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Heavy metal contents in commercial fishes consumed in Umuahia and their associated human health risks

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Abstract
This study evaluated the heavy metal contents in commercial fishes consumed in Umuahia and their associated health consequences. *Trachurus symmetricus*, *Clupea pallasii*, *Micropogonias undulatus*, *Ictalumus punctatus*, *Scomber japonicus*, *Merluccius paradoxus*, *Pomatomus saltatrix* and *Oreochromis niloticus* were fishes used for the study. The digestion of fish samples, heavy metal analyses and health risk aassessment were carried out using standard methods and models. The heavy analyses of the fishes show that chromium was not detected in all the fishes while lead was found to be significantly (P<0.05) higher than its permissible limit in all the fishes. With exception of *T. symmetricus*, *M. paradoxus*, *C. pallasii* and *S. japonicus* that showed detectable levels of Cd, Cu and Co respectively above their permissible limits. Mn and Ni concentrations detected in the fishes were significantly (P<0.05) lower than their respective permissible limits. The concentration of Fe detected in most of the fishes was significantly (P<0.05) higher than its permissible limit. The daily intake of the heavy metals were below their oral reference daily intake except for *I. punctatus* with daily intake of Fe above its oral reference daily dose. Target hazard quotients (THQ < 1) were observed in all the fishes except *I. punctatus* with THQ > 1 for Fe. The hazardous index in *I. punctatus*, *M. paradoxus* and *P. saltatrix* were greater than 1. The carcinogenic risks due to Pb, Cd and Nickel were within the acceptable range of predicted lifetime risks for carcinogens. The total cancer risks of carcinogenic metals in *C. pallasii*, *I. punctatus* and *M. paradoxus* are above the minimum acceptable range of predicted lifetime cancer risk for carcinogens while every other fishes have total cancer risks within the minimum range. The findings of this study show that commercial fishes consumed in Umuahia contain high heavy metals at varying concentrations across fish species with the concentration of safe been unsafe for consumption. There are increased risks of both carcinogenic and non-carcinogenic health risks associated with consumption of the fishes.

Keywords
heavy metals, cancer risk, target hazard quotient, fishes, health risk

Introduction

Commercially consumed commercial fishes and their products constitute significant portion of human diet due to their richness in proteins, essential fatty acids and minerals. However, many fishes are heavily laden with toxic contaminants like carcinogenic and non-carcinogenic metals that their consumption become a source of health concern due adverse health effects that may associated with their daily consumption. As result of their persistent and toxic effects in the body. Individuals that consume fishes or fish products laden with toxic metals like lead, cadmium, chromium, mercury, arsenic and nickel are highly predisposed to minor or severe adverse health effects including organ failure, oxidative stress, myocardial infarction and death in the ab-

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sence of adequate medical intervention (Rahman *et al.*, 2012). Despite the enormous nutritional contributions of fishes toward maintaining good health, when laden with heavy metals fishes become source of toxicants or poisons and usually avoided to remain healthy while the essential fatty acids, vitamins, proteins and minerals required can be gotten from other sources. Heavy metals are chemically, biologically and thermally stable which make them prone to accumulation to much level that will trigger massive toxic effects even in individuals that ingested substances containing them in low concentrations over a period (Lin *et al.*, 2016). The study was designed to evaluate the concentrations of heavy metals in commercial fishes consumed in Umuahia and their associated human health risks. Various fishes accumulate heavy metals in varying concentrations but the major factor determining the level of heavy metals in fish is the source of heavy metal contamination and the speciation of metals in the medium (Petrovic *et al.*, 2013). It has been shown by various studies that toxicity elicited by both carcinogenic (Pb, Cd, As, Cr and Ni) and non-carcinogenic (Fe, Co, Cu, Zn, and Mn) could overwhelm the body defence systems and greatly impair biochemical and physiological functions in humans that have ingestion unsafe dose of any or all the toxic metals in fish (El-moselhy *et al.*, 2014).

Materials and Methods

Eight fish species were used in this study and they include; Horse Mackerel (*Trachurus symmetricus*), Herring (*Clupea pallasii*), Croaker (*Micropogonias undulatus*), Catfish (*Ictalumus punctatus*), Mackerel (*Scomber japonicus*), Hake (*Merluccius paradox*), Blue whiten (*Pomatomus saltatrix*) and Tilapia (*Oreochromis niloticus*).

