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Metal Levels in *Trachurus mediterraneus ponticus* Aleev, 1956 and Their Health Fisk Appraisal for Consumers

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Research Article

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Abstract

This research was carried out to determine the levels of Cd, Hg, Pb, As, Al, Cu, Fe and Zn in the muscles of *Trachurus mediterraneus ponticus*. The fish samples were collected from the Samsun coasts of the Black Sea between September and December in both 2021 and 2022 and were analysed by using Inductively Coupled Plasma Mass Spectrophotometer. The metal values in the muscle tissues of horse mackerel were below the permissible values. Zn has the higher mean concentration (5.475 mg/kg wet weight (w.w.)) followed by Fe (mean concentration of 3.887 mg/kg w.w.) and Cu (mean concentration of 0.178 mg/kg w.w.) The Cd was found at the lowest (0.0077 mg/kg w.w.) mean concentration followed by Hg (0.0096 mg/kg w.w.), Pb (0.0453 mg/kg w.w.), and Al (0. 1077 mg/kg w.w.). The target hazard quotients (THQs) for individual metals and the total target hazard quotients (TTHQs) were <1 in horse mackerel indicating no health risk for consumption by infants, children, and adults. The risk indexes (RIs) for Pb were from 1.93×10^{-7} for adults in 2022 to 5.75×10^{-7} for infants in 2021, indicating their insignificant carcinogenic risks, whereas for As RIs were from 8.61×10^{-5} for adults in 2022 to 2.29×10^{-4} for infants in 2021, indicating their tolerable or acceptable carcinogenic risks.

Keywords: Horse mackerel, toxic metals, target hazard quotient, risk index

Trachurus mediterraneus ponticus Aleev, 1956 Türündeki Metal Seviyeleri ve Tüketiciler için Sağlık Riski Değerlendirmesi

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Öz

Bu araştırmada, *Trachurus mediterraneus ponticus* türünün kaslarındaki Cd, Hg, Pb, As, Al, Cu, Fe ve Zn düzeylerini belirlemek amaçlanmıştır. Karadeniz'in Samsun kıyılarından 2021 ve 2022 yılları Eylül ve Aralık ayları arasında toplanan balık örnekleri İndüktif Eşleşmiş Plazma Kütle Spektrofotometresi kullanılarak analiz edilmiştir. İstavritin kas dokularındaki metal değerleri izin verilen değerlerin altında bulunmuştur. Zn daha yüksek ortalama konsantrasyona sahip olarak bulunmuş (5.475 mg/kg yaş ağırlık (y.a.), bunu Fe (ortalama konsantrasyon 3.887 mg/kg y.a) ve Cu (ortalama konsantrasyon 0.178 mg/kg ya) izlemiştir. Cd en düşük konsantrasyon (0.0077 mg/kg y.a.) olarak bulunmuş, bunu Hg (0.0096 mg/kg y.a.), Pb (0.0453 mg/kg y.a.) ve Al (0.1077 mg/kg y.a.) izlemiştir. Metaller için tek tek hedef tehlike katsayıları (THQ'lar) ve toplam hedef tehlike katsayıları (TTHQ'lar) <1 olarak bulundu ve bebekler, çocuklar ve yetişkinler tarafından tüketilmesi için sağlık riski

	olmadığını göstermektedir. Pb için risk indeksleri (RI'ler) 2022'de yetişkinler için 1.93×10^{-7} 2021'de bebekler için 5.75×10^{-7} olarak önemsiz kanserojen risklerini gösterirken, As için RI'lar 2022'de yetişkinler için 8.61×10^{-5}'ten 2021'de bebekler için 2.29×10^{-4}'a olarak tolere edilebilir veya kabul edilebilir kanserojen risklerini göstermektedir. **Anahtar Kelimeler:** İstavrit, toksik metaller, hedef tehlike oranı, risk indeksi

