Trace Metals and Organochlorine Pesticide Residues in Imported Fishes in Bangladesh and Human Health Risk Implications

Md. Monirul Islam

University of Dhaka: Dhaka University

Nusrat Jahan Avha

Dhaka University

Shamim Ahmed

BCSIR: Bangladesh Council of Scientific and Industrial Research

Md. Ahedul Akbor

BCSIR: Bangladesh Council of Scientific and Industrial Research

Md. Sofiqul Islam

Department of Fisheries, Government of the People's Republic of Bangladesh

Farhana Mostafiz

Dhaka University

Md. Habibullah-Al-Mamun (✉ almamunhabib@du.ac.bd)

University of Dhaka <https://orcid.org/0000-0001-9568-5361>

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Abstract

Substantial quantity of fish has been imported to Bangladesh without adequate food safety assessment which can pose a serious health risk to local people. This study analyzed the trace metals and organochlorine pesticides residues and the associated human health risk in 33 imported fishes (9 species) from four countries (India, Myanmar, Oman and United Arab Emirates) collected from three different ports (Benapole, Bhomra, and Chittagong) of Bangladesh with invoice lists from the port authorities. Trace metal concentrations were determined using graphite furnace absorption spectrometry and flame absorption spectrometry. The two organochlorine pesticides (Aldrin and Chlordane) residues were determined by GC-MS and found as below detection level (BDL). The trace metal concentrations (mg/kg-ww) in imported fish samples ranged as: As: 0.008 to 0.558; Pb: 0.004 to 0.070; Cr: 0.010 to 0.109; Cd: 0.00 to 0.083; Ni: 0.011 to 0.059; Co: BDL to 0.067; Mn: BDL to 0.0780; Fe: 1.780 to 10.77; Cu: 0.055 to 0.632; and Zn: 0.898 to 9.245. Concentrations of As and Cd were higher than the food safety guideline. Considering the source country of imported fishes, fish samples from Oman were mostly contaminated by the trace metals. The estimated daily intake (EDI) was higher for As and Cr. However, the target hazard quotient (THQ) for individual metal and total THQ for combined metals were lower than 1, indicating no apparent non-carcinogenic health risk for consumers. But target cancer risk (TR) was higher for As, and Ni and the values exceeded the acceptable range indicating a high carcinogenic risk for the local people. Therefore, extensive monitoring of these toxic chemicals is needed prior to import these fishes to the country. Given the self-sufficiency in fish production this study also argues whether Bangladesh needs to import the fishes at all.

1. Introduction

Bangladesh is one of the dominant fish producing countries in the world as being bestowed with immense inland, coastal and marine water resources generating great potential in fisheries sector. According to the FAO, Bangladesh has ranked 3rd in inland open water capture production and 5th in world aquaculture production and also the fish production has increased more than five times over the last three decades (FAO, 2018). But a large amount of fish and fishery products are being imported every year to Bangladesh from India, Myanmar, Oman, Pakistan, United Arab Emirates and Yemen, whereas the country is self-sufficient in fish production according to the Department of Fisheries, Government of Bangladesh with per capita consumption per day which is about 62.58 grams against the demand of 60 grams (DoF, 2018).

In line with 2016-17 fiscal year, about 1 lakh tons of fish were imported (DoF, 2018) and from the first five months of 2016–2017 fiscal year, about 16,032 tonnes of imported fish costed about Tk 66.36 crore which is an issue of concern. Additionally, the port authority asserted that the average annual 48,000 tonnes of fishes were imported from the last four years (The Daily star, 21 January 2018, Page 11). The imported fishes were mostly Major carps, Cat fishes, Sardines, and Shads. Among these fishes, Sardines and Shads bear resemblance like Hilsa fish but the taste is not the equivalently upright. It was not evident also that from where these packages came from, but as per port sources around 90 percent of Bangladesh's fish consignment were from Myanmar, the Maldives, India and Oman and nearly half were from Oman.

BBC Bangla reported a large amount of imported fishes as was found to be in the local market of Bangladesh, e.g. Mohammadpur Bazar, Banani Bazar, etc. These frozen imported fishes were hardly identified by the buyer in the local fish market. Therefore, these foreign fish are sold referring as local fish of the country. The Bangladesh Food Safety Authority (BFSA) has articulated doubt about the quality of these imported fishes and the fact that if these fishes have been examined thoroughly as for harmful chemicals which are a major threat to public health. A report has been published on the Daily Star that the BFSA mandated to test and it found high detrimental level of heavy metals in the Chandana ilish fish which was imported (The Daily star, 21 January 2018, Page 4). However, neither BBC nor the BFSA were able to mention the exact sources of these fish when they were contacted by the authors.

Fish are regarded as one of the most susceptible aquatic organisms to noxious chemical substances in water such as trace metals, pesticides which accumulates in them and later are magnified up in the food chain (Thiyagarajan et al., 2012). These chemical hazards are persistent and in excess amount may lead to bioaccumulation ultimately posing serious human health consequences including possible carcinogenic risks (Chen et al. 2009; Medeiros et al. 2012; Ahmed et al., 2015; Saha et al., 2016).

To import these inessential fishes a significant amount of money has been paid by the country every year superfluously. Additionally, these fishes are substandard in terms of taste and quality as compared to local fishes. Local people do not even consume some imported species, for instance, Tonguesole fish and Pony fish. Moreover, they might contain elevated level pollutants or toxic chemicals. As far no studies has been published regarding the existing level of chemical toxicants in the fishes imported to Bangladesh. So, it's a prerequisite to investigate the level of trace metals and pesticides in those imported fishes to aware the concerned authority and the general people. The main aim of this study was to determine the concentration of 10 trace metals: arsenic (As), lead (Pb), chromium (Cr), cadmium (Cd), nickel (Ni), cobalt (Co), manganese (Mn), iron (Fe), copper (Cu), and zinc (Zn) and two organochlorine pesticides (Aldrin and Chlordane) in the imported fishes in Bangladesh and to assess the associated health risk to consumers.

2. Materials And Methods

2.1 Study area and sample collection

Thirty-three imported fish specimens of nine species were collected after acquiring the permission of port authority from Benapole land port (23°2'31"N 88°53'44"E); Bhomra land port (22.35°N 89.08°E); Chittagong port (22.313°N 91.800°E) (Fig. 1). As Chittagong port is the biggest and most of the products as well as fishes are imported from different countries through this port, this site was considered. Fish samples analyzed in this study were: *Labeo rohita* (Rui), *Otolithes ruber* (Tigertooth croaker), *Scomber australasicus* (Blue mackerel), *Etrumeus acuminatus* (Red-eye round herring), *Arius maculatus* (Spotted sea catfish), *Tenualosa toli* (Toli shad), *Lutjanus johnii* (Snapper), *Eubleekeria splendens* (Ponyfish), *Cynoglossus cynoglossus* (Tonguesole). After collecting the samples, the sampling ice box was used to keep the samples with an adequate amount of ices and transferred to INARS Laboratory, BCSIR, Bangladesh. Then the samples were washed with distilled water to avoid any possible contamination and kept in the drawer of a refrigerator wrapped with aluminum foil paper at a temperature of below – 20° C.

