

Heavy Metals Levels and Health Risks Assessment of Imported Frozen *Trachurus murphyi* Collected from a Market in Ibadan, Nigeria

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Abstract

There is dearth of information on quality control along the distribution chain to the final consumer of frozen fish imported into the country. In order to protect the health of the fish consumers, this study investigates the concentration of Lead (Pb), Cadmium (Cd), Chromium (Cr), Arsenic (As) and Mercury (Hg) in the gills, muscles and liver of imported frozen *Trachurus murphyi* (Jack Mackerel). Health risk of consumers was also assessed by adopting Total Hazard Quotient (THQ), Daily Intake of Metals (DIM), Hazard Indices (HI) and Target Cancer Risk (TCR). Forty (40) pieces of fish samples were collected each month from a popular cold store in Ibadan Metropolis across the three months of study. The concentrations of the selected heavy metals in the digested samples were analyzed using Atomic Absorption Spectrophotometer (AAS) and statistically using Analysis of Variance (ANOVA) followed by the Post-Hoc test which established significance level at $p < 0.05$. The result showed that Lead has the highest mean concentration in the gills (1.19 mg/kg), muscles (1.25 mg/kg) and liver (1.33 mg/kg) respectively for the three months of study. The concentration of Arsenic and Mercury were within the international standard limits while Pb, Cd and Cr were above. The health risk assessment indices obtained were however below the threshold, indicating that the consumption of imported frozen *Trachurus murphyi* is safe and non-hazardous. Due to the non-degradable nature and tendency of heavy metals to accumulate in tissues, regular monitoring is recommended to mitigate contamination and ensure compliance with food safety.

Keywords: Heavy Metals, Jack Mackerel, Imported Frozen Foods, Food Safety, Health Risk.

Introduction

Water plays a critical role in sustaining life and maintain ecological balance, yet it is increasingly threatened by pollution. The contamination of water bodies not only degrades water quality but also poses significant risks to human health and ecosystem (Singh, 2024). For decades, environmental pollution has remained a global problem causing a negative change in the natural phenomena of the environment to critically harmful conditions not only affecting human health and welfare but the sustainability of our natural resources in the environment (Xu et al., 2022). Water pollution arises from either point sources such as

the disposal of solids and organic waste that deplete dissolved oxygen, primarily from untreated urban sewers and industrial drains which also facilitate the spread of trace contaminants, hazardous compounds and heavy metals like lead, cadmium, zinc, chromium and mercury (Hossain, 2024) or non-point sources from diverse non-identifiable sources such as rainfall, snowfall or irrigation or through aquifers that picks up pollutants and deposits them in water bodies (Singh and Gupta, 2016).

Heavy Metals (HMs) are elements in the periodic table with an atomic number greater than 20 and an atomic density higher than 5 g cm⁻³ that exhibit the properties of metals (Raychaudhuri et al., 2021). Heavy metals (HMs) can be generically categorized into two groups: essential and non-essential (Khalef et al., 2022). The Chilean jack mackerel (*Trachurus murphyi*, Nichols, 1920) belongs to the genus *Trachurus* in the family *Carangidae*. It is often referred to as the Peruvian jack mackerel, a highly migratory pelagic species that its range of distribution extends from South America to Chile, New Zealand and even Australia, across the sub-tropical waters of the South Pacific Ocean (Ferrada et al., 2023). *Trachurus Murphyi* is particularly reported as wild captured and are either epipelagic or benthopelagic schooling species and most susceptible to water pollution; taking up metals from surrounding habitat and concentrate to ranges of varied levels in their body tissues (Abubakar et al., 2020). The concern about the high levels of trace metals in seafood has prompted several studies, and particularly frozen fish are of greater concern. Among the heavy metals (HMs), Cadmium is ranked as the seventh most dangerous and toxic element (Jaishankar et al., 2014). Lead exposure can result in a variety of health issues, including a decline in IQ, memory loss, infertility, mood swings, joint weakness, nausea, sleeplessness, anorexia, and even mortality (Sanders et al., 2009). Arsenic pollutes drinking water and can also lead to developmental anomalies, neuro-behavioral disorders, cardiovascular problems, and hearing impairments (Tchounwou et al., 2012).

