Journal homepage: www.fia.usv.ro/fiajournal
Journal of Faculty of Food Engineering,
Ştefan cel Mare University of Suceava, Romania
Volume XIX, Issue 4 - 2020, pag. 287 - 296

HUMAN HEALTH RISK ASSESSMENT OF HEAVY METAL CONTAMINANTS IN TABLE SALT FROM NIGERIA

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Recieved 20th August 2020, accepted 29th December 2020

Abstract

Table salt has continue to be an important part of human diet in many households around the world. Table salt is used for food flavouring, pickling, curing and in several industrial purposes. Therefore, the present of contaminants in table salt portends significant risk to human health. The study is aimed at investigating the concentration of heavy metals and human health risk associated with consumption of table salt in Nigeria. Four refined table salt samples (A, B, C, D) and four samples of unrefined table salt (E, F, G, H) were analysed for the concentration of copper (Cu), lead (Pb), iron (Fe), Cadmium (Cd) and arsenic (As) using atomic absorption spectrometry. The United State Environmental Protection Agency (USEPA) methods were used to estimate hazard indices and cancer risks associated with consuming table salt with these elements. Results indicated heavy metal concentrations were significantly higher in unrefined table salt than refined table salt, The estimated daily intake values of Cu, Fe, and Cd were lower than the established provisional tolerable daily intake. The hazard indices did not exceed 1 in all samples of refined and unrefined table salts. However, higher values of HI of Pb, Cd and As were noted in unrefined table salts. The carcinogenic values of As in refined salt sample B and C and all unrefined table salts were higher than the stipulated one in one million chances which implies that carcinogenic effects were more likely due to consumption of 6.35g/day of salt samples with those contaminants.

Keywords: *Table salt, Heavy metal, Contaminant, Health risk, Nigeria*

1. Introduction

Exposure of humans to environmental hazards especially toxic chemicals occurs spontaneously through different sources. These include the non-occupational exposed populations whose contact and exposure to heavy metal is through food and water. They constitute over 90% of the exposed populations and those whose exposure is as a result of inhalation and dermal contact [1]. Food contamination by environmental hazards have continued to be a subject of serious concern to researchers globally particularly due to their deleterious effects on human health. Among the chemical contaminants are toxic elements which constitutes a significant food safety risk because of their poor rate of metabolism, potential to bioaccumulate in the biological system resulting from their non-biodegradable nature and long biological half-lives [2]. Although some toxic elements occur naturally in the environment, anthropogenic inputs which originate from various human activities have continued to increase their concentrations [3, 4]. Some elements such as lead, cadmium, mercury and arsenic are non-essential and are toxic even at low concentrations. Others such as copper and zinc are essential for humans; they play important roles in biological systems. When their intake exceeds specific levels, they result in harmful and toxic effects. These non-essential heavy metals or toxic elements exert harmful effects to cardiovascular, neural, hematopoietic, immunological and gastrointestinal systems [5 - 6].

Edible salts is a frequently used in many homes as an food additive for the purpose of imparting taste to food. It is an essential additive which has been used from prehistoric times for flavouring, pickling and curing meat and fish and for tanning [7]. In addition to salty flavor, it is used as a flavor enhancerand also as a food preservative to inhibit the growth of some spoilage and pathogenic bacteria [6]. Sodium chloride content of food grade salt must not be below 97% on dry matter basis while the insoluble dry matter content should not exceed 0.2%. Also, with majority of table salt consumed globally coming from mines, it is expected that environmental contaminants such as heavy metal possess a serious health concern to consumers [1]. Table salt is consumed daily, hence any contamination, even at low concentrations, could be hazardous to the consumer’s health. Therefore, the concentration of heavy metals should be carefully monitored in this food additive [1].