Introduction

Fish is an important nutrient source, such as protein, omega-3 fatty acids, and a range of minerals and vitamins [1, 2]. Many health organizations recommend that people include a serving of fish in their diet at least a couple of times per week [3]. However, it is crucial to take into account potential risks associated with consuming fish, such as the potential for exposure to pollutants including metals. Fish consumption guidelines are often developed by health organizations to help people balance the potential health benefits of fish consumption with these risks. For example, the Food and Agriculture Organization (FAO), the World Health Organization (WHO) [4] and European Commission (EC) Regulation [5] have developed guidelines for fish consumption that provide recommendations on the species and amounts of fish that are safe to eat. These guidelines consider the contaminant levels including metals species in different fish and the potential health effects caused by exposure to these substances. It is important to follow the guidelines set by health organizations and to be mindful of the potential dangers caused by the consumption of fish. The toxic metals, including non-essential metals, such as cadmium (Cd), mercury (Hg), lead (Pb), arsenic (As), and aluminium (Al) can have significant impacts on fish. These metals can be dangerous for fish species at extremely low amounts and can accumulate in the tissues of fish through the process of biomagnification. Likewise, essential iron (Fe), copper (Cu), and zinc (Zn) can have the same harmful effects on fish at high concentrations. Whether essential or not metals can have a range of negative effects on fish, and exposure to these metals in contaminated seawaters can be especially harmful to the health of people via consumption of contaminated fish species. Principally, it is crucial to consider the potential risks associated with fish consumption and to take steps to reduce the risk of exposure to contaminants, while also taking advantage of the potential health benefits of including fish in the diet. Especially in the coastal ecosystems of the marine environment, fish accumulates metals which fish may absorb metals from the water directly or through their feed. The metals are natural components and non-biodegradable chemicals occurring in the marine environment naturally or as results of anthropogenic activities such as discharges from agricultural, touristic, fisheries and urban sewage, domestic and industrial wastes. This study is aimed to determine the concentration of cadmium (Cd), mercury (Hg), lead Pb), arsenic (As), aluminium (Al), copper (Cu), iron (Fe) and zinc (Zn) in the muscle tissue of *Trachurus mediterraneus ponticus* Aleev, 1956 captured in Samsun coastal waters of the Black Sea and, find whether the metal concentrations are in the allowable restricts informed by the national and international organizations. In addition, health risk assessment analyses were conducted for people consuming this fish. The horse mackerel has been one of the commercially significant fish species in the Black Sea. In 2021, 19590.1 tons of this fish were captured in the Turkish Black Sea [6].

Materials and Methods

Sample Collection

Mediterranean horse mackerel were captured with the help of the local fisherman between September and December in both 2021 and 2022. At least 25 samples (16±3 lengths; 33±5 weights) collected in each sample washed, labelled, put plastic bags, and stored at -12 °C in a deep freezer until analysis.

Determination of Metals

The muscle tissues of the fish samples were removed with a plastic knife. Inductively Coupled Plasma Mass Spectrometry (ICP-MS) was used for metal levels. m-AOAC 999.10- method was performed for metal analysis in the horse mackerel by authorised environment commercial analysis laboratory services trade corporation (TÜRKAK Test TS EN ISO IEC 17025 AB-0364-T). European Standard method (EN 15763) was used [7]. The standard reference material (SRM) used in this study for quality control was lobster TORT-2 [7]. The SRM's component accuracy varied by no more than 10%. The data were analysed using the mean values, with each analysis being done in triplicate. The results were presented in mg/kg wet weight.

Estimated Daily Intake

The equation below gives the estimated daily intake (mg/kg/day):

$$EDI = \frac{C_{samples}\ x\ CR}{Bwt}$$

where: $C_{samples}$ is the mean metal concentration in horse mackerel samples (mg/kg), CR is the daily fish consumption rate and Bwt represents the mean body weight. It is well known that consumers' daily fish intake varies depending on their weight and age groups [7, 8, 9]. The calculations in this study were based on three groups and the data from the United Nations Scientific Committee on the Effects of Atomic Radiation [10]. According to UNSCEAR [10], the average body weights of infants, children, and adults were 10, 30, and 70 kg, respectively. 5, 10, and 15 kg fish are consumed yearly by infants, children, and adults, respectively.

Hazard Quotient

The hazard quotient (HQ), which can be calculated as in the following equation, was used to estimate the noncarcinogenic health risks for each element in *Trachurus mediterraneus ponticus* samples [7, 8, 9]:

$$HQ = \frac{EDI}{Rf.D.}$$

where Rf. D. is the oral reference dose which shows the approximated maximal allowable health, risk related with daily intake of metals in fish by people, expressed in mg/kg/day. The total hazard quotient accurately captures the collective contribution of the investigated elements to the full potential threat to human well-being. The following are some mathematical ways to express the total hazard quotient (THQ):

$$THQ = \sum HQ$$

In this study, it was assumed that the cumulative effects of metals on one target organ were inversely correlated with the likelihood of a health risk. While THQ < 1 suggests no possible health risk, THQ >1 discloses possible chronic danger.