2.2 Trace Metal Analysis

In this study, fish muscle was mainly used for determining trace metals and pesticides. Homogenized sample was used for dry ashing at low temperature first to dry the sample to prevent the sample loss and then slowly the temperature was increased as $\leq 500^{\circ}\text{C}$. A high temperature muffle furnace was used which was capable of maintaining temperatures of between 500 and 600° C following the method of AOAC official method 999.11. In this study, the procedures of nitric acid digestion were applied. Concentrated nitric acid (5 ml) was poured into cooled sample and was transferred to hotplate to heat at 100-180° C. After digestion, sample was poured into the 50ml volumetric flask and distilled water was added up 50ml line very carefully. After 2–3 min the sample was filtered with Whatman® 90 milli-pore size filter paper and stored for the instrumental analysis. A flame atomic absorption spectrometer (Varian AA-240FS) and a graphite atomic absorption spectrometer (Varian AA-240Z) were used for the analysis of 10 metal concentration (As, Pb, Cr, Cd, Ni, Co, Mn, Fe, Cu, and Zn). Metal concentration were determined from the calibration curved obtained from standard solution.

2.3 Pesticides Residues Analysis

For pesticide residue analysis, n-Hexane residue analysis grade (95% n-hexane) and acetone residue analysis grade were used for extraction. Anhydrous sodium sulphate used as analytical reagent grade. 20g of previously minced fish muscle

was taken to a 250 ml conical flask and 50 ml n- hexane and 50 ml acetone were added to sample. After adding those the conical flask was placed to orbital shaker and shaken the sample at 300 rpm for 2 hrs. Next the sample was filtered by Whatman® filter paper of 42 milli-pore to a round flask. Then the sample was concentrated to 1ml by a rotary evaporator to follow the SPE procedures (Chen et al. 2009). After that the concentrated sample was washed with n- hexane where the proportion of sample and hexane was 1:2. Finally the sample was poured to 15 ml centrifuge tube. In this study, sample was analyzed by Gas chromatography (Shimadzu QP 2020 series), auto injector (Shimadzu AOC 20i) and sampler were used. Mass spectrometry detector was used and helium was used as carrier gas.

2.4 Clean up

10% H₂SO₄ was prepared in a volumetric flask and approximately 1g anhydrous sodium sulphate was mixed within it properly. Then about 1 ml solution was taken from volumetric flask by pipetting and poured it to the centrifuge tube containing sample. After that the cap of centrifuge tube was put well and vortexed it on a vortex mixer at 2500 rpm about 1–2 min. Then waited for few minutes. Then the supernatant was separated with syringe and taken into GC vial.

2.5 Quality assurance and accuracy check

Standard stock solution of 1000 mg/L of As, Pb, Cr, Cd, Ni, Co, Mn, Fe, Cu, and Zn was prepared by diluting 1 mL of each single element of stock in the combination list to 100 mL with deionized distilled water. For each batch of sample in digestion process, blank solution was prepared in the identical procedure with acid (nitric acid) to ensure about that samples and chemicals used were not contaminated. Standard solution of pesticide was prepared by dissolving 10 mg of each compound in 10 mL hexane and stored in amber bottles. A mixed standard solution was prepared from the individual stock solutions with a concentration of 100 mg/L. A series of calibration standards were prepared by diluting 100 mg/L of the mixed standard solution to produce a final concentration of 0.005, 0.05, 0.02, 0.01, 0.1, 0.2, 0.5 mg/L in hexane. Stock and working solutions were stored at 4⁰ C and used for no longer than 3 months and 1 week, respectively.

For each batch of sample in digestion process, blank solution was prepared in the identical procedure with acid (nitric acid) to ensure about that samples and chemicals used were not contaminated.

2.6 Health Risk Calculation

2.6.1 Estimated Daily Intake (EDI)

The estimated daily intake (EDI) of trace metals in fish was calculated by using metal concentration in fish muscles (wet weight basis), daily fish consumption and body weight. Following equation was used for calculation Estimated daily intake,

$$EDI = \frac{FIR \times C}{WAB}$$

Where,

C is the concentration of the heavy metals in fish (mg kg⁻¹); FIR is the daily average consumption of fish (62.58 g/person/day; DoF, 2018) and WAB represents the average body weight (60 Kg).

2.6.2 Target hazard quotient (THQ)

The target hazard quotient (THQ) is an estimate of the dangerous level of non-carcinogenic due to pollutant exposure. According to the USEPA (1989), it is assumed that the ingestion dose is similar the adsorbed contaminant dose and that cooking doesn't alter the contaminants. In this study, the non-carcinogenic health risks related to the consumption of fish by the native inhabitants were assessed based on the target hazard quotients (THQs) and calculations were made using the standard assumption for an integrate USEPA risk analysis.

$$THQ = \frac{EFr \times ED \times FIR \times C}{RfD \times WAB \times AT} \times 10^{-3}$$

Where, THQ is the target hazard quotient, EFr is the exposure frequency (365 days/year), ED is the exposure duration (70 years), FIR is the fish ingestion rate (62.58 g/person/day), C is the heavy metal concentration in fish muscle (mg/kg), WAB is the average body weight (60 Kg), AT is the average exposure time for non-carcinogens (EF×ED) (365 days/year for 70 years here AT = 25550 days). RfD is the reference dose of the metal (an estimate of the daily exposure to which the human population may be continuously exposed over a lifetime without an appreciable risk of deleterious effects). RfDs used for THQ calculation were: 0.0003, 0.0035, 0.003, 0.02, 0.001, 0.7, 0.04, 0.3, 0.14 for As, Pb, Cr, Ni, Cd, Fe, Cu, Zn and Mn, respectively (WHO, 2011; USEPA, 2000; 2019).

In this study, total THQ (TTHQ) was also evaluated considering the fact that humans are often exposed to more than one pollutant which can lead to combined or synergistic effects (Marengo et al., 2018). The greater the value of TTHQ, the greater the level of concern.

2.6.3 Target cancer risk (TR)

According to USEPA (1989), for carcinogens, risks were calculated as progressive chance of an individual to develop cancer over a lifetime exposure to that potential carcinogen. The formula which was used to calculate Target carcinogenic risk

$$TR = \frac{EFr \times ED \times Cons \times C \times CSF_0}{Bw \times AT} \times 10^{-3}$$

Here, CSF₀ is the oral carcinogenic factor from the Integrated Risk Information System (USEPA, 2010) database was 1.5, 8.5 × 10⁻³ and 1.7 (mg/kg/day) for As, Pb and Ni, respectively.

3. Result And Discussion

In this study, two organochlorine pesticides (Aldrin and Chlordane) were assessed in different fish samples imported to Bangladesh from overseas. Concentrations of the two pesticides were below the limit of detection and therefore, subsequent result and discussion will concentrate on the concentration of trace metals in fishes and associated health risk.