In studies conducted by the FAO and WHO experts on the assessment of several additives in foods and environmental pollutants reported that cadmium, lead and mercury are the major heavy metal implicated in food contamination [8]. Also in Nigeria, salt deposits are found in many parts of the country and have been exploited traditionally for over 400 years. The process though crude begins with the fetching of the brine from the salt lakes into a mound already built and tilled locally. The brine is then poured into it and the puddle is left under the sun to allow the water to evaporate leaving behind a crust that is rich in crystals. The crust is further broken and process locally into table salt [7]. The direct use of this unpurified or unrefined table salts for culinary and eating purposes have been discouraged by government health agencies and regulatory authorities. This is because of the expected adverse health effect that may occur due to toxic elements contamination which is widespread in the environment [9].

Unrefined table salt may contain some of these toxic elements which may create health risks to consumers even at low concentrations due to the daily consumption of salt. In spite of several warnings on the direct use of raw and unrefined table salt by government and regulatory agencies, their availability in the markets proof their deliberate usage [7]. In addition, several studies have shown the presence of heavy metals in both refined and unrefined salts [10, 11, 6]. It is therefore important to conscientiously monitor the concentration of toxic elements in edible salt as well as assess the related risks of dietary intake of these elements in food to human health for the purposes of quality control, food safety and other advisory purposes. There is little or no information about the levels of toxic elements contamination and their associated human health risks from consumption of edible salts produced and sold in Nigeria. Therefore, this study was conducted to investigate the concentrations of Cu, Pb, Fe, Cd, and As in refined and unrefined salts produced and marketed in Nigeria. Also, the potential human health risks associated with these metals through salt consumption were estimated

2. Materials and Methods

Study Area

The research was carried out in four locations in the country. These location have history of producing salt traditionally or locally. Edible salts are usually produced traditionally from salt lakes, seawater and Mines by women from these areas. Despite the present of refined table salts in the markets, some residents of these areas forechoose the local or unrefined salt sometimes for several reasons which are cultural and economical related.

Sample Collection

Four brands (500g) of refined packaged table salts consumed in Nigeria were obtained from their distributors in Uyo, Akwa Ibom State in June 2019. The selected brands were checked for their registration with the National Agency for Food and Drug Administration and Control (NAFDAC), Batch number and expiry date were also confirmed. The refined table salt samples were coded A, B, C, and D. For each brand, three samples with different batch numbers were obtained. Also. Four samples of locally processed table salt from salt production areas which are mainly found Port Harcourt, Abakaliki, Makurdi and Jos were obtained from vendors. Three samples of 500g were collected from vendors at each location in June 2019. They were also coded as E, F, G and H respectively. The table salts samples obtained were packaged and taken for analysis at the Food Processing Laboratory of the University of Uyo.

Heavy metal analysis

Heavy metals including copper (Cu), lead (Pb), iron (Fe) arsenic (As) and cadmium (Cd) were determined in the refined and unrefined table salt samples using Perkin – Elmer model 3030 Atomic Absorption spectrophotometer. The elements were analysed by dissolving 2g of salt samples into 3ml nitric acid this was followed by the addition of 1ml concentrated hydrochloric acid. The solution was diluted with distilled water to 100ml. Specific cathode hallow lamp for each element was used to determine their concentration at specific wavelengths [12].

Human Health Risk Assessment

Assessment of human health risk resulting from consumption of salt with heavy metals contaminants were determined based on methods outlined [13]. Firstly, the level of exposure resulting from consumption of heavy metal contaminants in salt samples were determined by estimating the daily intake levels;

$$EDI = \frac{CxIRxEFxED}{BWxAT.}$$

Where

EDI	=	Estimated Daily Intake (mg/kg – day)
IR	=	Ingestion rate of salt (kg/day)
C	=	Concentration of chemical contaminant in salt (mg/kg)
EF	=	Exposure Frequency (days/year)
ED	=	Exposure duration (years)

BW = Body weight (kg)
AT = Average time (days)

