# Determination of mercury concentrations in canned, fresh and frozen tuna in Tripoli markets in Libya and assessment of its risks to consumer health.

[1]Fathi Ali, [2]Maher Abed El Aziz, [3]Enas Elshibani

[1]Department of sciences and Environmental Enginaring, Basic Sciences School, Libyan Academy for Postgraduate Studies, Janzour

[2]Chemistry Department, Faculty of Education Qaser Ben Ghasher, University of Tripoli

[3]Marine Biology Research Center, Tripoli

Corresponding author: fathi.ali@academy.edu.ly

**Abstract**

Fishes are considered as good indicators of heavy metals pollution in aquatic ecosystem in addition to being a good source of protein. Thus the level of Mercury (Hg) in fish which become a health hazard, was examined. The aim of the study was to determine the concentrations of Hg in the studied tuna fish samples. Moreover, evaluation of associated health risks from fish consumption were conducted of which, the intake rates of Hg was gauged based on Hg concentrations in fish muscles and the rate of daily fish consumption by Libyan population. A total of Forty-five specimens (20 canned tuna samples, local and imported samples, five frozen tuna samples and 20 fresh tuna samples) were sampled from different markets, large commercial centers, and food distribution points in the Tripoli area. A quantity of 0.5 grams of muscle completely homogenized mixture of each canned, fresh, and frozen tuna were digested by a mixture of 5 ml of nitric acid and 5 ml of sulfuric acid. A cold vapor atomic absorption spectrometer was utilized for the tuna fish analysis. The results showed that the concentrations of Hg were at the limits set by WHO and FAO, except for three frozen tuna samples were higher than the safety limits for human consumption, (2.33, 0.64, and 1.45 mg/kg wet. weight), and one fresh tuna sample (0.51 mg/kg wet. weight). The results revealed that, the average concentration of Hg for canned, frozen, and fresh tuna samples were calculated as 0.12, 1.02, and 0.19 mg/kg wet weight, respectively. However, the target hazard quotient (THQ) for Hg was less than 1 in the analyzed canned, frozen, and fresh tuna samples indicating no potential health risks to the population in studied area. However, the risk of health effects is increased due to the presence of Hg in seafood. Therefore, groups most at risk, including

young children, the elderly, and pregnant women, limit their consumption of certain types of seafood, especially tuna. further comprehensive monitoring programs should be conducted.

**Key words:** mercury, risk assessment, canned tuna, Tripoli markets

**الملخص**

تُعتبر الأسماك مؤشرًا جيدًا لتلوث النظام البيئي المائي بالمعادن الثقيلة، بالإضافة إلى كونها مصدرًا جيدًا للبروتين. لذلك، تم تقدير مستوى الزئبق في الأسماك، والذي يُشكل خطرًا على صحة الناس والبيئة. هدفت الدراسة إلى تحديد تركيزات الزئبق في عينات أسماك التونة المدروسة. علاوة على ذلك، تم تقييم المخاطر الصحية المرتبطة باستهلاك الأسماك، حيث تم تحديد معدلات استهلاك الزئبق بناءً على تركيزات الزئبق في عضلات الأسماك ومعدل الاستهلاك اليومي للأسماك لدى السكان الليبيين. أُخذت خمس وأربعون عينة (عشرون عينة تونة معلبة، محلية ومستوردة، وخمس عينات تونة مجمدة، وعشرين عينة تونة طازجة) من أسواق مختلفة، ومراكز تجارية كبرى، ونقاط توزيع أغذية في منطقة طرابلس. تم هضم كمية 0.5 جرام من خليط متجانس تمامًا من كل من التونة المعلبة والطازجة والمجمدة، بمزيج من 5 مل من حمض النيتريك و5 مل من حمض الكبريتيك. أُجري تحليل الزئبق في العينات المدروسة باستخدام مطياف الامتصاص الذري بالبخار البارد. أظهرت النتائج أن تركيزات الزئبق كانت ضمن الحدود المسموح بها من قِبَل منظمتي الصحة العالمية والأغذية والزراعة، باستثناء ثلاث عينات التونة المجمدة تجاوزت حدود السلامة للاستهلاك البشري (2.33، 0.64، و1.45 ملغم/كغم وزن جاف)، وعينة تونة طازجة واحدة (0.51 ملغم/كغم وزن جاف). أظهرت النتائج أن متوسط تركيز الزئبق في عينات التونة المعلبة والمجمدة والطازجة 0.12 ملغم/كغم من الوزن الجاف، و1.02 ملغم/كغم من الوزن الجاف، و0.19 ملغم/كغم من الوزن الجاف، على التوالي. ومع ذلك، كان معدل الخطر المستهدف للزئبق أقل من 1 في عينات التونة المدروسة (المعلبة والمجمدة والطازجة)، مما يُشير إلى عدم وجود مخاطر صحية محتملة على السكان من استهلاك هذه الأسماك في المنطقة المدروسة. ومع ذلك، يزداد خطر الآثار الصحية بسبب وجود الزئبق في المأكولات البحرية. لذلك، يجب على الفئات الأكثر عُرضة للخطر، بما في ذلك الأطفال الصغار وكبار السن والنساء الحوامل، ان تقلل من استهلاك أنواع معينة من المأكولات البحرية، وخاصة التونة. وينبغي إجراء المزيد من برامج الرصد والمراقبة الدورية الكاملة.

