# Estimation of Heavy Metals Concentration in Canned Tuna and Parental Awareness of Its Health Risks Among Primary School Children in Nalut, Libya

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**ABSTRACT**

**Background:**

Canned tuna is a widely consumed food product due to its nutritional value and convenience. However, concerns have been raised regarding its potential contamination with heavy metals such as mercury (Hg), lead (Pb), tin (Sn), zinc (Zn), and copper (Cu), which may pose health risks, particularly for children.

**Objectives:**

This study aimed to assess the concentrations of selected heavy metals in commercially available canned tuna sold in Nalut, Libya, and therefore to evaluate the level of parental awareness regarding the health risks associated with consuming these products among primary school children.

**Methods:**

A total of 35 canned fish samples (33 tuna and 2 sardines) were collected from various markets in Nalut and analyzed for Hg, Pb, Cu, Sn, and Zn using flame atomic absorption spectrophotometry (AAS) after acid digestion. In parallel, a structured questionnaire was distributed to 362 parents of primary school children (ages 6–12) to assess their awareness, consumption habits, and perceived health impacts.

**Results:**

The concentrations of all tested metals were within the permissible limits set by Libyan and international food safety standards. Mercury concentrations ranged from 0.009 to 0.023 µg/g; lead from 0.007 to 0.060 µg/g; copper from 0.009 to 0.702 µg/g; tin from 0.794 to 3.019 µg/g; and zinc levels were consistently <0.003 µg/g across all samples. Survey results revealed that 96.4% of children consume canned tuna, with 49.6% eating it at home for breakfast. However, only 49.9% of parents were aware that tuna could contain heavy metals, and just 23.2% could identify related poisoning symptoms. Statistical analysis showed significant associations between tuna consumption and gender (p=0.048) as well as family size (p=0.031), but not with awareness levels (p=0.827).

**Conclusion:**

While chemical analyses confirm the safety of canned tuna products sold in Nalut in terms of heavy metal content, the high consumption rates among children and limited parental awareness highlight the need for targeted health education. Regular monitoring and public guidance are essential to minimize potential long-term health risks.

**Received: 16-02-2026 - Accepted: 24-02-2026 - Published: 02-03-2026**

**Keywords**: Canned tuna, heavy metals, mercury, lead, parental awareness, Nalut, Libya, food safety, AAS.

## 1. Introduction

Canned tuna is a popular dietary choice worldwide due to its affordability, high protein content, and convenience. It is especially common among school-aged children and families in Libya, including those in Nalut. However, despite its nutritional benefits, canned tuna has raised public health concerns due to the potential accumulation of heavy metals such as mercury (Hg), lead (Pb), copper (Cu), tin (Sn), and zinc (Zn), which can accumulate in fish tissues through environmental and food chain contamination (FAO, 2020; Gonzalez-Acuna *et al.*, 2017).

Mercury, in particular, is a well-known neurotoxicant that can adversely affect the central nervous system, especially in developing children and fetuses (Grandjean & Landrigan, 2014). Lead exposure, even at low levels, has been linked to reduced intelligence, behavioral issues, and developmental delays in children (Needleman *et al.*, 2002). Copper, zinc, and tin, though essential in trace amounts, may cause toxicity when consumed in excess. The accumulation of these metals in commonly consumed foods such as canned tuna raises serious concerns for long-term health impacts, especially in vulnerable populations.

Previous studies in Libya and other countries have detected varying concentrations of heavy metals in canned fish products. For example, a study in Khoms, Libya, reported mercury and cadmium contamination in local canned tuna (Hadia *et al.*, 2018), while other studies from Iran, Spain, and Turkey have documented similar findings in terms of metal content and associated health risks (Valiente-Diaz *et al.*, 2023; Rahmani *et al.,* 2018; Kosker *et al.*, 2023). Despite these findings, public awareness about the presence and potential health effects of heavy metals in canned fish remains limited in many communities.

In Libya, few studies have investigated not only the concentration of heavy metals in canned tuna but also the level of public awareness regarding these contaminants and their health risks, particularly among parents of children who frequently consume such products. Understanding both the chemical safety and the social

dimensions of food consumption is crucial for promoting informed dietary practices and improving public health policies.