Risk Index

The increasing lifetime cancer risk is one metric to measure the carcinogenic risk [7, 8, 9]. The equation below represents the risk index (RI) in terms of:

$$RI = EDI\ x\ SF$$

The risk associated with a lifetime average contaminant dose is determined by the slope factor (SF).

Statistical Analysis

During the statistical analysis, the non-parametric tests were implemented. The differences in the concentrations of heavy metals between the years (2021-2022) were as investigated with Mann Whitney-U test. The statistical significance level, P value, was set as 0.05.

Results and Discussion

Results of the study showed that Zn has the higher concentration (mean 5.475 mg/kg w.w.) among the other metals (Figure 1), Zn followed by Fe with a mean concentration of 3.887 mg/kg w.w. and Cu with mean concentration of 0.178 mg/kg w.w. The Cd was found at the lowest (0.0077 mg/kg w.w.) mean concentration followed by Hg (0.0096 mg/kg w.w.), Pb (0.0453 mg/kg w.w.), and Al (0. 1077 mg/kg w.w.). There were no statistical differences between the years (P<0.05).

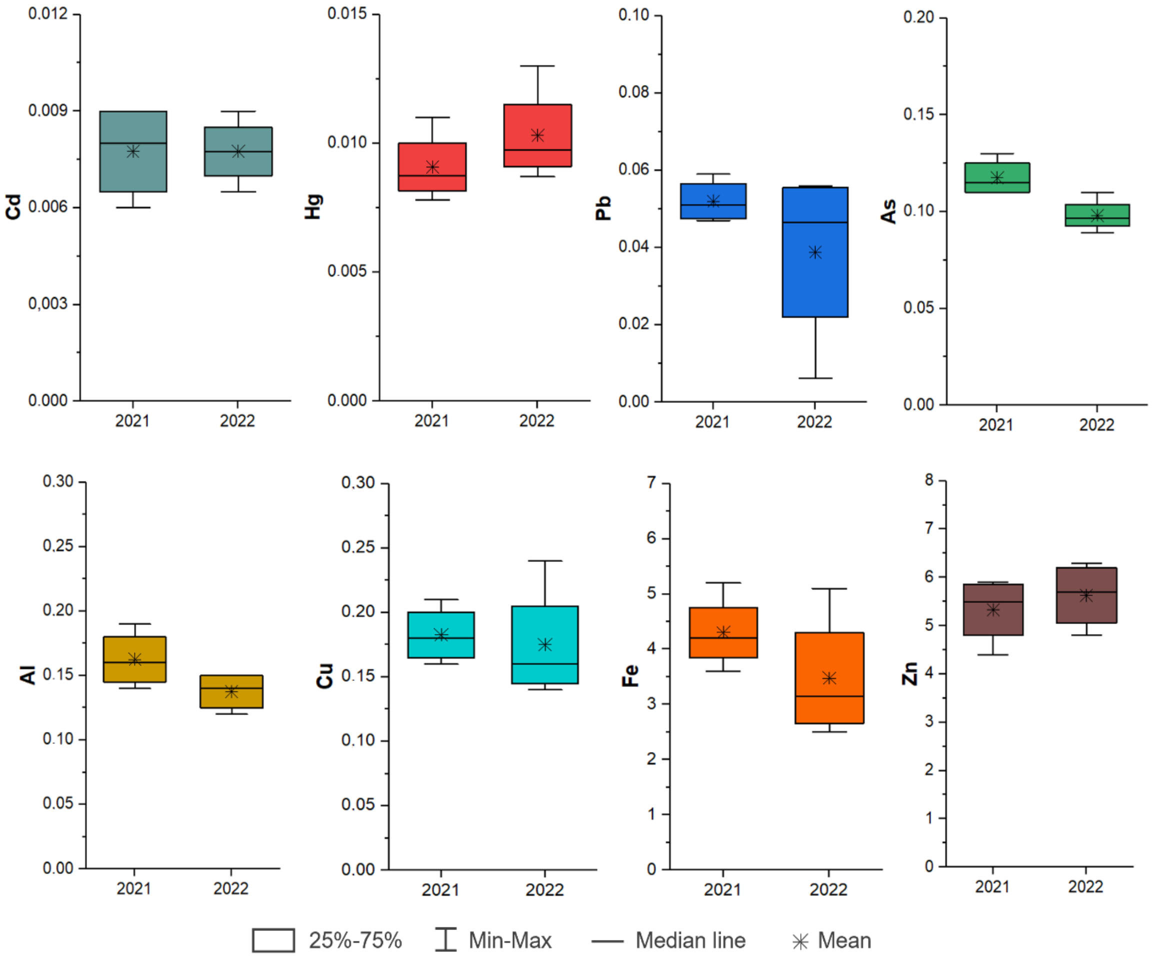

Figure 1. *The elements in the muscle tissues of Trachurus mediterraneus ponticus.*

Cd, Hg, Pb and As have been the broadest heavy metals that caused human threatening [11]. Cd, Pb and Hg are referred to as the "toxic trio" owing to their hazardous characteristics. These xenobiotics are extremely nephrotoxic, and high levels can result in renal failure [12]. European Commission [5] and Official Gazette of the Republic of Türkiye [13] determined the maximum level of Cd, Hg and Pb in fish as 0.05, 0.5 and 0.3 mg mg/kg w.w., respectively. Cd is an extremely toxic metal for both fish and humans. Cd accumulates in fish and is the primary source of human exposure through consumption. Cd had the highest level in this study, which was 0.009 mg/kg w.w., but it was below the safe limit. However, in terms of Cd, eating horse mackerel poses no threat to the general public's health. The mercury, an extremely hazardous metal, is mostly obtained through dietary sources and is generally acknowledged to be fish. In this study, horse mackerel had the maximum Hg, which was 0.011 mg/kg w.w. in September 2021. The value that was obtained was roughly 45 times below the safe limit value. The highest value of Pb, one of the toxic metals, found in the current study is 0.059 mg/kg w.w. in December 2021. Pb value was below the allowable limit in [5, 11]. The consumption of horse mackerel poses no risk to the general public's health. The highest concentration of As was 0.13 mg/kg w.w. in the current study in November 2021. This value was below the safe limit, 1 mg/kg w.w., specified in Official Gazette of the