Collection of fish samples

Eight varieties of fish samples used in this study were purchased from cold rooms located at Bank road, Isi gate, Ore Ugba and Urbani markets in Umuahia Metropolis. The fish samples are: Horse Mackerel (*Trachurus symmetricus* Ayres, 1855), Herring (*Clupea pallasii* Valenciennes, 1847), Croaker (*Micropogonias undulatus* Linnaeus, 1766), Blue catfish (*Ictalurus punctatus* Rafinesque, 1818)), Mackerel (*Scomber japonicus* Linnaeus, 1758), Hake (*Merluccius paradoxus* Franca, 1960), blue-whiten (*Pomatomus saltatrix* Linnaeus, 1766) and Tilapia (*Oreochromis niloticus* Linnaeus, 1758).

Preparation of the fish samples

Each of the fish samples was washed deionised water, sliced into smaller pieces and oven dried at 65 °C until a constant weight was obtained. The dried sample of each of the fishes was pulverised, weighed and stored under clean sample bottles ready for digestion.

Quality assurance and quality control

Chemicals used for the study were of high analytical grades and sourced MERCK Chemicals Company, Germany and Sigma Aldrich, USA. Deionized water was used for preparation of solution, washing of glassware in addition to 10% HNO_3. From respective stock solutions of each of the metals, standards and used for the calibration of the spectrophotometer for the determination of the respective metals. The analysis of each of the metals was carried out in triplicates to minimize errors and ensure reliability of the results.

Digestion and quantification of heavy metals

Each of the samples was digested using a concentrated acid mixture (HNO_3, and $HClO_4$, in 5:1 ratio). Fish sample (0.5 g) of pulverised sample was digested with HNO_3, and $HClO_4$, in a 5:1 ratio until a transparent solution was obtained as described by Allen *et al.* (1986). It was filtered and diluted to 50 and 25 ml, respectively, with deionised water. The heavy metals in the acid digests of the fish samples were analysed by atomic adsorption spectrophotometer (AAS).

Daily intake of heavy metals

The daily intake of heavy metals (DIM) were determined as described by Rattan *et al.* (2005) using the following equation [1]:

$$DIM = \frac{C_{metal} \text{ x } D_{foodintake}}{B_{average\ weight}} \qquad [1]$$

where C_{metal}, D_{food} and $B_{average}$ weight represent the heavy metal concentrations in fishes (mg kg^{-1}), daily intake of fish and average body weight of consumers of the fishes (350 g/kg/day stipulated by WHO/FAO, 2003) respectively. The average body weight used in this study was 62 kg.

Target hazard quotient (Non-carcinogenic health risk index)

Target hazard quotient (THQ) of heavy metals through consumption of commercial fishes were assessed by the ratio of daily intake of heavy metal to the oral reference dose for each of the heavy metals as described by USEPA (2013).

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$$\mathrm{THQ} = \frac{\mathrm{DIM}}{\mathrm{R_fD_o}} \quad [2]$$

where DIM = daily intake of metals (μg/kg/day) and R_fD_o = oral reference dose (μg/kg/day). Values of RfD for Cd, Cr, Zn, Fe, Pb, Mn, Ni, Cu, and Co used in this calculation were 0.001, 1.5, 0.3, 0.7, 0.004, 0.02 and 0.040 mg/kg/day respectively (Food and Nutrition Board, 2004; USEPA, 2010).

Hazardous index (HI)

Human health risk through more than one heavy metals, the hazard index were calculated by the summation of hazard quotients for all heavy metals as described by USEPA, (1989). Equation [3]:

$$\mathrm{HI} = \mathrm{STHQ} = \mathrm{THQ_{Fe}} + \mathrm{THQ_{Zn}} + \mathrm{THQ_{Cu}} + \mathrm{THQ_{Cd}} + \mathrm{THD_{Mn}} + \mathrm{THQ_{Cr}} + \mathrm{THQ_{Co}} + \mathrm{THQ_{N}i} + \mathrm{THQ_{Pb}} \quad [3]$$

It assumes that the magnitude of the adverse effect is proportional to the sum of multiple heavy metal exposures.