**الكلمات المفتاحية:** الزئبق، تقييم الضرر، التونة المعلبة، أسواق طرابلس

## 1. Introduction

Water pollution is considered as the biggest problem, which threatens the aquatic organisms and has become critical environmental threat (Baldantioni *et al*., 2004). Aquatic ecosystems exhibit significant sensitivity and vulnerability to numerous hazards, primarily due to the wide variety of pollutants generated by domestic, urban, and industrial activities, particularly in the aquatic environment (Sharma *et al*., 2024; Olgunoglu *et al*., 2025). When toxic metals are released into the environment, they contaminate the soil and accumulate in plants and organic tissues as they adversely affect the human health. The marine environment is also affected by natural phenomena that incorporate metals, trace elements and other compounds such as the upwelling of deep water containing nutrients and the dust or sand from deserts with metals (Raja *et al*., 2009).

Due to the dynamism, complexity and the changing nature of marine ecosystems the contaminates that enter the waters, cause unwanted results, which in turn, directly or indirectly impact the environmental balance of the environment (Li *et al*., 2017). The accumulation of heavy metals in marine ecology negatively impacts the ecosystems themselves and the fishes. The severity of heavy metals results in contamination of marine environment, which is very critical problem, especially human health. Emissions from industries and agricultural activities are considered as major source of pollution, especially in aquatic environment (Tarras-Wahlberg *et al*., 2001).

Heavy metals are considered as a major aquatic frequently detected in coastal areas (Duffus, 2002; Li *et al*., 2017). Contaminations of heavy metals are one of the extensive forms of marine pollution, as they do not rapidly decompose in marine environment, which deeply hinders the marine ecology due to the comparatively high concentrations and their toxicity even at low concentrations which affects the fishes and ultimately humans are affected through food web (Raja *et al*., 2009). Bioaccumulation assessment is a critical indicator for monitoring the biogeochemical cycles of heavy metals within aquatic ecosystems (Al-Bakush and Abu-Qasim, 2019).

Mercury is one of natural heavy metals that could cause food-borne toxicities by contaminating different nutritional levels. This element is also an environmental pollutant due to the stability and the ability to accumulate in biologic tissues (Li *et al*., 2017). Mercury is a highly toxic heavy metal; it accumulates and biomagnifies along the food chain, leading to higher concentrations in predatory fish (Garofalo *et al*., 2025). The

content of organic and inorganic mercury varies depending on the animal species, age, size, and water pH. However, methylmercury is the predominant form found in fish and other seafood (Alex, 2018; Garofalo *et al*., 2025). Consuming foods containing high levels of Hg is particularly dangerous for pregnant women due to its teratogenic effects, and for children during neurodevelopment (Counter and Buchanan, 2004).

Living organisms accumulate metals in their tissues by bioaccumulation, which causes increase in the amount of these toxic in an organism's tissues as a result of the absorption rate exceeding the body's ability to eliminate these toxic substances. The degree of accumulation depends on factors such as the chemical nature of the contaminant, type of organism, its physiological state, water temperature and salinity (Embaby *et al*., 2024). Fish living in aquatic systems contaminated with heavy metals are of great environmental concern, as these metals accumulate within various biological tissue structures (Hanis *et al*., 2025; Al- Kazaghly *et al*., 2025).

Fish, as a significant source of protein has been influenced by rapid industrialization and mechanized agricultural activities resulting to increase in the level concentration of heavy metals found in different varieties of fish (Embaby *et al*., 2024). The species that accumulate heavy metals in their tissues are known as bio-monitors, these are used to measure the level of heavy metal pollution in the environment (Phillips and Rainbow 1993). Normally fishes are used as the standard for scrutinizing the environmental pollution in aquatic ecosystems. As the position of fish is the final level of the food chain, when consumed, the contaminated diversities will easily pass the metals into the humans (Burger and Gochfeld 2005).

Moreover, the fishes can better replicate the history of pollution of the sampling location due to their exposure to contaminants that amass over their life span. Fish also have been popular targets of heavy metal monitoring programs in marine environments because sampling, sample preparation and chemical analysis are usually simpler, more rapid and less expensive than alternative choices such as water and sediments (Rayment and Barry 2000). According to Erkan *et al*., (2011), marine organisms especially fishes used to monitor heavy metals in the marine environment. However, it is essential to regularly monitor the chemical quality of aquatic organisms, especially the accumulations of toxic heavy metals, for maintaining the human health.

Tuna fish, scientifically referred to as Thunnus and part of the scombridae family, is a pelagic and migratory marine species that gathers in large schools across the Atlantic, Pacific, and Indian Oceans (Norhazirah *et al*., 2020). Tuna fish is the top predators in oceanic environments and play a vital role in marine ecosystems. They represent approximately 20% of the total economic value derived from marine fisheries, contributing significantly to meeting global protein demand (Voegborlo *et al*., 1999; Dhaneesh *et al*., 2014). The tuna fishery is the largest and most specialized of all commercial fisheries (Norhazirah *et al*., 2020). The population typically relies on local and imported tuna in various forms, including fresh, canned, and frozen. This study aims to determine the Hg levels in canned tuna, frozen tuna and fresh tuna fish samples and assess their health risks to consumers in Libya.

## 2. Materials and Methods

### 2.1. Study area

This research was conducted from December 2023 to July 2024. Were the samples collected from Tripoli area Figure (1), which located in the northwestern sector of Libya. It is bordered to the north by the Mediterranean Sea, to the south by the administrative borders of Qasr Ben Ghashir, to the east by the district of Al-Qarabulli, and to the west by Alzawia city. The study area located between Longitude: 13° 11' 14.86" E Latitude: 32° 52' 30.68" N.

