Foods and Raw Materials. 2023;11(1)
ISSN 2308-4057 (Print)
ISSN 2310-9599 (Online)

Research Article
Open Access

Available online at http://jfrm.ru/en
https://doi.org/10.21603/2308-4057-2023-1-554
https://elibrary.ru/QTTBXN

Assessment of trace elements in canned fish and health risk appraisal

Md Saiful Islam[1,*], Ramal Ahmed Mustafa[2]

[1] Patuakhali Science and Technology University, Patuakhali, Bangladesh
[2] University of Garmian, Kalar, Iraq

* e-mail: msaifulpstu@yahoo.com

Received 27.06.2022; Revised 18.07.2022; Accepted 09.08.2022; Published online 11.11.2022

Abstract:
Trace elements are dangerous to human health and there is a rising concern about the quality of processed foods in some parts of the world, especially in Iraq.
The chemical composition (total sold, moisture, and ash) and concentrations of trace elements in canned fish (Skipjack tuna, Sardines, Tuna fish, Sardines, and Mackerel) from the Kalar market, Iraq were determined by using an inductively coupled plasma-optical emission spectrometer.
The ranges obtained for the elements in mg/kg were as follows: Se (0.025–0.77), As (0.02–1.07), B (0.05–0.7), Ag (0.04–0.83), Ba (0.05–0.975), Mg (29.8–37.5), Mn (0.97–2.09), Cu (0.91–3.09), and Zn (5.12–11.7). The studied canned fishes pose no risk with respect to the estimated daily intake of Se, As, B, Ag, Ba, Mg, Mn, Cu, and Zn. The total target hazard quotients for the studied metals from individual fish species (except Fme, Fma, and Fsh) were more than one, which was responsible for non-carcinogenic risks. The target carcinogenic risk value for arsenic was also higher than the standard (10^{-4}) set by the United States Environmental Protection Agency.
It revealed that the consumption of canned fish causes a chronic cancer risk to humans.

Keywords: Proximate chemical composition, trace elements, toxic elements, health risk, canned fish, Iraq

Please cite this article in press as: Islam MS, Mustafa RA. Assessment of trace elements in canned fish and health risk appraisal. Foods and Raw Materials. 2023;11(1):43–56. https://doi.org/10.21603/2308-4057-2023-1-554

INTRODUCTION

Popular demand for healthy food supply has expanded globally in recent decades [1]. With a rise in environmental pollution, food contamination by various pollutants is now considered a major issue in industrialized, emerging, and developing countries [2–4]. In recent years, the problems of environmental contamination, particularly food contamination by a cultivar of chemical pollutants including potentially toxic elements, are receiving a lot of attention from scientists around the world [5, 6]. The environment may be exposed to trace elements from various sources, particularly processed canned food, where they pose a serious threat due to their toxicity and bioaccumulation in the food chain.

Potentially toxic elements are important due to their toxicity as well as essentiality. Potentially toxic elements are classed as potentially unhealthy (arsenic, cadmium, lead, mercury, and nickel, among others), probably toxic (vanadium and cobalt), and necessary (copper, zinc, iron, manganese, and selenium) [7, 8]. When consumed in large quantities, potentially toxic elements can be extremely hazardous even at low concentrations. When metal consumption is overly high, essential and possibly essential metals might generate hazardous effects [9]. As a result of increased concern about the health benefits and hazards of food intake, substantial attention has been dedicated in recent decades to the research of essential and harmful element content in foodstuffs, particularly canned foods. However, contamination of the food chain is a key mechanism for these potentially toxic elements to enter the human body [6, 10]. In Iraq, assessing the risks and benefits of canned fish consumption is critical because canned fish meets 60–80% of the country's animal protein needs. It is also a key source of essential minerals, vitamins, and fatty acids, all of which are important in child development and adult health [9]. Furthermore, it is critical to monitor the level of potentially toxic elements in canned fish to ensure the safety of fish protein supplied to consumers and to comprehend the adverse impacts of canned fish consumption among individuals and populations.

Canned fish is widely consumed because it contains protein, omega-3 fat acids, liposoluble vitamins, as well we micro- and macroelements [11]. Fish is a significant source of nutrition for many people since it supplies animal protein that is not available in cereal-based diets [12, 13]. Recently, the global consumption of fish has expanded in tandem with growing awareness of its nutritional and therapeutic benefits. In addition to being a good source of protein, fish is also rich in critical minerals, vitamins, and unsaturated fatty acids [14]. Although seafood is considered to be the primary source of high biological protein, polyunsaturated oil, and minerals such as calcium, potassium, and zinc, since they are at the top of the food pyramid, fish can potentially make for trace metals bio-magnification and act as a potential means of transmission to humans [15]. Fish has a high content of amino acids, which is very well suited for human dietary needs. The nutritional value of its protein compares favorably to that of egg, milk, and meat [16].

Minerals are important for certain functions of the body. Some metals, such as zinc, copper, and iron, are basic to life and play a significant role in the functioning of essential enzyme systems [17]. Fish is a healthy source of calcium, potassium, phosphorus, copper, iodine, cobalt, manganese, and other trace minerals that are vital for preserving healthy teeth and bones [18].

Canning increases the shelf life of a canned product for many years. Yet, producers, nutritionists, cooks, and customers are specifically interested in the composition of fish as they want to know its nutritional contribution to a healthy diet [20]. Canned fish is very popular in Iraq since it is convenient and inexpensive for most working families. Some studies have determined potentially toxic elements in canned fish, including the ones in Turkey, Iran, Egypt, USA, Italy, Spain, Lebanon, Austria, Czech Republic, and Poland [11, 17, 21–35]. However, information regarding potentially toxic elements concentrations in canned fish marketed in Iraq is scarce, although canned skipjack tuna, sardines, tuna fish, sardines, and mackerel are extensively consumed.

Until now, there has been no detailed scientific research in Iraq concerning potentially toxic elements contamination in canned or tinned fish and their probable risk to human health. Therefore, we aimed to determine the proximate chemical composition of canned fish (total solids, moisture, and ash content), to evaluate the concentration of potentially toxic elements (Se, As, B, Ag, Ba, Mg, Mn, Cu, and Zn) in an edible portion of some of the commercially imported canned fish species on the market in Kalar City, northern Iraq, and to estimate the risks of these trace elements in everyday intake.

STUDY OBJECTS AND METHODS

Samples collection and preparation. Canned fish samples (one brand of skipjack tuna, seven brands of sardines, one brand of tuna, and one brand of mackerel) were purchased from various supermarkets in Kalar City, northern Iraq (Fig. 1). A minimum of five canned fish samples per brand were obtained at random from various retail stores. After collection, combinations of at least five samples of each fish species were prepared and homogenized in stainless-steel blender cups. Their 100 g test portions were stored at −20°C in the central laboratory of College of Education, University of Garmian (Kalar City, Iraq). Then, all the samples were freeze-dried for 48 h until constant weight was attained and sealed in airtight plastic bags. For chemical analysis, each can's material was thoroughly homogenized in a food blender using stainless steel cutters [19].

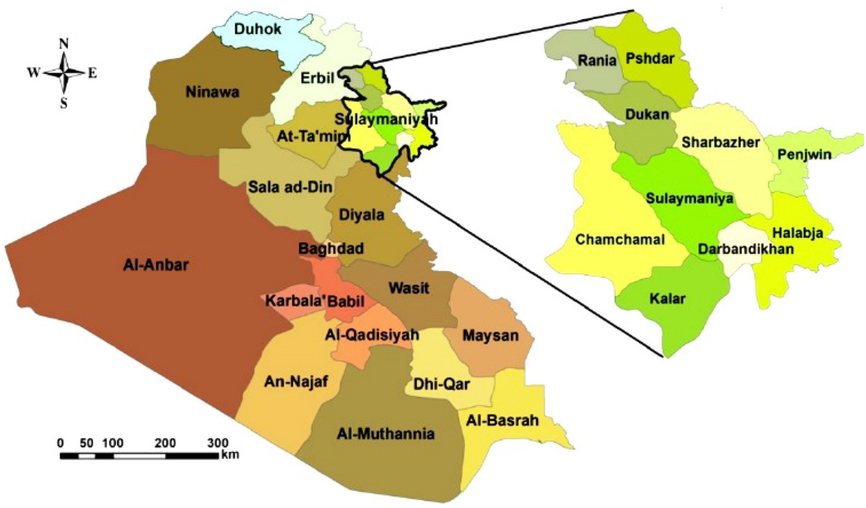

Figure 1 Map of the studied area of Kalar City, Iraq for canned fish sampling

Table 1 Fish samples collected from various supermarkets in Kalar City, Iraq

No.	Samples	Fish weight, g	Country of origin	Product local name	Scientific name	Storage media
1	Fru	130	Indonesia	Rubal	Skipjack tuna	Soya oil
2	Fsh	125	Iraq	Shabab	Sardines	Vegetable oil
3	Fsa	90	AL Maghreb	Sarden	Tuna fish	Vegetable oil
4	Fkl	120	Thailand	Klode	Sardines	Vegetable oil
5	Fal	52	Turkey	Altunsa	Sardines	Vegetable oil
6	Fze	104	Turkey	ZER	Sardines	Vegetable oil
7	Fsi	130	Vietnam	Siblue	Mackerel	Soya oil
8	Fme	112	Indonesia	Melo	Sardines	Sunflower oil
9	Fma	90	AL Maghreb	maria	Sardines	Vegetable oil
10	Fbe	120	Iran	berkeh	Sardines	Vegetable oil