3.1 Concentration of trace metals in fish muscles

In the present study, concentration of As, Pb, Cr, Cd, Ni, Co, Mn, Fe, Cu, and Zn (mg/kg-ww) were assessed in the samples of imported fishes from four countries (India, Myanmar, Oman and United Arab Emirates). Table 1 provides a summary of the mean concentrations of the trace metals in the analyzed fish samples. All metal concentrations were determined on a wet-weight basis.

Table 1
Mean concentrations (mg/kg ww) of trace metals in muscle tissues of some fishes imported to Bangladesh from different countries.

Sources	Sample name	As	Pb	Cr	Cd	Ni	Co	Mn	Fe	Cu	Zn
India	<i>L. rohita</i>	0.008	0.004	0.053	0.001	0.043	0.037	0.149	2.275	0.084	1.927
	<i>O. ruber</i>	0.05	0.070	0.083	0.005	0.016	BDL ^a	BDL	1.895	0.055	0.898
UAE	<i>S. australasicus</i>	0.124	0.065	0.069	0.074	0.034	BDL	BDL	10.77	0.112	9.245
	<i>E. acuminatus</i>	0.148	0.008	0.053	0.083	0.03	BDL	0.291	7.141	0.632	4.594
	<i>A. maculatus</i>	0.137	0.004	0.013	0.003	0.011	BDL	BDL	2.669	0.182	3.641
	<i>T. toli</i>	0.558	0.006	0.109	0.056	0.059	BDL	0.718	9.286	0.495	6.188
	<i>L. johnii</i>	0.022	0.004	0.01	0.001	0.023	BDL	BDL	2.38	0.199	3.154
Oman	<i>T. toli</i>	0.113	0.010	0.071	0.015	0.024	BDL	0.504	7.384	0.536	7.004
Myanmar	<i>L. rohita</i>	0.013	0.009	0.049	0.001	0.011	BDL	0.126	2.795	0.218	2.552
	<i>E. splendens</i>	0.034	0.013	0.017	0.007	0.044	BDL	0.456	1.78	0.106	2.007
	<i>C. cynoglossus</i>	0.027	0.070	0.038	0.008	0.036	BDL	0.78	4.576	0.09	2.975
^a Below Detection Limit											

Trace metal concentration varied in different fish species from 0.001–0.650 mg kg⁻¹ for As, 0.002–0.073 mg kg⁻¹ for Pb, 0.01–0.168 mg kg⁻¹ for Cr, 0.001–0.108 mg kg⁻¹ for Cd, 0.007–0.08 mg kg⁻¹ for Ni, ND- 0.080 mg kg⁻¹ for Co, ND- 0.0780 mg kg⁻¹ for Mn, 0.954–13.60 mg kg⁻¹ for Fe, 0.034–0.646 mg kg⁻¹ for Cu, and 0.812–17.248 mg kg⁻¹ for Zn, average of which leads to the following ranking: Fe (4.81) > Zn (4.02) > Mn (0.43) > Cu (0.25) > As (0.11) > Cr (0.05) > Co (0.04) > Ni (0.03) > Pb (0.024) > Cd (0.023).

3.1.1 Arsenic (As)

Arsenic concentration in the muscles of fish samples were 0.01 ± 0.007 mg kg⁻¹ in *L. rohita* (India); 0.05 ± 0.01 mg kg⁻¹ in *O. ruber* (India); 0.12 ± 0.02 mg kg⁻¹ in *S. australasicus* (UAE); 0.15 ± 0.001 mg kg⁻¹ in *E. acuminatus* (UAE); 0.14 ± 0.002 mg kg⁻¹ in *A. maculatus* (UAE); 0.56 ± 0.09 mg kg⁻¹ in *T. toli* (UAE); 0.02 ± 0.001 mg kg⁻¹ in *L. johnii* (UAE); 0.11 ± 0.001 mg kg⁻¹ in *T. toli* (Oman); 0.01 ± 0.001 mg kg⁻¹ in *L. rohita* (Myanmar); 0.03 ± 0.002 mg kg⁻¹ in *E. splendens* (Myanmar); 0.03 ± 0.001 mg kg⁻¹ in *C. cynoglossus* (Myanmar). This results shows that among all the fishes investigated, *T. toli* from UAE contained the highest amount of arsenic and *L. rohita* from India have been found to carry the minimum amount followed by *L. rohita* from Myanmar (Table 1). Considering the average As concentration, fish from UAE were more contaminated than fish imported from Oman, India and Myanmar (Fig. 2).

In literature, similar As accumulation level has been reported in fish from Bangladesh such as: 0.04–0.8 mg kg⁻¹ (Islam et al., 2015), 0.077–1.486 mg kg⁻¹ in highly consumed cultured fish (Ahmed et al., 2015), 0.139 ± 0.00 in *L. rohita* and 0.141 ± 0.01 in *T. ilisha* (Saha & Zaman, 2013). Previous studies also reported higher arsenic content comparing to present study in fish from Bangladesh (Raknuzzaman et al., 2016; Ahmed et al., 2019; Rahman et al., 2012). Fish from

India has been found to contain arsenic as $0.35 \pm 0.08 \text{ mg kg}^{-1}$ in *L. rohita* from tropical wetlands (Kumar & Mukherjee, 2011); $2.9 \pm 0.6 \text{ mg kg}^{-1}$ in hilsa shad from Ganga river of India (Mohanty et al., 2017). Arsenic concentration has been recorded in higher magnitude comparing to present study in previous studies for fish from Oman (Sadeghi et al., 2019), Arabian Gulf (Kamal et al., 2015), Persian Gulf (Cunningham et al., 2019), Pakistan (Shah et al., 2009).

Arsenic is a toxic component for all living beings including human; chronic contact with which has long been found to cause lung cancer, skin carcinoma, kidney and bladder cancer, neuropathy in both the peripheral and central nervous systems (Liu et al., 2011; Medeiros et al., 2012; Kapp, 2018). The International Agency for Research on Cancer (IARC) has also classified inorganic arsenic as class 1 human carcinogen. (IARC, 2012). The maximum arsenic level permitted for fish samples is 0.10 mg kg^{-1} (FAO, 2006). The present observation showed that level of As in all fish samples from UAE (except *L. johnii*) and from Oman was higher than this proposed acceptable limit.

3.1.2 Lead (Pb)

Present study found the amount of Pb in different imported fish samples as $0.004 \pm 0.002 \text{ mg kg}^{-1}$ in *L. rohita* (India), $0.07 \pm 0.003 \text{ mg kg}^{-1}$ in *O. ruber* (India), $0.07 \pm 0.01 \text{ mg kg}^{-1}$ in *S. australasicus* (UAE), $0.01 \pm 0.001 \text{ mg kg}^{-1}$ in *E. acuminatus* (UAE), $0.004 \pm 0.001 \text{ mg kg}^{-1}$ in *A. maculatus* (UAE), $0.01 \pm 0.001 \text{ mg kg}^{-1}$ in *L. rohita* (Myanmar), $0.01 \pm 0.003 \text{ mg kg}^{-1}$ in *T. toli* (UAE), $0.004 \pm 0.002 \text{ mg kg}^{-1}$ in *L. johnii* (UAE), $0.01 \pm 0.001 \text{ mg kg}^{-1}$ in *T. toli* (Oman), $0.01 \pm 0.001 \text{ mg kg}^{-1}$ in *E. splendens* (Myanmar), $0.07 \pm 0.003 \text{ mg kg}^{-1}$ in *C. cynoglossus* (Myanmar). Maximum lead content has been observed in *O. ruber* from India and *C. cynoglossus* from Myanmar and minimum was observed in *L. rohita* from India, *A. maculatus* from UAE, and *L. johnii* from UAE (Table 1). Fish from India were more contaminated with Pb than other samples and fish imported from Oman were with minimum concentration (Fig. 2).

