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Health risk assessment of heavy metals in *Sarda sarda* Bloch, 1793 for people through consumption from the Turkish Black Sea coasts

Levent Bat, Elif Arıcı

University of Sinop Fisheries Faculty Department of Hydrobiology, Akliman 57000 Sinop, Turkey.

Abstract

The concentrations of Fe, Ni, Zn, Cu, Cd, Pb, Cr, Mn, Co, Al and Hg have been measured in the edible muscle of Atlantic bonito (*Sarda sarda* Bloch, 1793) from Samsun and Sinop coasts of the southern Black Sea during September 2014 to December 2014. Cd, Pb, Al and Hg were not detected in the edible part of *S. sarda* in both coastal areas. These concentrations are lower than the maximum permissible values in European and Turkish regulation. The average weekly intakes of heavy metals per body weight values not exceeded the Provisional Tolerable Weekly Intake (PTWI) established. Therefore, it may be concluded that these eleven metals should not pose any health threat to the consumers resulting from the consumption of *S. sarda*.

Keywords: Heavy metals, Sinop, Samsun, Black Sea, Atlantic Bonito

1. Introduction

Marine coastal pollution is one of the important problems that emerge on the occasion of the increased uses of pollutants to meet the higher demands of seafood production specially fish for human consumption. Health risk assessment for heavy metal levels in fish is a very useful technique to give information about any threat regarding heavy metals contamination to people. Seafood safety is a major public concern European Commission. The Marine Strategy Framework Directive (MSFD, 2008/56/EC) establishes a framework for the development of marine strategies designed to achieve Good Ecological Status (GES) in the marine environment, by the year 2020, using 11 qualitative descriptors [1]. The concentration of contaminants including heavy metals in the marine environment and their effects needs to be assessed taking into account the impacts and threats to the ecosystem in Directive 2008/56/EC. Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards (Descriptor 9; Directive 2000/60/EC) [2]. In particular Bulgaria and Romania after they join the European Union countries, the Black Sea has become popular for European Union. The health and millions of people are affected by the ecological degradation in the Black Sea. Therefore, sufficient estimation of the ecosystem variability in the Black Sea is needed to identify, analyse and determine the cost of solutions for better marine environmental management and sustainable development of the resources. The Black Sea is one of the unique in the world as youngest inland sea connected to the small Sea of Marmara by the narrow Bosporus Strait; Strait of Dardanelles further connects to the Aegean Sea. Hence, there is very low natural circulation is self-cleaning ability remains limited. Turkey poured into the Black Sea off the coast of the Sakarya, Kızılırmak, Yeşilirmak, from the West, the Danube, from the North Dnieper and Dniester Rivers with a million tons of organic waste into the Black Sea basin are carrying the items, uses of fertilizers, many chemicals and other terrestrial origin. Most pollution in the Black Sea is caused by domestic wastes, industrial wastes, oil wastes, pesticides, insecticides, radioactive wastes and heavy metals [3]. As a result of pollution, the Black Sea ecosystem has been subject to extreme changes in recent years. One of the important pollutants due to heavy metals toxic property of natural concentrations of negatively affecting the ecosystem when they take on the biological activities of the organisms that make up the food chain, the balance between biota and the environment corruption and adversely affects the people at the top of the food chain [4]. Heavy metals cannot be destroyed and they can only be converted from one chemical compound to another [5]. The Black Sea ecosystem problems are multiple [6] and it is being seriously destroyed as a result of pollution listed by Polikarpov *et al.* [7]. They are from rivers by way of reduction of freshwater outflows, input of inorganic and organic matters, toxicants; from agriculture, industry, atmospheric fallout, ports, fishery and maritime traffic, change of natural beaches condition, tourism and litter of coastal zone. Also Chernobyl Nuclear Power Plants area is land-based source of radionuclides chronic pollution of the Black Sea through the Pripyat River and the Dnieper River.

Great numbers of the heavy metals are present in seawater in trace levels, whereas extravagant accumulation may affect marine organisms through food chain and pose risk to consumers of seafood when concentrations exceed. Essential metals as Cu, Zn, Co, Cr, Ni and Mn are trace amounts (smaller than 0.01% of the mass of the organism) in the diet and their absence may cause serious problem [8]. Nonessential metals such as Cd, Pb, As and Hg have no biological function and their presence even very small quantities may toxic. Nonetheless, it is clear that all heavy metals are potentially hazardous to living organisms and not necessarily at high exposure levels [8] and are extremely persistent in the marine environment, that's why they should be routinely monitored.