Table 2 Levels of metals in DORM-4 Fish protein certified reference material (mg/kg) for the validation of analytical method

Elements	Certified value	Measured value (n = 3)	Recovery, %
Se	3.45 ± 0.40	3.37 ± 0.21	98
As	6.87 ± 0.44	6.85 ± 0.78	100
B	n.a.	n.a.	n.a.
Ag	0.0252 ± 0.0050	0.0248 ± 0.0020	98
Ba	n.a.	n.a.	n.a.
Mg	910 ± 80	889 ± 39	98
Mn	3.17 ± 0.26	3.15 ± 0.21	99
Cu	15.70 ± 0.46	15.30 ± 0.22	97
Zn	51.6 ± 2.8	51.1 ± 1.3	99

n.a. – not available

Table 1 shows the fish types, brands, volumes, and other information used by canned fish makers, such as scientific names and storage media.

Digestion and elemental analyses. For each canned fish sample, 4 g of fish muscle (wet weight) was weighed and placed in a Teflon digestion vessel with 15 mL of pure nitric acid. The samples were then microwaved as follows: Step 1: 25°C for 10 min at 1000 W; Step 2: 96°C for 30 min; Step 3: 180°C for 10 min at 1000 W; 180°C for 10 min before cooling to room temperature; Step 4: 2 mL of 30% hydrogen peroxide was added, and the mixture was exposed to Step 3 again.

In the final step, hydrogen peroxide was used to break down organic materials that may have remained undissolved throughout the concentrated nitric acid digestion (Steps 1–3). Finally, the digests were prepared in acid-washed standard flasks to 25 mL with deionized water and placed in acid-washed 50-mL polyethylene bottles. The chemicals used to dissolve the samples were of analytical quality. Ultra-pure water was used in the study [36]. The moisture and ash contents were calculated using the AOAC method [37]. All metal concentrations were determined using an inductively coupled plasma–optical emission spectrometer in three replications [38].

Instrument analysis and quality assurance. The instrument conditions were as follows: a Scott spray chamber; nebulizer: cross flow; RF power: 1400 W; pump speed: 30 RPM; coolant flow: 14 L/min; auxiliary flow: 0.9 L/min; nebulizer gas flow: 0.8 L/min; preflush: 40 s; measure time: 28 s; replicate measurement: 3; multielement stock solutions containing 1000 mg/L obtained from Bernd Kraft (Duisburg, Germany).

Standard solutions were generated from stock solutions (Merck, multi-element standard). All of the instrumental conditions used for concentration determinations were defined [39]. The analytical procedure was confirmed using DORM-4 Fish protein-certified reference material for trace metals. The National Research Council of Canada prepared and supplied these fish samples. The results showed that the certified and observed values were in good agreement. Table 2 shows that the percentage recoveries of the analyzed potentially toxic elements ranged from 97 to 100 percent.

Calculation for health risk due to metal contamination. ***Estimated daily intakes.*** Estimated daily intakes (EDI) for potentially toxic elements were calculated by multiplying the respective average concentration in fish samples by the weight of food item consumed by a person (body weight of 60 kg for an adult in Iraq), as obtained from the household income and expenditure survey, and then using the following formula [40]:

$$EDI = (FIR \times C)/BWT \quad (1)$$

where EDI is the estimated daily intakes; FIR is the food ingestion rate, g/person/day; C is the metal content in fish samples, mg/kg; BWT is the body weight for adult residents of 60 kg [41]. On a wet weight basis, the daily consumption of fish is 10.96 g [9].

Non-carcinogenic risk. The procedure for assessing non-carcinogenic risks was based on the risk-based concentration table published by the United States Environmental Protection Agency (USEPA) Region III [42]. The target hazard quotient was used to quantify the non-carcinogenic danger of each specific metal from fish consumption (USEPA, Risk-Based Concentration Table). It is “the ratio of a single substance exposure level over a specified time period

Table 3 Approximate chemical configuration of the fish flesh samples collected from various supermarkets in Kalar City, Iraq (n = 3)

Fish samples	Total solid, %	Moisture, %	Ash, %
Fme	36.30 ± 1.80	64.00 ± 0.98	4.40 ± 1.10
Fsi	37.90 ± 2.01	62.10 ± 1.10	4.20 ± 0.03
Fma	32.80 ± 3.00	67.20 ± 2.10	4.70 ± 0.70
Fbe	39.70 ± 2.23	60.30 ± 1.20	4.30 ± 0.80
Fal	34.60 ± 1.87	65.40 ± 2.00	2.19 ± 0.39
Fru	31.30 ± 0.99	68.70 ± 0.90	1.22 ± 0.50
Fsh	32.40 ± 1.20	67.60 ± 1.07	3.20 ± 0.50
Fkl	29.80 ± 2.10	70.20 ± 1.01	1.50 ± 0.35
Fze	37.50 ± 1.40	62.50 ± 2.01	3.10 ± 0.70
Fsa	30.21 ± 2.50	69.79 ± 0.80	1.90 ± 0.80

(e.g., sub-chronic) to a reference dose (Rf.D.) for that substance derived from a similar exposure period". The following equation was used to calculate the target hazard quotient:

$$THQ = [(EFr \times ED \times FIR \times C)/(Rf.D. \times BWT \times AT)] \times 10^{-3} \quad (2)$$

$$\text{Total THQ (THQ)} = THQ_{\text{toxicant }1} + THQ_{\text{toxicant }2} + \ldots + THQ_{\text{toxicant }n} \quad (3)$$

where THQ is the target hazard quotient; EFr is the exposure frequency (365 days/year); ED is the exposure duration (30 years); FIR is the food ingestion rate (59.91 g/person/day); C is the metal concentration in foods, mg/kg; Rf.D. is the oral reference dose, mg/kg/day; AT is the averaging time for non-carcinogens (365 days/year×number of exposure years, assuming 30 years). The oral reference doses were based on 0.005, 0.0003, 0.2, 0.005, 0.07, 0.14, 0.04, and 0.3 mg/kg/day for Se, As, B, Ag, Ba, Mn, Cu, and Zn, respectively [42]. If the target hazard quotient is equal to or higher than 1, there is a potential health risk and related interventions and protective measures should be taken [43, 44].

Carcinogenic risks. The risk was calculated for carcinogens as an increasing probability of a person developing cancer over a lifetime of exposure to that probable carcinogen [42]. The target carcinogenic hazards associated with As consumption was computed using the calculation provided in the USEPA Region III Risk-Based Concentration Table:

$$TR = [(EFr \times ED \times FIR \times C \times CSFo)/(BWT \times AT)] \times 10^{-3} \quad (4)$$

where EFr is the exposure frequency (365 days/year); ED is the exposure duration (70 years) (USEPA, Regional Screening Level Summary Table: November 2011); AT is the averaging time for carcinogens (365 days/year×70 years); CSFo is the oral carcinogenic slope factor. For As, CSFo was 1.5 mg/kg/day from the Integrated Risk Information System (Risk-Based Concentration Table). Total As in marine food (fish) is mostly organic and a little amount may remain as inorganic. In this study, we assumed the conversion coefficient of total As to inorganic As by 0.05 in fish to produce a carcinogenic risk.