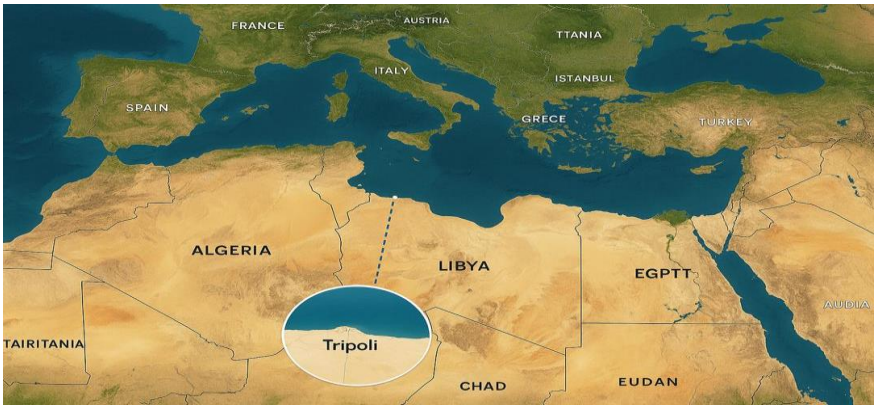



Fig. (1): the study area

### 2.2. Materials and reagents

All materials used in this study except mercury standard solution (1000 ppm, Merck Company). Also, all laboratory glass wares were put in nitric oxide 10% for 24 h and rinsed with deionized distilled water prior the usage to prevent any mercury contamination.

**2.3. Sample collection:**

A total of 45 comprehensive samples were collected from various markets, large shopping centers, and grocery stores in the Tripoli area. Twenty canned tuna samples were collected, including various types of canned tuna (local and imported). The content of one can is 80 g wet weight and is considered a single serving. five frozen tuna samples and 20 fresh tuna samples from aquaculture markets. After obtaining the frozen and fresh samples, they were transported in a manual container insulated with ice to ensure tissue integrity until they arrived at the marine chemistry and physics laboratory at the marine biology research center.

**2.4. Samples preparation:**

After arrival the samples to the laboratory, the samples were prepared for digestion by dissecting the tissue using plastic dissection tools. The muscle was isolated from the rest of the frozen and fresh tuna organs and mixed thoroughly to ensure complete homogeneity. The tuna fish muscles were separated from the brine (preservative) in the canned tuna sample and combined to form a homogeneous mixture. A precise quantity of 0.5 grams of the completely homogenized mixture of each canned, fresh, and frozen tuna (muscle) is measured and placed in a beaker. A mixture of 5 ml of nitric acid and 5 ml of sulfuric acid is added. This mixture is then placed in a water bath at 60°C for 4 hours. 5% potassium permanganate is then added, and the sample is returned to a water bath at 60°C for an additional 30 minutes. It is then cooled and 12% stannous chloride is added. Analysis was performed using a cold vapor atomic absorption spectrometer (Mercury Instrument, VM-3000) (Morgan *et al.*, 1997; Evans *et al.*, 2010). All digested samples were examined thrice against the aqueous standards for Hg.

**2.5. Evaluation of Health Risk**

2.5.1. Public health risk assessment of m in fish sample

Public health risk assessment of Hg under investigation in tuna samples was determined by calculating the daily intake, weekly intake and target hazard quotient.

2.5.2. Calculation of estimated daily intake (EDI)

The estimated daily intake (EDI) was calculated based on the mean of Hg content of each tuna species. by the following equation:

$$\mathbf{EDI} = \frac{\mathbf{FIR} \times \mathbf{C}}{\mathbf{BWa}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (\mathbf{1})$$

C is the Hg concentration in fish (mg $kg^{-1}$ wet weight); FIR is the food ingestion rate, equal to 36 g/person/day for fish and BWa is the reference body weight of 70 kg (Oktariani *et al*., 2023).

2.5.3. Calculation of estimated weekly intakes (EWIs)

The weekly intakes EWIs was calculated based on the mean of Hg content of each tuna species by the following equation:

$$\mathbf{EWI} = \frac{\mathbf{FIR \times C \times 7}}{\mathbf{BWa}} \quad \text{.....(2)}$$

C is the Hg level in fish (mg $kg^{-1}$ fresh weight); FIR is the food ingestion rate, equal to 36 g/person/day for fish and BWa is the reference body weight of 70 kg (Oktariani *et al*., 2023).

2.5.4. Calculation of target hazard quotient (THQ)

The target hazard quotient (THQ) is articulated as the ratio between exposure to a toxic element and the reference dose, which represents the maximum level at which no detrimental health effects are anticipated. The reference dose is tailored to the specific trace element under consideration. When the THQ values less than 1, this indicated that, muscle tissue of tuna fish may not cause any serious health risk to the consumers of Libyan. Conversely, if the THQ exceeds 1, there exists a potential for the manifestation of adverse health effects. The estimation of the THQ was conducted utilizing the methodology established by the United States Environmental Protection Agency (US EPA).

$$\mathbf{THQ} = \frac{\mathbf{FIR \times ED \times EF \times C}}{\mathbf{BWa \times RFD \times ATn}} \times \mathbf{10^{-3}}$$

In this context, EF denotes the frequency of exposure to the trace element (365 days/year); Ed signifies the exposure duration (70 years). FIR represents the food ingestion rate measured in grams per day for the pertinent food item. C indicates the concentration in wet weight of the trace element within the specified food item; RfD corresponds to the oral reference dose of the trace element 0.0016 (mg/kg bw/day). BWa refers to the reference body weight of 70 kg, and ATn constitutes the averaged exposure time (365 days multiplied by 70 years), with $10^{-3}$ serving as the unit conversion factor (Antoine *et al*., 2017; Mohamed *et al*., 2023).