Non-carcinogenic risk or target hazard quotient values (THQ) for each metal were then calculated according to equation below;

$$THQ = \frac{EDI}{RfD}$$

Where:
THQ = Non-cancinogenic risk value for heavy metal contaminant.
EDI = Estimated daily Intake or exposure rate (mg/kg –day)
RfD = Reference dose of chemical (mg/kg – day)

The calculations were made using the standard assumptions for an integrated risk analysis [14]. For the purpose of this study, the intake rate (IR) of salt in Nigeria was assumed to be 6.35g/day [15], average body weight of exposed individual (70kg), exposure frequency (365day/year) while duration of exposure was 70years. The average exposure was calculated as 365days x 70 years. For calculation of Target Hazard Quotient (THQ) for each metal, the following reference dose (RfD) [14]. were used; Pb = $3.6x10^{-3}$ mg/kg-day, Cd = 1.0 x 10^{-3} mg/kg-day, As = 3.0 x 10^{-4} mg/kg-day, Fe =$7.0x10^{-1}$ mg/kg-day and Cu = $4.0x10^{-2}$ mg/kg-day.

The hazard index (HI) is the sum of total hazard quotients; (HI = ΣTHQ).

The carcinogenic risk (CR) of Pb and As were expressed as a product of EDI and cancer potency value or cancer slope factor (CSf).

$$CR = EDI * CSf$$

Where: CR = Life time cancer risk
EDI = Estimated Daily Intake mg/kg-day
CSf = cancer slope factor mg/kg-day

The cancer slope factor for Pb = $8.5x10^{-3}$mg/kg-day; As = 1.5mg/kg-day [14].

Data Analysis

All analyses were carried out in triplicate. The experimental data generated were statistically analyzed using one way analysis of variance. The mean and standard deviation of the data was determined. Significant difference between mean were analysed using Duncan multiple range test (DMRT).

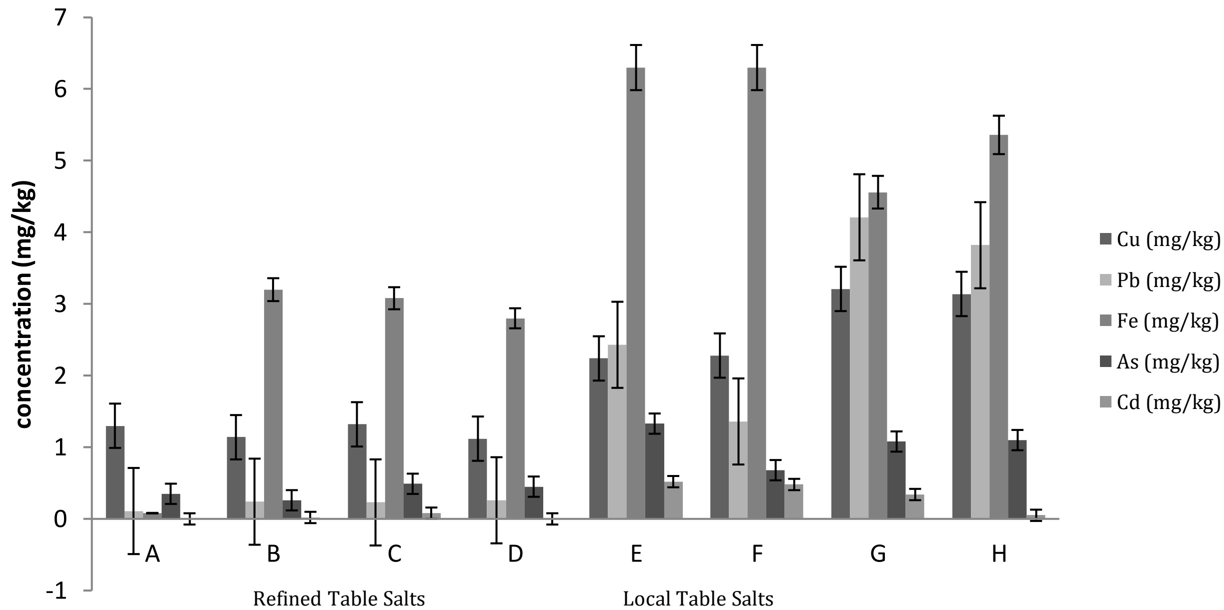
All analyses were done using Statistical Package for Social Science (SPSS) version 20 for windows. Statistical test was performed at 5% significant level.