Statistical analysis. Each experimental analysis was done in triplicate. All statistical analysis was performed using statistical package SPSS version 20.0 for Windows (IBM Corp., Armonk, NY, USA). Significance was accepted at 0.05 level of probability ($p < 0.05$). Difference in metal concentration in fish was detected using One Way Analysis of Variance (ANOVA). The tables were plotted with OriginPro 6.1 (Origin Lab Corporation, Northampton, Massachusetts, USA). The results were described as mean ± SD. The statistical differences between fishes were analyzed using mean concentrations of metals [45].

Ethical approval: The research received ethical approval because it did not involve human or animal use.

RESULTS AND DISCUSSION

Concentration of basic components in canned fish. Proteins, lipids (fat or oil), and ash (minerals) are the main constituents in the edible portion of fish. The analysis of these basic components is called proximate analysis. The estimated chemical composition of the fish examined is shown in Table 4. In the fish samples, the moisture content ranged from 70.2% (Fkl) to 60.3% (Fbe). The ash content in the fish flesh ranged between 1.22% in Fru and 4.7% in Fma fish samples. The opposite relationship between moisture and overall solid content could be seen from the results, as all fish processing technologists were well aware of it. We also found that only three of the fishes had an ash content below 2% – Fsa, Fkl, and Fru, so they were weak in minerals. The overall solid content was generally high in the same way, reaching from 37.9 to 39.7%, and crude ash ranged from 4.4 to 1.22%, as seen in Table 4. All the fish species studied were high in moisture and ash and they complied with the human dietary requirements [46]. Our data were in line with the study conducted by Tawfik [47]. The total solid concentrations of the necessary substrates provide valuable information on the expected biogas yield and efficiency of the process [48]. The highest moisture content was observed in sample Fkl (70.2%) and the lowest moisture was in Fsi Mackerel fish type (62.1%), but not significant with Fze samples (62.5%). In our study, the variations in the minerals of the studied canned fish types can be due to their water concentration, the biological state of the fish and/or their capability to consume the elements from their diet, as well their ability to absorb water [49].

Element concentration in fish species. Although researchers have presented the elemental concentrations in various tissues of fish, such as liver, kidneys, gills, gonads, and muscles, we evaluated only the

Table 4 Elements concentration (mg/kg) in studied fish flesh samples collected from various supermarkets in Kalar City, Iraq

Fish samples	Se	As	B	Ag	Ba	Mg	Mn	Cu	Zn
Fme	0.170 ± 0.002	0.02 ± 0.01	0.052 ± 0.001	0.04 ± 0.01	0.135 ± 0.010	37.50 ± 1.21	2.010 ± 0.029	1.23 ± 0.21	11.7 ± 0.5
Fsi	0.26 ± 0.10	0.300 ± 0.051	0.275 ± 0.010	0.057 ± 0.09	0.80 ± 0.02	32.30 ± 2.01	0.98 ± 0.04	2.46 ± 0.15	6.65 ± 0.71
Fma	0.170 ± 0.001	0.020 ± 0.001	0.052 ± 0.030	0.040 ± 0.005	0.690 ± 0.012	37.50 ± 2.91	1.21 ± 0.25	1.87 ± 0.31	5.55 ± 0.12
Fbe	0.4400 ± 0.0021	0.70 ± 0.06	0.425 ± 0.050	0.225 ± 0.004	0.90 ± 0.01	33.01 ± 1.01	1.12 ± 0.32	2.10 ± 0.01	7.430 ± 0.001
Fal	0.10 ± 0.01	0.250 ± 0.012	0.50 ± 0.07	0.210 ± 0.001	0.3750 ± 0.0015	29.8 ± 1.9	1.09 ± 0.32	3.11 ± 0.50	6.228 ± 0.210
Fru	0.73 ± 0.01	1.07 ± 0.08	0.53 ± 0.03	0.320 ± 0.001	0.1500 ± 0.0012	30.4 ± 2.1	0.97 ± 0.04	2.650 ± 0.116	6.625 ± 1.270
Fsh	0.175 ± 0.015	0.10 ± 0.05	0.25 ± 0.01	0.50 ± 0.00	0.85 ± 0.00	30.90 ± 0.98	1.73 ± 0.30	2.90 ± 0.51	9.05 ± 1.05
Fkl	0.275 ± 0.010	0.25 ± 0.02	0.05 ± 0.00	0.83 ± 0.05	0.70 ± 0.04	34.30 ± 1.08	0.99 ± 0.03	3.09 ± 0.32	5.12 ± 0.90
Fze	0.025 ± 0.001	0.30 ± 0.04	0.70 ± 0.03	0.320 ± 0.001	0.975 ± 0.090	35.1 ± 2.0	1.85 ± 0.06	0.910 ± 0.001	7.425 ± 0.980
Fsa	0.250 ± 0.001	0.65 ± 0.03	0.50 ± 0.07	0.220 ± 0.012	0.050 ± 0.013	36.5 ± 2.4	2.090 ± 0.053	2.10 ± 0.04	9.875 ± 1.070
Mean ± SD	0.26 ± 0.20	0.37 ± 0.34	0.33 ± 0.23	0.28 ± 0.24	0.56 ± 0.35	33.70 ± 2.89	1.40 ± 0.46	2.24 ± 0.75	7.56 ± 2.06
LOD	0.002	0.001	0.05	0.005	0.006	0.001	0.004	0.004	0.005

LOD – Limit of detection

edible portion of canned fish for elemental concentrations [50]. Table 5 shows nine potentially toxic elements (Se, As, B, Ag, Ba, Mg, Mn, Cu, and Zn) in ten imported canned fish species collected from various supermarkets in Kalar City, Iraq. The ranking of the elements' mean concentrations in the canned fish samples were Mg (33.7) > Zn (7.56) > Cu (2.24) > Mn (1.40) > Ba (0.56) > As (0.37) > B (0.33) > Ag (0.28) > Se (0.26) (mg/kg), respectively. The concentrations of different elements varied considerably among the canned fish species.

Selenium, copper, magnesium, manganese, and zinc are potentially toxic elements required for regular physiological function, but in high amounts they can be hazardous. The ranges of Se, As, B, Ag, Ba, Mg, Mn, Cu, and Zn in the canned fish items were 0.025–0.73, 0.02–1.07, 0.05–0.7, 0.04–0.83, 0.05–0.975, 29.8–37.5, 0.97–2.09, 0.91–3.11, and 5.12–11.7 mg/kg, respectively. A study conducted by Ashraf *et al.* found that mean concentrations of Cu and Zn in canned tuna were 2.94, and 10.4 mg/kg, respectively, which were identical to our study [51].

The lowest and highest selenium levels in the canned fish species were found as 0.025 mg/kg in Fze (Turkish sardines) and 0.73 mg/kg in Fru (Indonesian Skipjack tuna). Selenium contents in fish have been reported in literature to be in the range of 0.234–0.389 mg/kg from Puerto Rico, 0.041–1.13 mg/kg in fish and seafood, 1.1–3.0 mg/kg in edible fish muscle from Portugal [52–54]. For adults, the maximum daily dietary intake of selenium is 0.006 mg/kg-bwt/day [55].

Arsenic is a major heavy metal (metalloids) that is both hazardous and cancer-causing. All the analyses in this study were performed for total (including organic and inorganic) arsenic, despite the fact that the majority of arsenic detected in fish and seafood is in organic form, which is less harmful [56]. There was no standard limit for As in fresh water fish, as well as canned fish, but the Serbian Regulation [57]. Total arsenic levels have already been set at 3 mg/kg for freshwater and saltwater fish, 3 mg/kg for marine fish products, and 12 mg/kg for tuna fish products. In our study, As concentrations in all the examined samples were less than this level. Arsenic was found in all the fish samples with a mean (range) concentration of 0.37 (0.02–1.07 mg/kg) (Table 5). Andayesh *et al.* found arsenic values ranging from 0.257 to 1.452 mg/kg in canned tuna obtained from Tehran's seafood market, Iran, which was slightly higher than in our study [22]. Also, Ikem and Egiebor reported lower As levels with a maximum concentration of 1.72 mg/kg in canned tuna and 1.12 mg/kg in canned sardines collected from the market in Georgia and Alabama, USA [11]. Morgano *et al.* identified As in tuna to be in the range of 0.187–3.677 mg/kg, which is consistent with the findings of our study [58].