**2.5.5. Statistical analysis**

All data are presented as mean values ± SD, minimum, and maximum derived from three independent experiments. Statistical analysis was performed with SPSS software (Version 25.0). Excel program was used to create graphs.

## 3. Results and discussion

### 3.1. Mercury concentration in tuna fish

Understanding the toxic levels in fishes are very significant for regulating human and environmental safety, however, the migrating nature of fishes and the consequent variation in the duration of metal exposure make the process of gauging the toxic levels, quite a complicated task. Nevertheless, there is a considerable variation of individual tolerance of fish to metals, and many other ecological factors, affect metal toxicity (Moiseenko *et al*., 2001). Among the different aquatic organisms, fishes are probably the most mobile creatures and are capable of traveling a long distance (Ip *et al*., 2005).

#### 3.1.1. Mercury concentration in canned tuna samples

All results from analysis of canned tuna fish samples were consistent with the limits set by the (WHO and FAO 2009). The minimum recorded concentration was 0.01 mg/kg wet weight, while the maximum concentration was 0.41 mg/kg wet weight. The calculated mean was 0.12 mg/kg wet weight, and the standard deviation was 0.12 mg/kg wet weight, as shown in Table (1) and Figure (2). From the literature, a research conducted by Abolghait and Garbaj (2015), examined Hg concentration in canned yellow fin tuna samples purchased from the Libyan market, the average Hg concentration was 0.16 ± 0.12 mg/kg wet weight. This is consistent with another research study conducted by Rodriguez-Mendivil *et al*., (2019), on samples of canned tuna from Mexican markets. The results indicated that Hg concentrations in the wet weight of canned tuna ranged between 0.005 mg/kg and 1.17 mg/kg wet weight. Another study was conducted by Sharkawy *et al*., (2020), were forty samples of canned tuna collected from five brands from supermarkets in Assiut, Egypt were tested for Hg concentrations, the results were (6.39–6.81), (5.04–5.17), (6.61–7.04), (2.62–3.28), and (1.30 –2.19) mg/kg wet weight, the results were higher than the results of this study. Another research was conducted by Miedico *et al*., (2020), A total of 108 tuna samples, both canned and unprocessed. The mean Hg concentrations in canned tuna were 0.21 (0.18) mg $kg^{-1}$, these findings were consistent with current study. One more study was conducted by Hanis *et al*., (2023), the results showed the maximum Hg level in the examined tuna samples was 0.099 mg/kg. this result was at same range of the current research.

Table (1): Mercury results in tuna (canned, frozen and fresh) (mg/Kg w.w)

| Sample Tuna | No. of samples | minimum | Maximum | mean | (SD) |
|---|---|---|---|---|---|
| Canned | 20 | 0.01 | 0.41 | 0.12 | 0.12 |
| Frozen | 05 | 0.19 | 2.33 | 1.02 | 0.87 |
| Fresh | 20 | 0.02 | 0.51 | 0.19 | 0.12 |

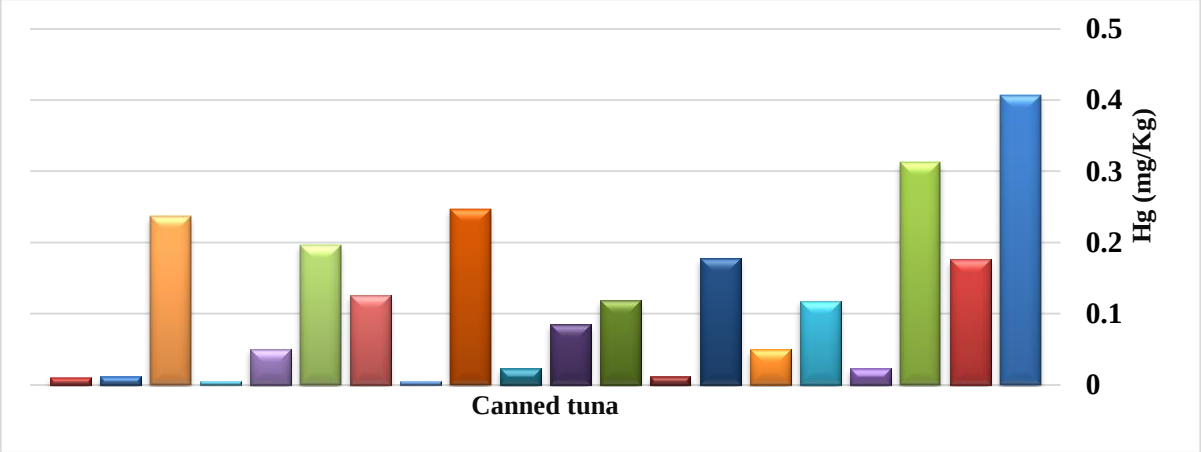



Fig. (2): Mercury concentration in canned tuna (mg/kg wet weight)

3.1.2. Mercury concentration in frozen tuna samples

Three out of five frozen tuna samples showed levels exceeding the limits recommended by (WHO and FAO 2009). The lowest recorded concentration was 0.19 mg/kg wet weight، and the highest concentration was 2.33 mg/kg wet weight, significantly exceeding the limits proposed by (WHO and FAO 2009). The average concentrations of the samples were 1.02 mg/kg wet weight, accompanied by a standard deviation of 0.87 mg/kg wet weight, as shown in Table (1) and Figure (3). From the literature, similar results were investigated by the results obtained were slightly higher than those reported by Ziarati *et al.*, (2017). Between October 2015 and June 2016, 150 samples of packed frozen fish were randomly collected from prestigious supermarkets in Tehran Province, Iran. The average Hg concentration in fish samples was 0.79 ± 0.11 µg/g, indicating that the average Hg concentration in the frozen fish analyzed in a study from the Arabian Gulf exceeded 0.5 µg/g, the maximum permissible limit recommended by the Joint FAO/WHO Expert Committee on Food Additives (JECFA). In a study conducted by Al-Masry and Rahma (2013) to examine processed meat imported into Syria, results from frozen fish produced from Lake Qatina were higher than the permissible limits set by (WHO and FAO 2009), with a Hg concentration in wet weight of 5.2 mg/kg.

