European Journal of Nutrition & Food Safety

Volume 17, Issue 1, Page 33-43, 2025; Article no.EJNFS.128959
ISSN: 2347-5641

Estimation of Some Heavy Metals in Different Types of Canned Tuna in the Egyptian Market

Naglaa A. El-Senousi [a], Ibrahim M. Ibrahim [b*], Mai M. Elkordy [a] and Shaimaa E. Abd El-Hamed [a]

[a] Department of Meat and Fish Technology Research, Agricultural Research Center, Egypt.
[b] Department of Special Food Research, Agricultural Research Center, Egypt.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ejnfs/2025/v17i11617

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/128959

Original Research Article

Received: 01/11/2024
Accepted: 30/12/2024
Published: 06/01/2025

ABSTRACT

Fish is a high-quality food, but it can contain toxic heavy metals that accumulate in its tissues, posing a risk to human health as it is at the end of the food chain. These metals threaten public health due to their toxicity and ability to accumulate in tissues, leading to the depletion of essential nutrients, psychological and social problems, weakened immunity, delayed growth, increased risk of gastrointestinal cancer, and disabilities resulting from malnutrition. This study aimed to measure and compare the content of heavy metals (lead, cadmium, nickel, mercury, tin, copper, manganese and chromium) in five brands of canned tuna and its three types (shredded, chunks, and one-piece) in the Egyptian market. Heavy metal concentrations were generally below safe limits except for nickel in one of the samples, but HQ (the target hazard quotient) and HI (the total target hazard

---

**Corresponding author: Email: ibr23ibr23@yahoo.com;*

Cite as: *El-Senousi, Naglaa A., Ibrahim M. Ibrahim, Mai M. Elkordy, and Shaimaa E. Abd El-Hamed. 2025. "Estimation of Some Heavy Metals in Different Types of Canned Tuna in the Egyptian Market". European Journal of Nutrition & Food Safety 17 (1):33-43. https://doi.org/10.9734/ejnfs/2025/v17i11617.*

quotient) still showed no significant health risk. Based on the results, it can be concluded that no major health risks were identified for consumption of canned tuna from these five brands in the Egyptian market.

Keywords: Canned tuna; heavy metals; lead; cadmium; nickel; dietary risk; Egyptian market.

1. INTRODUCTION

Red and white meats, including fish and seafood, are among the most popular foods (Rose, 2023). The latter is quick and easy to prepare, and it is a traditional dish enjoyed in many regions around the world. Health professionals often recommend it as part of a healthy and balanced diet (Li & Hsieh, 2004). Fish and seafood are very nutritious. They have many vitamins, proteins, and essential amino acids. They also contain omega-3 fatty acids and important minerals (Mei et al., 2019; Machate et al., 2020; de Lima et al., 2021). Consumption of seafood products is known to have many health benefits, including a reduced risk of cardiovascular and autoimmune disorders (Khalili & Sampels, 2018). The canning process increases the shelf life of the canned product by many years. However, producers, nutritionists, chefs and customers are particularly interested in the composition of fish because they want to know its nutritional contribution to a healthy diet (Tarley et al., 2004). Canned fish is very popular in Egypt because it is convenient and inexpensive for most working families. In both developed and developing countries around the world, canned fish is the most popular processed fish product. Tuna is one of the most widely consumed fish species used in canned products (Storelli et al., 2010). This product is manufactured by processing fish meat and preserving it by canning with the addition of edible oils and/or brine and undergoing commercial sterilization according to the Egyptian Standards and Metrology Organization (Egyptian Standards, 2005). However, fish are exposed to contaminants from heavy metals in the water due to human activity (Steinhausen et al., 2021; Rakib et al., 2022). Food can contain harmful heavy metals like mercury, tin, cadmium, lead, copper, nickel, manganese, and chromium. These metals are known to negatively affect human health (El-Sayed & Ali, 2020; Liu et al., 2023) because, they may accumulate in bodily tissues and travel up the food chain to people (Aytekin et al., 2019). According to (Altınok-Yipel et al., 2022), fish and fish products are the most affected members of the food chain because they are constantly exposed to pollutants such as toxic heavy metals through polluted water, especially tuna because they are predators and have a long life span (Chen et al., 2012). Consumption of food polluted with heavy metals can substantially deplete several vital minerals in the human body, causing poor psychosocial behavior, loss in immunological defenses, intrauterine development retardation, high prevalence of upper gastrointestinal cancer and disabilities associated with malnutrition (Arora et al., 2008). Over the last decade, significant research has concentrated on detecting levels of heavy and toxic metals in water and food, notably examining contamination of food sources, including canned goods such as tuna, with the goal of assuring food safety (Tuzen & Soylak, 2007; Storelli et al., 2010). Moreover, it is imperative to assess the concentration of potentially toxic elements in canned fish to guarantee the safety of the fish protein provided to consumers and to elucidate the adverse effects of canned fish consumption on individuals and populations. Given the lack of knowledge about the mineral elements in canned tuna available in the Egyptian market, as well as the close relationship between seafood consumption and associated health effects, whether beneficial or harmful, determining the amounts of harmful heavy metals and essential minerals is critical. The current study was undertaken to give fresh information concerning several heavy metal elements (lead, cadmium, nickel, mercury, tin, copper, manganese, and chromium) in five distinct brands on the Egyptian market. Each brand offers three forms of tuna: shredded tuna, chunks, and one-piece.

