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HEALTH RISK ANALYSIS OF MERCURY, LEAD AND CADMIUM IN SOME COMMERCIAL FISH SPECIES COLLECTED FROM MARKETS IN MONROVIA, LIBERIA

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ABSTRACT
The levels and health risks of mercury (Hg), lead (Pb) and cadmium (Cd) were evaluated in twenty-nine commercial fish species collected from markets in Monrovia, Liberia. A mixture of HNO_3, $HClO_4$ and H_2SO_4 was used for complete oxidation of organic tissue. Total mercury was determined by cold vapor atomic absorption technique using an automatic Mercury Analyzer; while the concentrations of lead and cadmium were determined by flame atomic absorption spectrometry. Estimation of the dietary exposure of the consumers to these metals were determined based on data from the American Food Consumption Index and the associated health risks were evaluated by comparing intakes with the Provisional Tolerable Weekly Intakes (PTWIs). The hazard quotient and total hazard index for the tested metals in all the species were less than the USEPA guideline value of 1, suggesting that the consumption of the tested fish species has no adverse health effects considering exposure to the tested metals.

Keywords: Health risk, Fish, Mercury, Lead, Cadmium, Monrovia.

Contribution/ Originality

This study contributes to the existing literature on heavy metal toxicity in commercial fish species and associated health risks to fish consuming populace. It is the first work of such nature covering a wide variety of fish species consumed in Monrovia, Liberia and thus provides a basis for future studies.

1. INTRODUCTION

Over the last few decades, the world has witnessed an increased awareness of problems concerning food contamination. Heavy metals are a major class of food contaminants which may enter aquatic ecosystem from different natural and anthropogenic sources causing metal pollution in water bodies [1]. Metals entering the aquatic ecosystem can be stored in fish and other aquatic organisms through the processes of bioaccumulation and biological magnification via the food chain and can become potentially toxic when accumulation reaches a substantially high level [2].

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Fish are excellent dietary sources of vitamins, fatty acids, minerals and relatively cheap proteins that are essential for healthy living [3]. For most non-occupationally exposed individuals, diet is the main route of exposure to environmental contaminants such as heavy metals. Since diet represents the main route of exposure to heavy metals, and fish represent a part of diet, it is likely that contaminated fish could be a dangerous dietary source of certain toxic heavy metals [4]. Metals such as mercury, cadmium and lead have no biological function in the human system and are potentially toxic even at trace concentrations. There is a growing concern that metals accumulated in fish tissues may represent a health risk, especially for high fish consuming population. In recent years, the focus of many researchers has been tailored towards assessment of health risk to human population from heavy metals through fish consumption [5-7].

There is currently no work available on health risk assessment of heavy metal contaminants in fish consumed in Monrovia, Liberia. Therefore, in this study the levels of some toxic metals (Hg, Pb, and Cd) were determined with an aim to elucidate the weekly intake of these metals by the population through the consumption of commonly available fish species. Additionally, potential health risks in terms of hazard quotient and total hazard index for the human population were evaluated. The study provides a useful reference for future health risk assessments in fish species consumed by the population of Monrovia.

2. MATERIALS AND METHODS

A total of 60 samples comprising of twenty nine fish species were purchased from major fish markets in and around Monrovia from June 1, 2013 to August 14, 2013. The species for analysis were based on their availability at the time of sampling. Species obtained were reflective of what was meant for human consumption. All samples were obtained fresh on different occasions from the markets and transported on ice to the laboratory and kept in a freezer. A portion of the edible muscle tissue was removed from the dorsal part of each fish, homogenized and stored in cleaned-capped glass vials and kept in a freezer. The samples were later transported to the chemistry laboratory of KNUST in cooled containers and kept in a freezer until analysis.

Double distilled water and analytical grade reagents (BDH Chemicals Ltd, Poole, England) were used for all the analyses, cleaning and sampling procedures. All glassware and vessels used were thoroughly washed by soaking them overnight in 10 % (v/v) HNO_3 and rinsing in double distilled water. They were then rinsed once with 0.5 % (w/v) $KMnO_4$ and three times with double distilled water and air-dried prior to use.