3. Results and Discussion

Concentration of Heavy metals in Edible Salt

Results of heavy metals concentration in various salt samples are shown in Fig.1.

Heavy metal concentrations were significantly higher in local or unrefined table salt samples when compared to those of refined table salt samples. Copper concentration in the refined table salt samples ranged from (1.12-1.32 mg/kg) and did not show significant difference among samples, however significant differences (2.21-3.21 mg/kg) existed among the unrefined table salt samples. Iron concentration in both local and refined table salts were within the regulatory acceptable limit of SON (30 mg/kg) and Codex (50 mg/kg) for edible table salt [16, 17]. This may require fortification of salt with iron to increase iron content.



Cu, copper; Pb, Lead; Fe, Iron; As, Arsenic; Cd, Cadmium

Fig. 1: Heavy metals content of refined and local table salts consumed in Nigerian

Lower concentrations copper and iron in foods are very important for human health. Copper is a major component of different enzymes involve in energy metabolism, synthesis of haemoglobin, connective tissue and phospholipids while Iron is present in cells of living organism and play significant functions in many biochemical processes. Iron is the major component of haemoglobin and myoglobin, pigments, cytochromes and other proteins participating in transport, storage and utilization of oxygen [7].

Although optimal levels of copper is useful in human body, higher concentrations have been linked to Wilson syndrome. The defect is characterized by dysfunction associated with the transmission of copper in the cells. This condition may result in hepatic cirrhosis and degradation of neurons as well as the presence of colourful ring in the cornea of human eye. Higher intake of copper can also lead to kidney and brain damage [18, 6].

As was noted for copper, similar variations also existed between the toxic elements such as in lead cadmium and arsenic. Lead content of local table salt was much higher (1.36 -

4.21 mg/kg) where samples E, G and F had values higher than the SON and Codex acceptable limit of 2.0 mg/kg. Values for lead as obtained in this study were comparable to lead concentration in local cooking salts reported at Akwana, Middle Benue Trough, in Nigeria [19]. It is important to note that Nigeria had experienced several cases of lead poisoning in North western and central states of Zamfara and Niger where over 200 people mostly children had died [20]. Also, Cadmium concentration in the refined table salts sample were lower than the acceptable limit of 0.5 mg/kg while those of the local table salt samples were higher than maximum permitted limit. The present of arsenic in table salts or any food item is however unacceptable. Heavy metals such as lead cadmium and arsenic are absorbed, stored and concentrated in living cells through food chain causing serious toxic effect to humans [21]. They are widespread environmental pollutants which promote serious adverse health effects, especially in young children, pregnant women and other vulnerable groups. They are also implicated in causing several diseases such as osteoporosis and renal failure [22]. Their toxicity are due to their ability to replace useful metals in the active sites of enzymes, form complexes and, catalyzes the breakdown of essential metabolites altering their permeability and hindering other elements in their metabolic functions [23]. For instance, lead and cadmium interact with essential elements such as zinc, iron, calcium and copper exerting an inhibitory effects on the activity of enzymes containing this mineral elements. This results in growth failure, improved nutrients tolerance, poor metabolism and absorption of these elements, reduction in plasma ceruloplasmic concentration among others [24, 25].

Human Health Risk Assessment

Estimated daily intake of Heavy Metals in Edible Salt

The results of the EDI for heavy metals through the consumption of local and refined table salts are shown in table 1. In determining the EDI for these metals, the mean concentration of each metal as presented in Fig.1. and the average consumption rate of salt in Nigeria was estimated at 6.35g/day/person [15].