Present results were almost similar to those reported earlier in fish from different regions of Bangladesh, for example, $0.07 - 0.63 \text{ mg kg}^{-1}$ (Raknuzzaman et al., 2016), $0.017 - 0.09 \text{ mg kg}^{-1}$ (Ahmed et al., 2015), $0.04 - 1.6 \text{ mg kg}^{-1}$ (Islam et al., 2015) and also fish (*Arius bilineatus*) from Oman studied by Al-Busaidi et al. (2011) ranging $0.02 - 0.154 \text{ mg kg}^{-1}$ and fish (*Scomber scombrus*) from Spain reported by Olmedo et al. (2013) as 0.004 mg kg^{-1} . Moreover, higher level of Pb in comparison to present results has been observed as well in fish from Bangladesh (Saha & Zaman, 2013; Ahmed et al., 2019; Rahman et al., 2012), India (Krishna et al., 2014; Malik et al., 2010), Oman (Sadeghi et al., 2019; Ali et al., 2013), Arabian Gulf (Kamal et al., 2015; Alizada, et al., 2020), Malaysia (Alam et al., 2012), Persian Gulf (Agah et al., 2009; Cunningham et al., 2019).

Lead is a non-essential environmental contaminant which can induce serious human health risk such as neurotoxicity, nephrotoxicity, increased risk of heart disease, decreased lung function and many other adverse health effects summarized in several reviews (Liu, et al., 2010, Medeiros et al. 2012, Cunningham, et al. 2019). The maximum legislative limit for Pb specified by EU standard and Bangladesh Gazette S. R. O. No. 233-Act 2014 is 0.30 mg kg^{-1} . In this study, Pb concentration in imported fish were all within this safe limit.

3.1.3 Chromium (Cr)

Concentrations of Cr were observed in the extent of: $0.05 \pm 0.02 \text{ mg kg}^{-1}$ in *L. rohita* (India), $0.08 \pm 0.01 \text{ mg kg}^{-1}$ in *O. ruber* (India), $0.07 \pm 0.001 \text{ mg kg}^{-1}$ in *S. australasicus* (UAE), $0.05 \pm 0.001 \text{ mg kg}^{-1}$ in *E. acuminatus* (UAE), $0.01 \pm 0.001 \text{ mg kg}^{-1}$ in *A. maculatus* (UAE), $0.11 \pm 0.06 \text{ mg kg}^{-1}$ in *T. toli* (UAE), $0.01 \pm 0.001 \text{ mg kg}^{-1}$ in *L. johnii* (UAE), $0.07 \pm 0.001 \text{ mg kg}^{-1}$ in *T. toli* (Oman), $0.05 \pm 0.001 \text{ mg kg}^{-1}$ in *L. rohita* (Myanmar), $0.02 \pm 0.001 \text{ mg kg}^{-1}$ in *E. splendens* (Myanmar), and $0.04 \pm 0.001 \text{ mg kg}^{-1}$ in *C. cynoglossus* (Myanmar). The highest level of Cr was detected in *T. toli* imported from UAE followed by *O. ruber* from India. The lowest amount of chromium was recorded in *L. johnii* (UAE). Fish from India and Oman had more Cr in the muscle samples than fish samples imported from other countries (Fig. 2).

Chromium concentration in literature has been documented in ranges: 1.054–1.349 mg kg⁻¹ in fish from Bangladesh (Ahmed et al., 2015), 7.52–10.2 mg kg⁻¹ in *O. ruber* from Oman Sea, Iran (Sadeghi et al., 2019), 12–27 mg kg⁻¹ in *O. ruber* from Persian Gulf (Agah et al., 2009), 10.4 ± 5.3 and 11.8 ± 5.1 mg kg⁻¹ in imported sardine and mackerel from Egypt (Abou-Arab et al., 1996), 0.96 mg kg⁻¹ in *L. rivulatus* from India (Sankar et al., 2006).

Lower level of Cr corresponding to present study has also been reported in previous studies: 0.04–1.75 mg/kg ww in seafood from Marmara, Aegean, and Mediterranean seas in Turkey (Turkmen et al. 2008), 0.04–1.5 mg kg⁻¹ in fish from Bangladesh (Islam et al., 2015), 0.79 ± 0.27 (µg/g dry wt) in *A. maculatus* from Malaysia (Alam et al., 2012), 0.422 ± 0.02 and 0.437 ± 0.01 mg kg⁻¹ in *L. rohita* and hilsa shad respectively from central market of Rajshahi in Bangladesh (Saha & Zaman, 2013), 0.219 ± 0.008 mg kg⁻¹ in muscles of *L. rohita* from India (Malik et al., 2010), 0.22 mg/kg in *Stolephorus indicus* from UAE (Alizada, et al., 2020), 0.3 ± 0.05 mg kg⁻¹ in *Scomberomorus commerson* (Narrow-barred Spanish mackerel) from Oman (Ali et al., 2013).

Chromium is considered as one of the 14 most toxic heavy metals (Irwin et al., 1997). Acute exposure of exceedingly high doses of chromium (VI) compounds to humans has been found to be associated with severe respiratory, neurological, cardiovascular, hematological, gastrointestinal, and renal effects (Chen et al., 2009, Carson et al., 1987). Also, numerous studies have revealed that hexavalent form of chromium can surge the odds of lung cancer (Ishikawa et al., 1994).

Maximum permissible limit for Cr has been set as 1 mg kg⁻¹ (EU, 2008); present results for Cr content in imported fish samples were below this limit.

3.1.4 Cadmium (Cd)

The level of Cd in studied imported fish samples was as such: 0.001 ± 0.01 mg kg⁻¹ in *L. rohita* (India), 0.005 ± 0.002 mg kg⁻¹ in *O. ruber* (India), 0.07 ± 0.04 mg kg⁻¹ in *S. australasicus* (UAE), 0.08 ± 0.01 mg kg⁻¹ in *E. acuminatus* (UAE), 0.003 ± 0.03 mg kg⁻¹ in *A. maculatus* (UAE), 0.06 ± 0.02 mg kg⁻¹ in *T. toli* (UAE), 0.001 ± 0.002 mg kg⁻¹ in *L. johnii* (UAE), 0.02 ± 0.001 mg kg⁻¹ in *T. toli* (Oman), 0.001 ± 0.001 mg kg⁻¹ in *L. rohita* (Myanmar), 0.01 mg kg⁻¹ in *E. splendens* (Myanmar), 0.01 ± 0.001 mg kg⁻¹ in *C. cynoglossus* (Myanmar). *E. acuminatus* from UAE was found to have the maximum Cd content followed by *S. australasicus* also from UAE and the minimum Cd content found in *L. rohita* from India and Myanmar and also *L. johnii* imported from UAE. In regard to the average Cd concentration in fish from different regions, fish from UAE contained the highest amount and fish from India had the minimal (Fig. 2).