The edible muscle tissues removed from the dorsal part of the fish were digested by an open tube procedure [8]. In the digestion procedure, 1.0 g of homogenized tissue was weighed into a 50-ml Pyrex glass test tube (26 mm x 47mm) and 2 ml H_2O, 4 ml HNO_3-$HClO_4$ (1:1) and 10 ml H_2SO_4 was added in turns. The mixture was then heated at a temperature of 210°C for about 30 minutes when a colorless solution was obtained. The digest was allowed to cool to room temperature and diluted with distilled water to the 50 ml mark. The solution was then shaken thoroughly and finally transferred into clean capped bottles and kept in a fridge for analysis. Blanks and replicates were obtained for over 13% of the samples.

Concentration of Cd and Pb in the digests were determined using Flame Atomic Absorption Spectrophotometer PG 990 (PG Instruments Ltd., China), while levels of Hg were determined using an automatic Mercury Analyzer HG-5000 (Sanso Seisakusho Co., Ltd, Japan). Before analysis, standard solutions (Merck NJ, USA) were used to calibrate the instrument and calibration curves were prepared. Each sample was analyzed in duplicate. For analytical quality control, reagent blanks and sample replicates were randomly inserted in the analysis process to assess contamination and precision. *Recovery studies were conducted to demonstrate the efficiency of the overall procedure. Recovery of the metals was determined by spiking one sample with increasing amounts of metal standard solution. The spiked samples were then digested (as all other samples) and analyzed for heavy metal contents. Certified reference material (CRM), Fish Homogenate IAEA-407 from International Atomic Energy Agency, Vienna was also included in quintuplicate.*

3. RESULTS AND DISCUSSION

A total of 60 samples comprising 29 fish species were analyzed for mercury (Hg), cadmium (Cd) and lead (Pb). To determine the degree of precision of the analytical procedure, three replicates of one sample were spiked with increasing concentrations of the metals of interest. The spiked sample was then digested and analyzed for the metals. *The recovery rates were in the range 90% - 105%.* Five replicates of certified reference material (*Fish Homogenate IAEA-407*) were processed along with samples to determine the accuracy of the method. Linsinger [9] method was used to compare the measured and certified values. The expanded uncertainty ($2U_{\Delta}$) for each of the tested metals was greater than the difference (Δm) between the certified and measured values; suggesting that there was no significant difference between the mean measured value and certified value for each metal (Table 1).

Table-1. Results (µg g^{-1}) of certified reference material IAEA-407 (Fish Homogenate), showing local laboratory values, recommended values and uncertainties

Metal	Measured value (Mean±SD)	Certified value (Mean±SD)	n	$2U_{\Delta}$	Δm
Hg	0.212 ±0.0092	0.222 ±0.024	5	0.025	0.010
Cd	0.191 ±0.0074	0.189 ±0.019	5	0.020	0.002
Pb	0.15 ±0.01	0.12 ±0.06	5	0.061	0.030

Note: n = number of samples; $2U_{\Delta}$= expanded uncertainty; Δm = difference between the certified and measured value.

Results of the tested metals levels in muscle of fish (µg g^{-1} on wet weight basis) from markets in Monrovia, Liberia are presented in Table 2. As shown in the table, the mean muscle concentrations of Hg, Cd and Pb ranged from 0.014-0.727, 0.002-0.347 and 0.027-0.256 µg g^{-1} wet weight respectively. The maximum concentrations of the tested metals in all samples were below the permissible limit except for Hg level in *Abula Vulpes* which was above the guideline value [10]. The total concentration ranges of metals found in fish from Monrovia were similar to or lower than the levels reported in Literature for fish from Ghana and Nigeria [11-13].