The adverse effects due to chronic exposure of humans to silver are a permanent bluish-gray discoloration of the skin (argyria) or eyes (argyrosis). The lowest and highest silver levels in the canned fish species were found as 0.04 mg/kg in Fme and Fma and 0.83 mg/kg in Fkl (Table 4). Silver contents in literature have been reported in the range of 0.00–0.20 mg/kg in canned fish from Georgia and Alabama, USA; 0.00–2.28 mg/kg in dietary fish in France, 0.021–0.580 mg/kg in marine fish from Southeast Asia, and 0.14–0.43 mg/kg in two marine fishes in China's Fujian province [11, 59–61]. The estimated daily intake of silver from the fish diet was reported to be 0.011 mg kg-bw/d. The USEPA has set a daily intake limit of 0.0132 mg/kg-bwt for all types of silver (Risk-Based Concentration Table, April, 2005). As a result, our daily silver consumption was substantially below the safe threshold.

Copper levels were found to be the lowest and highest in the canned fish species as 0.91 mg/kg in Fze and 3.11 mg/kg in Fal (Table 5). Copper levels have been reported in literature to be in the range of

Table 5 Comparison between the dietary intakes of trace elements from composite fish flesh samples collected from various supermarkets in Kalar City, Iraq and the corresponding maximum tolerable daily intake (MTDI)

Fish samples	Estimated daily intake of trace elements, mg								
	Se	As	B	Ag	Ba	Mg	Mn	Cu	Zn
Fme	0.010	0.001	0.003	0.002	0.008	2.247	0.120	0.074	0.701
Fsi	0.016	0.018	0.016	0.003	0.048	1.935	0.059	0.147	0.398
Fma	0.010	0.001	0.003	0.002	0.041	2.247	0.072	0.112	0.333
Fbe	0.026	0.042	0.025	0.013	0.054	1.978	0.067	0.126	0.445
Fal	0.006	0.015	0.030	0.013	0.022	1.785	0.065	0.186	0.373
Fru	0.043	0.064	0.032	0.019	0.009	1.821	0.058	0.159	0.397
Fsh	0.010	0.006	0.015	0.030	0.051	1.851	0.104	0.174	0.542
Fkl	0.016	0.015	0.003	0.050	0.042	2.055	0.059	0.185	0.307
Fze	0.001	0.018	0.042	0.019	0.058	2.103	0.111	0.055	0.445
Fsa	0.015	0.039	0.030	0.013	0.003	2.187	0.125	0.126	0.592
Total estimated daily intake	0.155	0.220	0.200	0.165	0.337	20.21	0.841	1.343	4.532
Maximum tolerable daily intake	0.3[a]	0.126[b]	0.50[a]	0.25[c]	12[d]	60[b]	2.0–5.0[e]	30[b]	60[b]

[a](EFSA, 2006), [b](FAO, 2006); [c](USEPA, 2005); [d](SCHER, 2012); [e](NRC, 1989)

Table 6 Relative contribution of estimated daily intakes of trace elements from consumption of canned fish species collected from various supermarkets in Kalar City, Iraq

Fish samples	% contribution of estimated daily intake of trace elements								
	Se	As	B	Ag	Ba	Mg	Mn	Cu	Zn
Fme	3.39	0.95	0.62	0.96	0.07	3.74	6.02	0.25	1.17
Fsi	5.19	14.26	3.30	1.37	0.40	3.23	2.94	0.49	0.66
Fma	3.39	0.95	0.62	0.96	0.34	3.74	3.62	0.37	0.55
Fbe	8.79	33.28	5.09	5.39	0.45	3.30	3.35	0.42	0.74
Fal	2.00	11.89	5.99	5.03	0.19	2.98	3.27	0.62	0.62
Fru	14.48	51.11	6.35	7.67	0.07	3.04	2.91	0.53	0.66
Fsh	3.49	4.75	3.00	11.98	0.42	3.09	5.18	0.58	0.90
Fkl	5.49	11.89	0.60	19.89	0.35	3.42	2.97	0.62	0.51
Fze	0.50	14.26	8.39	7.67	0.49	3.50	5.54	0.18	0.74
Fsa	4.99	30.91	5.99	5.27	0.02	3.64	6.26	0.42	0.99

0.30–4.87 mg/kg in canned fish from Serbia; 0.01–5.33 mg/kg in canned fish from Georgia and Alabama, USA; 5.17–9.45 mg/kg in fish species from Bangladesh, 0.06–0.35 mg/kg from the Pearl River Delta, South China; and 0.15–0.27 mg/kg in fish from Puerto Rico [11, 52, 62–64]. The maximum copper level that can be consumed through food is 0.50 mg/kg-bwt/day [65]. In our study, copper's estimated daily intake value was within acceptable limits.

Zinc deficiency has been linked to lack of appetite, growth retardation, skin changes, and immunological problems in humans [17]. The lowest and highest zinc concentrations were observed as 5.12 mg/kg in Fkl (sardines, Thailand) and 11.2 mg/kg in Fme (sardines, Indonesia). Zinc contents in literature have been reported in the range of 1.35–44.50 mg/kg in canned fish from Serbia; 42.83–418.00 mg/kg in some eatable fishes from Bangladesh; 38.8–93.4 mg/kg in commercial fish species from the Black Sea, Turkey; and 14.0–97.8 mg/kg in canned fish from Georgia and Alabama, USA [11, 17, 62, 66]. As shown in Table 8, the Zn content in our study was in a good ratio compared to other fish flesh.

The lowest and highest levels of barium were 0.05 mg/kg in tuna fish (Fsa) and 0.975 mg/kg in sardines (Fze). There is little information regarding Ba content in fish and fish products. However, literature has reported Ba contents in the range of 0.0001–0.9450 mg/kg in dietary fish of France; 3.44–6.96 mg/kg in different fish species from Turkey; and 0.003–0.208 mg/kg in edible marine fish from Rio de Janeiro, Brazil [14, 59, 67]. As presented in Table 6, Brazilian fish had a mean Ba concentration of 0.67 ± 0.07 in a recent study. Yet, other countries had higher mean Ba concentrations.

The amounts of trace element contamination in various canned fish species may vary depending on factors such as contamination gradient, aquatic physicochemical parameters, sex, species, metabolism, age, and diet [68]. Trace element contamination in canned fish products imported to Iraq may occur due

Table 7 Target hazard quotient and target carcinogenic risk of toxic elements due to consumption of canned fish collected from various supermarkets in Kalar City, Iraq

Fish samples	Target hazard quotient									Carcinogenic risk
	Se	As	B	Ag	Ba	Mn	Cu	Zn	Total	As*
Fme	3.4E-02	6.7E-02	2.6E-04	8.0E-03	1.9E-03	1.4E-02	3.1E-02	3.9E-02	1.9E-01	1.5E-02
Fsi	5.2E-02	1.0E+00	1.4E-03	1.1E-02	1.1E-02	7.0E-03	6.1E-02	2.2E-02	1.2E+00	2.2E-01
Fma	3.4E-02	6.7E-02	2.6E-04	8.0E-03	9.8E-03	8.6E-03	4.7E-02	1.8E-02	1.9E-01	1.5E-02
Fbe	8.8E-02	2.3E+00	2.1E-03	4.5E-02	1.3E-02	8.0E-03	5.2E-02	2.5E-02	2.6E+00	5.2E-01
Fal	2.0E-02	8.3E-01	2.5E-03	4.2E-02	5.3E-03	7.8E-03	7.8E-02	2.1E-02	1.0E+00	1.9E-01
Fru	1.4E-01	3.6E+00	2.6E-03	6.4E-02	2.1E-03	6.9E-03	6.6E-02	2.2E-02	3.9E+00	8.1E-01
Fsh	3.5E-02	3.3E-01	1.2E-03	1.0E-01	1.2E-02	1.2E-02	7.2E-02	3.0E-02	6.0E-01	7.5E-02
Fkl	5.5E-02	8.3E-01	2.5E-04	1.7E-01	1.0E-02	7.1E-03	7.7E-02	1.7E-02	1.2E+00	1.9E-01
Fze	5.0E-03	1.0E+00	3.5E-03	6.4E-02	1.4E-02	1.3E-02	2.3E-02	2.5E-02	1.1E+00	2.2E-01
Fsa	5.0E-02	2.2E+00	2.5E-03	4.4E-02	7.1E-04	1.5E-02	5.2E-02	3.3E-02	2.4E+00	4.9E-01
Total	5.2E-01	1.2E+01	1.7E-02	5.5E-01	8.0E-02	1.0E-01	5.6E-01	2.5E-01	1.4E+01	2.7E+00

*Assuming 10% inorganic As present in fish to produce carcinogenic risk (Saha and Zaman, 2013)
Bold indicates target hazard quotient value > 1

to transportation, production handling, canning process, and storage conditions [11].