Republic of Türkiye [14]. The consumption of horse mackerel poses is no risk for people, in terms of As. Cu is an essential trace element that is found in little amounts in many different types of cells, but it is toxic if taken in large quantities. The recommended maximum level of Cu is 20 mg Cu/kg by Official Gazette of the Republic of Türkiye [14] and the Ministry of Agriculture, Forestry and Fisheries [15]. In this investigation, the highest Cu level was found at 0.24 mg/kg w.w. in September 2022. The maximum Cu was found almost 83 times below the safe limit concentration. It can be claimed that horse mackerel consumption poses no concern to the general public's health, in terms of Cu. Zn is not considered to be toxic to humans, but extremely high exposure levels may have negative consequences. According to the Official Gazette of the Republic of Türkiye [14] and the Ministry of Agriculture, Forestry and Fisheries [15], Zn level recommended is 50 mg/kg w.w. The highest Zn concentration was 6.3 mg/kg w.w. in September 2022 and this amount was quite low compared to the safe limit. Thus, consuming horse mackerel does not cause any risk to public health in terms of Zn. No accepted value for Fe detected in fish is given in the regulations. In this current study, however, the highest value in horse mackerel was determined as 6.3 mg/kg w.w. in September 2022. Metal concentration may show variations among fish species depending on their habitats, age, size, and feeding habits [16-19]. Horse mackerel is pelagic and carnivorous and usually feeds on small crustaceans [20]. Comparing the present results with previous studies in the Black Sea, it is noted that the metals concentrations in this study were generally lower or similar found in the scientific literature on the sea (Table 1). The metal levels in horse mackerel are below the allowable limit by national and international organizations. It was found that the EDI and EWI values and THQs are below levels that are suitable for human consumption in fish samples (TTHQs<1) for 2021 and 2022 (Table 2). The RIs for Pb were from 1.93×10^{-7} for adults in 2022 to 5.75×10^{-7} for infants in 2021, indicating their insignificant carcinogenic risks, whereas for As RIs were from 8.61×10^{-5} for adults in 2022 to 2.29×10^{-4} for infants in 2021, indicating their tolerable or acceptable carcinogenic risks. In conclusion, the metal levels in the edible part of horse mackerel in the Black Sea are safe for consumers.