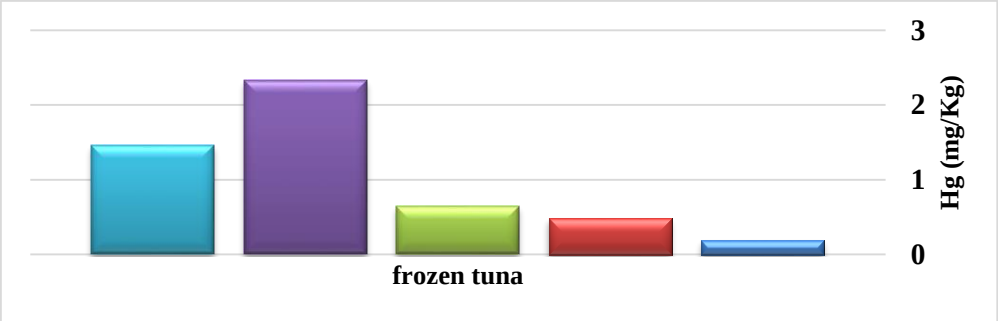



Fig. **(3):** Mercury concentration in frozen tuna (mg/Kg wet weight)

3.1.3. Mercury concentration in fresh tuna

All fresh tuna samples results adhered to the limits set by (WHO and FAW 2009). Only one sample exceeded the permissible limits, recording a value of 0.51 mg/kg wet weight, while the lowest concentration was recorded at 0.02 mg/kg wet weight. The mean concentration was determined to be 0.19 mg/kg wet weight, and the standard deviation was 0.12 mg/kg wet weight, as shown in Table (1) and Figure (4). Species of tuna fish (Thunnus spp.) and other large fish species have naturally high concentrations of mercury due to bioaccumulation and their position in the food chain. From the literature results of this study were lower than those reported by Abolghait and Garbaj (2015), were a small samples of fresh tuna taken from the Libyan market. It was observed that the average Hg concentration in small fresh tuna samples was (1.19 ± 0.97) mg/kg wet weight. Furthermore, the finding of this study were lower than those conducted by Rodriguez-Mendivil *et al*., (2019), which focused on 20 samples of different fish species available in Tijuana, Mexico were the results showed that Hg concentrations of fresh fish samples ranged between 0.14 and 2.14 mg/kg wet weight. Another study conducted by Al-Kazaghly *et al*., (2025), it was found that the Hg concentration in blue fin tuna (*Euthynnus alletteratus*) reached of 0.298 ± 0.061 µg/g wet weight. As a matter of fact, it has been acknowledged that, generally the accumulation of heavy metals in fishes are administered by various factors including, distinct ingestion, cleansing and removal mechanisms, the metabolic rate of organisms and the ecosystem (Canli and Atli, 2003). On the other hand, few other studies have identified the following factors that influence the concentration of toxic metals in fishes: feeding behaviours (Romeoa *et al*., 1999), environmental demands, metabolic processes, age and, length and weight of fishes, and their feeding routine (Canli and Atli, 2003).

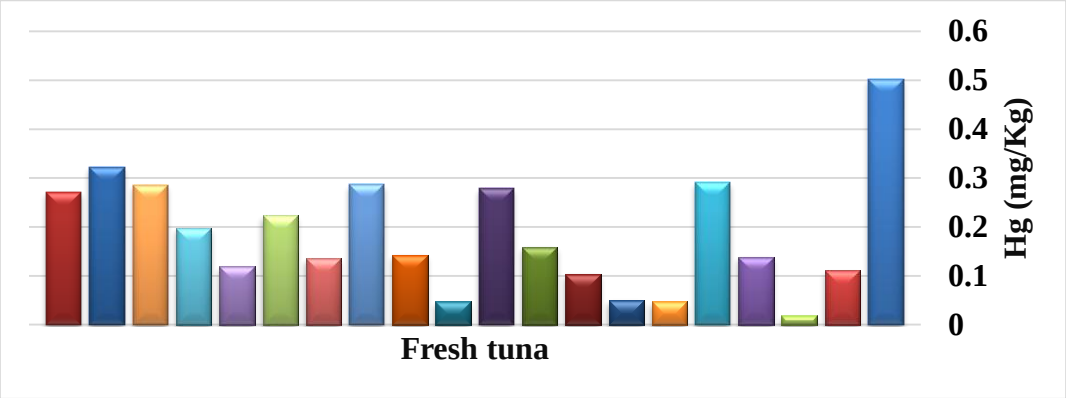



Fig. **(**4**):** Mercury concentration in fresh tuna (mg/Kg wet weight)

### 3.1.4. Evaluation of Health Risk

Risk assessment is the scientific evaluation of the probability of occurrence, and severity of known or potential adverse health effects, resulting from human exposure to food borne hazards (Moiseenko *et al*., 2001). Since seafood is one of the most important food sources in Libya, intake of heavy metals from seafood, especially, toxic elements, is of great concern for human health risk. The mean concentrations of heavy metal in fish muscles were used for this assessment, because it is the edible part of the fish. One of the major purposes of this present study was to identify and quantify the potentially Hg in the muscle tissues of tuna fish species, collected from Tripoli, consequently, perform a risk assessment, to determine, whether the consumption of these fish from these areas, poses health issues to the consumers. Determining dietary intake levels of these substances, which must meet established safety limits, is a key component in assessing the potential health risks posed by hazardous chemicals in food. Table (2) shows the calculated Target Daily Intake (EDI), Target Weekly Intake (EWI), and Target Hazard quotient (THQ) for Hg in tuna.