This study, therefore, aims to determine the concentration levels of mercury, lead, tin, copper, and zinc in various brands of canned tuna sold in Nalut. In addition, to evaluate the awareness of parents regarding the potential health risks associated with consuming heavy metal-contaminated tuna among their school-aged children. By combining laboratory analysis and survey data, this study seeks to provide a comprehensive understanding of the safety of canned tuna in the local market and to identify knowledge gaps that can inform future educational and policy efforts.

## 2. Materials and Methods

### 2.1 Study Design and Sampling Strategy

This cross-sectional study was conducted between November 11, 2024, and May 20, 2025, in the city of Nalut, Libya. A total of 35 canned fish products—comprising 33 tuna samples and 2 sardine samples (included for comparative purposes)—were randomly collected from various retail outlets across the city. The samples were selected based on brand diversity, preservation medium (e.g., sunflower oil, olive oil, brine), country of origin, price, and expiration date. All samples were stored under optimal conditions to preserve their integrity prior to analysis.

### 2.2 Heavy Metals Analysis

The quantitative analysis of five heavy metals—mercury (Hg), lead (Pb), tin (Sn), copper (Cu), and zinc (Zn)—was performed using Flame Atomic Absorption Spectrophotometry (AAS). The digestion and analysis protocols were adapted from international standards to ensure accuracy and comparability with previous studies.

#### 2.2.1 Sample Preparation and Digestion

- **Mercury Analysis**: Conducted at the Public Health Laboratory at the University of Benghazi.
- **Lead, Tin, Copper, Zinc Analysis**: Conducted at the Center for Food and Drug Control, Tripoli.

Samples were digested using a wet digestion method. A 5.0 g portion of each homogenized tuna sample was treated with a mixture of concentrated nitric acid ($HNO_3$) and sulfuric acid ($H_2SO_4$) in a 1:1 ratio, followed by the addition of 10–20 mg of vanadium pentoxide ($V_2O_5$) as a catalyst. The mixture was heated in a digestion flask fitted with a 300 mL Liebig condenser to prevent the loss of volatile components. After digestion, the solution was diluted to 100 mL with deionized water and filtered. All glassware was pre-cleaned with 0.1 M $HNO_3$ to avoid contamination.

### 2.2.2 Instrumental Conditions and Detection Limits

- **Hg**: Cold vapor AAS, wavelength 253.7 nm, detection limit 0.01 µg/L.
- **Pb**: Direct AAS, wavelength 283.3 nm, detection limit 0.1 µg/L.
- **Cu**: Direct AAS, wavelength 324.8 nm, detection limit 0.02 µg/L.
- **Zn**: Direct AAS, wavelength 213.9 nm, detection limit 0.01 µg/L.
- **Sn**: Direct AAS, wavelength 286.3 nm, detection limit 0.1 µg/L.

All measurements were performed in triplicate to ensure reliability. Calibration curves were generated for each element using certified standard solutions.

### 2.3 Questionnaire Survey

A structured questionnaire was distributed to parents or guardians of 362 primary school children aged 6 to 12 years in Nalut. The survey collected data on:

- Demographic information (child's age, gender, parental education, family income, and family size).
- Consumption patterns of canned fish (type, frequency, quantity, and timing of consumption).
- Parental awareness of heavy metal contamination, associated health risks, and food label reading habits.

The questionnaire was pilot-tested for clarity and reliability prior to full deployment.

### 2.4 Statistical Analysis

Data were analyzed using **SPSS v26**. Descriptive statistics (means, standard deviations, percentages) were used to summarize heavy metal concentrations and survey responses. Inferential statistics, including **Chi-square tests and correlation analysis**, were applied to examine relationships between sociodemographic variables and:

- Canned fish consumption frequency.
- Awareness levels.
- Heavy metal concentrations in relation to sample price, origin, and preservation method.

A p-value of $<0.05$ was considered statistically significant.