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Table 1. *Comparison of metal amounts in Trachurus mediterraneus ponticus with the literature as ppm (w.w.= wet weight.; d.w.= dry weight.; BDL = Below limit of detections).*

Location		Cd	Hg	Pb	As	Al	Cu	Fe	Zn	References
Bulgaria Black Sea	w.w.	0.008±0.001	0.16±0.02	0.06±0.01	0.73±0.05		0.56±0.04	4.2±0.3	8.5±0.6	[21]*
Bulgaria Black Sea	w.w.	0.004±0.001	0.09±0.010	0.04±0.01	1.42±0.130		0.42±0.03		6.4±0.5	[22]
Bulgaria Black Sea	w.w.	0.007±0.001	0.08±0.01	0.05±0.01	0.38±0.02		0.45±0.03		9±1	[23]
Romania Black Sea	w.w.	0.0163±0.0075		0.1023±0.045 2			0.69±0.05			[24]
Türkiye Black Sea	d.w.			<0.001	4.40		0.40	8.52	7.76	[25]
Türkiye Southwestern Black Sea	d.w.	0.25±0.03		0.02±0.01	2.58±0.10		1.71±0.04		18.13±0.95	[26]
Sinop/Türkiye Black Sea	w.w.	<0.02	<0.05	<0.05	0.39	<0.05	0.67	2.2	24.7	[27]
Türkiye Black Sea	w.w.	BLD	BLD	BLD	BLD		0.235	6.28	5.93	[28]
Türkiye/ Sinop Black Sea	w.w.	<0.002-0.021	<0.001-0.06	0.014-0.15						[9]
Türkiye/Samsun Black Sea	w.w.	0.0078±0.0015	0.009±0.001	0.052±0.006	0.118±0.010	0.163±0.022	0.183±0.022	4.3±0.67	5.33±0.69	This study$^{\alpha}$
		0.0077±0.0010	0.01±0.002	0.039±0.023	0.098±0.009	0.138±0.015	0.175±0.045	3.47±1.16	5.63±0.70	This study $^{\beta}$

*Whole fish, $^{\alpha}$The fish sampling were collected in 2021, $^{\beta}$The fish sampling were collected in 2022

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Table 2. The estimated daily intakes (EDIs), the estimated weekly intakes (EWIs), target hazard quotients (THQs), total target hazard quotients (TTHQs) of Cd, Hg, As, As, Al, Cu, Fe and Zn, as well as cancer risk index (RI) of Pb and As due to Trachurus mediterraneus ponticus consumption for infants, children, and adults

