Indian Journal of Geo Marine Sciences
Vol. 51 (03), March 2022, pp. 263-269

Heavy metal levels in tissues (gonads and fillets) of Horse mackerel collected from Ghazaouet Bay (Western Mediterranean coast of Algeria)

M Cherif*[,a], W Benguedda-Rahal[a], M Belhadj[b] & F Z Mokri[c]

[a]Laboratory of Valorisation of Human Actions for Environment Protection and Application in Public Health, PB 119, University of Tlemcen, Algeria

[b]Laboratory of Analytical chemistry and electrochemistry, PB 119, University of Tlemcen, Algeria

[c]Laboratory of catalysis and synthesis in organic chemistry, PB 119, University of Tlemcen, Algeria

*[E-mail: cherif_mohamed13@hotmail.com]

Received 21 April 2021; revised 28 February 2022

The concentration levels of Zn, Pb, Cd and Cu were evaluated in the gonads and fillets of Horse mackerel (*Trachurus trachurus)* collected from Ghazaouet bay. The results showed the accumulation of Pb, Cd, Cu and Zn in the gonads and fillets. The metal concentrations in the fillets and gonads decreased in the following order: Zn >Cd >Pb >Cu and Zn >Cd >Cu >Pb, respectively. The levels of essential metals (zinc and copper) in both target organs generally complied with the recommended value for fish while the levels of non-essential metals like cadmium and lead, which are toxic and present in traces, greatly exceeded the recommended values in both target organs, which are ascribed mainly to the industrial pollution in Ghazaouet area. Therefore, it can be concluded that these heavy metals in different tissues of Horse mackerel, which is highly consumed in the Algerian coastal regions, could pose adverse health effects on consumers.

[**Keywords**: Algeria, Fillets, Ghazaouet bay, Gonads, Heavy metals, Horse mackerel]

Introduction

Human activities are responsible for introducing a large number of substances such as heavy metals into the marine environment. According to UNEP (United Nations Environment Program), 80 % of marine pollution is from land-based sources and is anthropogenic. The sources of marine pollution are the industrial, agricultural, domestic and urban effluents, and many such factors.

Pollution related to heavy metals, particularly in the aquatic environment, raises several concerns both for the health of aquatic populations and for humans. Heavy metal ions are persistent environmental contaminants[1-4] and can accumulate in living organisms. Some metals are essential for living organisms (Cu, Zn, Co, Fe, Mn, Ni, Cr, V, Se, As) and for certain biological functions but their higher concentration can lead to toxicity. For other elements, such as Ag, Cd, Hg and Pb, this essential character was not detected[5]. They cause deleterious biological effects at very low concentrations and therefore, are considered to be priorities for marine environmental monitoring.

The metals introduced into the aquatic environment can remain in the water column, adsorbed into the bottom sediments or accumulate in the tissues of organisms such as fish and mussels[6-18].

Horse mackerel, *T. trachurus* (Linnaeus, 1758), a carangid species is a pelagic fish species that prefers temperate waters and can be found off the Atlantic coasts up to Norway and across the whole Mediterranean Sea. It grows to 15 – 40 cm in length and may reach 60 cm[19]. Their growth is fast during the initial years but becomes much slower after the age of 3. Horse mackerel is of commercial interest in the Mediterranean Sea, since it is highly consumed in the Algerian coastal regions.

This work aimed to evaluate the concentration level of Zn, Pb, Cd and Cu in different tissues (gonads and fillets) of Horse mackerel collected from Ghazaouet bay (western Mediterranean coast of Algeria), and to shed light on the relationship between the industrial plant of zinc electrolysis in the Ghazaouet city and the resulting heavy metal contamination in the Horse mackerel as a bio-indicator. So far, there is no report published on heavy metal contamination in different tissues of Horse mackerel from the Ghazaouet bay.