## 3. Results

### 3.1 Heavy Metal Concentrations in Canned Tuna Samples

A total of 35 canned fish samples were analyzed for heavy metal content. The average concentrations (in µg/g) of the tested metals are summarized in **Table 1**.

**Table 1. Descriptive Statistics of Heavy Metal Concentrations in Canned Tuna Samples (n = 35)**

| Metal | Mean (µg/g) | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| **Lead (Pb)** | 0.0158 | 0.0119 | 0.007 | 0.060 |
| **Mercury (Hg)** | 0.0119 | 0.0033 | 0.009 | 0.023 |
| **Copper (Cu)** | 0.3898 | 0.1551 | 0.009 | 0.702 |
| **Tin (Sn)** | 1.834 | 0.7333 | 0.794 | 3.019 |
| **Zinc (Zn)** | <0.003 | 0.0000 | <0.003 | <0.003 |

All values were within the permissible limits set by Libyan and EU standards. Zinc levels were below the detection limit across all samples.

### 3.2 Correlation Between Metal Concentrations and Sample Attributes.

The relationship between heavy metal concentrations and certain product attributes (e.g., price, origin, preservation oil) was tested using correlation analysis. The significant findings are summarized in **Table 2**.

**Table 2. P-values for Associations Between Heavy Metals and Sample Attributes**

| Variable | Pb | Hg | Cu | Sn | Zn |
|---|---|---|---|---|---|
| **Sample price** | 0.488 | 0.857 | 0.558 | **0.036** | - |
| **Country of origin** | 0.473 | 0.874 | 0.852 | 0.317 | - |
| **Type of oil used** | 0.376 | 0.613 | 0.786 | 0.886 | - |

Only the tin concentration was significantly associated with the price of the product ($p = 0.036$). No significant associations were found between heavy metal levels and either the country of origin or oil type.

- No statistically significant correlation was found between sample price and concentrations of lead, mercury, or copper ($P > 0.05$).
- A statistically significant relationship was identified between sample price and tin concentration ($P = 0.036$), indicating that higher-priced products may contain higher or more variable levels of tin.

- Zinc data was excluded from this test as all samples had identical values (<0.003 ppm), making correlation analysis impossible.

There were no statistically significant relationships between country of origin and concentrations of any tested heavy metals ($P > 0.05$). This suggests that the geographic source of the product did not influence the heavy metal levels in the tested samples.

The type of oil used in preserving the tuna had no statistically significant effect on the concentration of any of the tested heavy metals ($P > 0.05$). Zinc was excluded due to uniform concentration across samples.

**3.3 Questionnaire Results: Demographics and Consumption Patterns.**

A total of 362 valid questionnaires were analyzed. The key demographic and consumption-related findings are presented in **Table 3**.

**Table 3. Demographic Characteristics and Tuna Consumption Patterns (n = 362)**

| Variable | Category | Frequency (%) |
|---|---|---|
| **Child's Gender** | Male / Female | 181 (50%) each |
| **Child's Age** | 6–7 / 8–9 / 10–11 / 11–12 | 21.3 / 32.6 / 27.9 / 18.2 |
| **Parental Education** | Primary / Secondary / Univ. / Other | 13 / 12.7 / 68.2 / 6.1 |
| **Family Monthly Income (LYD)** | <500 / 500–1000 / 1000–2000 / >2000 | 1.4 / 25.1 / 60.2 / 13.3 |
| **Family Size** | 2–3 / 4–5 / 6–7 / >7 members | 5 / 38.4 / 43.1 / 13.5 |
| **Child Eats Tuna** | Yes / No | 96.4 / 3.6 |
| **Frequency (per week)** | 1x / 2x / 3x / 4–5x / >5x | 21.5 / 24.9 / 31.2 / 17.2 / 5.2 |
| **Quantity per Meal** | 160g / 120g / 80g / 40g / 20g | 15.2 / 1.1 / 6.0 / 30.7 / 47.0 |
| **Preferred Fish Type** | Tuna / Sardine / Other | 91.4 / 4.9 / 3.7 |
| **Meal Timing** | Home breakfast / School breakfast / Snack / Dinner / >1 time daily | 49.6 / 36.1 / 4.6 / 2.0 / 7.7 |
| **Price of Tuna Consumed** | <5 / 5 / 7 / 10 / >10 LYD | 6.6 / 59.0 / 28.9 / 4.9 / 0.6 |

### 3.4 Awareness and Health Impact Perception

Respondents' awareness of heavy metals and their perceived health risks were assessed in several questions. Results are summarized in **Table 4**.