Chromium is referred to as a very hazardous heavy metal due to its ability to pierce the cell membrane through the sulphate transport system and induce denaturation and mutation in proteins and nucleic acids. Important health concerns such as skin disorders, nasal irritation, hearing loss, and lung cancer are also brought on by it (Shin et al., 2023). Aquatic ecosystems have been exposed to heavy metals through a variety of natural and man-made sources, such as home or industrial effluent, pesticide and inorganic fertilizer application, storm runoff, landfill leaching, shipping and harbour operations, atmospheric deposits, and geological weathering of the earth (Nikiema and Asiedu, 2022). Heavy metals are extremely detrimental to aquatic life, even at very low concentrations which have the potential to significantly alter an aquatic organism's histology and physiological makeup, including those of fish (Sonone et al., 2020). While many studies indicate low health risks associated with consuming contaminated fish, the potential for bioaccumulation and bio-magnification in food chains remains a concern (Yadav et al., 2024). Accumulation of heavy metals in marine organisms is growing in several global regions and the need for quality assurance has prompted studies on the toxic effects of these elements in food that they are present. Similar studies carried out by Wangboje, (2023), Akinsorotan et al. (2023) Useh et

al. (2022) and Abubakar et al. (2020) on concentration of heavy metals in fish and its health implication were however not exhaustive.

This study investigates the levels of heavy metals concentration of Lead (Pb), Cadmium (Cd), Chromium (Cr), Arsenic (As) and Mercury (Hg) in the gills, muscles and liver of frozen *Trachurus murphyi* commonly known as Jack Mackerel and health risk assessment in relation to the established international standard limits.

Materials and Methods

Fish Sample Collection

One hundred and twenty (120) pieces of frozen samples of *Trachurus murphyi* (Jack Mackerel) was purchased from the cold store at 40 pieces per month. The fish were collected from a popular cold store in Lagelu Local Government Area of Ibadan, located approximately on longitude 3° 50' East of the Greenwich meridian and Latitude 7° 23' North of the equator and 275 meters above sea level. The analysis was carried out in the months of January, February and March, 2024. Samples were wrapped in a foil paper and placed in polythene bags and conveyed to the laboratory in a cooler with ice packs to prevent deterioration and maintain freshness prior to the heavy metal analysis. Accurate weight measurement was taken with a weighing balance (Electronic TM, SF-400) in grams; the total length and standard length were measured using a measuring board and recorded in centimeters before dissecting for analysis.

Sample Preparation

The fish samples were allowed to thaw and dissected to separate the muscle, gills and liver. The separated part was neatly placed in a labelled sample bottle and formalin was added as preservative before digestion and analysis.

Digestion of Samples

0.5g of each tissue was weighed into a beaker and 5mL of 2:1 nitric and perchloric acid ($\text{HNO}_3/\text{HClO}_4$) was added, the beaker content was gently swirled and placed on a hot plate at a regulated temperature to 80°C for two hours under a fume cupboard. The heating continues and there was a colour change from brownish colour to colourless indicating that it has been fully digested as recommended by Igwemmar et al., (2013). After cooling, the digests were filtered into 25mL volumetric flasks using Whatman No. 1 filter paper and diluted with de-ionized water. Sample blanks were conducted throughout the digestion process following the FAO/SIDA (1983) protocols. The heavy metal content of both the digested samples and blanks was measured using Buck Scientific Atomic Absorption Spectrophotometer model 210/211 VGP. The concentrations of Pb, Cd, Cr, As and Hg were expressed in mg /kg.

Health Risk Assessment

It includes the evaluation of certain indices to quantify the potential health risks associated with the consumption of the muscle tissue of *Trachurus murphyi*. These include the Target

Hazard Quotient (THQ), Daily Intake Metal (DIM), Hazard Index (HI) and Target Cancer Risk (TCR). The calculation methodologies employed for these indices were based on the approaches outlined by Khan *et al.*, (2022) and Jajere *et al.*, (2023).