Lifetime cancer risks and cumulative cancer risk

The lifetime cancer risks due carcinogenic metals in the commercial fishes consumed in Umuahia Metropolis was calculated using the method described by Liu *et al.* (2013). Equation [4]:

$$\text{Lifetime carcer risk} = \mathrm{DIM} \times \mathrm{CSF} \quad [4]$$

where DIM = daily intake of metals (mg/kg/day) and CSF = cancer slope factor. The oral cancer slope factors (CSF) for Cd, Cr, Pb, and Ni are 0.38, 0.5, 0.0085, and 1.7 respectively. Any cancer risk in the range of 10^{-6}–10^{-4} is considered acceptable by the USEPA (1989). The cumulative cancer risk due to exposure to multiple carcinogenic heavy metals via consumption of a particular type of commercial was assumed the sum of the individual heavy metal incremental risks and calculated as described by Liu *et al.*, 2013. Equation [4]:

$$\text{Total cancer risks} = \sum_{k=1}^{n} \mathrm{DIM_k CSF_k} \quad [4]$$

where EDI is the estimated daily intake of carcinogenic substance (mg/kg/day) and CSF is the slope factor of substance k (mg/kg/day).

Statistical analysis

The data were analysed statistically using a Statistical Products and Service Solutions (SPSS) version 21. The data were expressed in terms of means ± standard deviation of the triplicates. Statistical significance were computed using One Way Analysis of Variance (ANOVA) with a significance level of $P < 0.05$.

Results

Heavy metal contents in commercial fishes consumed in Umuahia Metropolis

The heavy metal contents detected in the commercial fishes consumed in Umuahia Metropolis show that all the commercial fishes contained high levels of lead significantly ($P < 0.05$) above its permissible limit in fishes as indicated in the Table 1. With exception of *T. symmetricus* that had significantly ($P < 0.05$) lower level of cadmium relative to its permissible limit in fishes, all the other commercial fishes showed no detectable levels of cadmium. The level of chromium was not detectable in all the commercial fishes. Significantly, ($P < 0.05$) low levels of manganese (Mn) was detected in all the commercial fishes except for *I. punctatus* that had significantly ($P < 0.05$) high level of Mn relative to its permissible limit in fishes. Nickel was not detected in *O. niloticus* while all the other commercial fishes had significantly ($P < 0.05$) lower nickel contents relative to its permissible limit in fishes. Copper was not detected in all the commercial fishes except for *M. paradoxus* that contained significantly ($P < 0.05$) low level of it when compared with its permissible limit. Only *C. pallasii* and *S. japonicus* had detectable levels of cobalt but significantly ($P < 0.05$) lower than its permissible limit in fishes. The iron contents detected in all the commercial fishes were significantly ($P < 0.05$) high relative to its permissible limit in fishes with *I. punctatus* having the highest concentration. Also, significantly ($P < 0.05$) lower level of zinc was detected in all the commercial fishes except for *M. paradoxus* that had significantly ($P < 0.05$) high level of zinc when compared with its permissible in fishes.

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Fish types	Pb	Cd	Cr	Mn	Ni (ppm)	Cu	Co	Fe	Zn
Trachunis symmetricus	0.400 ±0.020[b]	0.007 ±0.001[a]	ND	0.046 ±0.003[a]	0.023 ±0.002[b]	ND	ND	3.553 ±0.020[e]	0.318 ±0.011[a]
Clupea pallasii	0.422 ±0.011[bc]	ND	ND	0.031 ±0.002[a]	0.109 ±0.005[d]	ND	0.033 ±0.001[a]	10.244 ±0.044[f]	0.601 ±0.001[a]
Miocroponias undulatus	0.439 ±0.011[c]	ND	ND	0.239 ±0.010[c]	0.070 ±0.002[c]	ND	ND	0.413 ±0.002[a]	3.338 ±0.031[ab]
Ictalurus. punctatus	0.557 ±0.010[f]	ND	ND	0.843 ±0.010[f]	0.179 ±0.002[e]	ND	ND	180.77 ±0.180[g]	0.492 ±0.006[a]
Scomber japonicus	0.476 ±0.019[d]	ND	ND	0.044 ±0.002[a]	0.078 ±0.003[c]	ND	0.005 ±0.001[b]	0.438 ±0.002[a]	0.216 ±0.005[a]
Merluccius paradoxus	0.514 ±0.012[e]	ND	ND	0.089 ±0.001[b]	0.287 ±0.003[f]	0.524 ±0.004[a]	ND	1.696 ±0.021[c]	13.741 ±0.021[c]
Pomatomus saltatrix	0.583 ±0.011[g]	ND	ND	0.031 ±0.002[a]	0.081 ±0.001[c]	ND	ND	2.088 ±0.012[d]	0.356 ±0.011[a]
Oreochromis niloticus	0.582 ±0.020[g]	ND	ND	0.281 ±0.023[d]	ND	ND	ND	0.759 ±0.021[b]	0.580 ±0.022[a]
permissible limit	0.300 ±0.000[a]	0.050 ±0.000[b]	0.150 ±0.000	0.500 ±0.000[e]	0.600 ±0.000[g]	3.000 ±0.000[b]	0.140 ±0.001[c]	0.500 ±0.000[a]	5.000 ±0.000[b]
ND = Not detected									