2. MATERIALS AND METHODS

Chemicals and reagents: All chemicals utilized were of analytical grade.

Sample collection: Forty-five samples of canned tuna from five brands were examined to determine the concentration of heavy metals in them. The samples were collected during 2023-2024 from Egyptian supermarkets located in Elshiekh Zayed -Giza (Egypt) due to the region's dense population, canned tuna is consumed in large quantities there. Canned tuna fish were examined after each can was opened, drained of oil, and then homogenized.

Preparation of the samples for determination heavy metals: The microwave (closed system) was used for digestion of samples according to (European Commission, 2014). Briefly, a 1 g of homogenized sample was weighted and transferred in the PTFE vessels for microwave digestion. Subsequently, 9 ml of nitric acid (69%) and 1 ml H_2O_2 were added to the sample. The vessel was securely sealed and placed in the microwave until digestion was complete. Digestion was performed in the microwave oven by temperature-controlled program: heating to 200 °C for 15 min, holding time 15 min, cooling to 85 °C for 15 min. After cooling to room temperature, the content of the vessel was transferred to a volumetric flask (25 mL) and diluted with ultrapure water to the mark, then ready for analysis by Atomic Absorption.

Determination of heavy metals: Heavy metals like Pb, Cd, Ni, Sn , Cu, Mn and Cr were determined using atomic absorption spectrophotometer ICE 3500 series (Thermo) at Food Toxicology and Contaminants Department, National Research Centre according to (Abdel-Rahman et al., 2018). Hg was determined using ICP (Inductively Coupled Plasma Emission Spectrometer, iCAP 6200, Central Laboratory - National Research Center.

Human health risk assessment: The potential health risks associated with heavy metal contamination of canned tuna were estimated as EDI, HQ, and HI.

EDI: Estimated daily intake (mg/day); HQ: Hazard quotient; HI: Hazard index

Estimated Daily Intake (EDI): For heavy metals detected through fish consumption by the Egyptian population were calculated according to (Pappalardo et al., 2017) based on the following equation:

$$EDI\ (mg/day) = Cm*FIR/BW$$

Where:

Cm is the concentration of the tested metal (mg/kg ww)
FIR is the rate of fish intake by the Egyptian population, which established at 48.57 g/day (FAO, 2010).
BW: adult Egyptian body weight is 70 kg.

The non-carcinogenic hazard quotient (HQ): HQ (hazard quotient for each element) for the tested heavy metals was calculated based on the following equation from (Guo et al., 2016).

$$HQ = (EDI/RFD)*10^{-3}$$

Where:

RFD is the oral reference dose and its values are shown in Table 1.

The carcinogenic hazard quotient (HI): HI (the total target hazard quotient or cancer-causing risk quotient for all elements under study) was calculated from the following equation:

$$HI = \sum HQi$$

Where: i represents each metal

Statistical analyses: Duncan's test was used to compare the means of the different species for each brand at ($p < 0.05$) using the statistical program SPSS 16.

3. RESULTS AND DISCUSSION

This study aimed to estimate heavy metal elements in five brands of canned tuna available in Egyptian markets. All samples were taken during the period 2023-2024, with three types of canned tuna: Shredded, chunks, and one-piece. Table 2 are shown the concentrations of the heavy metals as follows: lead, cadmium, nickel, mercury, tin, copper, manganese, and chromium. Table 2 data indicate that lead concentrations in five tuna brands ranged from (<d.l.) to 0.103 mg/kg, without exceeding the permissible limit (0.3 mg/kg) according to EC regulations (European Commission, 2006). Based on the daily intake of lead (calculated on an idealized body weight of 70 kg and a daily consumption of 48.5 g tuna), the maximum daily dose (0.071 mg/day) was less than one-third of the permissible limit (0.3 mg/day), confirming the safety of the brands. Elevated levels of lead may be due to water pollution caused by mining and industrial activities, which can cause serious health effects on the heart, kidney, and nervous system with chronic consumption (Institute of Medicine, 2001; World Health Organization, 2008).

Table 1. Values of recommended reference dose (RFD) for equation 2 according Mistretta and Durkin (Mistretta & Durkin, 2006)

Heavy metal	Pb	Cd	Ni	Hg	Sn	Cu	Mn	Cr
RFD	0.0035	0.001	0.002	0.001	0.0003	0.04	0.14	0.003

RFD: oral recommended reference dose

Table 2 Heavy metals concentration (mg/kg fresh tuna) in studied tuna brand samples collected from Egypt markets