The Black Sea is an area of crucial importance for European Union also for Turkey as a candidate country, considering its geographical location and its socio-economic, cultural and environmental attributes [4]. Fish is healthy seafood because of its proteins of high biological quality, desirable lipid composition, valuable mineral compounds and vitamins [9] and are widely consumed in many parts of the Black Sea coastal cities by people [4].

Most of the heavy metals are the natural constituents of earth's crust and from there they are taken by organisms and thus transferred to food chain. These metal concentrations vary from species to species and may be related to their feeding habits and the bio-concentration capacity of each species [10]. Fish, as a predator, is able to concentrate high amounts of heavy metals via food chain. Large fish such as Atlantic bonito (*Sarda sarda* Bloch, 1793), which is the top of marine food webs, is particularly exposed to high amounts of heavy metals through their food [11]. This pelagic fish is high performance organisms with very high metabolic rates, and consequently high food intake rates, a property that accentuates the exposure to heavy metals [12].

The heavy metals not only affect the nutritive values of fish but also affect the health of people and thus, the safe limits of the heavy metals are lowered regularly in seafood. This legislation is the responsibility of national [13] and international [14] regulatory authorities. This study was conducted to investigate the contamination of ten heavy metals in the edible tissues of commercially important fish Atlantic bonito and to evaluate risks to human health associated with its consumption. The aim of this study is to provide information on the Fe, Ni, Zn, Cu, Cd, Pb, Cr, Mn, Co, Al and Hg in the muscle of *S. sarda* from the southern Black Sea coast during September 2014 to December 2014. Atlantic bonito is frequently consumed and commercially available groups of fish in the Black Sea coast of Turkey [15, 16]. It is also attempted to compare the measured values with national [13] and international [14, 17] standards for food and human health.

2. Materials and methods

Atlantic bonito used in this study was sampled during September 2014 to December 2014 directly from local fishing vessels in the southern of the Black Sea (Figure 1).

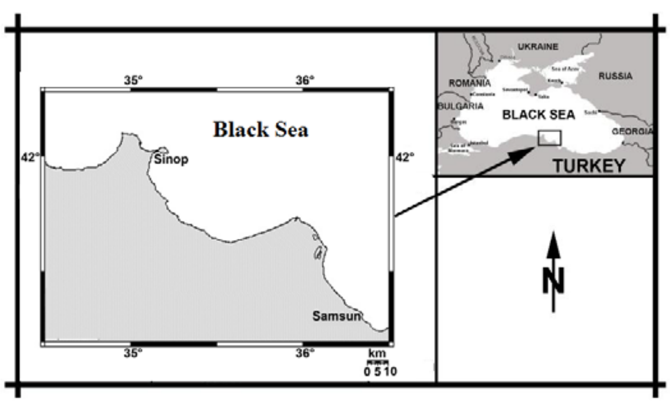

Fig 1: Fish sampling area from Samsun and Sinop coasts of the Black Sea, Turkey.

2.1 Preparation fish samples and determination of heavy metals

The fish samples were taken randomly and only consumed sizes were used. Fish samples were then labelled and were preserved using ice and transported to the main laboratory. All the samples were stored at -21 ^{0}C prior to pre-treatment and analysis.

Heavy metal analysis in Atlantic bonito was performed using m-AOAC 999.10- ICP/MS (Inductively Coupled Plasma – Mass Spectrometer) method by accredited ÇEVRE Industrial Analysis Laboratory Services Trade Company (TÜRKAK Test TS EN ISO IEC 17025 AB-0364-T). EN 15763 European Standard methods was applied. The limits of detection (µg/l) used for analysis of Fe, Ni, Zn, Cu, Cd, Pb, Cr, Mn, Co, Al and Hg were 0.5, 0.15, 0.5, 0.5, 0.02, 0.05, 0.78, 0.58, 0.166, 0.5 and 0.05, respectively.