Table 1. *Heavy metal concentrations in commercial fishes consumed in Umuahia metropolis.*

The data in Table 2 show that intake of heavy metals from daily ingestion of commercial fishes consumed in Umuahia Metropolis which indicate that there is no daily ingestion of chromium from consumption of the commercial fishes. Apart from *T. symmetricus* that account for daily intake of cadmium, and *M. paradoxus* that account for daily intake of copper below their respective oral reference doses, all the other commercial fishes do contribute to daily intake of cadmium and copper. Also, only *C. pallasii* and *S. japonicus* contributed to daily intake of cobalt among the entire commercial fishes though below the oral reference dose. There is high daily intake of lead from consumption of any of the commercial fishes but their individual contribution is within the oral reference dose for lead. The level of Zn, Mn and Ni ingested from the consumption of commercial fishes with the detectable levels of these heavy metals below their respective oral reference dose. It was observed that *I. punctatus* accounted for excess daily ingestion of iron from commercial fishes consumed in Umuahia Metropolis.

Fishes	Pb	Cd	Cr	Zn	Mn (mg/kg/day)	Ni	Cu	Co	Fe
T. symmetricus	2.3E-03	4.0E-05	-	1.8E-03	2.6E-04	1.3E-04	-	-	2.0E-02
C. pallassi	2.4E-03	-	-	3.4E-03	1.8E-04	6.2E-04	-	1.8E-04	5.8E-02
M. undulates	2.5E-03	-	-	1.9E-02	1.4E-03	4.0E-04	-	-	2.3E-03
I. punctalus	3.1E-03	-	-	2.8E-03	4.8E-03	1.0E-03	-	-	1.02
S. japonicas	3.1E-03	-	-	1.2E-03	2.5E-04	4.4E-04	-	2.8E-05	2.5E-03
M. paradoxus	2.9E-03	-	-	7.8E-02	5.0E-04	1.6E-03	3.0E-04	-	9.6E-03
P. saltatrix	3.3E-03	-	-	2.0E-02	1.8E-04	4.6E-04	-	-	1.2E-02
O. niloticus	3.3E-03	-	-	3.3E-03	1.6E-03	-	-	-	4.3E-03
R_fD_O	4.0E-03	1.0E-03	1.5E-01	3.0E-01	1.4E-02	2.0E-02	4.0E-02	4.3E-02	7.0E-01

Table 2. *Daily intake of heavy metals from consumption of commercial fishes.*

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Target hazard quotients (THQ) of heavy metals in commercial fishes consumed in Umuahia Metropolis. The target hazard quotients (THQ) of heavy metals in commercial fishes consumed in Umuahia Metropolis (Table 3) show that among all the commercial fishes and detected heavy metals, only iron in *I. punctatus* has target hazard quotient greater than 1 (THQ > 1).

Fishes	Pb	Cd	Cr	Mn	Ni	Cu	Co	Fe	Zn
T. symmetricus	0.575	0.040	-	0.019	0.007	-	-	0.029	0.006
C. pallasii	0.600	-	-	0.013	0.031	-	0.004	0.083	0.011
M. undulatus	0.625	-	-	0.100	0.020	-	-	0.003	0.063
I. punctatus	0.775	-	-	0.343	0.050	-	-	1.457	0.009
S. japonicus	0.775	-	-	0.018	0.022	-	0.001	0.004	0.004
M. paradoxus	0.725	-	-	0.036	0.050	0.072		0.014	0.260
P. saltatrix	0.825	-	-	0.013	0.230	-	-	0.017	0.007
O. niloticus	0.825	-	-	0.114	-	-	-	0.006	0.011

THQ < 1 indicates no adverse health effects, while THQ > 1 or = 1 indicates that adverse health effects are likely to occur.