Target Hazard Quotient (THQ)

THQ represents the non-carcinogenic health risks posed by the consumption of heavy metals (Njoga *et al.*, 2021). THQ is calculated using the USEPA (2021) formula:

$$THQ = [(Ef \times Ed \times QFC \times C) / (RfD \times BW \times Et)] \times 10^{-3} \quad (1)$$

Where;

Ef = exposure frequency in days (365)

Ed = exposure duration (equivalent to life expectancy of Nigerian set at 55years) Bernard *et al.*, 2020). QFC is the estimated quantity of frozen fish consumed daily (kg/person/day) = 0.0345 kg.

C = mean concentration of heavy metal in the frozen fish (mg/kg),

RfD = Oral reference dose

BW = average body weight in kg (Children 0-17 years = 30 kg; Adult $\geq$ 18 years = 60 kg)

Et (Ef $\times$ Ed) = Exposure time (365days $\times$ 55years)

Daily Intake Metal (DIM)

The Daily Intake Metal (DIM) denotes the quantity of a substance present in food, typically measured in milligrams per kilogram of body weight, which humans can safely consume daily throughout their lifetime without facing substantial health hazards (Benard *et al.*, 2020).

The DIM values for Pb, Cd, Cr, As and Hg was determined according to USEPA, (2021) formula:

$$DIM = [C \times QFC] / BW \quad (2)$$

Where; C = mean concentration of heavy metal in the frozen fish (mg/kg),

BW = average body weight in kg (Children 0-17 years = 30 kg;

Adult $\geq$ 18 years = 60 kg) and

QFC is the estimated quantity of frozen fish consumed daily (kg/person/day) = 0.0345 kg.

Hazard Index (HI)

The hazard index determines the potential risk to human health from the combined effect of pollutants. Fish may be contaminated with multiple toxic heavy metals having similar adverse effects. The individual fish THQs of selected heavy metals is therefore aggregated using the formula:

$$HI = THQPb + THQCd + THQCr + THQAs + THQHg \quad (3)$$

Target Cancer Risk (TCR)

TCR was calculated to assess the potential carcinogenic risks associated with life time exposure to selected heavy metals. This is determined according to USEPA (2021) formula:

$$\text{TCR} = \text{CSF} \times \text{EDI} \quad (4)$$

Where; CSF = Cancer slope factor

EDI = Estimated daily intake

If $\text{TCR} > 1$ = carcinogenic risk

Statistical Analysis

All data were statistically analyzed by using analysis of variance (ANOVA) to identify specific differences between means followed by the Duncan Multiple Range Test and the statistical significance level was established at $p < 0.05$ using SPSS version 17 computer statistical software package.

Results

The heavy metal concentration in fish sample in January shows lead (Pb) with $1.12 \pm 0.02 \text{ mg/kg}$ in the muscle and the least was Arsenic ($0.01 \pm 0.00 \text{ mg/kg}$) in liver while Mercury was not found in the sample. February shows Lead with highest concentration ($1.66 \pm 0.05 \text{ mg/kg}$) in liver and least was Arsenic with $0.01 \pm 0.00 \text{ mg/kg}$ in the muscle of sample. Mercury was also absent. In March, lead also recorded the highest concentration of $1.28 \pm 0.02 \text{ mg/kg}$ in fish muscle. Mercury however was least with $0.03 \pm 0.02 \text{ mg/kg}$ in gills and muscle of fish sample (Table 1).