### 3.1.5. Weekly intakes (EWIs)

Estimates of weekly Hg intake were derived from analyses of canned, frozen, and fresh tuna and compared to the Provisional Tolerable Weekly Intake (PTWI = 0.025 mg/kg/week body weight) (Olgunoglu *et al*., 2025). All samples were not exceeded the Provisional Tolerable Weekly Intake (PTWI). In a study conducted by El-Senousi *et al*. (2025) to determine the estimated daily and weekly consumption of potentially toxic elements in (milligrams per day/week) in the five most popular canned tuna varieties on the Egyptian market, the total daily or weekly mercury consumption was below the maximum permissible limit according to (European Commission, 2006; FAO, 2006; WHO, 2008).

### 3.1.6. Target hazard quotient (THQ)

The target hazard quotient (THQ) for Hg levels in canned, frozen, and fresh tuna was calculated to be less than 1 (table 2), indicating no potential health risks to the Libyan population in studied area after consuming canned, frozen, or fresh tuna. A THQ of less than or equal to 1 indicates no significant health risk; in contrast, a THQ greater than 1 indicates a health problem (Okbah *et al*., 2014). In a study conducted by Olgunoglu *et al*., (2025), THQ values in female scorpionfish approached 1, reaching 0.7 during the summer months, indicating a potential increased risk during this period. Stamatis *et al*., (2019) reported THQ values for Hg exceeding 1 in white tuna (*Thunnus alalunga*) from the North Aegean Sampling Station Area (NASSA) and the Southeastern Aegean sampling station Area (SASSA) in Greece, with ranges of 1.34–5.04, and 0.76–4.05 (mg/kg wet weight), respectively. Another study conducted by Traven *et al*. (2023), showed that, the THQ levels for Hg were less than 1 in the analyzed species. However, the risk of health effects is increased due to the presence of Hg in seafood. Therefore, we recommend that groups most at risk, including young children, the elderly, and pregnant women, limit their consumption of certain types of seafood, especially tuna.

Table (2): Estimated daily intake (EDI), Estimated weekly intake (EWI) of Hg and target hazard quotient (THQ) in muscles of (canned, frozen and fresh) tuna fish

| Sample tuna | Mean | (SD) | EDI (mg/kg b.w/day) | EWI (mg /kg b.w /week) | THQ |
|---|---|---|---|---|---|
| **Canned** | **(0.01- 0.41)** | **0.12** | **$6.15 \times 10^{-5}$** | **$4.3 \times 10^{-4}$** | **$3.84 \times 10^{-2}$** |
| **Frozen** | **(0.19- 2.33)** | **0.87** | **$5.24 \times 10^{-4}$** | **$3.67 \times 10^{-3}$** | **$3.28 \times 10^{-1}$** |
| **Fresh** | **(0.02- 0.51)** | **0.12** | **$9.6 \times 10^{-5}$** | **$6.72 \times 10^{-4}$** | **$6.00 \times 10^{-2}$** |

## 4. Conclusion

The analysis of results showed that, the concentrations of Hg in most of tuna fish samples were within the permissible limits for canned tuna, except one sample of fresh tuna exceeded the permissible limits, and high readings exceeding four times the permissible limits were recorded in frozen tuna. Contamination may be linked to multiple sources, particularly natural and anthropogenic. A THQ levels for Hg were less than 1 in all the species analyzed indicates no significant health risk to the consumers of Libyan. However, the risk of health effects is increased due to the presence of Hg in seafood. Therefore, we recommend that groups most at risk, including young children, the elderly, and pregnant women, limit their consumption of certain types of seafood, especially tuna. further comprehensive monitoring programs should be conducted.