Health risk assessment. ***Estimated daily intake.*** Table 6 shows the estimated daily intake for potentially toxic elements (mg/kg-bwt/day) from canned fish in our study. The dietary exposure to potentially toxic elements from eating canned fish as part of the daily diet of adults in the study area is determined by the estimated daily intake. The mean concentration of individual potentially toxic elements and the individual consumption rate can be used to estimate the daily intake [69].

We received information regarding potentially toxic element intake on a daily basis from the estimated daily intake from canned fish consumption. We found that the total daily potentially toxic element intake was lower than the maximum tolerated intake value (Table 5). Although the total estimated daily intake was low due to low canned fish consumption, a long-term intake of contaminated canned fish from the research area could have major health consequences for Iraq's people [44, 70]. Due to Iraqis' low consumption of canned fish, the estimated daily intake was lower than the maximum tolerated intake value. The total estimated daily intakes for Se, As, B, Ag, Ba, Mg, Mn, Cu, and Zn were 0.155, 0.220, 0.200, 0.165, 0.337, 20.21, 0.841, 1.343, and 4.532 mg/kg-bwt/day, respectively (Table 5).

Table 6 shows the estimated daily intake of potentially toxic elements [estimated daily intake (percent contribution)] from canned fish species compared to the recommended daily dietary requirements. For estimated daily intake, the contribution percentage of As ranged from 0.95 to 51.11. The largest percentage of As contribution was found in Fru (51.11%), while the lowest was reported in Fme and Fma (0.95 percent). The percentage of contribution of Se for estimated daily intake ranged from 0.50–14.48. The highest Ag percentage was observed in Fkl (19.89%). Manganese contribution in estimated daily intake was estimated to be between 2.9 and 6.26%. The maximum Mn percentage for estimated daily intake contribution was found in Fsa (6.26%), while the lowest was found in Fru (2.9%). From the contribution of heavy metals, we concluded that eating these fish species taken from several shops in Kalar, Iraq, was safe and that the health risks associated with consuming these canned fishes were minimal.

Non-carcinogenic and carcinogenic risk. Table 5 shows the non-carcinogenic (target hazard quotient) and carcinogenic risks of heavy metals (Se, As, B, Ag, Ba, Mn, Cu, and Zn) in canned fish contaminated with potentially toxic elements. In decreasing sequence, the target hazard quotients for four heavy metals were calculated as As > B > Ba > Mn > Zn > Se > Ag > Cu. The total THQ values for Se, As, B, Ag, Ba, Mn, Cu, and Zn were 5.2E-01, 1.2E+01, 1.7E-02, 5.5E-01, 8.0E-02, 1.0E-01, 5.6E-01, and 2.5E-01, respectively.

Considering individual elements from individual fish species, the target hazard quotient value for As exceeded the standard value (> 1) for some of the fish species, which was a serious concern for the consumption of these canned fishes. Humans are exposed to non-carcinogenic Arsenic risks by eating these canned fishes. The target hazard quotient values of As for all the canned fish species were (in the decreasing order) Fru > Fbe > Fsa > Fze > Fsi > Fkl > Fal > Fsh > Fme > Fma (Table 7). However, Fru presented the maximum target hazard quotient for As (3.6E+00) followed by Fbe (2.3E+00) and Fsa (2.2E+00). The lowest target hazard quotient for arsenic as a single metal was in Fma and Fme (6.7E-02).

Our analysis revealed that the total target hazard quotient from different fish species was quite high (except Fma, Fme, and Fsh), with potentially toxic elements investigated having an ability to cause non-carcinogenic hazards (target hazard quotient > 1). (Table 7). In Kalar City, Iraq, excessive and continuous

Table 8 Comparison between present study's results and those of various other studies

Country	Se	As	B	Ag	Ba	Mg	Mn	Cu	Zn	References
Present study	0.26 ± 0.20	0.37 ± 0.34	0.33 ± 0.23	0.28 ± 0.24	0.56 ± 0.35	33.70 ± 2.89	1.40 ± 0.46	2.24 ± 0.75	7.56 ± 2.06	[75]
Nigeria	0.27 ± 0.01	0.47 ± 0.07	0.24 ± 0.08	0.29 ± 0.35	0.51 ± 0.21	35.2 ± 2.0	0.9 ± 0.8	2.11 ± 0.60	3.4 ± 0.5	[66]
China	0.41 ± 0.31	0.57 ± 0.20	0.27 ± 0.04	0.24 ± 0.21	0.59 ± 0.10	25.7 ± 0.9	1.3 ± 0.5	n.f.	13.1 ± 2.6	Risk-Based Concentration Table, April, 2005
Macedonia	n.f.	0.61 ± 0.31	0.46 ± 0.05	0.31 ± 0.04	0.55 ± 0.13	n.f.	1.1 ± 0.4	n.f.	n.f.	[24]
India	0.21 ± 0.04	0.45 ± 0.14	n.f.	n.f.	0.50 ± 0.32	29.8 ± 0.7	0.90 ± 0.09	n.f.	10.6 ± 1.7	[19]
Brazil	0.20 ± 0.03	n.f.*	0.29 ± 0.9	0.28 ± 0.08	0.61 ± 0.07	40.1 ± 0.5	1.5 ± 0.3	1.98 ± 0.40	8.20 ± 10.98	[16]
Bangladesh	0.300 ± 0.025	0.33 ± 0.50	0.34 ± 0.06	0.29 ± 0.41	0.48 ± 0.05	42.1 ± 2.6	1.60 ± 0.12	1.50 ± 0.17	n.f.	[32]
Iran	n.f.	0.23 ± 0.21	0.31 ± 0.21	0.19 ± 0.09	n.f.	38.8 ± 2.6	1.38 ± 0.07	2.02 ± 0.9	9.3 ± 0.3	[39]

*n.f. – not found

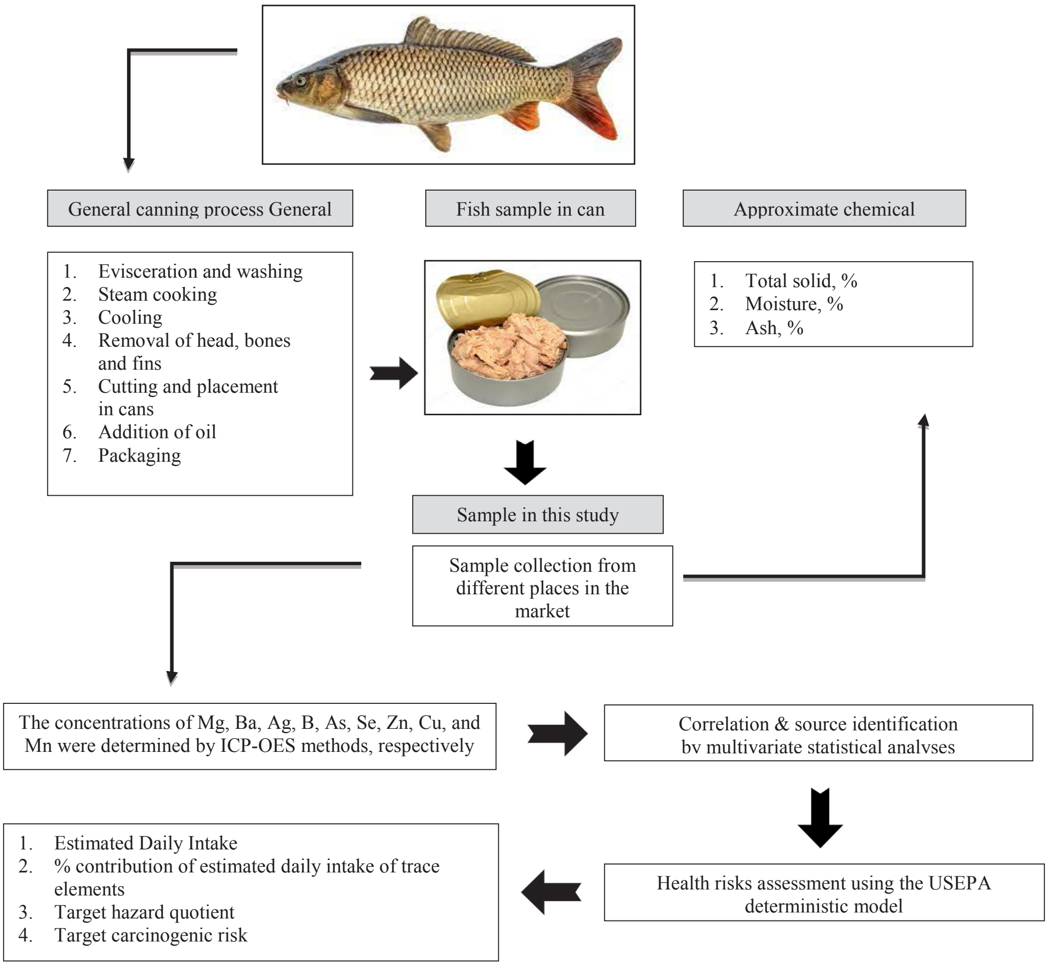

Figure 2 A flow diagram of the research process

eating of the examined fish species could pose serious non-carcinogenic dangers.