- = no health risk

Table 3. *Target hazard quotients (THQ) in commercial fishes.*

The target has quotients for lead in each of the commercial fishes was lower than 1 but on approximation equal to 1 with that of *P. saltatrix* and *O. niloticus* been closest to 1. All the commercial fishes with detectable levels Cd, Mn, Ni, Cu, Co and Zn has target hazard quotients for each of these metals below 1.

Total hazard index (HI) of heavy metals in commercial fishes consumed in Umuahia Metropolis. The total hazard index (HI) of heavy metals in commercial fishes consumed in Umuahia Metroplois indicate that only *I. punctatus, M. paradoxus* and *P. saltatrix* have total hazard index greater than 1 (HI > 1). The total hzard index obtained for the other commercial fishes were lower than 1 but on approximation equal to 1 especially for O. niloticus with hazardous index of 0.9563. Thus, *T. symmetricus* has the least total hazard index while *I. punctatus* has the highest total hazard index among all the commercial fishes tested (Table 4).

Fishes	Hazardous Index (HI)
T. symmetricus	0.6747
C. pallasii	0.7423
M. undulatus	0.8116
I. punctatus	1.6342
S. japonicus	0.8237
M. paradoxus	1.1558
P. saltatrix	1.0917
O. niloticus	0.9563

HI *values* > 1 *indicates that there is increased chance that non-carcinogenic risk may occur, and when* HI < 1 *the reverse applies.*

Table 4. *Total Hazard index in commercial fishes.*

The cancer risk index of carcinogenic heavy metals in commercial fishes consumed in Umuahia Metropolis (Table 5) show that all the commercial fishes have cancer risks for lead (Pb) within the minimum acceptable range of predicted lifetime risks for carcinogens (10^{-6} – 10^{-4}).

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Fishes	Pb	Cd	Ni
T. symmetricus	2.0 E-05	2.0 E-05	2.0 E-04
C. pallasii	2.0 E-05	-	1.1 E-04
M. undulatus	2.0 E-05	-	7.0E-04
I. punctatus	3.0 E-05	-	1.7 E-03
S. japonicus	3.0 E-05	-	8.0 E-04
M. paradoxus	3.0 E-05	-	2.7 E-03
P. saltatrix	3.0 E-05	-	7.0 E-04
O. niloticus	3.0 E-05	-	-

Cancer risk index 10^{-6} (1 in 1,000,000) to 10^{-4} (1 in 10,000) represent a minimum acceptable range of predicted lifetime risks for carcinogens.
- = No health risk

Table 5. *Cancer risk of heavy metals in commercial fishes consumed in Umuahia Metropolis.*

It shows that 2-3 persons out of 100, 000 persons that consume the commercial fishes have increased lifetime cancer risk due to toxic effects of lead ingest from their consumption. Most consumers of commercial fishes consumed in Umuahia do not have cancer risk due cadmium toxicity except those that consume *T. symmetricus* which has cadmium cancer risk within the minimum acceptable range of predicted lifetime risks for carcinogens. The nickel cancer risk in the commercial fishes show that *I. punctatus* and *M. paradoxus* have cancer risks due nickel above the minimum acceptable range of predicted lifetime risks for carcinogens as 2-3 persons out of 1,000 of their consumers have increased lifetime cancer risk. It was observed that *O. niloticus* has no cancer risk due to nickel toxicity while *T. symmetricus, C. pallasii, M. undulatus, S. japonicus* and *P. saltatrix* have cancer risks due to nickel within the minimum acceptable range of predicted lifetime risks for carcinogens.

The total cancer risks observed for carcinogenic heavy metals detected in commercial fishes consumed in Umuahia metropolis in the Table 6 show that each of the commercial fishes has total cancer risks within the minimum acceptable range of predicted lifetime risks for carcinogens (10^{-6} - 10^{-4}). The *M. paradoxus* has the highest total cancer risk of 2.7E-03 indicating that 3 out 1,000 persons that consumed it have increased lifetime chance of developing cancer due to cumulative effects carcinogenic metals ingested from its consumption. It was also, observed that *O. niloticus* has the least total cancer risk among all the commercial fished investigated. The trend observed in the total cancer risk indicate that the total cancer risk for *M. paradoxus* > *I. punctatus* > *C. pallasii* > *P. saltatrix* > *M. undulatus* > *T. symmetricus* > *O. niloticus* respectively.