2.2 Intake Levels Calculation

The average heavy metal weekly intake was calculated according to the following formula [18]:

Heavy metals intake level = average heavy metal content X consumption of fish per person/ body weight

The annual quantity of fish consumed is 6.3 kg/person [19], which are equivalent to 17.3 g/day for Turkey. The body weight of adult person is 70 kg.

2.3 Statistical Analysis

Data were expressed as mean ± standard deviation (SD). Data were analysed by ANOVA at $\alpha = 0.05$. Comparison of means was performed by Duncan test and difference was considered significant at $p < 0.05$ [20]. IBM SPSS Statistics version 21 software is used for statistical analysis.

3. Results & Discussion

The Black Sea Atlantic bonito from the south coast of the Black Sea, during September 2014 to December 2014 were analysed for Fe, Ni, Zn, Cu, Cd, Pb, Cr, Mn, Co, Al and Hg. The concentration of examined metals in edible tissues of Atlantic bonito from the southern Black Sea demonstrated regional differences. Cd, Pb, Al and Hg were not detected in the edible part of *S. sarda* in both coastal areas. Figures 2-8 show the mean concentrations of heavy metals in the muscle of Atlantic bonito from Samsun and Sinop coasts of the southern Black Sea, Turkey. The concentrations of measured heavy metals decrease in the order of Fe > Zn > Mn > Cr > Co > Cu >Ni.

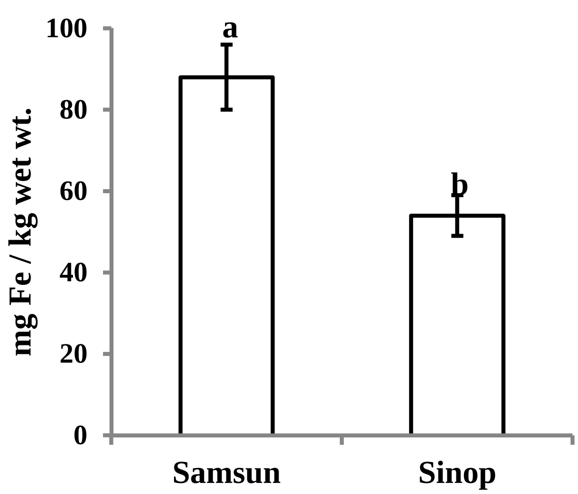

Fig 2: The means with standard deviations (vertical line) of Fe concentrations (mg/kg wet wt.) in the edible tissues of *S. sarda* collected from Samsun and Sinop coasts of the Black Sea during September 2014 to December 2014. a, b= The same letters beside the vertical bars in each graph indicate the values are not significantly different (P>0.05).

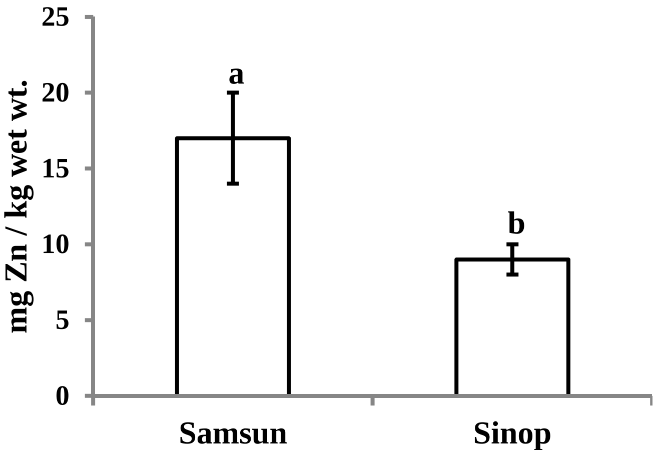

Fig 3: The means with standard deviations (vertical line) of Zn concentrations (mg/kg wet wt.) in the edible tissues of *S. sarda* collected from Samsun and Sinop coasts of the Black Sea during September 2014 to December 2014. a, b= The same letters beside the vertical bars in each graph indicate the values are not significantly different (P>0.05).