**Table 4. Parental Awareness and Health Risk Perception (n = 349)**

| Question | Yes (%) | No (%) | Somewhat (%) |
|---|---|---|---|
| **Aware tuna may contain heavy metals?** | 49.9 | 36.4 | 13.8 |
| **Believe heavy metals affect child health?** | 65.0 | 17.5 | 17.5 |
| **Aware of heavy metal poisoning symptoms?** | 23.2 | 62.2 | 14.6 |
| **Noticed symptoms after tuna consumption (e.g. headache)?** | 24.9 | 75.1 | - |
| **Change in appetite post-consumption?** | 12.3 | 71.3 | 16.3 |
| **Frequency of reading tuna labels** | Always / Sometimes / Never | 26.4 / 60.5 / 13.2 | |

### 3.5 Statistical Associations with Consumption

**Table 5. Significant Associations Between Variables and Tuna Consumption**

| Variable | p-value | Interpretation |
|---|---|---|
| **Child's age** | 0.583 | No significant association |
| **Child's gender** | **0.048** | Significant association (more consumption in males) |
| **Family size** | **0.031** | Significant association (larger families consume more) |
| **Awareness of risk** | 0.827 | No significant association |

- **Age:** No significant relationship with consumption ($P > 0.05$).
- **Gender:** Statistically significant relationship ($P = 0.048$). Suggests that boys and girls consume tuna at different rates.
- **Family Size:** Statistically significant ($P = 0.031$). Larger families may consume more tuna due to cost-effectiveness or availability.
- **Awareness of health risks:** No significant correlation with actual consumption behavior ($P = 0.827$), indicating that **awareness alone did not affect consumption frequency**.

## 4. Discussion

This study investigated the levels of heavy metals—mercury (Hg), lead (Pb), copper (Cu), tin (Sn), and zinc (Zn)—in canned tuna products sold in Nalut, Libya, while also assessing parental awareness regarding their potential health risks to children. The findings provide important insights into the safety of these products and the behavioral patterns associated with their consumption.

### 4.1 Heavy Metals in Canned Tuna: Risk Evaluation and Comparison

The analytical results showed that all canned tuna and sardine samples contained metal concentrations within the permissible limits set by the Libyan National Center for Standardization and Metrology (LNCSM) and, where local limits were absent (e.g., zinc), within European Commission standards.

- **Mercury (Hg):** Detected in all samples with values ranging from 0.009 to 0.023 µg/g. These values are significantly lower than the thresholds reported in international studies. For example, Ozyurt *et al.* (2024) reported Hg levels ranging from 0.046 to 0.099 mg/kg in Turkish tuna products. Similarly, Aboglida *et al.* (2022) documented higher values in Libya, reaching up to 7.543 µg/g in some samples.
- **Lead (Pb):** Concentrations ranged from 0.007 to 0.060 µg/g with a mean of 0.0158 µg/g, similar to Moroccan findings by Chahid *et al.* (2015) (max 0.064 µg/g), but lower than those from Brazil, where De Paiva *et al.* (2017) reported values up to 59 µg/kg.
- **Copper (Cu):** Values ranged from 0.009 to 0.702 µg/g, aligning with studies by Bushanati (2023) in Derna (0.010–0.20 µg/g). In contrast, an Iraqi study by Jasim & Shakhair (2016) reported copper levels exceeding 2.0 µg/g in some sardine products.
- **Tin (Sn):** The mean concentration was 1.834 µg/g, with a maximum of 3.019 µg/g. While this is within safety margins, it differs from the Lebanese study by Al Ghoul *et al.* (2020), which found 100% of canned fish samples contaminated with tin, raising potential chronic toxicity concerns.
- **Zinc (Zn):** All samples had zinc concentrations below the detection limit (<0.003 µg/g). This contrasts with local data by Ahmed *et al.* (2023), where Zn levels ranged from 0.410–1.3 µg/g, although still within safe intake limits.