Materials and Methods

Fish samples were purchased monthly from local fishermen at the fishing harbour of Ghazaouet (Fig. 1)

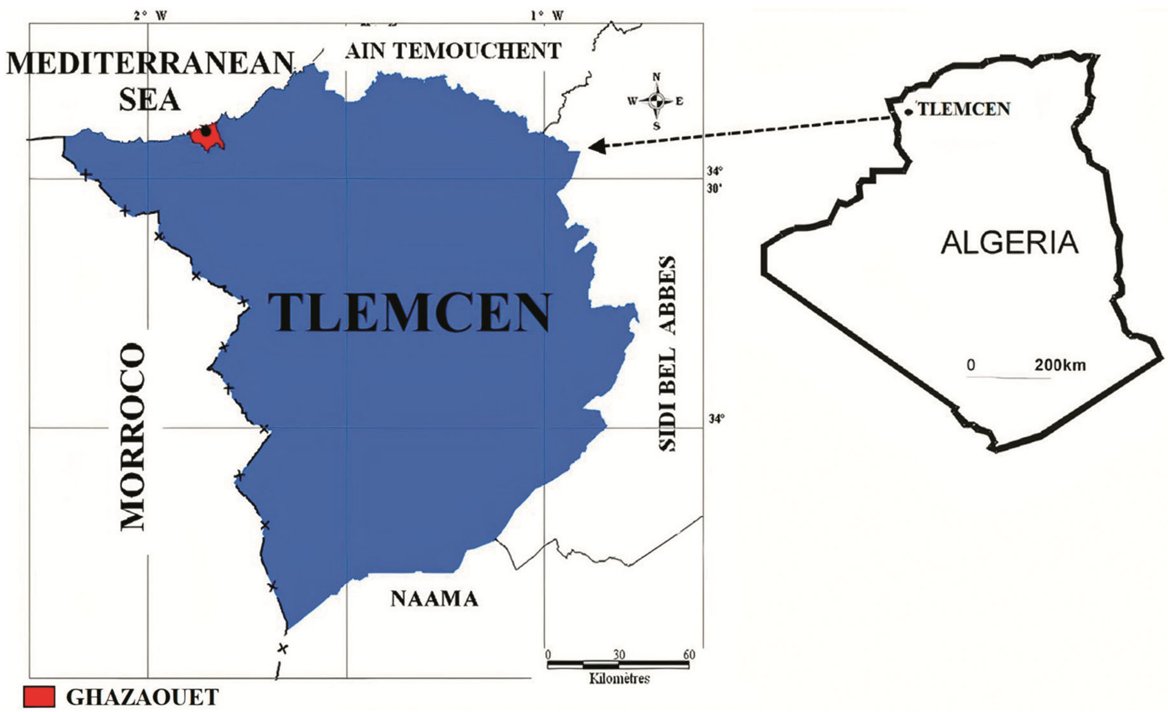

Fig. 1 — Map showing the Ghazaouet bay where samples were collected (Reprinted with permission from Belhadj *et al.*[18])

between January and December, 2018. This station was chosen as it is subjected to the industrial and domestic effluents[20].

One hundred twenty individuals of Horse mackerel (HM) were purchased at different intervals. The fishes were immediately preserved in a cooler and brought to the laboratory on the same day. Thereafter, total length and weight were measured for each fish. After the measurements, the gonads and fillets were taken out and kept in petri dishes. The protocol of mineralization was performed using the Malaiyandi & Barette method[21]. One gram of each organ was placed in a flask and treated with concentrated nitric acid at 95 °C for 1 h 30 min to mineralize the sample. After cooling, the flask content was filtered using swinex and a 0.45 µm porosity membrane. Double-distilled water was added to the filtrate for a final volume of 20 mL. The resulting filtrate was stored in the refrigerator until further analysis.

The concentrations of Zn, Pb, Cu, and Cd were determined by an atomic absorption spectrometer PERKIN-ELMER A analyst 300 model. Blank and standard solutions were used to check the accuracy of these analytical procedures. Metal contents were expressed as mg/kg dry weight for the gonads and fillets. These analyses were carried out at the Laboratory of catalysis and synthesis in organic chemistry, University of Tlemcen.

Statistical analysis was performed using Minitab 16 software.

Results and Discussion

The mean and the standard deviation of the weight and the total length of the samples for each month (between January and December 2018) are shown in Table 1. Pearson coefficient and *p*-value were employed to exhibit the correlation between weight and total length of *T. trachurus*.