Table-2. Mean concentrations (µg g^{-1} wet weight) of Hg, Cd and Pb in muscle of commercial fish samples from markets in Monrovia, Liberia (2013)

Scientific Name	Local Name(s)	n	Hg (µg g^{-1})	Cd (µg g^{-1})	Pb (µg g^{-1})
Albula vulpes	Morlay	1	0.727*	0.117	0.079
Arius latiscutatus	Catfish	3	0.167	0.064	0.134
Cephalopholis taeniops	Rock fish	2	0.095	0.004	0.039
Chloroscombrus chrysurus	Porjoe	2	0.067	0.131	0.093
Elops lacerta	Shinny lady	2	0.132	0.347	0.178
Elops senegalensis	Tenpound	2	0.120	0.130	0.112
Epinephelus goreensis	Black grouper	1	0.039	0.009	0.045
Euthynnus alletteratus	Blood fish	1	0.434	0.231	0.051
Galeoides decadactylus	Butter Nose	3	0.096	0.070	0.155
Harengula jaguana	Zipper fish	2	0.079	0.132	0.067
Lepomis gibbosus	Pumpkin fish	2	0.171	0.230	0.030
Lutjanus campechanus	Red Snapper	3	0.173	0.006	0.103
Pagrus caeruleostictus	Snapper	3	0.170	0.072	0.070
Pomadasys rogerii	Grunter	3	0.125	0.087	0.120
Priacanthus arenatus	Chicken soup fish	3	0.206	0.113	0.149
Pseudotolithus elongatus	White boy	1	0.122	0.002	0.041
Pseudotolithus senegalensis	Cassava fish	2	0.157	0.008	0.078
Sardinella aurita	Sardine fish	3	0.070	0.061	0.120
Sardinella maderensis	Bonny	3	0.014	0.047	0.027
Scomber colias	Sea Mackerel	1	0.132	0.193	0.081
Scomberomorus tritor	Mackerel fish	2	0.093	0.055	0.032
Selene setapinnis	Big head Porjoe	2	0.035	0.134	0.078
Seriola carpenteri	Judusloyah, Wakie	2	0.225	0.245	0.120
Stromateus fiatola	Marry fish	2	0.055	0.115	0.041
Thunnus obesus	Tuna fish	3	0.226	0.092	0.179
Trachinotus goreensis	Small Corvally	1	0.124	0.186	0.034
Trachinotus maxillosus	Pompano	1	0.043	0.072	0.082
Trichiurus lepturus	Silver fish	2	0.054	0.160	0.256
Tylosurus crocodilus crocodilus	Penten, Gar fish	2	0.171	0.112	0.231
WH0/FAO Guideline			0.50[a]	2.0[b]	2.0[c]

Note: n (sample size) = 60; Local name(s): name(s) of fish species in Monrovia, Liberia [a] FAO/WHO [10] guideline limit for mercury in fish [b,c] FAO/WHO [14] guideline limits of cadmium and lead in fish *Above guideline limit

Health risk was assessed by comparing estimates of weekly intakes with the Provisional Tolerable Weekly Intakes (PTWIs) recommended by the Joint FAO/WHO Expert Committee on Food Additives (JECFA). For mercury and cadmium, the PTWI guidelines of 5.0 and 7.0 µg/kg body wt/wk were respectively used in this study [15]. There is currently no evidence of a threshold of critical lead induced-effects. The last PTWI value of 25 µg/kg/week was withdrawn following data from several epidemiological studies on neurodevelopment in children [16] and systolic blood pressure in adults [17-20]. However this withdrawn value is still being used by some authors for health risk assessments [7, 21]; hence the value was used in the current study.

The potential hazards of metals transferred to humans are probably dependent on the amount of fish consumed by an individual. Data on the amount of fish consumed by an average Liberian adult per day or week is not available; thus data from American food consumption index were employed in the current study. According to surveys, the average American consumes about 228 grams of fish and shellfish per week and this consumption rate was used in the health-risk assessment. The estimated weekly intake was calculated using Eq. 1[22].

$$EWI = (Cs \times CR) / BW \tag{1}$$

Where EWI (μg/ kg/ week) is the estimated weekly intake of the metal; Cs (μg g^{-1} wet weight) is the measured metal concentration in fish muscle tissues; CR is the fish consumption rate (228 g/wk), and BW is the average body weight for an adult (70 kg). These parameter values were obtained from the reference values of USEPA. The health risk of the metals could be divided into two types, i.e., carcinogenic risk and non-carcinogenic risk. Since the toxicity values of carcinogenic risk for the analyzed metals were unavailable, only non-carcinogenic risk was calculated in this study. Hazard quotient (HQ) was calculated by Eq. 2. [22].

$$HQ = EWI / PTWI \tag{2}$$

In this equation, EWI is the estimated weekly intake obtained from Eq. 1; PTWI is the Provisional Tolerable Weekly Intake recommended by JEFCA [15].