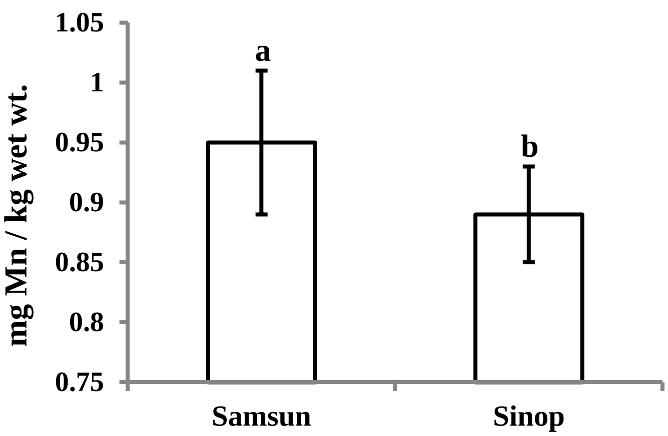

Fig 4: The means with standard deviations (vertical line) of Mn concentrations (mg/kg wet wt.) in the edible tissues of *S. sarda* collected from Samsun and Sinop coasts of the Black Sea during September 2014 to December 2014. a, b= The same letters beside the vertical bars in each graph indicate the values are not significantly different (P>0.05).

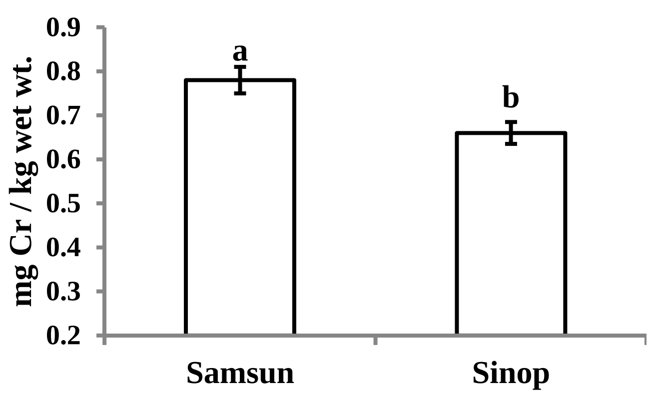

Fig 5: The means with standard deviations (vertical line) of Cr concentrations (mg/kg wet wt.) in the edible tissues of *S. sarda* collected from Samsun and Sinop coasts of the Black Sea during September 2014 to December 2014. a, b= The same letters beside the vertical bars in each graph indicate the values are not significantly different (P>0.05).

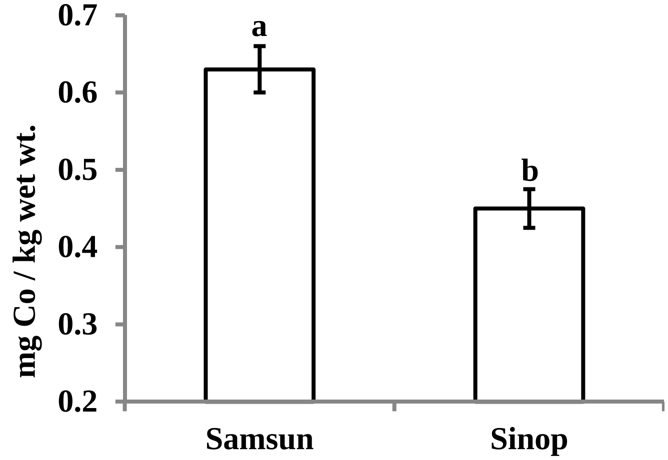

Fig 6: The means with standard deviations (vertical line) of Co concentrations (mg/kg wet wt.) in the edible tissues of *S. sarda* collected from Samsun and Sinop coasts of the Black Sea during September 2014 to December 2014. a, b= The same letters beside the vertical bars in each graph indicate the values are not significantly different (P>0.05).

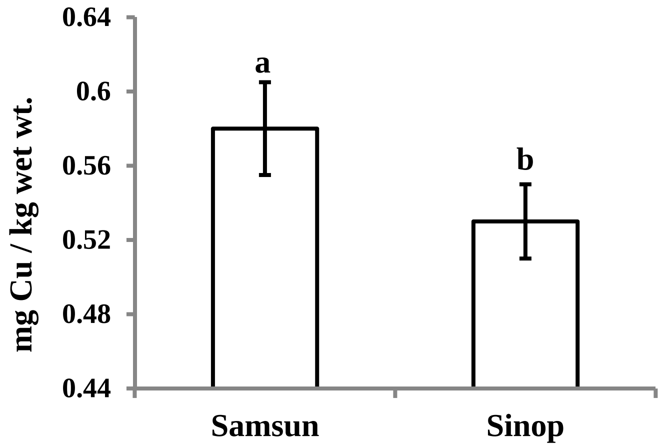

Fig 7: The means with standard deviations (vertical line) of Cu concentrations (mg/kg wet wt.) in the edible tissues of *S. sarda* collected from Samsun and Sinop coasts of the Black Sea during September 2014 to December 2014. a, b= The same letters beside the vertical bars in each graph indicate the values are not significantly different (P>0.05).