Table 1

Estimated daily intake (EDI) of heavy metals (mg/kg/d) from salt consumption

	Refined Table Salts				**Local Table Salts**			
Parameters	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Cu	0.00013	0.00011	0.00013	0.00011	0.00022	0.00023	0.00031	0.00029
Pb	0.000011	0.000023	0.000031	0.000025	0.00024	0.00013	0.00041	0.00038
Fe	0.00014	0.00031	0.00080	0.00027	0.00062	0.00061	0.00044	0.00053
Cd	0.000034	0.000025	0.000048	0.000044	0.00013	0.00011	0.00013	0.00011
As	0.00000	0.0000029	0.0000048	0.00000	0.000053	0.000049	0.000047	0.000053

This was based on the assumption that the ingested dose of each metal in the salt sample was equal to the absorbed dose and processing had no effect on the metal [13]. In the determination of potential human health risk resulting from daily consumption of edible salt containing these heavy metals, the concept of an estimated daily intake (EDI) for these metals from edible salt have become quite significant. For both the refined and unrefined or local table salts, the levels of EDI was consistent with the concentration level of each element present in the salts. The EDI values of the refined table salts samples were lower when compared to EDI values of the local or unrefined table salts samples. However, the EDI values were generally lower than the established provisional tolerable daily intake (PTDI) as outlined by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) [8]. The EDI values for Fe and Cu for both refined and unrefined edible table salt samples were far below the provisional tolerable daily intake (PTDI) (Fe; 0.8 mg/kg/day) and (Cu; 0.5 mg/kg/day). Similarly, EDI values for Cd in the refined table salt was far lower when compared with the tolerable daily intake of 0.0008 mg/kg/day. Also, according to Joint FAO/WHO Expert Committee on Food Additives (JECFA) the PTDI for Pb and As were no longer considered to be health protective, therefore it was withdrawn. This was on account of several studies not presenting any threshold for the key effects of Pb and As, hence it was concluded that it was not possible to establish PTDI that would be considered health protective. Therefore, human exposure to lead and arsenic through food need to be seriously discouraged [8].

Non- carcinogenic Health Risk

The non-carcinogenic risks resulting from consumption of edible salts with heavy metal contaminants were estimated through the target hazard quotient (THQ) and hazard index (HI) as presented in Table 2 and 3 respectively.

Table 2

Toxic hazard quotient (THQ) values of heavy metals from salt consumption

	Refined Table Salts				**Local Table Salts**			
Parameters	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Cu	0.0032	0.0028	0.0032	0.0028	0.0055	0.0056	0.0078	0.0073
Pb	0.0030	0.0060	0.0090	0.0070	0.066	0.067	0.12	0.11
Fe	0.0002	0.0004	0.0004	0.0003	0.0089	0.0087	0.0063	0.0076
Cd	0.034	0.025	0.048	0.044	0.13	0.11	0.13	0.11
As	0.000	0.0096	0.0026	0.00	0.18	0.17	0.13	0.18

Table 3

Hazard indexvalues of heavy metals from salt consumption

Parameters	**Refined Table Salt**	**Local Table Salt**
Cu	0.012	0.03
Pb	0.025	0.36
Fe	0.001	0.031
Cd	0.150	0.50
As	0.025	0.66