Previous studies exhibited lower or equivalent Cd range to present study in fish from Bangladesh are: 0.001–0.003 mg kg⁻¹ (Ahmed et al., 2015), 0.033 – 0.075 mg kg⁻¹ in coastal areas (Raknuzzaman et al., 2016), 0.001–0.6 mg kg⁻¹ (Islam et al., 2015), 0.09– 0.87 mg kg⁻¹ (Rahman et al., 2012). Saha & Zaman (2013) found higher Cd (1.365mg kg⁻¹) in fish from central market of Rajshahi City in Bangladesh. Present study observed lower cadmium level comparing to fish from India (Krishna et al., 2014; Malik et al., 2010; Sankar et al., 2006). In case of fish from Oman, Al-Busaidi et al. (2011) found corresponding range of Cd (0.01–0.034 mg kg⁻¹) in *Arius bilineatus* to present study while Ali et al. (2013) found higher level of Cd (1.1 ± 0.5 mg kg⁻¹) in Indian Mackerel (*Rastrelliger kanagurta*). Olmedo et al. (2013) reported 0.003–0.046 mg kg⁻¹ Cd in *Scomber scombrus* from Spain which coincides to present observations. Present study also observed similar Cd level to those reported in fish from Arabian Gulf (Kamal et al., 2015; Alizada, et al., 2020) and Turkey (Turkmen et al., 2008).

In human system Cd has no biological role and is a highly toxic component potential to cause chronic toxicity even with a presence of a very low concentration (Turkmen et al., 2009). Its bioaccumulation in the human body may lead to pulmonary, hepatic, skeletal, reproductive and renal effects, and even cancer (Misra et al., 1997; Baselt, 2000; Rahmani et al., 2018). Regulatory agencies such as the U.S. Department of Health and Human Services (DHHS), the International Agency for Research on Cancer (IARC) have declared Cd and its compounds as carcinogenic to human (ATSDR, 2012).

According to EU standards and FAO/WHO, Cd concentration in fish should not exceed 0.05 mg/kg (WHO, 2011; EC, 2006). In the present study, *E. acuminatus*, *S. australasicus* and, *T. toli* from UAE exceeded this legislative limit.

3.1.5 Nickel (Ni)

The observed level of nickel in the muscle of imported fish was as $0.04 \pm 0.02 \text{ mg kg}^{-1}$ in *L. rohita* (India), $0.02 \pm 0.002 \text{ mg kg}^{-1}$ in *O. ruber* (India), $0.03 \pm 0.006 \text{ mg kg}^{-1}$ in *S. australasicus* (UAE), $0.03 \pm 0.001 \text{ mg kg}^{-1}$ in *E. acuminatus* (UAE), $0.01 \pm 0.003 \text{ mg kg}^{-1}$ in *A. maculatus* (UAE), $0.06 \pm 0.02 \text{ mg kg}^{-1}$ in *T. toli* (UAE), $0.02 \pm 0.002 \text{ mg kg}^{-1}$ in *L. johnii* (UAE), $0.02 \pm 0.001 \text{ mg kg}^{-1}$ in *T. toli* (Oman), $0.01 \pm 0.001 \text{ mg kg}^{-1}$ in *L. rohita* (Myanmar), $0.04 \pm 0.003 \text{ mg kg}^{-1}$ in *E. splendens* (Myanmar), $0.04 \pm 0.002 \text{ mg kg}^{-1}$ in *C. cynoglossus* (Myanmar). Highest amount of Ni was observed in *T. toli* (UAE) among all the fishes and the lowest nickel concentration was found in *A. maculatus* (UAE) and *L. rohita* (Myanmar). Figure 2 shows that in average Ni content were almost in similar level in imported fish muscle samples from all the regions; only fish samples from Oman amidst were in the lowest margin in terms of nickel accumulation.

As compared to present observations, earlier studies reported higher nickel accretion in fish from Bangladesh ranging: $0.04\text{--}1.4 \text{ mg kg}^{-1}$ (Islam et al., 2015); $0.69\text{--}4.36 \text{ mg kg}^{-1}$ in edible fish from Bangshi River (Rahman et al., 2012); $0.1\text{--}0.56 \text{ mg kg}^{-1}$ in commercial fish from coastal areas (Raknuzzaman et al., 2016). Higher level of Ni accumulation ($3.49 \pm 0.97 \text{ mg kg}^{-1}$) has also been documented in fish from India (Kumar & Mukherjee, 2011). Sadeghi et al. (2019) found considerably elevated amount of nickel ($64.45\text{--}94.71 \text{ mg kg}^{-1}$) in muscles of *O. ruber* collected from Oman Sea. Earlier studies also articulated higher Ni concentration in relation to present study in fish from Arabian Gulf (Kamal et al., 2015; Alizada et al., 2020), Persian Gulf (Agah et al., 2009; Cunningham et al., 2019). With regard to imported fish, El-Nemr (2003) found $4.73 \pm 2.85 \text{ mg kg}^{-1}$ as average Ni concentration in imported frozen fish in Egypt which is quite higher to present study.

Nickel exists in very low levels in the environment usually but its compounds are an eminent environmental threat to human causing a variety of pulmonary adverse health effects, such as lung inflammation, fibrosis, asthma, bronchitis, emphysema and higher risk of lung and nasal cancers (ATSDR, 2005; Forti et al., 2011). Nickel and nickel compounds have been concluded as human carcinogen according to IARC working group (IARC, 1990). Values of Ni concentration in imported fish samples of present study did not exceed the maximum permissible limit for Ni set as $0.5\text{--}0.6 \text{ mg kg}^{-1}$ in fish food (WHO, 1985).

3.1.6 Cobalt (Co)

In the present study, the extent of Co was only found in *L. rohita* from India as $0.04 \pm 0.03 \text{ mg kg}^{-1}$ and was below the detection limit for the rest of the imported fish samples. In literature, Co concentration was reported in imported frozen fish in Egypt as ranging from below the detection limit to 17.27 mg kg^{-1} by El-Nemr (2003). Andreji et al. (2006) also recorded a minor level of Co ranging from 0.06 to 0.28 mg/kg wet weight in fish muscle collected from Lower Nitra River, Slovakia. Moreover, Co extent of current study also coincides with the observations conducted by Alizada et al. (2020) in tissues of Indian anchovy (*Stolephorus indicus*) from the UAE coast, Arabian Gulf where the concentration of Co was specified as below the detection limit.

Sivaperumal et al. (2007) investigated fish, shellfish and fish products from internal markets of India and documented the average Co ranged as $0.02\text{ to }0.85 \text{ mg kg}^{-1}$. Turkmen et al. (2008) reported the cobalt level as $0.04\text{--}0.41 \text{ mg kg}^{-1}$ in sea food captivated from Marmara, Aegean and Mediterranean Sea. Earlier studies exhibited higher level of cobalt accumulation in fish from Persian Gulf (Agah et al., 2009; Cunningham et al., 2019), Turkey (Mendil et al., 2010), Iran (Hosseini et al., 2015) with respect to the present study.