		Pb	Cd	Ni	Hg	Sn	Cu	Mn	Cr
Brand 1	Shredded (SB1)	0.049^{C} ± 0.002	0.0024^{b} ± 0.001	0.341^{b} ± 0.019	0.073^{b} ±0.002	0.119^{a} ± 0.011	1.770^{a} ± 0.027	0.333^{a} ± 0.008	0.111^{b} ± 0.039
	Chunk (CB1)	0.103^{a} ±0.007	0.005^{a} ± 0.001	0.216^{C} ± 0.016	0.050^{c} ±0.002	0.098^{b} ± 0.007	0.527^{c} ± 0.015	0.074^{b} ± 0.006	0.123^{a} ± 0.041
	One piece (OB1)	0.070^{b} ±0.002	0.002^{b} ± 0.000	0.452^{a} ± 0.021	0.093^{a} ± 0.001	0.070^{c} ± 0.005	0.596^{b} ± 0.024	<d.l.	0.113^{b} ± 0.042
Brand 2	Shredded (SB2)	<d.l.	<d.l.	0.164^{a} ± 0.010	<d.l.	0.022^{b} ± 0.002	0.874^{a} ± 0.021	0.303^{a} ± 0.008	0.122^{c} ± 0.037
	Chunk (CB2)	<d.l.	<d.l.	0.157^{a} ± 0.006	<d.l.	0.049^{a} ± 0.003	0.679^{c} ± 0.014	0.092^{b} ± 0.006	0.146^{b} ± 0.031
	One piece (OB2)	<d.l.	<d.l.	0.128^{b} ± 0.004	0.024^{a} ± 0.001	0.025^{b} ± 0.002	0.806 ^{b} ± 0.017	0.005^{c} ± 0.001	0.163^{a} ± 0.048
Brand 3	Shredded (SB3)	0.097^{a} ± 0.003	0.007^{a} ± 0.001	0.235^{a} ± 0.009	0.049^{c} ± 0.001	0.073^{b} ± 0.004	1.210^{a} ± 0.0230	0.036^{b} ± 0.002	0.164^{a} ± 0.050
	Chunk (CB3)	0.068^{b} ± 0 .002	0.005^{b} ± 0.000	0.043^{b} ± 0.005	0.068^{b} ± 0.001	0.091^{a} ± 0.003	0.698^{c} ± 0.022	<d.l.	0.146^{b} ± 0.034
	One piece (OB3)	0.049^{c} ± 0.001	0.003^{c} ± 0.000	0.022^{c} ± 0.003	0.074^{a} ± 0.001	0.025^{c} ± 0.002	0.763^{b} ± 0.011	0.076^{a} ± 0.004	0.163^{a} ± 0.031
Brand 4	Shredded (SB4)	<d.l.	<d.l.	1.017^{a} ± 0.009	<d.l.	0.044^{c} ± 0.003	1.177^{a} ± 0.027	0.239^{a} ± 0.010	0.144^{b} ± 0.039
	Chunk (CB4)	<d.l.	<d.l.	0.278^{c} ± 0.013	<d.l.	0.085^{a} ± 0.005	0.815^{c} ± 0.014	<d.l.	0.147^{b} ± 0.031
	One piece (OB4)	<d.l.	<d.l.	0.456^{b} ± 0.014	0.025^{a} ± 0.001	0.075^{b} ± 0.004	1.059^{b} ± 0.029	0.127^{b} ± 0.006	0.171^{a} ± 0.049
Brand 5	Shredded (SB5)	0.063^{b} ± 0.002	0.004^{b} ± 0.000	0.277^{b} ± 0.012	0.042^{b} ± 0.001	0.042^{a} ± 0.004	0.803^{b} ± 0.016	0.070^{a} ± 0.005	0.154^{b} ± 0.034
	Chunk (CB5)	0.093^{a} ± 0.002	0.007^{a} ± 0.000	0.133^{c} ± 0.005	0.023^{c} ± 0.001	0.023^{b} ± 0.002	0.828^{b} ± 0.013	<d.l.	0.170^{a} ± 0.044
	One piece (OB5)	<d.l.	<d.l.	0.425^{a} ± 0.007	0.071^{a} ± 0.001	0.048^{a} ± 0.004	1.080^{a} ± 0.019	0.042^{b} ± 0.005	0.163^{a} ± 0.034

Different small letters in the same column for one brand indicate significant differences among types (p<0.05)
<d.l. below detection limit

The cadmium concentrations in the samples ranged from (< dL) to 0.00723 mg/kg, which is well below the maximum permissible limit (0.05 mg/day) according to the regulations (European Commission, 2006), so all samples from Egyptian brands were within safe limits. Cadmium is a highly toxic pollutant (Jarup, 2003), as the European Union sets a maximum limit for it in fish ten times lower than mercury, as it poses a serious health risk due to its accumulation in tissues, which affects the kidneys and bones, damages the nervous and respiratory systems, and disrupts endocrine and reproductive functions. It also increases the risk of cancer and birth defects.

Nickel concentrations were measured in canned tuna, ranging from 0.022 to 1.017 mg/kg. The lowest level of nickel was recorded in canned tuna grade 3 (single piece) at 0.022 mg/kg, while the highest level was recorded in canned tuna grade 4 (shredded) at 1.017 mg/kg. Although the human body only absorbs about 10% of the nickel found in food, high levels of this metal may negatively affect the absorption of essential nutrients such as magnesium, manganese and zinc. According to the studies, the concentration of nickel in canned tuna from Saudi Arabia was between 0.09 and 0.48 mg/kg, while in Turkish fish it ranged from 0.03 to 0.63 mg/kg. In Iraq, the concentration of nickel in canned fish was very low, ranging from 0.0001 to 0.0003 mg/kg (Areej et al., 2012), while in Iraqi fish muscle it was between 0.11 and 0.31 mg/kg (Yesser et al., 2013). In summary, nickel concentrations in tuna and canned fish vary depending on the source and variety, and high levels may affect human health.