**5. References**

1. Abolghait, S.K. and Garbaj, A.M. (2015) Determination of cadmium, lead and mercury residual levels in meat of canned light tuna (*Katsuwonus pelamis* and *Thunnus albacares*) and fresh little tunny (*Euthynnus alletteratus*) inlibya. Open Vet. J., 5(2): 130–137.
2. Al- Kazaghly R., Altunsi H., Ighwela K., Shukshuk A., and Howas M. (2025). A comparative study of some heavy metals in blue fin tuna (*Euthynnus alletteratus*) and *sardinella aurita* in the coastal waters of Zliten, Libya. Journal of Basic Sciences, 38(1), 39-49.
3. Al-Bakoush, A., and Al-Qasim, A. (2019). Determination of the percentages of some heavy elements in local and imported canned tuna and its preservation medium in Libyan markets. Scientific Journal of Applied Sciences of Sabratha University. 2. 81-89.
4. Alex, S. (2018). Mercury and its Associated Impacts on Environment and Human Health: A Review. (2018). J Environ Health Sci 4(2): 37-43.
5. Al-Kazaghly, R. F., Altunsi, H. O., Ighwela, K. A., Shukshuk, A. H., and Howas, M. M. (2025). A comparative study on the accumulation of some heavy metals in bluefin tuna (*euthynnus alletteratus*) and sardinella (*Sardinella aurita*) in the coastal waters in zliten libya. Journal of Basic Sciences, 38(1), 39-49.
6. Al-Masry, Mohamed and Rahma, Soha. (2013). Detection of some heavy metal elements in locally manufactured or imported meat and meat products. Tishreen University Journal for Scientific Research and Studies: Biological Sciences Series, Vol. 35, No. 2, pp. 215-236.
7. Al-Mazoughi. S. B. A (2020). The impact of natural factors on seawater intrusion in the Tajoura area, Journal of the Faculty of Arts (33), September.
8. Antoine, J. M., Fung, L. A. H., and Grant, C. N. (2017). Assessment of the potential health risks associated with the aluminium, arsenic, cadmium and lead content in selected fruits and vegetables grown in Jamaica. Toxicology reports, 4, 181-187.
9. Baldantoni, D., Alfani, A., Di Tommasi, P., Bartoli, G. & De Santo, A. V. 2004. Assessment of Macro and Microelement Accumulation Capability of Two Aquatic Plants. Environmental Pollution 130(2): 149-156.

10. Burger, J. & Gochfeld, M. 2005. Heavy Metals in Commercial Fish in New Jersey. Environmental Research 99(3): 403-412.
11. Canli, M. & Atli, G. 2003. The Relationships between Heavy Metal (Cd, Cr, Cu, Fe, Pb, Zn) Levels and the Size of Six Mediterranean Fish Species. Environmental Pollution 121(1): 129-136.
12. Counter, S.A.; Buchanan, L.H. (2004). Mercury exposure in children: A review. Toxicol. Appl. Pharmacol. 198, 209–230.
13. Dhaneesh, K.V., Noushad, K.M., Biju Kumar, A., Nobi, E.P. and Nabeel, A.M., (2014). Heavy metal content in yellow fin tuna *Thunnus albacares* (Bonnaterre) of Lakshadweep Sea. Carpathian Journal of Earth and Environmental Sciences, 9(4), pp.55-59.
14. Duffus, J. H. (2002). " Heavy metals" a meaningless term? (IUPAC Technical Report). Pure and applied chemistry, 74(5), 793-807.
15. 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.
16. Embaby, M. A., Mehasseb, H. T., Moniem, S. M. A., and El-Kady, A. A. (2024). Risk assessment of trace metals in canned fish commercialized for human consumption in Egypt. Journal of Food Composition and Analysis, 125, 105724.
17. Erkan, N., Özden, Ö. & Ulusoy, Ş. 2011. Seasonal Micro- and Macro-Mineral Profile and Proximate Composition of Oyster (*Ostrea edulis*) Analyzed by ICP-MS. Food Analytical Methods 4(1): 35-40.
18. European Commission. (2006). Commission Regulation No. 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in food stuffs. Official Journal of the European Union, 20.12.2006.
19. Evans, S., Johnson, M., Lea, R., (2010). Determination of mercury in fish tissue. A Rapid, Automated Technique for Routine Analysis Varian, 1986. Agilent Technologies, USA. https://www.agilent.com/cs/library/applications/AA060.pdf
20. FAO. (2006). The state of world fisheries and aquaculture Food and Agriculture Organization of the United Nations, Rome.

21. FAO/WHO, (2009). Codex General Standard for Food Additives. Food and Agricultural Organization of the United Nations and World Health Organization., Rome. 1.120 p.
22. Garofalo L, Sala M, Focardi C, Pasqualetti P, Delfino D, D'Onofrio F, Droghei B Pasquali F, Nicolini V, Galli FS, *et al*. (2025) .Monitoring of Cadmium, Lead, and Mercury Levels in Seafood Products: A Ten-Year Analysis. Foods. 14(3):451.
23. Hanis, F., Messaoudi, M., Bouamra, M. *et al.* (2024). Analysis and Risk Assessment of Essential and Toxic Elements in Algerian Canned Tuna Fish. Biol Trace Elem Res 202, 1212–1223.
24. Hanis, F., Messaoudi, M., Bouamra, M., SiAmeur, A., Ouanezar, A., Malki, A., ... and Zahnit, W. (2023). Determination of some toxic and essential elements in canned tuna fish commercialized in Algeria and Risk Assessment for Consumer Health.
25. Kalay, M. & Canli, M. 2000. Elimination of Essential (Cu, Zn) and Nonessential (Cd, Pb) Metals from Tissue of a Freshwater Fish *Tilapia zillii* Following an Uptake Protocol. Tukrish Journal Zoology 24: 429-436.
26. Ip, C. C. M., Li, X. D., Zhang, G., Wong, C. S. C. & Zhang, W. L. 2005. Heavy Metal and Pb Isotopic Compositions of Aquatic Organisms in the Pearl River Estuary, South China. Environmental Pollution 138(3): 494-504.
27. Li, F., Qiu, Z., Zhang, J., Liu, W., Liu, C., and Zeng, G. (2017). Investigation, pollution mapping and simulative leakage health risk assessment for heavy metals and metalloids in groundwater from a typical brownfield, middle China. International journal of environmental research and public health, 14(7), 768.
28. Miedico, O., *et al.* (2020). Lead, cadmium and mercury in canned and unprocessed tuna: six-years monitoring survey, comparison with previous studies and recommended tolerable limits. Journal of Food Composition and Analysis, 94, p.103638.
29. Moiseenko, T. I. & Kudryavtseva, L. P. 2001. Trace metal accumulation and fish pathologies in areas affected by mining and metal lurgical enterprises in the Kola region, Russia. Environmental Pollution 114(2): 285-297.
30. Mohamed, N.H., *et al*. (2023). Detection and health risk assessment of toxic heavy metals in chilled and frozen meat collected from Sharkia province in Egypt. Open Veterinary Journal, 13(12), p.1729.