Table 1: Mean value and standard deviation (mg/kg) of heavy metal concentrations across the time of study

	Tissues	Pb	Cd	Cr	As	Hg
January	Gills	1.04 ± 0.01^a	0.00 ± 0.00^a	0.05 ± 0.00^a	0.01 ± 0.00^a	0.00 ± 0.00^a
	Muscles	1.21 ± 0.02^b	0.12 ± 0.03^b	0.13 ± 0.04^a	0.01 ± 0.00^a	0.00 ± 0.00^a
	Liver	1.16 ± 0.03^b	0.14 ± 0.05^b	0.12 ± 0.00^a	0.01 ± 0.00^a	0.00 ± 0.00^a
February	Gills	1.38 ± 0.04^a	0.00 ± 0.00^a	0.08 ± 0.00^a	0.03 ± 0.02^a	0.00 ± 0.00^a
	Muscles	1.25 ± 0.02^a	0.05 ± 0.07^a	0.13 ± 0.02^a	0.01 ± 0.00^a	0.00 ± 0.00^a
	Liver	1.66 ± 0.05^b	0.10 ± 0.14^a	0.20 ± 0.14^a	0.02 ± 0.00^a	0.00 ± 0.00^a
March	Gills	1.17 ± 0.01^a	0.06 ± 0.01^a	0.23 ± 0.02^b	0.12 ± 0.03^a	0.03 ± 0.02^a
	Muscles	1.28 ± 0.02^b	0.15 ± 0.06^a	0.16 ± 0.01^a	0.18 ± 0.01^a	0.03 ± 0.02^a
	Liver	1.17 ± 0.02^a	0.14 ± 0.01^a	0.12 ± 0.01^a	0.14 ± 0.02^a	0.04 ± 0.01^a

Values in each row marked by the same superscript letter are not significantly different at $p < 0.05$

Table 2 shows the average mean concentrations of the selected heavy metals; Lead (Pb), Cadmium (Cd), Chromium (Cr), Arsenic (As), and Mercury (Hg), in the gills, muscle, and liver tissue of *Trachurus Murphyi* over the three months of study. It also provides the safe limits

recommended by the Food and Agriculture Organization (FAO) and the World Health Organization (WHO) for these heavy metals in seafood.

Table 2: Average values of concentration and safe limits (mg/kg) of heavy metals

Tissues	Pb	Cd	Cr	As	Hg
Gills	1.19	0.06	0.12	0.16	0.03
Muscles	1.25	0.10	0.14	0.07	0.03
Liver	1.33	0.13	0.15	0.06	0.04
Safe limits (FAO)	2	0.1	0.15-1.0	1.0	0.5
Safe limits(WHO)	0.5	0.1	0.1	1.0	0.5

The results presented in Table 3 provide a comprehensive assessment of the potential human health risks associated with the consumption of the muscle tissue of *Trachurus murphyi*. The analysis encompasses the evaluation of various heavy metals, including Lead (Pb), Cadmium (Cd), Chromium (Cr), Arsenic (As), and Mercury (Hg), and their potential impact on both children and adults. The THQ for Pb, Cd, Cr, As and Hg in children and adult given as: 4.11E-4, 2.30E-4, 5.37E-5, 2.68E-4 and 3.45E-1 respectively for children and 2.05E-4, 1.15E-4, 2.68E-5, 1.34E-4 and 1.72E-1 respectively in adults. The DIM in mg/kg/day for children and adult Pb, Cd, Cr, As and Hg is estimated as follows: 1.44E-3, 1.15E-4, 1.61E-4, 8.05E-5 and 3.45E-5 respectively in children and 7.19E-4, 5.75E-5, 8.05E-5, 4.03E-5 and 3.45E-5 respectively in adults. The TCR for Pb, Cd, Cr and As in children is given by; 1.15E-5, 4.37E-5, 6.60E-3 and 1.21E-4 and for adults; 5.75E-6, 2.19E-5, 3.3E-3 and 6.05E-5 respectively.