Cobalt in trace amount is essential nutritionally for humans and other mammals as it is a key constituent of the vitamin B₁₂ complex, however it has harmful health effects when taken in higher concentrations (ATSDR, 2004; Medeiros et al., 2012). Chronic exposure to Co can initiate vomiting, diarrhea, increased blood pressure, dermatitis, thyroid damage, nerve damage, severe effects on the lungs, including asthma, pneumonia (ATSDR, 2004). As information about maximum permissible limits of Co has not been designated yet in case of fish and fishery products (Rahman et al., 2012), present samples can't be stated as completely safe or not for human consumption.

3.1.7 Manganese (Mn)

Manganese quantity was detected as $0.15 \pm 0.12 \text{ mg kg}^{-1}$ in *L. rohita* (India), $0.29 \pm 0.004 \text{ mg kg}^{-1}$ in *E. acuminatus* (UAE), $0.72 \pm 0.28 \text{ mg kg}^{-1}$ in *T. toli* (UAE), $0.5 \pm 0.02 \text{ mg kg}^{-1}$ in *T. toli* (Oman), $0.13 \pm 0 \text{ mg kg}^{-1}$ in *L. rohita* (Myanmar), $0.46 \pm 0.005 \text{ mg kg}^{-1}$ in *E. splendens* (Myanmar), $0.78 \pm 0.041 \text{ mg kg}^{-1}$ in *C. cynoglossus* (Myanmar). In parallel, Mn concentration was below the detection limit for *O. ruber* (India), *S. australasicus* (UAE), *A. maculatus* (UAE), *L. johnii* (UAE).

Highest level of Mn was recorded in *C. cynoglossus* (Myanmar) followed by *T. toli* (UAE) and the lowest was found in *L. rohita* (Myanmar). Fish samples from India contained the lowest amount of manganese followed by fish samples imported from Myanmar (Fig. 2).

Earlier analysis on Mn concentration in fish samples of Bangladesh has indicated a relatively higher extent in respect to present study (Saha & Zaman, 2013; Rahman et al., 2012; Ahmed et al., 2015). Kumar et al. (2012) recorded $2.0 \pm 0.7 \text{ mg kg}^{-1}$ Mn in hilsa shad collected from Ganga River of India. Sankar et al. (2006) studied heavy metal residues in fish and shellfish collected from Calicut region of Kerala in India and found 0.49 mg kg^{-1} manganese in muscles of *Lutjanus rivulatus* which coincides to the Mn level of present study. Present study also coincides with the former investigations by Ali et al. (2013) as reported $0.2 \pm 0.1 \text{ mg kg}^{-1}$ Mn in samples of *Scomberomorus commerson* (Narrow-barred Spanish mackerel) and *Rastrelliger kanagurta* (Indian Mackerel) collected from Oman and Turkmen et al. (2008) in fish from Marmara, Aegean and Mediterranean Sea. Studies on fish samples of Persian Gulf have denoted lower level of Mn as regards to the present findings (Agah et al., 2009; Cunningham et al., 2019). Higher level of Mn has also been exhibited in former investigations (El-Nemr, 2003; Islam et al., 2010; Mendil et al., 2010).

The essential trace metal, Mn is a cofactor for a number of enzymatic reactions and plays a pivotal role in cerebral function, in the maintenance of well-balanced nervous and immune system, blood sugar regulation, blood clotting and the formation of cartilage, bone formation, metabolism of amino acids, cholesterol and carbohydrates (Goyer and Clarkson, 2001). While insufficient intake of Mn may result in manganese deficiency leading to bone malformation and skeletal defects, heart disease, abnormal glucose tolerance, and so forth; chronic exposure to excessive levels can cause severe clinical neurological disease, and also affects the respiratory system, an inflammatory response in the lung able to induce impaired lung function over time (ATSDR, 2012). As the maximum allowable limit of Mn in fish and fishery products has not been set, comparison of the present findings was not conceivable in case of Mn toxicity.

3.1.8 Iron (Fe)

The amount of Fe was discerned in the present observation was as $2.28 \pm 1.63 \text{ mg kg}^{-1}$ *L. rohita* (India), $1.9 \pm 0.14 \text{ mg kg}^{-1}$ *O. ruber* (India), $10.77 \pm 3.36 \text{ mg kg}^{-1}$ *S. australasicus* (UAE), $7.14 \pm 0.05 \text{ mg kg}^{-1}$ *E. acuminatus* (UAE), $2.67 \pm 0.02 \text{ mg kg}^{-1}$ *A. maculatus* (UAE), $9.29 \pm 3.95 \text{ mg kg}^{-1}$ *T. toli* (UAE), $2.38 \pm 0.11 \text{ mg kg}^{-1}$ *L. johnii* (UAE), $7.38 \pm 0.03 \text{ mg kg}^{-1}$ *T. toli* (Oman), $2.8 \pm 0.04 \text{ mg kg}^{-1}$ *L. rohita* (Myanmar), $1.78 \pm 0.002 \text{ mg kg}^{-1}$ *E. splendens* (Myanmar), and $4.58 \pm 0.05 \text{ mg kg}^{-1}$ *C. cynoglossus* (Myanmar).

Maximum amount of Iron was found in *S. australasicus* (UAE) and the minimal was in *E. splendens* (Myanmar). Considering the average amount in fish samples from different countries, fish samples imported from Oman were with the highest magnitude and fish from India were with the least amount (Fig. 2).

In comparison to present findings, relatively higher level of iron content has been reported in previous studies on fish muscles from Bangladesh as in ranging from 0.55 to 14.43 mg Fe/100 g fish samples by Wheal et al. (2016), 31.80–296.02 mg kg⁻¹ in freshwater fish of Bangladesh recorded by Sharif et al. (1993). Higher iron accumulation has also been exhibited in earlier reports in fish samples from India (Dhanakumar et al., 2015), Marmara, Aegean and Mediterranean Sea (Turkmen et al. 2008), Black sea of Turkey (Mendil et al., 2010), commonly consumed fish in Iran (Hosseini et al., 2015), frozen and canned marine fish of Korea (Islam et al., 2010). The current results of iron concentration coincide with those found in commonly consumed fish in Oman (Ali et al., 2013), fish from Red Sea and Arabian Gulf (Kamal et al. 2015), imported sardine in Egypt (Abou-Arab et al., 1996), fish from Persian Gulf. (Agah et al., 2009; Cunningham et al., 2019).

Iron is an essential nutrient for all living organisms and it plays a crucial role in human health supporting oxygen binding and transport, electron transport, oxidative metabolism, DNA synthesis and cellular proliferation. (Valko et al., 2005). However, toxicological aspects are significant concerning iron deficiency, chronic iron overload and unintentional severe exposures to iron which possibly can initiate liver damage, inducing fibrosis, cirrhosis, and increased risk of hepatic cancer; iron overload also may bring about endocrinopathies and cardiac dysfunction and *iron deficiency is related to anemia resulting in depleted working capacity and inhibit intellectual development* (Goyer and Clarkson, 2001; Medeiros et al., 2012). The maximum permissible limit for iron concentration in fish has been set as 100 mg/kg by WHO (1989) and present findings were far beyond this safe limit.

