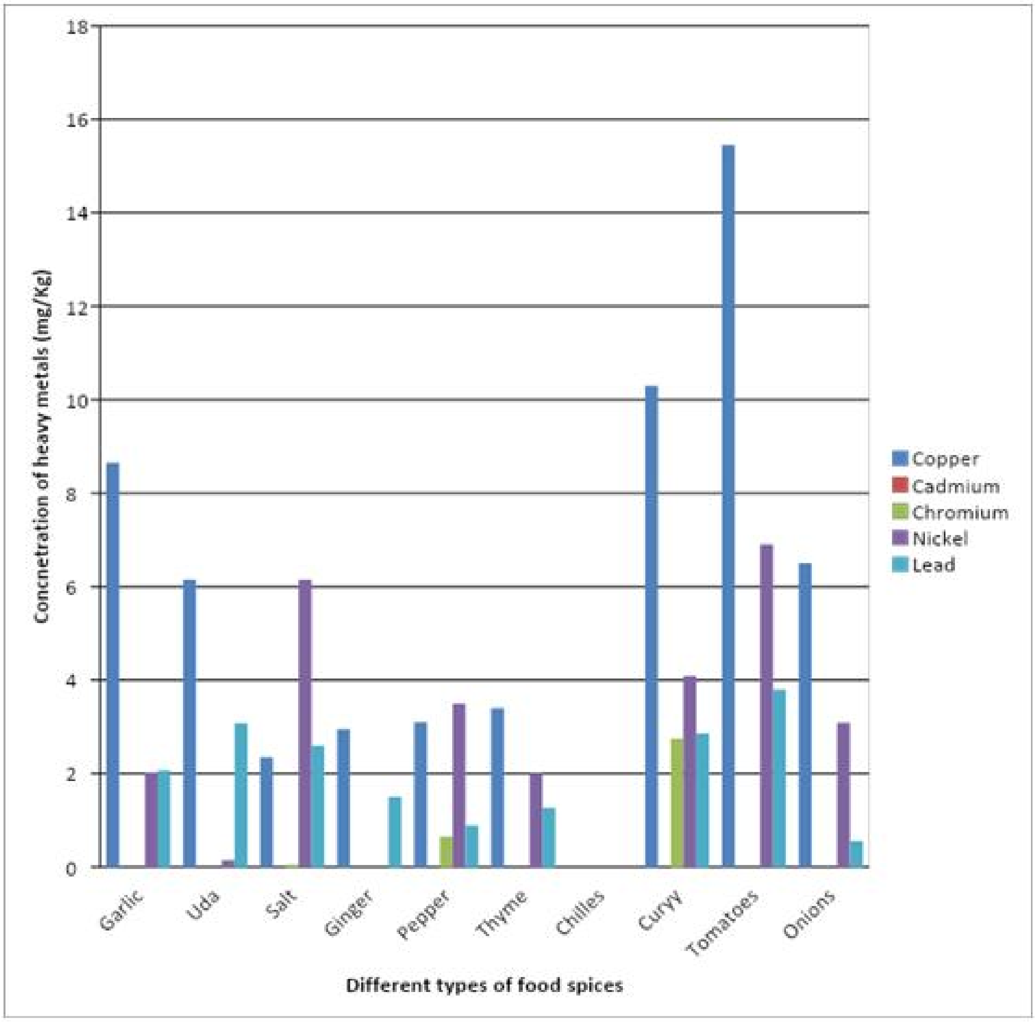

Fig. 1. Concentration of heavy metals in different food spices

Nickel was present in majority of the spices sampled with concentrations ranging from 0.15±0.21 mg/kg to 6.90±4.89 mg/kg. The highest concentration of 6.91±4.88 mg/kg was detected in tomatoes. The lowest concentrations occurred in garlic (2.03±1.55 mg/Kg), thyme (2.01±0.43 mg/Kg) and uda (0.15±0.21 mg/Kg). Nickel was not found in ginger and chilles. These results were also far below the limit of 50 mg/Kg for nickel in food set by World Health Organisation. The result is however is higher than that reported by [28] on spices and food seasoning around the city of Hamedan, Iran.

Lead was detected in all the samples except chilles. Tomatoes had the highest concentration of (3.80±1.28 mg/Kg), followed by uda (3.08±2.87 mg/Kg), curry (2.86±1.34 mg/Kg), salts (2.60±0.76 mg/Kg) and garlic (2.07±1.07 mg/Kg), thyme (1.27±1.02 mg/Kg), ginger (1.50±0.05 mg/Kg), pepper (0.88±0.05 mg/Kg) and onions (0.55±0.04 mg/Kg) respectively. Lanre-Iyanda and Adekunle [29] observed lower levels of lead in their work on some food spices in Nigeria. The spices with the highest concentrations of heavy metals were Tomatoes, curry, onions, garlic, uda and salt had the higher levels of heavy metals, while the lowest concentrations were found in ginger, thyme and pepper.