The amount of As in various canned fishes was used to determine the carcinogenic risk. Based on the amount, arsenic can have a non-carcinogenic or carcinogenic effect. Table 8 shows the cancer risks for the participants in the study area who ate various canned fishes. Arsenic had a cancer risk value ranging from 1.5E-03 to 8.1E-02. Arsenic is a potentially harmful element found in fish mostly as a result of its presence in the aquatic environment. It is classified as a carcinogen (USEPA group A) and enters aquatic habitats through the weathering of bedrock, but more frequently through anthropogenic sources [71]. Several health problems induced by chronic exposure to inorganic As have been described in the human body. They affect the gastrointestinal and respiratory tracts, skin, liver, neurological, cardiovascular, and hematological systems [72]. The cancer risk reference value ranges from 10^{-6} to 10^{-4}. The risk of cancer is insignificant if the target carcinogenic risk value is less than 10^{-6}, whereas target carcinogenic risk values greater than 10^{-4} are not safe for humans and may induce cancer [42]. In our study, the cancer risk for As was slightly higher than the reference value. Our results showed that customers in Kalar City, Iraq are exposed to As through canned fish eating and have an increased lifetime chance of developing cancer.

CONCLUSION

According to our results for trace elements (essential and harmful), the analyzed canned fish species, except for Indonesian canned fish, were nutritionally and toxically safe for human consumption. Skipjack tuna had a high arsenic level. The levels of magnesium, selenium, and ash were high in Indonesian sardines. We concluded that the concentrations of trace elements in the muscles of the commercial canned fish studied fall within the limits of international law and are appropriate for human consumption. The target hazard quotient was higher than one in As for most of the fish items and as a single element. In the study area, arsenic may pose a non-carcinogenic health risk. There was a high risk of cancer from consuming hazardous element-contaminated canned salmon. Those who consume canned fish polluted with arsenic on a regular basis have a lifetime risk of cancer.

We evaluated canned fish consumption, which accounts for only 5% of daily calorie intake per capita in Iraq. Other food sources include rice, vegetables, fruits, cereals, seafood, and non-piscine protein sources. They may need to be investigated to determine the exact health hazards associated with trace element intake from such food products. Education and public awareness of the appropriate levels of potentially toxic elements in commercially imported fish are critical, and such information must be made available to the public to ensure that nature and human health coexist in peace.

CONTRIBUTION

The authors were equally involved in writing the manuscript and are equally responsible for plagiarism.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests related to the publication of this article.

ACKNOWLEDGEMENTS

The authors offer their heartfelt thanks to the resource and scientific support center at Garmian University, College of Education, Department of Chemistry, and Garmian University Research Center.

REFERENCES

1. Zhang FF, Barr SI, McNulty H, Li D, Blumberg JB. Health effects of vitamin and mineral supplements. BMJ. 2020;369. https://doi.org/10.1136/bmj.m2511
2. Ahmed MK, Shaheen N, Islam MS, Habibullah-al-Mamun M, Islam S, Mohiduzzaman Md, *et al.* Dietary intake of trace elements from highly consumed cultured fish (*Labeo rohita*, *Pangasius pangasius* and *Oreochromis mossambicus*) and human health risk implications in Bangladesh. Chemosphere. 2015;128:284–292. https://doi.org/10.1016/j.chemosphere.2015.02.016
3. Islam MS, Ahmed MK, Idris AM, Phoungthong K, Habib MA, Mustafa RA. Geochemical speciation and bioaccumulation of trace elements in different tissues of pumpkin in the abandoned soils: Health hazard perspective in a developing country. Toxin Reviews. 2021. https://doi.org/10.1080/15569543.2021.1977325
4. Thompson LA, Darwish WS. Environmental chemical contaminants in food: Review of a global problem. Journal of Toxicology. 2019;2019. https://doi.org/10.1155/2019/2345283
5. Islam MS, Ahmed MK, Habibullah-Al-Mamun M, Raknuzzaman M. The concentration, source and potential human health risk of heavy metals in the commonly consumed foods in Bangladesh. Ecotoxicology and Environmental Safety. 2015;122:462–469. https://doi.org/10.1016/j.ecoenv.2015.09.022
6. Kormoker T, Proshad R, Islam MS, Shamsuzzoha M, Akter A, Tusher TR. Concentrations, source apportionment and potential health risk of toxic metals in foodstuffs of Bangladesh. Toxin Reviews. 2020;40(4):1447–1460. https://doi.org/10.1080/15569543.2020.1731551
7. Munoz-Olivas R, Camara C. Speciation related to human health. In: Ebdon L, Pitts L, Cornelis R, Crews H, Donard OFX, Quevauviller P, editors. Trace element speciation for environment, food and health. Cambridge: The Royal Society of Chemistry; 2001, pp. 331–353. https://doi.org/10.1039/9781847552204-00331
8. Islam MS, Proshad R, Asadul Haque M, Hoque MF, Hossin MS, Islam Sarker MN. Assessment of heavy metals in foods around the industrial areas: Health hazard inference in Bangladesh. Geocarto International. 2020;35(3):280–295. https://doi.org/10.1080/10106049.2018.1516246

9. Mohammad MJ, Akbay C. An econometric analysis of urban households' meat consumption in Erbil-Iraq. Tarım Ekonomisi Araştırmaları Dergisi. 2020;6(2):65–73.

10. Islam MS, Islam ARMT, Phoungthong K, Ustaoğlu F, Tokatli C, Ahmed R, *et al.* Potentially toxic elements in vegetable and rice species in Bangladesh and their exposure assessment. Journal of Food Composition and Analysis. 2022;106. https://doi.org/10.1016/j.jfca.2021.104350

11. Pittas A, Dawson-Hughes B, Staten M. Vitamin D supplementation and prevention of type 2 diabetes. The New England Journal of Medicine. 2019;381(18):1785–1786. https://doi.org/10.1056/NEJMc1912185

12. Lall SP, Kaushik SJ. Nutrition and metabolism of minerals in fish. Animals. 2021;11(9). https://doi.org/10.3390/ani11092711

13. Ali MM, Ali ML, Proshad R, Islam S, Rahman Z, Kormok, T. Assessment of trace elements in the demersal fishes of a coastal River in Bangladesh: A public health concern. Thalassas. 2020;36(2):641–655. https://doi.org/10.1007/s41208-020-00227-7

14. Medeiros RJ, dos Santos LMG, Freire AS, Santelli RE, Braga AMCB, Krauss TM, *et al.* Determination of inorganic trace elements in edible marine fish from Rio de Janeiro State, Brazil. Food Control. 2012;23(2):535–541. https://doi.org/10.1016/j.foodcont.2011.08.027

15. El Shehawy SM, Gab-Alla AA, Mutwally HMA. Proximate and elemental composition of important fish species in Makkah central fish market, Saudi Arabia. Food and Nutrition Sciences. 2016;7:429–439. https://doi.org/10.4236/fns.2016.76044

16. Adewumi AA, Adewole HA, Olaleye VF. Proximate and elemental composition of the fillets of some fish species in Osinmo Reservoir, Nigeria. Agriculture and Biology Journal of North America. 2014;5(3):109–117.