Related studies showed that large predatory fish such as tuna are important sources of human exposure to toxic forms of mercury (Jinadasa et al., 2021). Mercury is a heavy metal known to be toxic. Aquatic organisms that grow in polluted waters contain it in their tissues. Mercury poisoning or ingestion can have serious consequences for the brain, immune system, digestive system, lungs, and kidneys and can be fatal. When ingested, inorganic mercury salts can poison the kidneys and damage the skin, eyes, and digestive system (Bernhoft, 2012). It also has some other harmful consequences, including decreased hearing and vision, dizziness, nausea, muscle weakness, allergies, weakened immune system, kidneys, and cardiovascular system, brain damage, and even death (Risher, 2003). Mercury concentrations ranged from below the limit of detection (<d.l.) to 0.0933 mg/kg. The highest amount of mercury in this study was 0.093 mg/kg in the one-piece sample from Brand 1, which is four times higher than the lowest amount of 0.023 mg/kg recorded in Brand 5 chunk.

The tin concentration ranged from 0.022 to 0.098 mg/kg in different tuna samples. This may be attributed to corrosion of the can material, which results in the leaching of tin into the fish flesh and subsequently into the human body. Tin has been demonstrated to induce metabolic disruptions in essential elements, including zinc (Zn), copper (Cu), and iron (Fe). Additionally, it has been shown to diminish the calcium content of bones and to cause damage to organs, particularly the kidneys (Rader, 1991).

Copper concentrations exhibited a range of 0.527 to 1.771 mg/kg, while manganese concentrations demonstrated a range of < d.l. to 0.333 mg/kg. Chromium concentrations also exhibited a range of 0.111 to 0.171 mg/kg. It was found that none of the brands or types exceeded the maximum permissible limits for any of the other heavy metal elements, namely copper, manganese, or chromium.

Fig. 1 shows the differences in the content of heavy elements in tuna samples between the different types (shredded, chunk, and one-piece) of the five tuna brands under study. For the three elements that represent the highest concentration in tuna, namely copper, followed by nickel and manganese, it is noted that the concentration of these elements is higher in the shredded types than in one-piece samples. While the chunk samples were the lowest in the concentration of the three elements. Although the concentration of copper was the highest among all heavy metal elements, its concentration was lower than the UK Ministry of Agriculture and Food's reference value of 30 mg Cu/kg (Collings et al., 1996). It is considered a vital element for optimal health; however, excessive intake can lead to adverse health effects, including liver and kidney damage (Zhu et al., 2011). As for the other five elements, namely chromium, tin, mercury, lead and cadmium, their concentration varied from one species to another as shown in the Fig. 1, and generally their concentration was less than 0.2 ppm in tuna samples of the three different types (shredded, chunk, and one-piece).

Table 3. The estimated intake by mg /kg body weight of toxic elements per day and its comparison with the permissible limits

		Estimated intake by mg /kg body weight /d							
		Pb	**Cd**	**Ni**	**Hg**	**Sn**	**Cu**	**Mn**	**Cr**
Brand 1	Shredded (SB1)	0.0005	0.0000	0.0034	0.0007	0.0012	0.0176	0.0033	0.0011
	Chunk (CB1)	0.0010	0.0001	0.0021	0.0005	0.0010	0.0052	0.0007	0.0012
	One piece (OB1)	0.0007	0.0000	0.0045	0.0009	0.0007	0.0059	0.0000	0.0011
Brand 2	Shredded (SB2)	0.0000	0.0000	0.0016	0.0000	0.0002	0.0087	0.0030	0.0012
	Chunk (CB2)	0.0000	0.0000	0.0016	0.0000	0.0005	0.0067	0.0009	0.0014
	One piece (OB2)	0.0000	0.0000	0.0013	0.0002	0.0002	0.0080	0.0000	0.0016
Brand 3	Shredded (SB3)	0.0010	0.0001	0.0023	0.0005	0.0007	0.0120	0.0004	0.0016
	Chunk (CB3)	0.0007	0.0000	0.0004	0.0007	0.0009	0.0069	0.0000	0.0015
	One piece (OB3)	0.0005	0.0000	0.0002	0.0007	0.0002	0.0076	0.0008	0.0016
Brand 4	Shredded (SB4)	0.0000	0.0000	0.0101	0.0000	0.0004	0.0117	0.0024	0.0014
	Chunk (CB4)	0.0000	0.0000	0.0028	0.0000	0.0008	0.0081	0.0000	0.0015
	One piece (OB4)	0.0000	0.0000	0.0045	0.0002	0.0007	0.0105	0.0013	0.0017
Brand 5	Shredded (SB5)	0.0006	0.0000	0.0027	0.0004	0.0004	0.0080	0.0007	0.0015
	Chunk (CB5)	0.0009	0.0001	0.0013	0.0002	0.0002	0.0082	0.0000	0.0017
	One piece (OB5)	0.0000	0.0000	0.0042	0.0007	0.0005	0.0107	0.0004	0.0016
Maximum permissible limits daily intake		0.004[ad]	0.001[a]	0.007-0.008[c]	0.007[cd]	0.004[cd]	0.429[b]	0.029-0.071[d]	0.003-0.005[ad]

[a]EC(2006) [b]FAO (2006), [c]WHO (2008), [d]EOS(2010)

Table 4. Estimated daily intake (EDI, mg/day) of heavy metals in examined canned tuna samples collected from Egypt markets