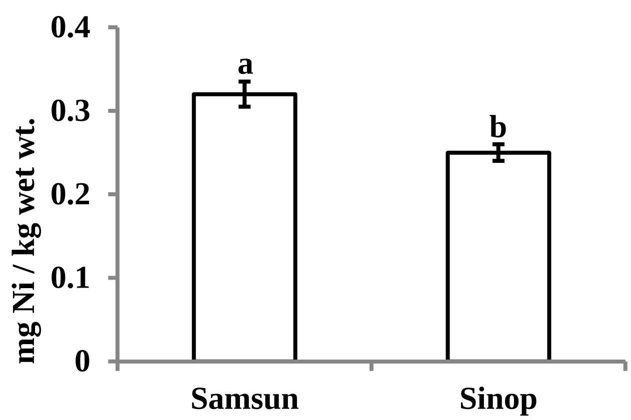

Fig 8: The means with standard deviations (vertical line) of Ni concentrations (mg/kg wet wt.) in the edible tissues of *S. sarda* collected from Samsun and Sinop coasts of the Black Sea during September 2014 to December 2014. a, b= The same letters beside the vertical bars in each graph indicate the values are not significantly different (P>0.05).

S. sarda is a migratory fish and able to concentrate large amounts of heavy metals. In this study, the statistical results indicate that there is a considerable greater accumulation of the metals in muscle tissues of *S. sarda* from Samsun than those in muscle tissues of fish from Sinop coast ($P<0.05$) and that there was a statistically significant difference between the concentrations of the metals (see Figs. 2-8). Contamination with heavy metals on local and regional scales, have been intensively studied in the Black Sea recent years [4]. Because of the fact that heavy metals are persistent and toxic, they tend to accumulate and pose a risk to people and marine coastal ecosystems health. The main reason for this is the increasing metal input to the coastal zone from both rivers and non-point sources which comes from many diffuse sources. Non-point sources pollution are caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away pollutants, finally depositing them into coastal waters [9]. Intense human development in the Black Sea coasts may have negative consequences on the marine ecosystem. The mountains in the Black Sea region of Turkey are rich in mineral deposits [21]. Besides, the main industrial organizations are exists in Samsun of the region.

The local Black Sea environment especially Sinop coasts is not facing serious heavy metal pollution problem [22, 23]. However, the research area of Sinop coasts, affected with intensive land-based pollution and organic matter originating from domestic discharge [24] these finding are supporting by Bat *et al.* [25]. Moreover, solid waste storage areas are available in the vicinity of Samsun and Sinop [25].

Fe is the most accumulated in the edible tissues of the Atlantic Bonito from both Samsun and Sinop costs of the Black Sea, Turkey followed by Zn. Particle materials contaminated with metals reach to shelf area via both rivers and soil erosion. FeOOH comes from land and atmospheric play important role transport reactive phosphorus to sediment hence cause the reduction of eutrophication in oxic water column [21]. In the aquatic systems, metals adsorb on the calcium carbonate minerals, clay minerals, organic matter and ferric oxide hydroxides [21]. Background heavy metal pollution in the sediment of the southern Black Sea were found as 41,94 ppm for Cu; 17,47 ppm for Pb; 79,5 ppm for Zn; 0,14 ppm for Cd; 61,0 ppm for Cr and 0,03 ppm for Hg [26].

Legal thresholds are not available for essential elements in Europe. EC [14, 33] and TGK [13] indicate that maximum levels of Hg, Pb and Cd are 0.5, 0.30 and 0.05 mg/kg wet wt., respectively. Cd, Pb, Al and Hg in the edible part of *S. sarda* in both coastal areas were below the detection limit as mentioned in material and methods. Also, the findings from the present study revealed that Fe, Ni, Zn, Cu, Cr, Mn and Co in the muscle of *S. sarda* from the southern Black Sea coast during September 2014 to December 2014 were lower than the maximum permissible limit as recommended by the National Academy of Sciences [34], MAFF [17] and IAEA-407 [35].