17. Antony Jesu Prabhu P, Holen E, Espe M, Silva MS, Holme MH, Hamre K, *et al.* Dietary selenium required to achieve body homeostasis and attenuate pro-inflammatory responses in Atlantic salmon post-smolt exceeds the present EU legal limit. Aquaculture. 2020;526. https://doi.org/10.1016/j.aquaculture.2020.735413

18. Watanabe T, Kiron V, Satoh S. Trace minerals in fish nutrition. Aquaculture. 1997;151(1–4):185–207. https://doi.org/10.1016/S0044-8486(96)01503-7

19. Boadi NO, Twumasi SK, Badu M, Osei I. Heavy metal contamination in canned fish marketed in Ghana. American Journal of Scientific and Industrial Research. 2011;2(6):887–882. https://doi.org/10.5251/ajsir.2011.2.6.877.882

20. Tarley CRT, Visentainer JV, Matsushita M, de Souza NE. Proximate composition, cholesterol and fatty acids profile of canned sardines (*Sardinella brasiliensis*) in soybean oil and tomato sauce. Food Chemistry. 2004;88(1):1–6. https://doi.org/10.1016/j.foodchem.2004.01.016

21. Malakootian M, Tahergorabi M, Daneshpajooh M, Amirtaheri K. Determination of Pb, Cd, Ni concentration in canned fish in southern Iran. Bimonthly Journal of Hormozgan University of Medical Sciences. 2013;16(6):445–451.

22. Andayesh S, Hadiani MR, Mousavi Z, Shoeibi S. Lead, cadmium, arsenic and mercury in canned tuna fish marketed in Tehran, Iran. Food Additives and Contaminants: Part B Surveillance. 2015;8(2):93–98. https://doi.org/10.1080/19393210.2014.993430

23. Pourjafar H, Ghasemnejad R, Noori N, Mohammadi K. Heavy metals content of canned tuna fish marketed in Tabriz, Iran. Iranian Journal of Veterinary Medicine. 2014;8(1):9–14.

24. El Morsy FA, El-Sadaawy MM, Ahdy HHH, Abdel-Fattah LM, El-Sikaily AM, Khaled A, *et al.* Potential human health risks from toxic metals, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and organochlorine pesticides via canned fish consumption: Estimation of target hazard quotients. Journal of Environmental Science and Health – Part A Toxic/Hazardous Substances and Environmental Engineering. 2013;48(12):1470–1478. https://doi.org/10.1080/10934529.2013.796782

25. Hassan A-RHA, Zeinhom MMA, Abdel-Wahab MA, Tolba MH. Heavy metal dietary intake and potential health risks for university hostel students. Biological Trace Element Research. 2016;170(1):65–74. https://doi.org/10.1007/s12011-015-0451-z

26. Shiber JG. Arsenic, cadmium, lead and mercury in canned sardines commercially available in eastern Kentucky, USA. Marine Pollution Bulletin. 2011;62(1):66–72. https://doi.org/10.1016/j.marpolbul.2010.09.008

27. Storelli MM, Stuffler RG, Marcotrigiano GO. Polycyclic aromatic hydrocarbons, polychlorinated biphenyls, chlorinated pesticides (DDTs), hexachlorocyclohexane, and hexachlorobenzene residues in smoked seafood. Journal of Food Protection. 2003;66(6):1095–1099. https://doi.org/10.4315/0362-028X-66.6.1095

28. Storelli MM, Barone G, Cuttone G, Giungato D, Garofalo R. Occurrence of toxic metals (Hg, Cd, and Pb) in fresh and canned tuna: Public health implications. Food and Chemical Toxicology. 2010;48(11):3167–3170. https://doi.org/10.1016/j.fct.2010.08.013

29. Russo R, Voi AL, De Simone A, Serpe FP, Anastasio A, Pepe T, *et al.* Heavy metals in canned tuna from Italian markets. Journal of Food Protection. 2013;76(2):355–359. https://doi.org/10.4315/0362-028X.JFP-12-346

30. González-Estecha M, Martínez-García MJ, Fuentes-Ferrer M, Bodas-Pinedo A, Calle-Pascual A, Ordóñez-Iriarte JM, *et al.* Mercury in canned tuna in Spain. Is light tuna really light? Food and Nutrition Sciences. 2013;4:48–54. https://doi.org/10.4236/fns.2013.47A007

31. Olmedo P, Pla A, Hernández AF, Barbier F, Ayouni L, Gil F. Determination of toxic elements (mercury, cadmium, lead, tin and arsenic) in fish and shellfish samples. Risk assessment for the consumers. Environment International. 2013;59:63–72. https://doi.org/10.1016/j.envint.2013.05.005

32. Obeid PJ, El-Khoury B, Burger J, Aouad S, Younis M, Aoun A, *et al.* Determination and assessment of total mercury levels in local, frozen and canned fish in Lebanon. Journal of Environmental Sciences. 2011;23(9):1564–1569. https://doi.org/10.1016/S1001-0742(10)60546-3

33. Suppin D, Zahlbruckner R, Krapfenbauer-Cermak CH, Hassan-Hauser CH, Smulders FJM. Mercury, lead and cadmium content of fresh and canned fish collected from Austrian retail operations. Ernährung/Nutrition. 2005;29(11):456–460.

34. Kral T, Blahova J, Sedlackova L, Kalina J, Svobodova Z. Mercury in canned fish from local markets in the Czech Republic. Food Additives and Contaminants: Part B Surveillance. 2017;10(2):149–154. https://doi.org/10.1080/19393210.2017.1284904

35. Ciecierska M, Obiedzinski M. Canned fish products contamination by polycyclic aromatic hydrocarbons. Acta Scientiarum Polonorum, Technologia Alimentaria. 2007;6(2):19–28.

36. Alturiqi AS, Albedair LA. Evaluation of some heavy metals in certain fish, meat and meat products in Saudi Arabian markets. Egyptian Journal of Aquatic Research. 2012;38(1):45–49. https://doi.org/10.1016/j.ejar.2012.08.003

37. Official Methods of Analysis. 18th Edition, Association of Official Analytical Chemists; 2005.

38. Turkmen M, Turkmen A, Tepe Y, Tore Y, Ates A. Determination of metals in fish species from Aegean and Mediterranean seas. Food Chemistry. 2009;113(1)233–237. https://doi.org/10.1016/j.foodchem.2008.06.071

39. Nascimento RS, Mendes DBC, Matos JMG, Silva JCJ, Ciminelli VST, Neto EB, *et al.* Determination of trace elements in Brazilian human milk by quadrupole inductively coupled plasma mass spectrometry and microwave-assisted digestion. Atomic Spectroscopy. 2008;29(3):77–82.

40. Shaheen N, Irfan NM, Khan IN, Islam S, Islam MS, Ahmed MK. Presence of heavy metals in fruits and vegetables: Health risk implications in Bangladesh. Chemosphere. 2016;152:431–438. https://doi.org/10.1016/j.chemosphere.2016.02.060

41. Heikens A. Arsenic contamination of irrigation water, soil and crops in Bangladesh: Risk implications for sustainable agriculture and food safety in Asia. Bangkok: Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific; 2006. 46 p.

42. Screening level ecological risks assessment protocol for hazardous waste combustion facilities. Appendix E: Toxicity reference values. USEPA; 1999. 98 p.

43. Wang X, Sato T, Xing B, Tao S. Health risks of heavy metals to the general public in Tianjin, China via consumption of vegetables and fish. Science of the Total Environment. 2005;350(1–3):28–37. https://doi.org/10.1016/j.scitotenv.2004.09.044

44. Islam MS, Ahmed MK, Habibullah-Al-Mamun M, Raknuzzaman M, Ali MM, Eaton DW. Health risk assessment due to heavy metal exposure from commonly consumed fish and vegetables. Environment Systems and Decisions. 2016;36(3):253–265. https://doi.org/10.1007/s10669-016-9592-7

45. Kormoker T, Idris AM, Khan MM, Tusher TR, Proshad R, Islam MS, *et al.* Spatial distribution, multivariate statistical analysis, and health risk assessment of some parameters controlling drinking water quality at selected primary schools located in the southwestern coastal region of Bangladesh. Toxin Reviews. 2022;41(1):247–260. https://doi.org/10.1080/15569543.2020.1866012

46. Sajeena BB, Jose PP, Madhu G. Effect of total solid concentration on anaerobic digestion of the organic fraction of municipal solid waste. International Journal of Scientific and Research Publications. 2013;3(8).