		Estimated daily intake (EDI)of heavy metals(mg/d)							
		Pb	**Cd**	**Ni**	**Hg**	**Sn**	**Cu**	**Mn**	**Cr**
Brand 1	Shredded (SB1)	0.034	0.002	0.237	0.050	0.083	1.229	0.231	0.077
	Chunk (CB1)	0.071	0.004	0.150	0.035	0.068	0.365	0.052	0.086
	One piece (OB1)	0.049	0.002	0.314	0.065	0.049	0.414		0.079
Brand 2	Shredded (SB2)			0.114		0.015	0.607	0.210	0.085
	Chunk (CB2)			0.109		0.034	0.472	0.064	0.101
	One piece (OB2)			0.089	0.017	0.017	0.559	0.003	0.113
Brand 3	Shredded (SB3)	0.067	0.005	0.163	0.034	0.051	0.840	0.025	0.114
	Chunk (CB3)	0.047	0.003	0.030	0.047	0.063	0.485		0.102
	One piece (OB3)	0.034	0.002	0.015	0.051	0.017	0.530	0.053	0.113
Brand 4	Shredded (SB4)			0.705		0.031	0.817	0.166	0.100
	Chunk (CB4)			0.193		0.059	0.566		0.102
	One piece (OB4)			0.317	0.017	0.052	0.735	0.088	0.119
Brand 5	Shredded (SB5)	0.044	0.003	0.192	0.029	0.029	0.557	0.049	0.107
	Chunk (CB5)	0.064	0.005	0.092	0.016	0.016	0.574		0.119
	One piece (OB5)			0.295	0.049	0.033	0.749	0.029	0.114
Maximum tolerable daily intake		0.3[ad]	0.1[a]	0.5-0.6[c]	0.5[cd]	0.3[cd]	30[b]	2.0-5.0[d]	0.2-0.5[ad]

[a]EC(2006) [b]FAO (2006), [c]WHO (2008), [d]EOS(2010)

Table 5. Estimated weekly intake (EWI mg/kg/week) of metals in examined canned tuna samples collected from Egypt markets

		Estimated weekly intakes							
		Pb	**Cd**	**Ni**	**Hg**	**Sn**	**Cu**	**Mn**	**Cr**
Brand 1	Shredded (SB1)	0.238	0.012	1.656	0.353	0.579	8.600	1.615	0.540
	Chunk (CB1)	0.499	0.025	1.049	0.242	0.476	2.558	0.362	0.599
	One piece (OB1)	0.340	0.011	2.195	0.453	0.342	2.896	0.000	0.551
Brand 2	Shredded (SB2)	0.000	0.000	0.795	0.000	0.107	4.246	1.470	0.593
	Chunk (CB2)	0.000	0.000	0.764	0.000	0.238	3.301	0.448	0.710
	One piece (OB2)	0.000	0.000	0.623	0.118	0.119	3.916	0.024	0.794
Brand 3	Shredded (SB3)	0.471	0.035	1.143	0.236	0.355	5.878	0.175	0.798
	Chunk (CB3)	0.330	0.022	0.210	0.332	0.442	3.392	0.000	0.712
	One piece (OB3)	0.240	0.012	0.107	0.358	0.121	3.707	0.371	0.794
Brand 4	Shredded (SB4)	0.000	0.000	4.938	0.000	0.215	5.718	1.161	0.703
	Chunk (CB4)	0.000	0.000	1.350	0.000	0.414	3.960	0.000	0.716
	One piece (OB4)	0.000	0.000	2.216	0.121	0.364	5.144	0.617	0.831
Brand 5	Shredded (SB5)	0.306	0.020	1.344	0.205	0.204	3.902	0.341	0.750
	Chunk (CB5)	0.450	0.034	0.644	0.112	0.112	4.020	0.000	0.830
	One piece (OB5)	0.000	0.000	2.062	0.343	0.231	5.246	0.205	0.795
Maximum tolerable weekly intake		2.1^{ad}	0.7^{a}	$3.5\text{-}4.2^{c}$	3.5^{cd}	2.1^{cd}	210.0^{b}	$14\text{-}35^{d}$	$1.4\text{-}3.5^{ad}$

[a]EC(2006) [b]FAO (2006), [c]WHO (2008), [d]EOS(2010)

Table 6. The health risk assessment of heavy metals due to consumption of tuna samples collected from Egypt markets

		HQ								HI
		Pb	**Cd**	**Ni**	**Hg**	**Sn**	**Cu**	**Mn**	**Cr**	
Brand 1	Shredded (SB1)	0.008	0.001	0.118	0.050	0.019	0.031	0.002	0.026	0.255
	Chunk (CB1)	0.017	0.002	0.075	0.035	0.016	0.009	0.000	0.029	0.182
	One piece (OB1)	0.011	0.001	0.157	0.065	0.011	0.010		0.026	0.282
Brand 2	Shredded (SB2)			0.057		0.004	0.015	0.002	0.028	0.105
	Chunk (CB2)			0.055		0.008	0.012	0.000	0.034	0.109
	One piece (OB2)			0.045	0.017	0.004	0.014	0.000	0.038	0.117
Brand 3	Shredded (SB3)	0.016	0.004	0.082	0.034	0.012	0.021	0.000	0.038	0.206
	Chunk (CB3)	0.011	0.002	0.015	0.047	0.015	0.012		0.034	0.136
	One piece (OB3)	0.008	0.001	0.008	0.051	0.004	0.013	0.000	0.038	0.123
Brand 4	Shredded (SB4)			0.353		0.007	0.020	0.001	0.033	0.415
	Chunk (CB4)			0.096		0.014	0.014		0.034	0.158
	One piece (OB4)			0.158	0.017	0.012	0.018	0.001	0.040	0.246
Brand 5	Shredded (SB5)	0.010	0.002	0.096	0.029	0.007	0.014	0.000	0.036	0.194
	Chunk (CB5)	0.015	0.003	0.046	0.016	0.004	0.014		0.040	0.138
	One piece (OB5)			0.147	0.049	0.008	0.019	0.000	0.038	0.261