Commercial fishes	Total cancer risk
T. symmetricus	2.4E-04
C. pallasii	1.1E-03
M. undulatus	7.2E-04
I. punctatus	1.7E-03
S. japonicus	8.3E-04
M. paradoxus	2.7E-03
P. saltatrix	7.3E-04
O. niloticus	3.0E-05

Table 6. *Total cancer risk index of carcinogenic heavy metals in commercial fishes consumed in Umuahia Metropolis.*

Total cancer risk index 10^{-6} (1 in 1,000,000) to 10^{-4} (1 in 10,000) represent a minimum acceptable range of predicted lifetime risks for carcinogens.

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Discussion

This study evaluated heavy metal contents in commercial fishes consumed in Umuahia Metropolis and their impact on human health. This was to understand the level of various heavy metals in commercial fishes, and to enable us inform the public of their health consequences and offer them the opportunity to make informed decisions. The high level of lead detected in the commercial fishes show that there is high possibility of adverse health effects occurring in the individuals that consume these fishes regularly. Lead is a toxic heavy metal that has no beneficial metabolic functions in the body and could elicit acute or chronic toxicity based on the ingested doses. The significantly ($P < 0.05$) high level of lead observed in the commercial fishes when compared with the permissible limit of lead in fishes could be attributed to their sources, preservatives and contaminations from the environment where they are stored. Lead toxicity can negatively impair sexual hormones, depletion of antioxidant enzymes, mineral deficiency and in extremely toxicity result to death. In view of its adverse effects including delayed puberty in women, the amount of lead in staple food products fishes should be monitored regularly to ensure that fish consumers are free from increased risk of lead toxicity.

The high daily intake of iron from *T. symmetricus* could be attributed to the high level of iron detected in the commercial fishes. Ingestion of excess amount of iron from daily ingestion *I. punctatus* could impair biochemical and metabolic functions. This call for further investigation of the sources of commercial *I. punctatus* consumed in Umuahia, preservatives applied and hygienic status of their storage and possibly understands ways of reducing its concentration in fishes in order to safeguard the health of consumers. The daily intake of lead (Pb) from consumption of the commercial fishes contribute significant amount of lead to the body and if not monitored could elicit lead toxicity. Individuals that consume these commercial fishes gradually enrich their systems with lead which may inevitably result to chronic toxicity, as its daily intake is closer to the oral reference dose aside contribution from other sources. The absence of daily intake of chromium from the consumption of any of the commercial fishes could be attributed to the non-detectable level of chromium in the commercial fishes. This indicate that individuals that consumers of these commercial fishes were not exposed to any toxic effects associated with lead toxicity. Similarly, the low daily intake of cadmium from *T. symmetricus*, copper from *M. paradoxus* and cobalt from *C. pallasii* an *S. japonicas* and their absence from consumption of all other commercial fishes indicate that low or no adverse health maybe associated with their consumption. The low daily intake of zinc, manganese and iron from the commercial fishes are not sufficient to elicit toxic effects. However, daily intake of lead, zinc, manganese, nickel and iron respectively from other food sources when combined with the daily intake of these metals from these commercial fishes could lead to their excess ingestion and cause enormous adverse health effects.

Target hazard quotients are used to estimate the non-carcinogenic health risk associated with ingestion of excess amount of toxic substances like heavy metals by comparing the daily intake of the substance with its oral reference dose. Generally, target hazard quotients less than 1 is considered safe while target hazard quotient equal to 1 or greater 1 suggest that its consumers are predisposed to non-carcinogenic health effects. In this study, only the target hazard quotient of iron among all the heavy metals was greater than 1 and suggested that it is unsafe for human consumption due to toxic effects of excess amount of iron that can be ingested through it. The no or low daily intake of cadmium, chromium, manganese, nickel, copper and zinc in the commercial fishes show that there is no likelihood of consumers of these fishes experiencing non-carcinogenic adverse health effects and except when their contributions from other sources cause their excess ingestion. The target hazard quotients of lead in all the commercial fishes were below 1 and indicate no adverse health effects of lead toxicity on the consumers of these fishes. However, because the values of target hazard quotient of lead in the each of the commercial fishes can be approximately equal to 1, lead concentration should be monitored regularly in all the fishes to prevent consumers from ingesting excess amount of lead metal. The amount of daily ingestions of these fishes should be reduced to avoid excess lead ingestion since there is possibility of taken some amount of lead from other food sources and environment. Lead as a heavy metals is a chemical carcinogen without any vital function in living organisms aside toxicological effects such as cardiotoxicity, haematotoxicity, organ failures, impaired sexual development and neurological functions that results from its excess ingestion (FAO/WHO., 2011). The high level of lead in all the commercial fishes in this study may be attributed to efficient absoption and accumulation of lead in fish liver when excess amount of lead in the body overwhelm the ability of liver to detoxify it (Uzairu *et al.*, 2009; Storelli *et al.*, 2012).