Overall, these findings suggest that the canned fish products available in Nalut do not currently pose a significant risk of heavy metal toxicity under typical consumption patterns. Nevertheless, long-term exposure through cumulative dietary intake remains a concern, particularly for vulnerable groups such as children and pregnant women (Grandjean & Landrigan, 2014).

**Sample-Specific Comparisons**

Mercury levels in brands like Al-Wafaa, Americana, Al-Sayyad, Al-Jayyid, and Campos ranged between 0.009 and 0.013 ppm, while copper levels ranged from 0.221 to 0.700 ppm, and lead levels from 0.010 to 0.042 ppm. A study by Ommar *et al.* (2023) also evaluated these brands and reported:

- Higher mercury values in brands like Al-Wafaa (0.0232), Americana (0.0583), and Al-Sayyad (0.0544),
- Some copper concentrations were below the detection limit,
- Lead concentrations in some brands were undetectable due to instrument sensitivity limits.

These variations highlight inconsistencies in heavy metal content across studies, possibly due to differences in sample sources, analytical techniques, or product batches.

**International Health Risk Indicators**

A Brazilian study by Leite *et al.* (2022) reported that all samples exceeded safety thresholds based on Hazard Quotients (HQ) and Cancer Risk Index (Hi)—deeming the products unfit for human consumption. By contrast, the current study confirms that all samples were within Libyan and European safety standards.

**4.2 Associations with Sample Characteristics**

Interestingly, only tin concentrations were significantly correlated with sample price ($p = 0.036$), potentially indicating that more expensive brands may use superior preservation materials or undergo more rigorous quality control. No significant relationships were found between metal concentrations and country of origin or oil type, a result also observed in the study by Aberoumand & Baesi (2023), who noted no consistent correlation between metal content and preservation medium.

**4.3 Parental Awareness and Children's Consumption Behavior**

The survey findings show a high prevalence of tuna consumption among children (96.4%), with nearly half of respondents (47%) reporting that their child consumes just a spoonful (~20 g) per serving. While this suggests moderate intake in most cases, 31.2% of children consume tuna 3 times per week or more, which could pose risks over time if metal accumulation occurs.

However, parental awareness was limited:

- Only 49.9% knew that tuna may contain heavy metals.
- Just 23.2% could identify symptoms of heavy metal poisoning.

- Only 26.4% reported always reading nutritional labels when purchasing canned fish.

These results align with findings by Gonzalez-Acuna *et al.* (2017), who found that many parents underestimate or are unaware of metal contamination in fish products. Similarly, in Saudi Arabia, Almoallem (2022) found that although canned tuna was frequently consumed by students, knowledge of food safety was lacking among caregivers.

**4.4 Demographic Correlates of Consumption**

Statistical tests revealed that:

- **Gender** was significantly associated with tuna consumption frequency ($p = 0.048$), with boys consuming more than girls.
- **Family size** was also significant ($p = 0.031$), suggesting that larger households consume more canned tuna, possibly due to cost-effectiveness.

These trends were also observed in a Libyan study by Younis *et al.* (2023), where families with more than five members had higher fish consumption rates. Conversely, no significant associations were found between age or awareness level and consumption frequency ($p > 0.05$), indicating that knowledge alone may not influence dietary choices without additional education or motivation.

**4.5 Observed Health Symptoms and Risk Perception**

Only 10% of parents reported observing attention-related disorders after tuna consumption, and 6% reported skin issues or allergic reactions. Although these symptoms cannot be conclusively linked to heavy metals based on survey data alone, they warrant further toxicological study. The relatively low concern reported by parents reflects a **gap in risk perception**, which could be addressed through targeted public health campaigns.

In summary, while the canned tuna products analyzed were chemically safe, there is:

- A **significant lack of consumer awareness**,
- A **potential risk of overconsumption** in children,
- And **demographic factors** (gender and family size) influencing consumption habits.