Heavy metal concentrations in the Black Sea Atlantic bonito were compared with the other studies and given in Table 1. These values were similar or lower than those in edible tissues reported by other studies in the Turkish Black Sea coats. In terms of metal pollutants load from Turkish coast of the Black Sea especially in Igneada, Trabzon, Bartin and Samsun were higher than other cities of Turkish coast of Black Sea [4].

In 2014, quantity of caught sea fish was 231058.3 metric tonnes and 19031.5 tons Atlantic bonito were caught from Turkish waters [36]. Fish having toxic metals could present a toxic threat for the consumer which is dependent on the metal concentration and amount of fish consumed [18]. Therefore, the tolerable weekly intakes were estimated by means of references for edible tissues of fishes consumed by people. The annual quantity of fish consumed is 6.3 kg / person [19], which is equivalent to 17.3 g/day for Turkey. The tolerable weekly intake of heavy metals as PTWI (Provisional Tolerable Weekly Intake), are set by the Food and Agriculture Organization/World Health Organization (FAO/WHO) Joint Expert Committee on Food Additives (JECFA) [37, 38]. PTWI is the maximum amount of a contaminant to which a person can be exposed per week over a lifetime without an unacceptable risk of health effects. The estimated daily intake (EDI) and estimated weekly intake (EWI) in this study were calculated and presented in Table 2. Intake estimates were expressed as per unit body weight (mg/kg body wt. /weekly and daily).

The estimated Co intake is 0.2 to 1.8 mg/day according to Codex Alimentarius Commission [39], JECFA [37] and FAO/WHO [38] have not evaluated Co. There is no evidence that the intake of Co is ever limiting in the human diet, and no Recommended Dietary Allowances (RDA) is necessary [34]. It seems that the use of Co in general causes no problems [14].

Table 1: Metal concentrations in the edible muscle of *Sarda sarda* in the Black Sea coasts of Turkey.

Metals	Locality	Mean metal concentrations (mg /kg)	References
Fe	Samsun	9.52±0.81 (dry wt.)	27
	Black Sea	73.5 ± 6.3 (dry wt.)	28
	Sinop	12.18 (wet wt.)	29
	Black Sea	68.5 ± 5.4 (wet wt.)	30
	Samsun, Ordu, Trabzon, Rize	25.5 ± 2.3 (dry wt.)	31
	Samsun, Sinop, Terme, Fatsa, Ordu	25.96±2.73 (dry wt.)	32
Zn	Samsun	11.20±1.44 (dry wt.)	27
	Black Sea	48.7 ± 3.7 (dry wt.)	28
	Sinop	12.66 (wet wt.)	29
	Black Sea	64.9 ± 5.2 (wet wt.)	30
	Samsun, Ordu, Trabzon, Rize	21.0 ± 2.1 (dry wt.)	31
	Samsun, Sinop, Terme, Fatsa, Ordu	19.55±1.20 (dry wt.)	32
	Sinop	12.75-17.56 (wet wt.) (min.-max.)	15
Cu	Samsun	1.28±0.14 (dry wt.)	27
	Black Sea	0.84 ± 0.05 (dry wt.)	28