The variations in the mean content of Zn, Pb, Cu, and Cd in the gonads and fillets during the study period are depicted in Figure 2. Moreover, the recommended value for each metal in fish according to FAO/WHO[22] is shown by the horizontal line in each graph. As seen in Figure 2, the extent of accumulation of studied heavy metals in HM depends on the metal type, organ and exposure period.

Variations of metal distribution in the fillets and gonads

Zinc

The mean concentration of zinc observed in the fillets and gonads is 37.67±17.175 mg/kg and 51.88±31.60 mg/kg, respectively. The highest accumulation of zinc is observed in the gonads (116.54±123.21 mg/kg) during October. This value outstrips the recommended[22] value which is 50 mg/kg. Zinc is an essential element for the conduct of

Table 1 — Correlation between weight (W) (g) and total length (L) (cm) of *Trachurus trachurus* between January and December 2018

Months	L ranges	W ranges	Regression equation	R value	*P* value
January	21.760 ± 0.997	85.302 ± 11.117	L = 0.0773 W + 15.2	0.862	0.001
	21.047 – 22.473	77.350_93.254			
February	21.350 ± 1.901	74.99 ± 21.317	L = 0.0858 W + 14.9	0.962	0.000
	19.990 – 22.710	59.743 – 90.241			
March	18.030 ± 0.906	47.084 ± 8.673	L = 0.0850 W + 14.0	0.814	0.004
	18.382 – 18.678	40.880 – 53.88			
April	18.960 ± 0.886	52.507 ±8.559	L = 0.0918 W + 14.1	0.887	0.001
	18.326 – 19.954	46.384 – 58.630			
May	20.150 ±1.827	71.000 ±18.578	L = 0.0889 W +13.8	0.904	0.000
	18.843 – 21.457	57.710 – 84.290			
June	16.500 ±0.698	39.151 ± 4.824	L = 0.127 W +11.5	0.878	0.001
	16.001 – 16.999	35.700 – 42.602			
July	17.190 ± 1.601	41.740 ± 7.642	L = 0.120 W + 12.2	0.574	0.083
	16.045 – 18.335	36.273 – 47.207			
August	24.180 ± 0.898	125.33 ± 17.96	L = 0.0463 W +18.4	0,926	0.000
	23.538 – 24.822	112.48 – 138.17			
September	18.200 ± 0.583	47.927 ± 6.183	L = 0.0837 W +14.2	0.888	0.001
	17.783 – 18.617	43.504 – 52.350			
October	21.130 ± 0.542	77.693 ± 7.030	L = 0.0549 W +16.9	0.713	0.021
	20.742 – 21.518	72.664 – 82.772			
November	21.830 ± 0.989	81.964 ± 8.431	L = 0.0960 W +14.0	0.818	0.004
	21.123 – 22.537	75.933 – 87.995			
December	19.720 ± 0.990	60.623 ± 6.199	L = 0.138 W +11.3	0.867	0.001
	19.012 – 20.428	56.189 – 65.057			
January-December	19.91 ± 2.42	67.10 ± 26.06	L = 0,0875W+ 14.0	0.942	0.000
	19.47 – 20.35	62.39 – 71.82			