These findings echo the need for **nutritional education, food labeling improvements**, and **routine food safety monitoring** in Libya and similar settings.

**Consumer Behavior**:

- Most respondents selected tuna brands based on **quality** and **price**.
- This pattern is similar to findings by **Zaeema & Hassan (2016)** in the Maldives, who concluded that **product characteristics strongly influenced consumer decisions**.

**Oil Type Analysis**:

- No statistically significant relationship was observed between **oil type** and **metal concentrations**.
- This contradicts the Iranian study by **Aberoumand & Baesi (2023)**, which found oil composition significantly influenced heavy metal content after storage.

**5. Conclusion**

This study assessed the concentrations of heavy metals (Hg, Pb, Cu, Sn, Zn) in canned tuna products sold in Nalut, Libya, and examined parental awareness of the associated health risks, especially regarding their children's consumption. The analytical results confirmed that all tested metal concentrations were within the permissible limits established by Libyan and international standards, indicating that the sampled products are chemically safe for human consumption under typical dietary conditions.

However, despite the absence of toxic levels in the tested products, the findings raise concerns about long-term health risks due to high consumption frequencies, particularly among children. Nearly one-third of surveyed children consumed canned tuna more than twice per week, and almost half of the parents were unaware of the potential presence of heavy metals in such products. Awareness of the symptoms of heavy metal toxicity and proper reading of product labels were also limited.

Furthermore, the statistical associations between consumption and demographic factors such as gender and family size highlight the need for more nuanced and targeted health interventions. Although no direct health hazards were identified in this study, the potential for chronic exposure necessitates sustained public health vigilance, education, and policy support.

**6. Recommendations**

Based on the findings, the following recommendations are proposed:

1. **Enhance Public Awareness:**
   Health authorities should initiate awareness campaigns to educate consumers—especially parents—about the potential risks of heavy metals in canned fish and the importance of moderation in consumption.

2. **Encourage Moderate Intake:**

   Even with safe metal levels, overconsumption of canned tuna may lead to bioaccumulation over time. It is recommended that families limit tuna consumption, particularly for young children and pregnant women.

3. **Promote Safer Product Selection:**

   Consumers should be encouraged to select tuna products from reputable brands and sources with established quality assurance programs. Preference should be given to certified organic or sustainable products when available.

4. **Improve Food Labeling and Transparency:**

   Government agencies and manufacturers should ensure that product labels clearly indicate the country of origin, type of preservation oil, and any relevant food safety certifications.

5. **Support Local Laboratory Capacity:**

   Investment in regional laboratory infrastructure—particularly in cities like Nalut—is essential for continuous monitoring of food safety and the detection of contaminants.

6. **Future Research:**

   Further studies are recommended to assess cumulative exposure to heavy metals from various dietary sources and to evaluate the long-term health outcomes of high-frequency tuna consumption in children.

**7. Study Limitations**

Although this study provides valuable insights into the safety of canned tuna products and parental awareness in Nalut, several limitations should be acknowledged:

1. **Limited Laboratory Access in Nalut:**

   The absence of specialized laboratories for heavy metal analysis in Nalut required sample transportation to Tripoli and Benghazi. This increased logistical complexity and risk of sample degradation or delays.

2. **Loss of Questionnaire Responses:**

   A significant portion of distributed questionnaires was lost or not returned, primarily due to reliance on schoolchildren to deliver and retrieve the forms. This may have introduced a non-response bias and reduced sample size for the survey portion.

3. **Lack of Baseline Data for Comparison:**

   There is a scarcity of previous local studies that assess both heavy metal contamination and consumer knowledge using similar methodologies, making direct benchmarking or trend analysis difficult.

4. **Cross-Sectional Nature of the Study:**

   The study's design limits the ability to establish causality between consumption habits and observed symptoms or health outcomes in children.

5. **Underestimation of Exposure Risk:**

   Other dietary sources of heavy metals were not accounted for (e.g., other seafood, rice, water), which may contribute to cumulative exposure in children and families.

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