47. Tawfik MS. proximate composition and fatty acids profiles in most common available fish species in Saudi market. Asian Journal of Clinical Nutrition. 2009;1(1):50–57. https://doi.org/10.3923/ajcn.2009.50.57

48. Kelly Orhorhoro E, Okechukwu Ebunilo P, Ejuvwedia Sadjere G. Experimental Determination of effect of total solid (TS) and volatile solid (VS) on biogas yield. American Journal of Modern Energy. 2017;3(6):131–135. https://doi.org/10.11648/j.ajme.20170306.13

49. Mogobe O, Mosepele K, Masamba WRL. Essential mineral content of common fish species in Chanoga, Okavango Delta, Botswana. African Journal of Food Science. 2015;9(9):480–486. https://doi.org/10.5897/AJFS2015.1307

50. Ahmed MK, Parvin E, Islam MM, Akter MS, Khan S, Al-Mamun MH. Lead- and cadmium-induced histopathological changes in gill, kidney and liver tissues of fresh water climbing perch *Anabas testudineus* (Bloch, 1792). Chemistry and Ecology. 2014;30(6):532–540. https://doi.org/10.1080/02757540.2014.889123

51. Ashraf W, Seddigi Z, Abulkibash A, Khalid M. Levels of selected metals in canned fish consumed in Kingdom of Saudi Arabia. Environmental Monitoring and Assessment. 2006;117(1–3):271–279. https://doi.org/10.1007/s10661-006-0989-5

52. Mansilla-Rivera I, Rodríguez-Sierra CJ. Metal levels in fish captured in Puerto Rico and estimation of risk from fish consumption. Archives of Environmental Contamination and Toxicology. 2011;60(1):132–144. https://doi.org/10.1007/s00244-010-9538-x

53. Noël L, Chekri R, Millour S, Vastel C, Kadar A, Sirot V, *et al.* Li, Cr, Mn Co, Ni, Cu, Zn, Se and Mo levels in foodstuffs from the Second French TDS. Food Chemistry. 2012;132(3):1502–1513. https://doi.org/10.1016/j.foodchem.2011.12.009

54. Carvalho ML, Santiago S, Nunes ML. Assessment of the essential element and heavy metal content of edible fish muscle. Analytical and Bioanalytical Chemistry. 2005;382(2):426–432. https://doi.org/10.1007/s00216-004-3005-3

55. Tolerable Upper Intake Levels for vitamins and minerals. Parma: European Food Safety Authority; 2006. 482 p.

56. Storelli MM, Marcotrigiano GO. Total organic, and inorganic arsenic in some commercial species of crustaceans from the Mediterranean Sea (Italy). Journal of Food Protection. 2001;64(11):1858–1862. https://doi.org/10.4315/0362-028X-64.11.1858

57. Serbian regulation, maximum allowable contaminants in Food and Feed Act. 2014. Ministry of Agriculture; 2014.

58. Morgano MA, Rabonato LC, Milani RF, Miyagusku L, Quintaes KD. As, Cd, Cr, Pb and Hg in seafood species used for sashimi and evaluation of dietary exposure. Food Control. 2014;36(1):24–29. https://doi.org/10.1016/j.foodcont.2013.07.036

59. Millour S, Noe L, Chekri R, Vastel C, Kadar A, Sirot V, *et al.* Strontium, silver, tin, iron, tellurium, gallium, germanium, barium and vanadium levels in foodstuffs from the Second French Total Diet Study. Journal of Food Composition and Analysis. 2012;25(2):108–129. https://doi.org/10.1016/j.jfca.2011.10.004

60. Agusa T, Kunito T, Sudaryanto A, Monirith I, Kan-Atireklap S, Iwata H, *et al.* Exposure assessment for trace elements from consumption of marine fish in Southeast Asia. Environmental Pollution. 2007;145(3):766–777. https://doi.org/10.1016/j.envpol.2006.04.034

61. Onsanit S, Ke C, Wang X, Wang K-J, Wang W-X. Trace elements in two marine fish cultured in fish cages in Fujian province, China. Environmental Pollution. 2010;158(5):1334–1342. https://doi.org/10.1016/j.envpol.2010.01.012

62. Novakov NJ, Mihaljev ŽA, Kartalović BD, Blagojević BJ, Petrović JM, Ćirković MA, *et al*. Heavy metals and PAHs in canned fish supplies on the Serbian market. Food Additives and Contaminants: Part B Surveillance. 2017;10(3):208–215. https://doi.org/10.1080/19393210.2017.1322150

63. Ahmed MK, Ahamed S, Rahman S, Haque MR, Islam MM. Heavy metals concentration in water, sediments and their bioaccumulations in some freshwater fishes and mussel in Dhaleshwari River, Bangladesh. Terrestrial and Aquatic Environmental Toxicology. 2009;3(1):33–41.

64. Cheung KC, Leung HM, Wong MH. Metal concentrations of common freshwater and marine fish from the Pearl River Delta, South China. Archives of Environmental Contamination and Toxicology. 2008;54(4):705–715. https://doi.org/10.1007/s00244-007-9064-7

65. Nauen CE. Compilation of legal limits for hazardous substances in fish and fishery products. Rome: Food and Agriculture Organization of the United Nations; 1983. 102 p.

66. Rahman MS, Molla AH, Saha N, Rahman A. Study on heavy metals levels and its risk assessment in some edible fishes from Bangshi River, Savar, Dhaka, Bangladesh. Food Chemistry. 2012;134(4):1847–1854. https://doi.org/10.1016/j.foodchem.2012.03.099

67. Yılmaz AB, Sangün MK, Yaghoglu D, Turan C. Metals (major, essential to non-essential) composition of the different tissues of three demersal fish species from Iskenderun Bay, Turkey. Food Chemistry. 2010;123(2):410–415. https://doi.org/10.1016/j.foodchem.2010.04.057

68. Storelli MM, Giacominelli-Stuffler R, Storelli A, Marcotrigiano GO. Accumulation of mercury, cadmium, lead and arsenic in Swordfish and Bluefin tuna from the Mediterranean Sea: A comparative study. Marine Pollution Bulletin. 2005;50(9):1004–1007. https://doi.org/10.1016/j.marpolbul.2005.06.041

69. Santos EE, Lauria DC, Porto Da Silveira CL. Assessment of daily intake of trace elements due to consumption of foodstuffs by adult inhabitants of Rio de Janeiro city. Science of the Total Environment. 2004;327(1–3):69–79. https://doi.org/10.1016/j.scitotenv.2004.01.016

70. Elnabris KJ, Muzyed SK, El-Ashgar NM. Heavy metal concentrations in some commercially important fishes and their contribution to heavy metals exposure in Palestinian people of Gaza Strip (Palestine). Journal of the Association of Arab Universities for Basic and Applied Sciences. 2013;13(1):44–51. https://doi.org/10.1016/j.jaubas.2012.06.001
71. Mustafa RA Role Medicinal Plant Extracts Glossostemon bruguieri and (Moghat) On Bio-Yogurt Quality During Storage. International Journal of Advanced Science and Technology. 2020;29(11):3341–3352.
72. Mandal BK, Suzuki KT. Arsenic round the world: A review. Talanta. 2002;58(1):201–235. https://doi.org/10.1016/S0039-9140(02)00268-0
73. Assessment of the tolerable daily intake of barium. European Union, 2012. 13 p. https://doi.org/10.2772/49651
74. Manganese. In: Recommended dietary allowances: 10th ed. Washington: National Academies Press; 1989. pp. 230–235. https://doi.org/10.17226/1349
75. Guidelines for drinking-water quality. Vol. 2, Health criteria and other supporting information, 2nd ed. Geneva: World Health Organization; 1996.
76. Kortei NK, Heymann ME, Essuman EK, Kpodo FM, Akonor PT, Lokpo SY, *et al.* Health risk assessment and levels of toxic metals in fishes (*Oreochromis noliticus* and *Clarias anguillaris*) from Ankobrah and Pra basins: Impact of illegal mining activities on food safety. Toxicology Reports. 2020;7:360–369. https://doi.org/10.1016/j.toxrep.2020.02.011
77. Thakur J, Mhatre M. Bioaccumulation of heavy metals in Tilapia mossambicus fish from industrially polluted Patalganga River, India. International Journal of Advanced Research. 2015;3(2):486–490.

ORCID IDs

Md Saiful Islam https://orcid.org/0000-0002-3598-0315
Ramal Ahmed Mustafa https://orcid.org/0000-0002-1071-9022