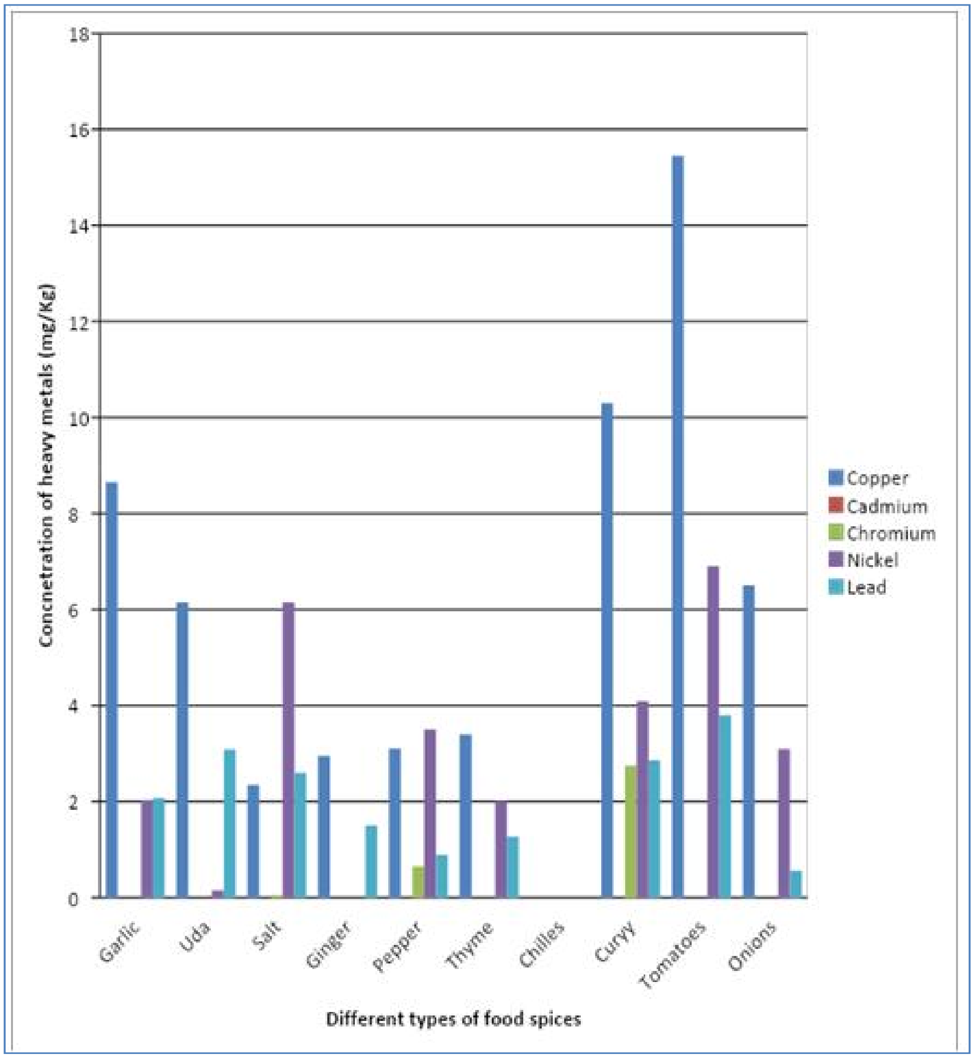

Fig. 2. Concentration of heavy metals different food spices

The trend of pollution index (PI) from the food spices revealed a very low pollution index. The PI values were all less than unity. The implication of PI value <1 is that there are no health implications. The low PI values suggests that the food spices used in the study are safe for human consumption, however, bioaccumulation as a result of continued consumption may to unhealthy consequences.

The estimated daily intake for food showed high heavy metal daily intake in garlic, copper with a value of 1.44E-3, followed by nickel (3.38E-4) and lead (3.45E-4) with no values for cadmium and chromium. These values are below maximum risk level for the respective metals except lead for curry, thyme, salt, uda and garlic which showed a daily intake values that were a bit higher than the maximum risk level of 2E-4. The calculations carried out to estimate the daily intake of Pb if 10 g of the spice was ingested daily by a 60 kg body weight also show that it would be at risk. The WHO/FAO MRL of Pb is stated as 0.0002 mg/kg/day.

5. CONCLUSION

All the heavy metals analysed were detected in virtually all the food spices, except chromium that was absent in garlic, uda thyme chilles tomatoes and onions. The concentrations of the heavy metals ranged within the standards of WHO/FAO for metals in food spices. Based on the low Pollution Index of PI<1, the result indicated that the food spices contains some mineral elements that may be essential for the body and its consumption may not be of risk to human health. The consumption daily intake shows that the Minimum Risk Level is very much below the approved standard by WHO. The only exception is the concentration of Pb with levels in some of the spices been a bit higher. Food spices producers, retailers and vendours should be enlightened on the dangers of exposing their produce to contamination with heavy metals in order to safeguard the health of consumers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/55422