3.1.9 Copper (Cu)

The mean magnitude of Cu in the imported fish samples were as 0.08 ± 0.05 mg kg⁻¹ *L. rohita* (India), 0.06 ± 0.01 mg kg⁻¹ *O. ruber* (India), 0.11 ± 0.01 mg kg⁻¹ *S. australasicus* (UAE), 0.63 ± 0.01 mg kg⁻¹ *E. acuminatus* (UAE), 0.18 ± 0.01 mg kg⁻¹ *A. maculatus* (UAE), 0.5 ± 0.09 mg kg⁻¹ *T. toli* (UAE), 0.2 ± 0.02 mg kg⁻¹ *L. johnii* (UAE), 0.54 ± 0.01 mg kg⁻¹ *T. toli* (Oman), 0.22 ± 0.01 mg kg⁻¹ *L. rohita* (Myanmar), 0.11 ± 0.02 mg kg⁻¹ *E. splendens* (Myanmar), and 0.09 ± 0.01 mg kg⁻¹ *C. cynoglossus* (Myanmar).

E. acuminatus (UAE) contained highest amount of Cu content among all the imported fish samples and *O. ruber* (India) had the lowest level of Cu followed by *L. rohita* (India). Figure 2 showed that fish samples of Oman had the most copper concentration and fish samples imported from India had the minimal copper amount.

Comparatively elevated level of Cu in earlier studies has been recorded as ranging from 1.3 – 1.4 mg kg⁻¹ in commercial fish and crustaceans collected from coastal area of Bangladesh (Raknuzzaman et al., 2016); 8.33– 43.18 mg kg⁻¹ in edible fishes collected from Bangshi River, Dhaka (Rahman et al., 2012); 0.658–3.459 mg kg⁻¹ in cultured fish in Bangladesh (Ahmed et al., 2015); 10.27–16.41 mg kg⁻¹ in fish from Karnaphuli River estuary (Ahmed et al., 2019). Kumar & Mukherjee (2011) investigated fish collected from Tropical Wetlands in India and found 5.30 ± 0.31 mg kg⁻¹ Cu in *L. rohita* which is higher than present findings. Malik et al. (2010) found 0.398 ± 0.002 mg kg⁻¹ Cu in muscles of *L. rohita* from freshwater lake of Bhopal which is similar to present results. Present results also coincide with earlier investigations of Cu in fish from Persian Gulf (Agah et al., 2009), fish from Marmara, Aegean and Mediterranean Sea (Turkmen et al., 2008). The current study found lower copper level in fish muscles with respect to those earlier reports (Krishna et al., 2014; Sadeghi et al., 2019; Ali et al., 2013; Kamal et al., 2015; Alizada et al., 2020; El-Nemr, 2003; Mendil et al., 2010).

Copper is an essential nutrient which plays a crucial role in biological transfer of electrons and as an indispensable part of numerous metalloenzymes associated with hemoglobin formation, metabolism of carbohydrate and drug/xenobiotic, maintenance of nervous system structure and function, antioxidant defense mechanism (ATSDR, 2004; Medeiros et al., 2012). Copper deficiency can lead to blood and nervous system disorders, leukopenia, normocytic and hypochromic anemia, and osteoporosis in adults (ATSDR, 2004). Nevertheless, exposure to higher doses of copper has been disclosed to have noxious health effects. Copper accumulation has been found to be associated with hepatic cirrhosis, renal tubular damage, gastrointestinal distress, death of neurons with neurological symptoms, impaired immune system, abnormalities of the nervous system and cornea (ATSDR, 2004; Goyer and Clarkson, 2001). Copper concentration in present study was found as below the maximum allowable limit which is 30 mg kg^{-1} (FAO, 1983).

3.1.10 Zinc (Zn)

Zinc level was perceived in the present study as $1.93 \pm 1.09 \text{ mg kg}^{-1}$ in *L. rohita* (India), $0.9 \pm 0.07 \text{ mg kg}^{-1}$ in *O. ruber* (India), $9.25 \pm 7.1 \text{ mg kg}^{-1}$ in *S. australasicus* (UAE), $4.59 \pm 0.004 \text{ mg kg}^{-1}$ in *E. acuminatus* (UAE), $3.64 \pm 0.85 \text{ mg kg}^{-1}$ in *A. maculatus* (UAE), $6.19 \pm 2.36 \text{ mg kg}^{-1}$ in *T. toli* (UAE), $3.15 \pm 0.002 \text{ mg kg}^{-1}$ in *L. johnii* (UAE), $7 \pm 0.1 \text{ mg kg}^{-1}$ in *T. toli* (Oman), $2.55 \pm 0.14 \text{ mg kg}^{-1}$ in *L. rohita* (Myanmar), $2.01 \pm 0.04 \text{ mg kg}^{-1}$ in *E. splendens* (Myanmar), $2.98 \pm 0.19 \text{ mg kg}^{-1}$ in *C. cynoglossus* (Myanmar).

The maximal Zn concentration was recorded in *S. australasicus* (UAE) followed by *T. toli* (Oman) and the minimal was found in *O. ruber* (India). Considering the original source, fish samples imported from Oman were with the highest amount of Zn and fish from India were with the lowest amount.

Considerably higher level of Zn has been noted in previous studies on fish samples from Bangladesh (Raknuzzaman et al., 2016; Rahman et al., 2012), fish collected from India (Kumar & Mukherjee, 2011, Krishna et al., 2014), fish from Red Sea and Arabian Gulf (Kamal et al., 2015), frozen and canned marine fish of Korea (Islam et al., 2010). Several studies found similar Zn content in fish (Sankar et al., 2006, Ali et al., 2013, Alizada, et al., 2020, Agah et al., 2009, Cunningham et al., 2019, Turkmen et al. 2008). Ahmed et al. (2015) reported trace elements from highly consumed cultured fish (*Labeo rohita*, *Pangasius pangasius* and *Oreochromis mossambicus*) and observed lower amount of Zn ($1.850\text{--}3.735 \text{ mg kg}^{-1}$) in comparison to the present study. Malik et al. (2010) also mentioned insubstantial amount of Zn, $0.48 \pm 0.02 \text{ mg kg}^{-1}$ in muscles of *L. rohita* sampled from freshwater lake of Bhopal, India which is comparatively lower concerning present observations.

Zinc, ubiquitous in the environment, is an essential micronutrient for rudimentary cell activities and a constitutional component of numerous proteins, including enzymes concerning cellular signaling pathways and transcription factors (Goyer and Clarkson 2001; ATSDR, 2005). Zinc deficiency results in severe health consequences such as growth retardation, poor appetite, skin changes, mental lethargy and immunological abnormalities (Ahmed et al., 2015). Even though Zn toxicity is rare, ingesting excessive levels considerably higher than the Recommended Dietary Allowances (RDAs) for zinc can likewise have adverse health effects. Taking too much zinc into the body through food, water, or dietary supplements for several months may lead to anemia, suppressed immunity, damage of pancreas, and decrease levels of high-density lipoprotein (HDL) cholesterol, copper deficiency, and possible genitourinary complications (ATSDR, 2005). Maximum allowable limit of zinc as set by FAO (1983) is 30 mg/kg for fish and current findings were much lower than this safe limit.