Table 3: THQ, DIM AND TRC for Adult and Children responses of Heavy Metals in Muscle Tissues of *Trachurus murphyi*

Heavy metals	Range (mg/kg)	Mean (mg/kg)	Individuals	THQ	DIM (mg/kg/day)	TCR
Pb	1.21- 1.28	1.25	Children	4.11E-4	1.44E-3	1.15E-5
			Adult	2.05E-4	7.19E-4	5.75E-6
Cd	0.05- 0.15	0.10	Children	2.30E-4	1.15E-4	4.37E-5
			Adult	1.15E-4	5.75E-5	2.19E-5
Cr	0.13-0.16	0.14	Children	5.37E-5	1.61E-4	6.60E-3
			Adult	2.68E-5	8.05E-5	3.3E-3
As	0.01-0.18	0.07	Children	2.68E-4	8.05E-5	1.21E-4
			Adult	1.34E-4	4.03E-5	6.05E-5
Hg	0.00-0.03	0.03	Children	3.45E-1	3.45E-5	–
			Adult	1.72E-1	1.73E-5	–

THQ = Total Health Quotient, DIM= Daily Intake Metal, TRC = Target Cancer Risk

Figure 1 shows the heavy metal concentration in the gills, muscle and liver tissue of *Trachurus murphyi* between January and March 2024. The heavy metal accumulation in descending order as observed was Pb > As > Cr > Cd > Hg in the gills, Pb > Cr > Cd > As > Hg in the muscles and liver respectively.

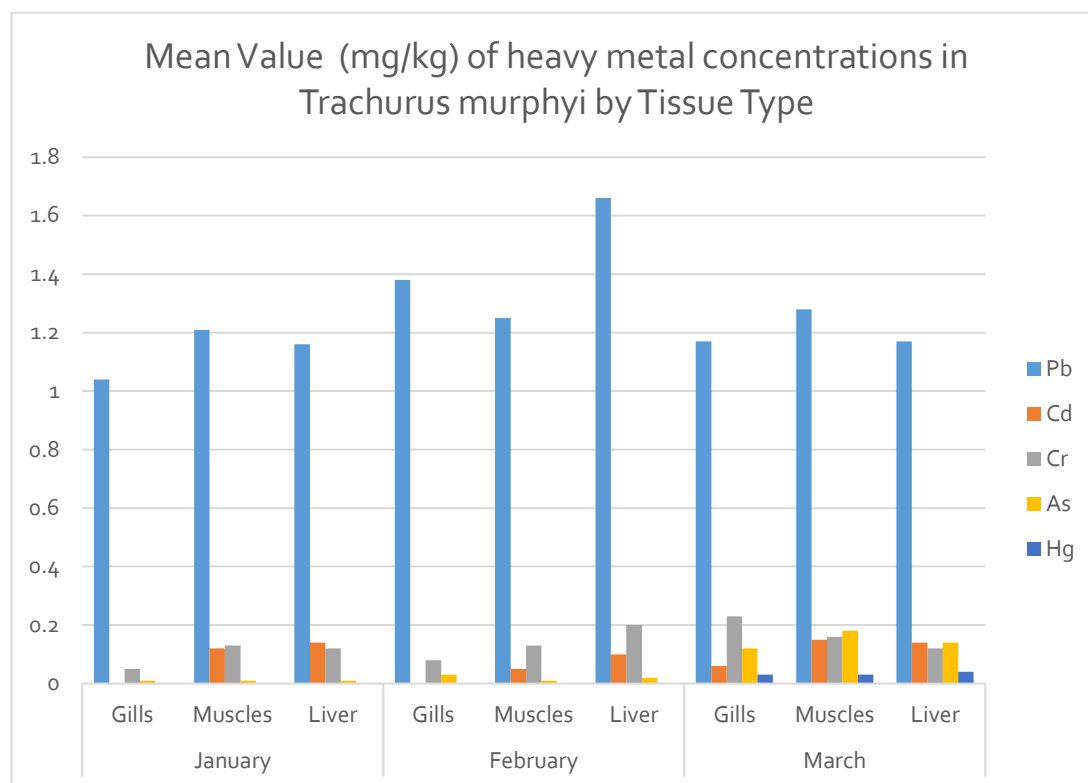


Figure 1: Heavy Metal Concentrations in Gills, Muscles and Liver Tissue of *Trachurus murphyi* between January and March.