The estimated non carcinogenic risk values were determined on the basis of the reference dose (RfD) for toxic elements [14]. The RfD values represent the estimated daily exposure to which human population may continually be exposed over a life time without any appreciable health risk [26]. When the intake or average daily dose (EDI) is equal to the reference dose, the non-carcinogenic value or THQ is one. When the estimated daily intake (EDI) exceeds the reference dose and thus, the THQ is greater than one or equal to one, it is likelihood that non-carcinogenic adverse health effects will be observed due to ingestion of 6.35g of salt per day but when THQ is less than one its indicate that adverse health effects are not likely to occur due to ingestion of 6.38g of salt per day. Therefore a THQ value below 1 is an indication of no significant risk of non-carcinogenic effects for the exposed consumers. With the possibility to cumulative and synergic effects of these toxic metals, the THQ values of individual metals are summed up to give the HI or the total THQ caused by exposure to multiple metals, which is also explained in a similar manner as THQ [27]. The THQ and HI values of each estimated element did not exceed 1 in all samples of refined and unrefined table salt, suggesting that the exposed population would not experience significant health risks when consuming these individual elements from daily consumption of 6.35g/day of salt. The result as obtained in this study was similar to that reported on edible salt from neighboring Ghana [22]. It is worthy to note that, higher THQ values is an indication of a higher probability of an exposed risk, even if the THQ value was not greater than 1. It is also important note that hazard indices for the unrefined or local table salt was of serious concerned. This is because the consumption of 6.35g of local or unrefined table salt per day accounted for non-carcinogenic risk of 36%, 50% and 66% from Pb, Cd and As respectively. This suggests the need for consumers to regulate the intake of the unrefined or local table salts as the continuous consumption may result in adverse non-carcinogenic health effect.

Carcinogenic Health Risk

The carcinogenic risk indices for Pb and As in the refined and local and unrefined salt samples are presented in Table 4.

Table 4

Carcinogenic index for Lead and Arsenic from salt consumption

	Refined Table Salt				**Local Table Salt**			
Parameters	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Pb	$9.35X10^{-8}$	$1.96\ X10^{-7}$	$2.60\ X10^{-7}$	$2.10\ X10^{-7}$	$2.04\ X10^{-6}$	$1.0\ X10^{-6}$	$3.40\ X10^{-6}$	$3.21\ X10^{-6}$
As	0.00	$4.35\ X10^{-6}$	$7.20\ X10^{-6}$	0.00	$7.95\ X10^{-5}$	$7.35\ X10^{-5}$	$7.05\ X10^{-5}$	$7.95\ X10^{-5}$

The result indicated that cancer risk index of Pb in the refined salt samples were within the acceptable limit of one in one million (1.0×10^{-6}) chances of developing cancer as a consequent of consuming refined salt contaminated with Pb [14]. The carcinogenic risk value as obtained in this study was consistent with values reported by Weremfo (2019).

However, carcinogenic values of Pb for the local or unrefined table salt samples were higher than the acceptable limit of $1.0x10^{-6}$ chances. Also, carcinogenic values of As in refined salt sample B and C and all the local or unrefined table salts were higher than the acceptable limit and according to regulatory directives of the United State of America and European Union Commission and in this case a consequential risk is deduced [14, 28].

5. Conclusion

The study provided a significant information on varying concentrations Cu, Pb, Fe, Cd and As in refined and local or unrefined table salt available in Nigerian markets. Heavy metal concentrations were significantly higher in local or unrefined table salt samples than the refined table salt samples. Cu and Fe concentrations in the refined and unrefined table salt samples were far below the stipulated limits of regulatory agencies. The concentration of Pb, Cd, and As in local or unrefined table were higher than their safety limits as prescribed by SON and Codex regulations. The estimated daily intake values of Cu, Fe, and Cd were lower than the established provisional tolerable daily intake as outlined by the Joint FAO/WHO Expert Committee on Food Additives. The THQ and HI values of all estimated element did not exceed 1 in all samples of refined and unrefined table salt, suggesting that the exposed population would not experience significant health risks when consuming these individual elements from daily consumption of 6.35g/day of salt. However higher HI of Pb, Cd and As in the local unrefined table salts indicated a higher probability of exposed risk resulting from cumulative and synergistic effects of these elements. The carcinogenic values of As in refined salt sample B and C and all the local or unrefined table salts were higher than the stipulated one in one million ($1.0x10^{-6}$) chances which implies that carcinogenic effects were more likely due to consumption of 6.35g/day of salt samples with those contaminants

Conflict of Interest

The author declares no conflict of interest

6. References

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