31. Morgan, J., Berry Jr., M., Graves, R., (1997). Determination of total mercury in raw and cooked fish tissue by microwave digestion/cold vapours atomic absorption spectroscopy. In: Poster session presented at: U. S. Environmental, Protection agency environmental Monitoring Systems Laboratory, Quality Assurance Research Division, Development and Evaluation Branch. Cincinnati: Ohio
32. Norhazirah, A.A., *et al*. (2020), May. Heavy metals in tuna species meat and potential consumer health risk: A review. In IOP Conference Series: Earth and Environmental Science (Vol. 494, No. 1, p. 012013). IOP Publishing.
33. Okbah, M., AS Dango, E., and M El Zokm, G. (2018). Heavy metals in Fish Species from Mediterranean Coast, Tripoli Port (Libya): A comprehensive assessment of the potential adverse effects on human health. Egyptian Journal of Aquatic Biology and Fisheries, 22(5 (Special Issue)), 149-164.
34. Oktariani, A. F., *et al*. (2023). Heavy metals content in fresh tuna and sword fish caught from Hindian and Pacific Oceans: Health risk assessment of dietary exposure. Veterinary World, 16(4), 858.
35. Olgunoglu, M. P., Olgunoglu, I. A., and Artar, E. (2025). Seasonal Variability and Sex-Specific Accumulation of Trace Metals in Black Scorpionfish (*Scorpaena porcus* Linnaeus, 1758) from Izmir Bay (Aegean Sea), Türkiye: Implications for Human Health Risk Assessment. Life, 15(3), 501.
36. Olgunoglu, Mine Percin, Ilkan Ali Olgunoglu, and Engin Artar. (2025). Seasonal Variability and Sex-Specific Accumulation of Trace Metals in Black Scorpionfish (*Scorpaena porcus* Linnaeus, 1758) from Izmir Bay (Aegean Sea), Türkiye: Implications for Human Health Risk Assessment. Life 15, no. 3: 501.
37. Phillips, D. J. H. & Rainbow, P. S. 1993. Biomonitoring of trace aquatic contaminants. Elsevier Applied Science.
38. Raja, P. V. S., Suresh, G., Marichamy, G., Venkatachalapathy, R. 2009. Heavy metals concentration in four commercially valuable marine edible fish species from parangipettai coast, south east coast of India. International Journal of Animal and Veterinary Advances 1(1): 10-14.
39. Rayment, G. E. & Barry, G. A. 2000. Indicator tissues for heavy metal monitoring – additional attributes. Marine Pollution Bulletin 41(7-12): 353-358.

40. Rodriguez-Mendivil, D. D., Garcia-Flores, E., Temores-Pena, J., and Wakida, F. T. (2019). Health risk assessment of some heavy metals from canned tuna and fish in Tijuana, Mexico. Health Scope, 8(2).
41. Roméo, M., Siau, Y., Sidoumou, Z. N. & Gnassia-Barelli, M. 1999. Heavy metal distribution in different fish species from the Mauritania Coast. Science of the Total Environment 232(3): 169-175.
42. Sharkawy A.A., El-Sayed A.M., and ALI M.A.M. (2020). Heavy Metals Content in Canned Tuna Fish Marketed in Assiut City, Egypt and Its Related Human Health Risk Assessment. Assiut Vet. Med. J. Vol. 66 No. 165, pp.1-20
43. Sharma, M., Kant, R., Sharma, A. K., and Sharma, A. K. (2024). Exploring the impact of heavy metals toxicity in the aquatic ecosystem. International Journal of Energy and Water Resources, 1-14.
44. Stamatis, N., Kamidis, N., Pigada, P., Stergiou, D., and Kallianiotis, A. (2019). Bioaccumulation Levels and Potential Health Risks of Mercury, Cadmium, and Lead in Albacore (*Thunnus alalunga*, Bonnaterre, 1788) from The Aegean Sea, Greece. International Journal of Environmental Research and Public Health, 16(5), 821. https://doi.org/10.3390/ijerph16050821
45. Tarras-Wahlberg, N. H., Flachier, A., Lane, S. N. & Sangfors, O. 2001. Environmental Impacts and Metal Exposure of Aquatic Ecosystems in Rivers Contaminated by Small Scale Gold Mining: The Puyango River Basin, Southern Ecuador. Science of the Total Environment 278(1–3): 239-261.
46. Traven, L., Marinac-Pupavac, S., Žurga, P., Linšak, Ž., Pavičić Žeželj, S., Glad, M., and Vukić Lušić, D. (2023). Assessment of health risks associated with heavy metal concentration in seafood from North-Western Croatia. Scientific Reports, 13(1), 16414.
47. Voegborlo, R. B., El-Methnani, A. M., and Abedin, M. Z. (1999). Mercury, cadmium and lead content of canned tuna fish. Food Chemistry, 67(4), 341-345.
48. World Health Organization. (2008). Guidelines for drinking-water quality (3rd ed., incorporating 1st and 2nd addenda). Vol. 1. Recommendations. Geneva: World Health Organization.
49. Ziarati, P., and Makki, F. M. (2017). Levels of mercury in Persian Gulf frozen fish species. Journal of Pharmaceutical & Health Sciences, 5(1), 15-22.