Metal	Years	EDI			EWI			THQ			RI		
		(infants)	(children)	(adults)	(infants)	(children)	(adults)	(infants)	(children)	(adults)	(infants)	(children)	(adults)
Cd	2021	$1.01x10^{-5}$	$6.98x10^{-6}$	$4.54x10^{-6}$	$7.10x10^{-5}$	$4.88x10^{-5}$	$3.18x10^{-5}$	$1.01x10^{-2}$	$6.98x10^{-3}$	$4.54x10^{-3}$			
	2022	$1.00x10^{-5}$	$6.93x10^{-6}$	$4.51x10^{-6}$	$7.01x10^{-5}$	$4.85x10^{-5}$	$3.16x10^{-5}$	$1.00x10^{-2}$	$6.93x10^{-3}$	$4.51x10^{-3}$			
Hg	2021	$1.18x10^{-5}$	$8.17x10^{-6}$	$5.32x10^{-6}$	$8.26x10^{-5}$	$5.72x10^{-5}$	$3.72x10^{-5}$	$3.93x10^{-2}$	$2.72x10^{-2}$	$1.77x10^{-2}$			
	2022	$1.34x10^{-5}$	$9.27x10^{-6}$	$6.03x10^{-6}$	$9.37x10^{-5}$	$6.49x10^{-5}$	$4.22x10^{-5}$	$4.46x10^{-2}$	$3.09x10^{-2}$	$2.01x10^{-2}$			
Pb	2021	$6.76x10^{-5}$	$4.68x10^{-5}$	$3.05x10^{-5}$	$4.73x10^{-4}$	$3.28x10^{-4}$	$2.13x10^{-4}$				$5.75x10^{-7}$	$3.98x10^{-7}$	$2.59x10^{-7}$
	2022	$5.04x10^{-5}$	$3.49x10^{-5}$	$2.27x10^{-5}$	$3.53x10^{-4}$	$2.44x10^{-4}$	$1.59x10^{-4}$				$4.28x10^{-7}$	$2.97x10^{-7}$	$1.93x10^{-7}$
As	2021	$1.53x10^{-4}$	$1.06x10^{-4}$	$6.88x10^{-5}$	$1.07x10^{-3}$	$7.40x10^{-4}$	$4.82x10^{-4}$	$5.09x10^{-1}$	$3.53x10^{-1}$	$2.29x10^{-1}$	$2.29x10^{-4}$	$1.59x10^{-4}$	$1.03x10^{-4}$
	2022	$1.27x10^{-4}$	$8.82x10^{-5}$	$5.74x10^{-5}$	$8.92x10^{-4}$	$6.17x10^{-4}$	4.02x10-^{4}	$4.25x10^{-1}$	$2.94x10^{-1}$	$1.91x10^{-1}$	$1.91x10^{-4}$	$1.32x10^{-4}$	$8.61x10^{-5}$
Al	2021	$2.11x10^{-4}$	$1.46x10^{-4}$	$9.52x10^{-5}$	$1.48x10^{-3}$	$1.02x10^{-3}$	$6.66x10^{-4}$	$2.11x10^{-4}$	$1.46x10^{-4}$	$9.52x10^{-5}$			
	2022	$1.79x10^{-4}$	$1.24x10^{-4}$	$8.05x10^{-5}$	$1.25x10^{-3}$	$8.66x10^{-4}$	5.64x10-^{4}	$1.79x10^{-4}$	$1.24x10^{-4}$	$8.05x10^{-5}$			
Cu	2021	$2.37x10^{-4}$	$1.64x10^{-4}$	$1.07x10^{-4}$	1.66x10-^{3}	$1.15x10^{-3}$	$7.48x10^{-4}$	$5.93x10^{-3}$	$4.11x10^{-3}$	$2.67x10^{-3}$			
	2022	$1.98x10^{-3}$	$1.58x10^{-4}$	$1.03x10^{-4}$	$1.38x10^{-2}$	$1.10x10^{-3}$	$7.18x10^{-4}$	$4.94x10^{-2}$	$3.94x10^{-3}$	$2.56x10^{-3}$			
Fe	2021	$5.59x10^{-3}$	$3.87x10^{-3}$	$2.52x10^{-3}$	$3.91x10^{-2}$	$2.71x10^{-2}$	$1.76x10^{-2}$	$7.99x10^{-3}$	$5.53x10^{-3}$	$3.60x10^{-3}$			
	2022	$4.52x10^{-3}$	$3.13x10^{-3}$	$2.04x10^{-3}$	$3.16x10^{-2}$	$2.19x10^{-2}$	$1.42x10^{-2}$	$6.45x10^{-3}$	$4.47x10^{-3}$	$2.91x10^{-3}$			
Zn	2021	$6.92x10^{-3}$	$4.79x10^{-3}$	$3.12x10^{-3}$	$4.85x10^{-2}$	$3.35x10^{-2}$	$2.18x10^{-2}$	$2.31x10^{-2}$	$1.60x10^{-2}$	$1.04x10^{-2}$			
	2022	$7.31x10^{-3}$	$5.06x10^{-3}$	$3.29x10^{-3}$	$5.12x10^{-2}$	$3.54x10^{-2}$	$2.31x10^{-2}$	$2.44x10^{-2}$	$1.69x10^{-2}$	$1.10x10^{-2}$			
TTHQ	**2021**							**0.5958**	**0.4125**	**0.2684**			
	2022							**0.5598**	**0.3572**	**0.2325**			

Conclusion

In the current study, the essential and non-essential metal levels in horse mackerel have been analysed. The results of metals levels in the fish samples were not exceeded the allowable limits set for these metals. The results of this study are found lower recommended values. All of the metals that were taken into consideration, TTHQs were below the value of 1 for infants, children, and adults in 2021 and 2022, hence the metals in horse mackerel do not appear to be toxic or dangerous for consumers.

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Conflict of Interests The authors declare no conflict of interest.

Authors Contribution All authors read and approved the final manuscript.

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