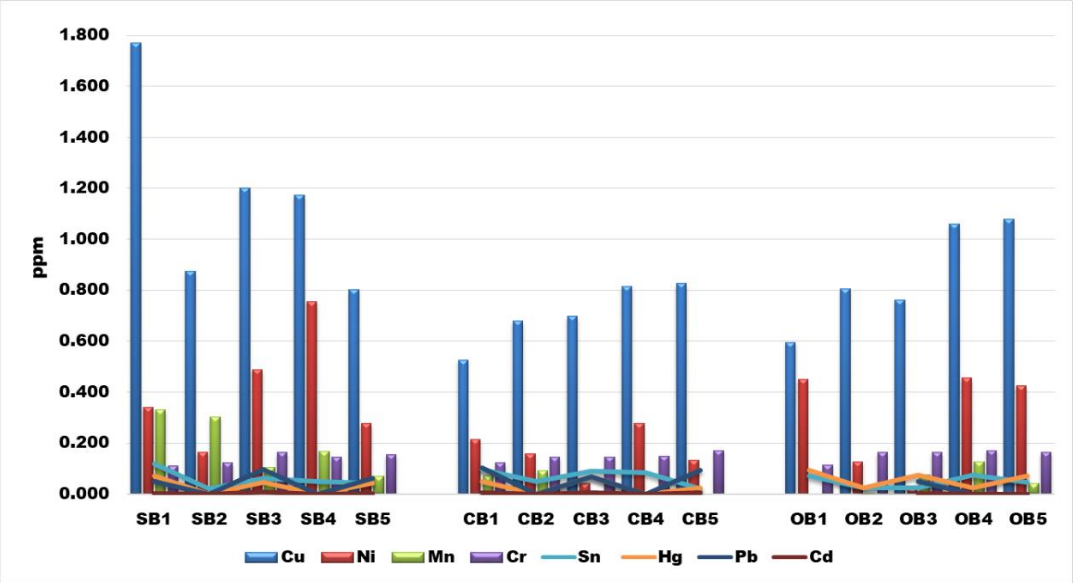

Fig. 1. Comparing shredded, chunk, one piece, heavy metals concentrations (ppm) for different brands of examined canned tuna samples

It is clear from Table 3 that all heavy metal elements in tuna were below the permissible limits for consumption per mg/kg of body weight, except for the element nickel in the shredded sample of the brand four (0.0101 mg/kg), which exceeded the permissible limits per kg of body weight by (0.007-0.008 mg/kg) according to (World Health Organization, 2008). Exceeding the permissible limits leads to the possibility of considering the possibility of allergic reactions or eczema caused by sudden oral exposure. Differences in immune response between individuals with nickel allergy should be taken into account (European Food Safety Authority, 2014).

Tables 4, 5 shows the estimated daily amounts and estimated weekly intakes of potential toxic elements (in milligrams per day/week) in the five most popular canned tuna fish in the Egyptian market, which were included in our study. The results indicate that the total daily or weekly amount of heavy toxic elements was below the maximum allowable limit for consumption according (European Commission, 2006; FAO, 2006; World Health Organization, 2008; Egyptian Organization for Standardization, 2010), except for the nickel in shredded sample of brand 4 was increased about the maximum tolerable daily or weekly intake of nickel (0.5-0.6 mg daily) or (3.5-4.2mg weekly) according to (World Health Organization, 2008). Although the estimated total daily intake was low due to low consumption of canned fish, long-term consumption of contaminated canned fish may lead to significant health repercussions. Due to the low consumption of canned fish in Egypt (48.5 grams per day), the estimated daily/weekly intake was below the maximum allowable consumption limit.

The literature suggests a high likelihood of human exposure to pollutants from food, which can be evaluated using HQ (the target hazard quotient or non-cancer risk quotient) calculation. If the HI (the total target hazard quotient or cancer-causing risk quotient) is less than 1, the food does not cause acute adverse health effects (Djedjibegovic et al., 2020). In Table 6 considering each element individually, the value of the target risk quotient (HQ) did not exceed the standard value (>1) for any of the five brands or types (shredded, chunks, and one piece), therefore no concern or adverse effects are associated with the consumption of canned tuna from these five brands or types in Egypt. The total target hazard quotient (HI) for the various metals was less than 1, which means they are not capable of causing carcinogenic risks. Based on the results, the concentrations of the heavy metals under study are within the permissible limits for lead, cadmium, mercury, mercury, nickel, tin, copper, manganese, and chromium. The HI values for all metals were also below the safe limits. Therefore, it can be concluded that the target population may not have potential significant health risks through the consumption of canned tuna fish.