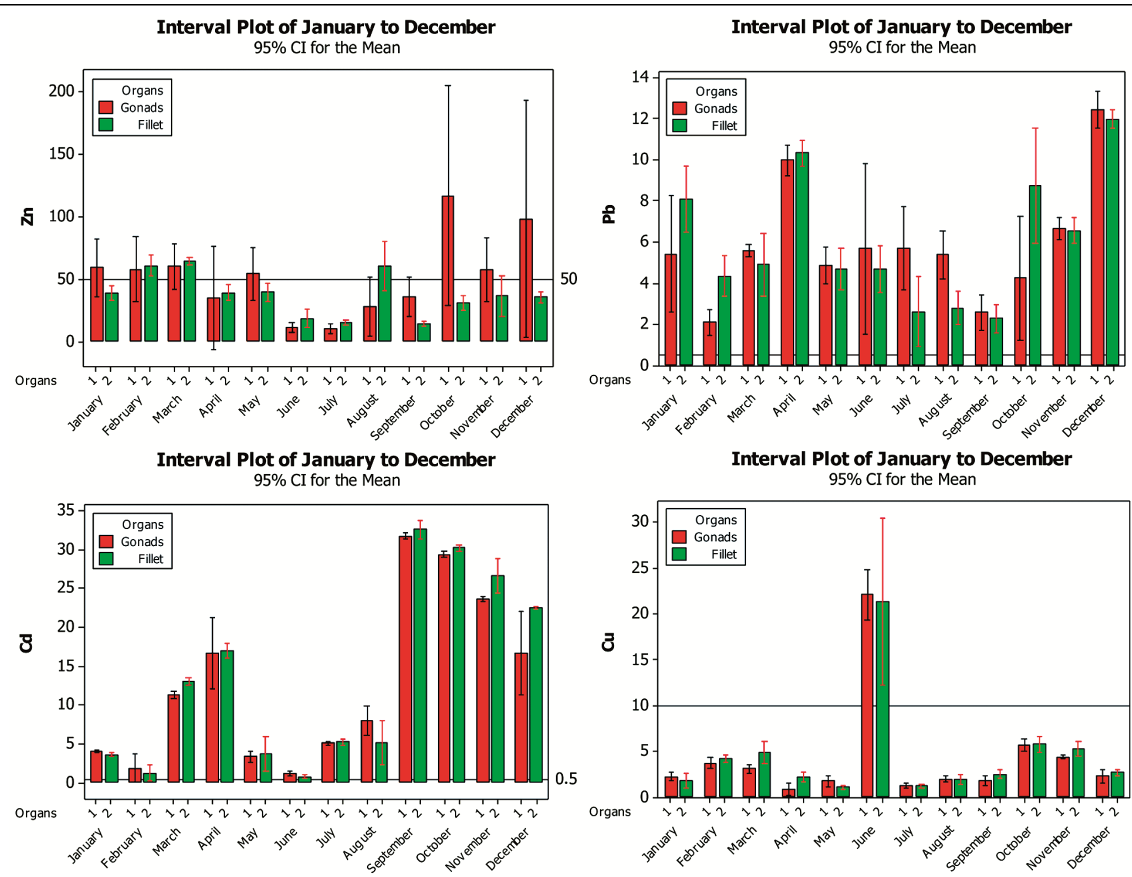

Fig. 2 — Temporal variations in the concentrations of Zn, Cd, Pb and Cu in the gonads and fillets

biological processes[23] and also serves as a cofactor in many enzyme systems implicated in the use of almost all nutrients. However, at higher concentrations, it may have deleterious effects on fish[24,25]. The lowest (10.24±5.45 mg/kg) accumulation of zinc is observed in the gonads during July. Metal concentrations in gonads may vary with season[26]. It is also worth noting that Zn is less toxic to fish as compared to Cu[27].

Cadmium

Throughout the study duration, the cadmium concentrations greatly exceeded the recommended value of 0.1 mg/kg, with the approximate mean level of accumulation of 13.42±11.90 mg/kg for filet and 12.68±10.82 mg/kg for Gonads. The maximum concentration was in the fillet (32.58±1.67 mg/kg) in September and the minimum in the same organ (0.70±0.34 mg/kg) in June. Cadmium can be taken directly from seawater or assimilated with contaminated food. At low concentrations, dissolved cadmium and its compounds are toxic to all life, especially to aquatic biota[28].

Lead

The average lead concentrations in fillet (5.99± 3.19 mg/kg) and gonads (5.87±2.87 mg/kg) are significantly higher than the recommended value for fish (0.5 mg/kg) according to FAO/WHO[22]. The highest concentration of lead was observed in the gonads in December (12.47±0.95 mg/kg), and the lowest was obtained in the same organ during February (2.07±0.91 mg/kg). Lead is an extremely toxic metal in aquatic environments. Fishes are most vulnerable to the toxic effects of Pb exposure, which can be fatal even at lower concentrations due to bioaccumulation[29].

Copper

The highest (22.03±2.23 mg/kg) and the lowest (0.84±0.54 mg/kg) copper concentrations were observed in the gonads in June and April, respectively.