	Sinop	0.659 (wet wt.)	29
	Black Sea	1.43 ± 0.12 (wet wt.)	30
	Samsun, Ordu, Trabzon, Rize	1.9 ± 0.2 (dry wt.)	31
	Samsun, Sinop, Terme, Fatsa, Ordu	1.74±0.18 (dry wt.)	32
	Sinop	2.75-4.12 (wet wt.) (min.-max.)	15
Mn	Samsun	1.06±0.27 (dry wt.)	27
	Black Sea	2.68 ± 0.22 (dry wt.)	28
	Sinop	1.72 (wet wt.)	29
	Black Sea	4.72 ± 0.24 (wet wt.)	30
	Samsun, Ordu, Trabzon, Rize	2.0 ± 0.2 (dry wt.)	31
	Samsun, Sinop, Terme, Fatsa, Ordu	3.53±0.48 (dry wt.)	32
Ni	Sinop	0.307 (wet wt.)	29
	Black Sea	2.70 ± 0.18 (wet wt.)	30
	Samsun, Sinop, Terme, Fatsa, Ordu	3.04±0.24 (dry wt.)	32
Co	Sinop	Below Detection Limit	29
	Samsun, Ordu, Trabzon, Rize	0.40 ± 0.04 (dry wt.)	31
Pb	Samsun	0.22±0.04 (dry wt.)	27
	Black Sea	0.76 ± 0.05 (dry wt.)	28
	Sinop	0.537 (wet wt.)	29
	Black Sea	0.61 ± 0.04 (wet wt.)	30
	Samsun, Ordu, Trabzon, Rize	0.28 ± 0.03 (dry wt.)	31
	Samsun, Sinop, Terme, Fatsa, Ordu	0.90±0.11 (dry wt.)	32
	Sinop	0.13-0.19 (wet wt.) (min.-max.)	15
Cd	Samsun	0.09±0.02 (dry wt.)	27
	Black Sea	0.90 ± 0.07 (dry wt.)	28
	Sinop	0.031 (wet wt.)	29
	Black Sea	0.13 ± 0.01 (wet wt.)	30
	Samsun, Ordu, Trabzon, Rize	0.35 ± 0.04 (dry wt.)	31
	Samsun, Sinop, Terme, Fatsa, Ordu	0.025±0.005 (dry wt.)	32
	Sinop	0.023-0.028 (wet wt.) (min.-max.)	15

It can be seen from Table 2 that the estimated EWIs and EDIs of eleven heavy metals in *S. sarda* are far below the recommended PTWIs and/or PTDIs and indicated no adverse effects to the consumers. However it should be bear in mind that adverse human health effects may occur if metal contaminated fish is consumed too much.

Table 2: Estimated Weekly Intakes (EWI) and Estimated Daily Intakes (EDI) of heavy metals in edible tissues of Atlantic bonito from Samsun and Sinop coastal waters of the Black Sea, Turkey.

Metals	PTWI[a]	PTDI[b]	EWI[c]		EDI[d]	
			Minimum	Maximum	Minimum	Maximum
Fe	392	56	5.934	11.63	0.848	1.661
Ni	2.45	0.35	0.029	0.041	0.004	0.006
Zn	490	70	0.969	2.422	0.138	0.346
Cu	245	35	0.062	0.073	0.009	0.010
Cd	0.49	0.07	Below Detection Limit			
Pb	1.75	0.25	Below Detection Limit			
Cr	1.631	0.233	0.077	0.098	0.011	0.014
Mn	140-350	20-50	0.103	0.122	0.015	0.017
Co	*	*	0.051	0.080	0.007	0.011
Al	70	10	Below Detection Limit			
Hg	0.28	0.04	Below Detection Limit			

[a]PTWI (Provisional Tolerable Weekly Intake) (mg/week/70 kg body wt.)
[b]PTDI (Permissible Tolerable Daily Intake) (mg/day/70 kg body wt.)
[c]EWI (Estimated Weekly Intake) (mg/week/ kg body wt.)
[d]EDI (Estimated Daily Intake) (mg/day/ kg body wt.)
*There is no PTWI set for Co

4. Conclusions

In the light of the results of the present study it was indicated that Fe, Ni, Zn, Cu, Cd, Pb, Cr, Mn, Co, Al and Hg levels in the edible tissues of Atlantic bonito (*Sarda sarda*) from Samsun and Sinop coasts of the southern Black Sea during September 2014 to December 2014were considerably lower than the maximum levels set by the national [13] and international [14, 17, 33] standards. In other words the data of the present study provided that these eleven heavy metals in the commercially important fish Atlantic bonito do not present any noxious to people health.

Contamination with heavy metals of marine ecosystems continued attention in the field of Marine Environment Policy Marine Strategy Framework Directive [1]. The Black Sea is a unique marine ecosystem and fisheries became such a vital part of the commerce of coastal provincials specially Samsun and Sinop near the Black Sea coast of Turkey. The anthropogenic activities in the marine environment and relative proportions of the heavy metals in the Black Sea coast, investigations of fish, especially which of commercial importance, must be continued.

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