3.2 Health Risk Assessment

3.2.1 Estimated Daily Intake

The Estimated daily intake (EDI) values of trace metals from the consumption of imported fish are tabled and compared with the Tolerable Daily Intake (TDI) values in Table 2 to assess the risk associated with the consumption of these imported fish species. The results from Table 2 exhibited that EDI value of arsenic exceeded the limit of tolerable daily intake in the case of fish samples from UAE and also EDI values of Cr were higher for fish samples imported from India and Oman. These results indicate possible human health risks associated with these trace metals with the consumption of the studied fish samples. However, the EDI values of remaining trace metals (Pb, Ni, Cd, Mn, Fe, Cu, and Zn) were found as all below the tolerable limits. The EDI values were evaluated taken into account that a 60 kg person consumes about 62.58 g fish per day. Present results were slightly higher than those reported in previous literature regarding fish from Bangladesh (Ahmed et al., 2015; Saha & Zaman, 2013; Rahman et al., 2012). Higher EDI values of trace metals in fish were also observed in earlier studies in respect to present results (Kumar & Mukherjee, 2011; Krishna et al., 2014; Sadeghi et al., 2019).

Table 2
Comparison of the estimated daily intake (EDI) of trace metals from consumption of imported fishes in Bangladesh with the corresponding tolerable daily intake (TDI).

Sample Origin	As	Pb	Cr	Cd	Ni	Co	Mn	Fe	Cu	Zn
India	0.02	0.03	0.06	0	0.02	0.03	0.12	1.72	0.06	1.17
UAE	0.16	0.01	0.04	0.04	0.03	-	0.42	5.32	0.27	4.43
Oman	0.09	0.01	0.06	0.01	0.02	-	0.42	6.09	0.44	5.78
Myanmar	0.02	0.03	0.03	0	0.03	-	0.37	2.52	0.11	2.07
TDI (µg/kg- bw/day)	0.126 ^a	3.57 ^b	0.05–2 ^c	0.5 ^d	0.3 ^b	-	2–5 ^c	12500 ^c	30 ^d	60 ^b
^a (FAO, 2006), ^b (WHO, 2011), ^c (NRC, 1989), ^d (FAO, 1983)										

3.2.2 Non-carcinogenic Risk

To estimate the non-carcinogenic risk associated with the consumption of imported fishes in Bangladesh, THQs (Target Hazard Quotients) and TTHQs (Total Target Hazard Quotients) were calculated (Table 3). The acceptable guideline value for THQ is 1, as suggested by USEPA (2011). THQ values in present study were below this threshold limit for all individual trace metal indicating that exposure level to be below the reference dose and thus consumption of these imported fishes would possibly not cause any non-carcinogenic health risk. The THQ values in average for individual trace metal through consumption of these imported fishes followed the descending order of Cd > As > Cr > Zn > Pb > Fe > Cu > Mn > Ni. The TTHQ values listed in Table 3 were also below 1 but values for fish imported from UAE and Oman were near the threshold limit implying the possibility of noncarcinogenic health concerns. Ahmed et al. (2015) studied trace elements from highly consumed cultured fish in Bangladesh and reported lower THQ values comparing present study except for the trace metal As and Cu. Saha & Zaman (2013) also found lower THQ values associated with the consumption of fish from central market of Rajshahi City, Bangladesh in respect to present study except for the Pb. In regard to present results, Ahmed et al. (2019) reported much lower THQ values for some commercially important fishes from a tropical river estuary of Bangladesh.

Table 3
Target hazard quotient (THQ) and total target hazard quotient (TTHQ) associated with the consumption of imported fishes in Bangladesh.

Sample Origin	As	Pb	Cr	Cd	Ni	Mn	Fe	Cu	Zn	TTHQ
India	0.068	0.007	0.016	0.105	0.001	0.001	0.002	0.001	0.003	0.206
UAE	0.466	0.004	0.012	0.357	0.001	0.003	0.007	0.006	0.013	0.867
Oman	0.266	0.002	0.017	0.356	0.001	0.003	0.007	0.009	0.017	0.678
Myanmar	0.058	0.006	0.008	0.321	0.001	0.002	0.003	0.002	0.006	0.408

3.2.3 Carcinogenic Risk

The Target Cancer Risk (TR) of As, Pb and Ni related to the consumption of imported fish samples of Bangladesh were evaluated to assess the carcinogenic risks and were as listed in Table 4. Generally, TR values lying between 10^{-4} and 10^{-6} are considered an acceptable range, values less than this limit are considered as negligible cancer risk and higher than this limit suggests high risk of cancer development associated with the consumption (USEPA, 2010). Present results found TR values to be within the acceptable range for Pb and Ni. But for TCR values of arsenic with the consumption of imported fish from UAE and Oman exceeded the threshold limit. These results point toward a high a risk of cancer development associated with the consumption of these imported fish. In literature lower TR values for As associated to the consumption of fish comparing to present results have been reported by Saha & Zaman (2013) and Ahmed et al. (2019).

Table 4
Target cancer risk (TR) associated with the consumption of imported fishes in Bangladesh.

Sample Origin	As	Pb	Ni
India	3.08E-05	2.22E-07	3.55E-05
UAE	2.10E-04	1.05E-07	3.77E-05
Oman	1.20E-04	6.01E-08	2.89E-05
Myanmar	2.62E-05	1.84E-07	3.65E-05

4. Conclusion

It can be concluded from the present investigation that imported fish samples contained higher level of As and Cd which may be related to the presence of such pollutants in the habitat of these fishes. Metal accumulation pattern depends on the species, growth rate, age of the fish and different environmental factor such as pH, temperature, salinity etc. The concentration of two pesticides (Aldrin and Chlordane) was found as below the limit of detection (BDL). Heath risk calculation revealed higher dietary intakes in case of As and Cr. Though THQ and TTHQ were below the threshold limit, target carcinogenic risks were quite high by arsenic and nickel. At this moment as some of these pollutants found in fish muscles at a lower concentration, but in future, it may not be the case as we are not sure about the habitat of these fish how they were cultured or captured. Changes in fish culture practice or adulteration in the marketing channel may pollute the fish within a short period of time. Moreover, as Bangladesh is self-sufficient in fish production, a question may arise whether the country needs to import more fish at all.

5. Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and materials

Not applicable

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Nusrat Jahan Avha, Md. Monirul Islam, Md. Sofiqul Islam and Md. Habibullah-Al-Mamun. The first draft of the manuscript was written by Nusrat Jahan Avha and Farhana Mostafiz and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Figures

Figure 1

Map showing the location of land ports (1-Benapole, 2-Bhomra, and 3-Chittagong) from where the imported fish samples were collected.

Figure 2

Concentrations of trace metals (mg/kg ww) in imported fishes in Bangladesh.