4. CONCLUSION

Fish products are a staple of a healthy human diet, but they can sometimes carry health risks due to the heavy metals they contain. Tuna is one of the most prominent predatory fish that is a major source of these metals in the human diet. The concentrations of heavy metals were analyzed in five different brands of tuna available in the Egyptian market, where each brand included three different types of tuna. The results showed that the concentration of heavy metals in all samples did not exceed the permissible limits (>1) for the non-carcinogenic risk quotient value for each element individually (HQ) or for the carcinogenic risk quotient value for the total elements (HI) under study in all five brands and their three types (shredded, chunks, and one piece). Thus, there are no health risks or adverse effects associated with the consumption of canned tuna from these brands in Egypt, as they do not pose a threat of developing any chronic diseases or cancers.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Abdel-Rahman, G. N., Ahmed, M. B. M., Saleh, E. M., & Fouzy, A. S. M. (2018). Estimated heavy metal residues in Egyptian vegetables in comparison with previous studies and recommended tolerable limits. *Journal of Biological Sciences, 18*(3), 135–143. https://doi.org/10.3923/jbsci.2018.135.143

Altınok-Yipel, F., Yipel, M., & Tekeli, İ. O. (2022). Health risk assessment of essential and toxic metals in canned/pouched food on kitten and adult cats: An animal health risk assessment adaptation assay. *Biological Trace Element Research, 200*, 1937–1948. https://doi.org/10.1007/s12011-021-02749-4

Areej, A., Adem, K., & Angham, A. A. (2012). Determination of mercury, nickel, and copper in some types of canned fish and meat. *Basrah Journal of Veterinary Research, 11*(2), 1–9.

Arora, M., Kiran, B., Rani, S., Rani, A., Kaur, B., & Mittal, N. (2008). Heavy metal accumulation in vegetables irrigated with water from different sources. *Food Chemistry, 111*, 811–815. https://doi.org/10.1016/j.foodchem.2008.04.029

Aytekin, T., Kargın, D., & Çoğun, H. Y. (2019). Accumulation and health risk assessment of heavy metals in tissues of the shrimp and fish species from the Yumurtalık coast of Iskenderun Gulf, Turkey. *Heliyon, 5*, e02131. https://doi.org/10.1016/j.heliyon.2019.e02131

Bernhoft, R. A. (2012). Mercury toxicity and treatment: A review of the literature. *Journal of Environmental and Public Health, 2012*, 460508. https://doi.org/10.1155/2012/460508

Chen, C. Y., Driscoll, C. T., Lambert, K. F., Mason, R. P., Rardin, L. R., Schmitt, C. V., Serrell, N. S., & Sunderland, E. M. (2012). Sources to seafood: Mercury pollution in the marine environment. In *Toxic Metals Superfund Research Program*, Dartmouth College, Hanover, NH.

Collings, S. E., Johnson, M. S., & Leah, R. T. (1996). Metal contamination of angler-caught fish from the Mersey Estuary. *Marine Environmental Research, 41*(3), 281–297. https://doi.org/10.1016/0141-1136(96)00055-4

de Lima, N. V., Granja Arakaki, D., Melo, E. S. D. P., Machate, D. J., & do Nascimento, V. A. (2021). Assessment of trace elements supply in canned tuna fish commercialized for human consumption in Brazil. *International Journal of Environmental Research and Public Health, 18*, 12002. https://doi.org/10.3390/ijerph181212002

Djedjibegovic, J., Marjanovic, A., Tahirovic, D., Caklovica, K., Turalic, A., Lugusic, A., Omeragic, E., Sober, M., & Caklovica, F. (2020). Heavy metals in commercial fish and seafood products and risk assessment in the adult population in Bosnia and Herzegovina. *Scientific Reports, 10*(1), 13238. https://doi.org/10.1038/s41598-020-70205-9

Egyptian Organization for Standardization. (2010). Maximum levels for certain contaminants in foodstuffs. No 7136/2010. Egyptian Standards, Ministry of Industry, Egypt.

Egyptian Standards. (2005). Canned tuna and bonito and canned sardine. Egyptian Organization for Standardization and Quality, Arab Republic of Egypt. No. 804 and 287.

El-Sayed, M., & Ali, A. M. (2020). Heavy metals content in canned tuna fish marketed in Assiut City, Egypt and its related human health risk assessment. *Assiut Veterinary Medical Journal, 66*(165), 1–20.

European Commission. (2006). Commission Regulation No. 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. *Official Journal of the European Union*, 20.12.2006.

European Commission. (2014). Commission Regulation (EU) No 488/2014 of 12 May 2014 amending Regulation (EC) No 1881/2006 as regards maximum levels of cadmium in foodstuffs. *Official Journal of the European Communities, 138*, 75–79.

European Food Safety Authority. (2014). Scientific opinion on the risks to public health related to the presence of chromium in food and drinking water. *EFSA Journal, 9*, 11–25. https://doi.org/10.2903/j.efsa.2014.3716

FAO. (2006). *The state of world fisheries and aquaculture*. Food and Agriculture Organization of the United Nations, Rome.

FAO. (2010). Recent developments in the tuna industry. In *Stocks, Fisheries, Management, Processing, Trade, and Markets*. SSN 2070-7010.