Non-carcinogenic HQs for each metal were summed and expressed as hazard index (HI) by Eq. 3 to indicate the overall non-carcinogenic risk [22].

$$HI = HQ_{Hg} + HQ_{Pb} + HQ_{Cd} \tag{3}$$

From the concentration of the metals in each species, the health risk was calculated using Equations 1 and 2. The HQ and HI values of the tested metals from the consumption of the fish species are presented in Table 3. In general, when the hazard value (HQ, HI) of a contaminant is greater than 1, the contaminant might pose potential adverse health effects and needs further analysis. As shown in the table, the HQ values of Hg, Cd and Pb ranged from 0.009-0.474, 0.001-0.161 and 0.004-0.003 respectively. The HI for the tested metals in the fish was computed using Eq.3. The HI due to exposure to the tested metals from fish intakes was in the range 0.035-0.538. With the observed range of HQ and HI being lower than the acceptable safe risk level (HQ, HI≤1), this study has shown that the tested metals pose no health risk to the population of Monrovia.

However, it is worth noting that there were some uncertainties during the risk assessment. Firstly, all the fish samples were collected from June 1, 2013 to August 14, 2013, which is somewhat limited. The number of samples tested for each species was also limited by resources available and availability of fish during the sampling period. In order to better reflect and characterize the status of these metals, periodic determination of metal contents in fish is required. More samples for each species will better reflect the metal levels. Secondly, only three metals were considered in this study; other metals that are toxic to humans may increase the overall potential health risk

Table-3. Hazard values of Hg, Pb and Cd in commercial fish species from markets in Monrovia, Liberia (2013)

Species	Hg HQ	Pb HQ	Cd HQ	HI
Albula vulpes	0.474	0.010	0.054	0.538
Arius latiscutatus	0.109	0.017	0.030	0.156
Cephalopholis taeniops	0.062	0.005	0.002	0.069
Chloroscombrus chrysurus	0.044	0.012	0.061	0.117
Elops lacerta	0.086	0.023	0.161	0.270
Elops senegalensis	0.078	0.015	0.060	0.153
Epinephelus goreensis	0.025	0.006	0.004	0.035
Euthynnus alletteratus	0.283	0.007	0.107	0.397
Galeoides decadactylus	0.063	0.020	0.033	0.116
Harengula jaguana	0.051	0.009	0.061	0.121
Lepomis gibbosus	0.111	0.004	0.107	0.222
Lutjanus campechanus	0.113	0.013	0.003	0.129
Pagrus caeruleostictus	0.111	0.009	0.034	0.154
Pomadasys rogerii	0.081	0.016	0.040	0.137
Priacanthus arenatus	0.134	0.019	0.053	0.206
Pseudotolithus elongatus	0.079	0.005	0.001	0.085
Pseudotolithus senegalensis	0.102	0.010	0.004	0.116
Sardinella aurita	0.046	0.016	0.028	0.090
Sardinella maderensis	0.009	0.004	0.022	0.035
Scomber colias	0.086	0.011	0.090	0.187
Scomberomorus tritor	0.061	0.004	0.026	0.091
Selene setapinnis	0.023	0.010	0.062	0.095
Seriola carpenteri	0.147	0.016	0.114	0.277
Stromateus fiatola	0.036	0.005	0.054	0.095
Thunnus obesus	0.147	0.023	0.043	0.213
Trachinotus goreensis	0.081	0.004	0.087	0.172
Trachinotus maxillosus	0.028	0.011	0.034	0.073
Trichiurus lepturus	0.035	0.033	0.074	0.142
Tylosurus crocodilus crocodilus	0.111	0.030	0.052	0.193

Note: Hazard values based on equations 1,2 & 3 [22].

Health risk analysis models were applied to evaluate the potential health risks of three toxic metals (Hg, Pb, and Cd) in 29 commercial fish species from markets in Monrovia, Liberia. The results showed that the tested metals posed no health risk for local residents. Although there are some limitations in this study, the result could provide useful reference for future health risk assessments.

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