Discussion

The results provide important information about the distribution and concentration of the selected heavy metals (lead, cadmium, chromium, arsenic, and mercury) in different tissues (muscles, liver, and gills) of frozen *Trachurus murphyi* fish sample. The concentration of Lead was found to be the highest of all the analyzed heavy metal in the fish tissues across the three months of study. These findings align with Olaifa and Fawole (2025), who reported highest concentration of Pb in frozen *Clupea harengus* tissues collected from a cold store in Ibadan. Highest Lead concentration was also obtained by Abubakar et al., (2020) in frozen *Trachurus murphyi* sold in Zaria, Nigeria. According to Rahman et al., (2023), when fish feeds on organisms that have already accumulated Lead (Pb), it can lead to an accumulation of higher Pb concentrations in their tissue. Studies have shown that the liver can act as a major site of heavy metal accumulation in fish, as it plays a significant role in the biotransformation and elimination of these metals from the body (Javed et al., 2016). Higher concentrations of heavy metals was recorded in liver by Kacar (2024) compared to muscle tissue of *Squalius pursakensis* and *Cyprinio carpio*. This result is in agreement with Akinsorotan et al. (2023) who discovered elevated concentration of Cd, Cr, and Pb in fish

tissue fish tissues selected fish farms in Ekiti state, Nigeria. Average Cr and Cd concentration in the fish tissue were high but within the standard safe limit. This is similar to the work of Ogbuene et al. (2024) who reported heavy metals like Cd and Arsenic in *Clarias gariepinus* and *Oreochromis niloticus* in Anambra River. Overconsumption of Cr according to Suchana et al. (2021) can lead to alteration of blood parameters and damage kidney and liver. Promotion of apoptosis oxidative stress and DNA damage were traced to Cd exposure (Engwa et al., 2019). Elevated mercury levels in fish are linked to neurotoxic effects, particularly in vulnerable populations such as pregnant women and children (Vergara et al., 2024; A-Sulaiti et al., 2023).

The Target Hazard Quotient (THQ) values are well below the threshold of 1, which is considered the level of concern as also reported in recent study by Torabi et al. (2024). According to Yin et al (2024), THQ value below 1 indicates a low risk for human consumption. The Daily Intake of Metals (DIM) values for children are relatively low, same for adults, indicating a reduced exposure risk to the heavy metals. This is supported by Jajere et al. (2023) who also reported below harmful threshold level of THQ and DIM in recent study. The Total Carcinogenic Risk (TCR) values are within the generally accepted risk range, suggesting a relatively low cancer risk associated with the consumption of *Trachurus murphyi* muscle tissue. The hazard index (HI) value for both children and adults was also less than 1. This according to Njoga et al. (2021) suggests low or non-carcinogenic health risks. Overall, the findings suggest that, with the exception of Hg, the individual heavy metal contaminants pose a relatively low non- carcinogenic and carcinogenic health risk for both children and adults. However, the THQ value for Hg in children is notably higher, warranting further investigation and potential risk management strategies to ensure the safety of fish consumption, particularly for vulnerable populations such as children.

Conclusion and Recommendations

The results obtained from the study revealed that Lead (Pb) exhibited the highest concentration among all the heavy metals analyzed in the fish tissues which is above the acceptable limits recommended by WHO but within the safe limits recommended by FAO. There is therefore the need for further investigation and potential risk management strategies to ensure safety of consumers.

Based on the findings highlighted above, the paper recommends the following:

- i. Relevant authorities should assume an interventionist role through regulations and policy to define minimum standard for frozen fish meant for consumption.
- ii. Periodic surveillance by regulatory authorities is also necessary to enforce compliance to national and local food laws.
- iii. Regulatory authorities should also assume responsibility for ensuring operation of fair trading practices and prioritize safety.
- iv. Consumer education should also be encouraged to ensure that public health problems arising from consumption of fish products are controlled.

Data Availability

Data is available upon reasonable request from the first author.

Conflict of Interests

The authors declare that there is no conflict of interest related to this article and no grants or fund was assessed to carry out this work.

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