Guo, J., Yue, T., Li, X., & Yuan, Y. (2016). Heavy metal levels in kiwifruit orchard soils and trees and its potential health risk assessment in Shaanxi, China. *Environmental Science and Pollution Research, 23*, 14560–14566. https://doi.org/10.1007/s11356-016-6466-5

Institute of Medicine. (2001). *Dietary reference intakes for vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc* [Internet]. National Academies. Available from: http://www.iom.edu/object.file/

Jarup, L. (2003). Hazards of heavy metal contamination. *British Medical Bulletin, 68*, 167–182.

Jinadasa, B. K. K. K., Jayasinghe, G. D. T. M., Pohl, P., & Fowler, S. W. (2021). Mitigating the impact of mercury contaminants in fish and other seafood—a review. *Marine Pollution Bulletin, 171*, 112710. https://doi.org/10.1016/j.marpolbul.2021.112710

Khalili, T. S., & Sampels, S. (2018). Nutritional value of fish: Lipids, proteins, vitamins, and minerals. *Reviews in Fisheries Science & Aquaculture, 26*, 243–253. https://doi.org/10.1080/23308249.2018.1484139

Li, J. R., & Hsieh, Y. H. P. (2004). Traditional Chinese food technology and cuisine. *Asia Pacific Journal of Clinical Nutrition, 13*(2).

Liu, Q., Wu, P., Zhou, P., & Luo, P. (2023). Levels and health risk assessment of polycyclic aromatic hydrocarbons in vegetable oils and frying oils by using the margin of exposure (MOE) and the incremental lifetime cancer risk (ILCR) approach in China. *Foods, 12*, 811. https://doi.org/10.3390/foods12030811

Machate, D. J., Figueiredo, P. S., & Marcelino, G. (2020). Fatty acid diets: Regulation of gut microbiota composition and obesity and its related metabolic dysbiosis. *International Journal of Molecular Sciences, 21*, 4093. https://doi.org/10.3390/ijms21114093

Mei, J., Ma, X., & Xie, J. (2019). Review on natural preservatives for extending fish shelf life. *Foods, 8*, 490. https://doi.org/10.3390/foods8110490

Mistretta, P., & Durkin, P. R. (2006). Human health and ecological risk assessment Brandon Generating Station: Licence Review. https://doi.org/¦le:///C:/Users/mesaoudi_med/Desktop/vol3_appendix_n.pdf

Pappalardo, A. M., Copat, C., Ferrito, V., Grasso, A., & Ferrante, M. (2017). Heavy metal content and molecular species identification in canned tuna: Insights into human food safety. *Molecular Medicine Reports, 15*, 3430–3437. https://doi.org/10.3892/mmr.2017.6376

Rader, J. I. (1991). Anti-nutritive effects of dietary tin. *Advances in Experimental Medicine and Biology, 289*, 509–524. https://doi.org/10.1007/978-1-4899-2626-5_34

Rakib, M. R. J., Rahman, M. A., & Onyena, A. P. (2022). A comprehensive review of heavy metal pollution in the coastal areas of Bangladesh: Abundance, bioaccumulation, health implications, and challenges. *Environmental Science and Pollution Research, 29*, 67532–67558. https://doi.org/10.1007/s11356-022-22065-7

Risher, J. F. (2003). Elemental mercury and inorganic mercury compounds: Human health aspects. Geneva: World Health Organization.

Rose, M. (2023). Pollutants, residues, and other contaminants in foods obtained from marine and freshwater. In *Present knowledge in food safety* (pp. 128–141). Elsevier.

Steinhausen, S., Agyeman, N., Turrero, P., Ardura, A., & Garcia-Vazquez, E. (2021). Heavy metals in fish nearby electronic waste may threaten consumers' health: Examples from Accra, Ghana. *Marine Pollution Bulletin, 175*, 113208. https://doi.org/10.1016/j.marpolbul.2021.113208

Storelli, M. M., Barone, G., Cuttone, G., Giungato, D., & Garofalo, R. (2010). Occurrence of toxic metals (Hg, Cd, and Pb) in fresh and canned tuna: Public health implications. *Food and Chemical Toxicology, 48*, 3167–3170. https://doi.org/10.1016/j.fct.2010.07.029

Tarley, C. R. T., Visentainer, J. V., Matsushita, M., & de Souza, N. E. (2004). Proximate composition, cholesterol, and fatty acids profile of canned sardines (*Sardinella brasiliensis*) in soybean oil and tomato sauce. *Food Chemistry, 88*(1), 1–6. https://doi.org/10.1016/j.foodchem.2004.01.016

Tuzen, M., & Soylak, M. (2007). Determination of trace metals in canned fish marketed in Turkey. *Food Chemistry, 101*, 1378–1382. https://doi.org/10.1016/j.foodchem.2006.06.012

World Health Organization. (2008). *Guidelines for drinking-water quality* (3rd ed., incorporating 1st and 2nd addenda). Vol. 1. Recommendations. Geneva: World Health Organization.

Yesser, A. T., Al-Taee, M. A. J., & Al-Abdul-Nebi, S. A. S. (2013). Determination of some toxic trace elements of dead fresh fish, frozen, and canned fish species. *Basrah Journal of Veterinary Research, 12*(2), 139–148.

Zhu, F., Fan, W., Wang, X., Qu, L., & Yao, S. (2011). Health risk assessment of eight heavy metals in nine varieties of edible vegetable oils consumed in China. *Food and Chemical Toxicology, 49*(12), 3081–3085. https://doi.org/10.1016/j.fct.2011.09.014

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/128959