Hazard index (HI) is the cumulative non-carcinogenic

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effects associated with various toxic substances like heavy metals ingested an individual over certain period. It is considered that hazard index greater than 1 (HI > 1) indicate significant adverse non-carcinogenic health effects are likely to be experienced by the consumers of the products with the hazard index. Such adverse health effects are greater than that caused by any of the individual toxic substance or contaminant contributing to the observed additive effects. Thus, the high HI > 1 observed in I. punctalus, *M. paradoxus* and *P. saltatrix* indicate high non-carcinogenic risk effects on the consumers of these commercial fishes. This requires urgent intervention to reduce the levels of heavy metals contained in the commercial fishes to minimize the adverse health effects associated with their consumption. The low hazardous index observed in *T. symmetricus*, *C. pallasii*, *M. undulates, S. japonicus* and *O. niloticus* below (HI < 1) can be attributed to their low heavy metal contents and daily intake. It show that their consumers are not likely to suffer much non-carcinogenic health effects due to toxic effects of heavy metals contained in them. However, their heavy metal contents should be monitored to ensure that their hazardous index remain below 1 especially for *O. niloticus* with hazardous index very close to 1.

The cancer risk index of carcinogenic heavy metals in commercial fishes consumed in Umuahia Metropolis showed that lead and nickel constitute major cancer risk in the commercial fishes and contributed significantly to the observed total cancer risks observed in this study. The absence of cancer risks due cadmium in *C. pallasii*, *M. undulates*, *I. punctatus*, *S. japonicus*, *M. paradoxus*, *P. saltatrix* and *O. niloticus* showed that their consumers are not exposed to any increased cancer risk resulting from cadmium toxicity. However, the low cancer risk due cadmium toxicity in *T. symmetricus* indicated that 5 out 100, 000 that consumed the fish are likely to have increased cancer risk in lifetime. The high cancer risk due to nickel toxicity observed in *I. punctalus* and *M. paradoxus* are attributed to high nickel content in these commercial fishes and require intervention to reduce the level of nickel in these fishes. All the commercial fishes have lead cancer risk index within the acceptable range of predicted lifetime risk for carcinogenic substances which can be ascribed to the high level of lead in the commercial fishes. Thus, good efforts should be made significantly reduce the lead and nickel contents in the commercial fishes from their respective point of production, transportation and storage to enhance the safety of their consumers.

The total cancer risk index of carcinogenic heavy metals in commercial fishes consumed in Umuahia Metropolis indicate that the additive carcinogenic effects of all the carcinogenic metals in the commercial fishes were contributed largely by lead and nickel. The total cancer risk in *C. pallasii*, *I. punctatus* and *M. paradoxus* show that individuals that consume these commercial fishes are likely to experience increased lifetime cancer risk as their risk value exceeded the minimum acceptable predicted range of lifetime risk for carcinogens. Also, T. *symmetricus*, *M. undulatus*, *S. japonicus*, and *P. saltatrix* with total cancer risks which indicate that 1-8 out of 10,000 persons and 3 out of 100, 000 persons that consume O. niloticus have increased likelihood of lifetime cancer risk due to toxic effects on heavy metals in these commercial fishes. Reduction of heavy metal contents in the commercial fishes are key to minimize the level of cancer and total cancer risk in the fishes associated with their consumption. As result of this, all the imported commercial fishes should be subjected to thorough screening for carcinogenic metals and toxicants to protect the lives of fish consumers.

Conclusions

The findings of this study show that commercial fishes consumed in Umuahia Metropolis contain varied concentrations of heavy metals with lead been higher than the allowed permissible limit in fishes. There were no detectable levels of cadmium, chromium, copper and cobalt in most of the commercial. Furthermore, *I. punctatus*, *M. paradoxus* and *P. saltatrix* have increased non-carcinogenic risk for their consumers. Also, consumers of these commercial fishes have increased lifetime cancer risks due to their carcinogenic heavy metal contents contributed mainly by lead, cadmium and nickel.

Conflict of Interest

Authors declare no conflict of interests.

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