During the study period, all copper concentrations, except for June, comply with the recommended value for fish (10 mg/kg)[22] with an average concentration of 4.51±5.51 mg/kg and 6.95±15.16 mg/kg in the fillet and gonads, respectively. The significant increase in the copper levels, during June, in both target organs remains unexplained.

Copper is an important micronutrient that serves as a cofactor in many enzyme systems linked to body processes indispensable for survival in both humans and animals[30]. However, it is known that high concentrations of copper can be toxic to both fish and humans[30].

The heavy metals uptake mainly occurs through water, food and the sediments. Various studies show that the metal accumulation in fish tissues depends mainly on the concentrations of metals in the environment, but also on the exposure duration and other environmental factors such as salinity, pH and temperature[31]. In addition, the toxicity of metals with regard to living organisms depends on their nature, mode of action, speciation and therefore, their bioavailability[32]. Furthermore, metal concentrations in organisms depend on whether they are essential or not, while non-essential metals are present in traces and are toxic, essential metals tend to be highly regulated.

The metal concentrations in the fillets and gonads decreased in the following order: Zn >Cd >Pb >Cu and Zn >Cd >Cu >Pb, respectively. It is worth noting that most of the time, metal accumulations were different between the target organs (fillets and gonads) (Fig. 2).

The levels of essential metals (zinc and copper) are higher in the gonads than in the fillets probably owing to their function as a cofactor in many enzymes systems[23,30]. Yilmaz[33] reported that generally heavy metals are more concentrated in the gonads than in the skins or muscles of *Mugil cephalus* and *Trachurus mediterraneus*.

In this study, it is important to note that the levels of non-essential metals (cadmium and lead), greatly exceed the recommended values both in the gonads and fillets. These results are in agreement with Belhadj *et al.*[18] where it was reported that the sediments of Ghazaouet Bay are highly polluted by the heavy metals such as Cd and Pb.

Jovanović *et al.*[34] reported that direct transfer of heavy metals from sediments is the major route of passage in many aquatic species *i.e.* metals accumulate in the body of bottom feeders and transfer up the food chain through biomagnification.

The data on heavy metals concentrations in the muscles and gonads of *T. trachurus* collected from Ghazaouet Bay were compared with other studies and are presented in Tables 2 & 3. The data revealed that all heavy metals levels reported in the current study are higher than those reported by the previous studies, except the Zn level in the muscles reported by Tuzen[35]. It is important to note that Pb and Cd levels largely exceed those reported by other studies.

Table 2 — Comparison of the overall heavy metal concentrations in the muscles of *T. trachurus* collected from Ghazaouet bay (western Mediterranean coast of Algeria) with other studies

Studies	Sites	Zn (mg/kg)	Pb (mg/kg)	Cu (mg/kg)	Cd (mg/kg)
Tuzen[36]	Middle Black Sea, Turkey	12.05	0.85	1.52	0.47
Tuzen[37]	Purchased from popular supermarkets in Turkey	13.20	0.16	1.10	0.25
Tuzen[35]	Black Sea, Turkey	52.70	0.82	0.65	0.32
Mendil *et al.*[38]	Black Sea, Turkey	25.70	0.64	2.40	0.22
Mingant *et al.*[39]	Cavi di Lavagna, Liguriansea, Italy	15-22	-	1.30 ±2.20	<0.01
Nisbet *et al.*[40]	Middle Black Sea, Turkey	27.70	0.60	1.79	0.012
Gundogdu *et al.*[41]	Coast of Sinop Black Sea, Turkey	19.98	0.02	3.25	0.01
Present study	Ghazaouet bay	37.67 ± 17.17	5.99 ± 3.19	4.51 ± 5.51	13.42 ± 11.90

Table 3 — Comparison of the overall heavy metal concentrations in the gonads of *T. trachurus* collected from Ghazaouet bay (western Mediterranean coast of Algeria) with other studies

Studies	Sites	Zn (mg/kg)	Pb (mg/kg)	Cu (mg/kg)	Cd (mg/kg)
Alkan *et al.*[42]	Black Sea	4.63	0.10	2.43	0.29
Aydın & Tokalıoğlu[43]	Black Sea	/	3.85	/	/
Present study	Ghazaouet bay	51.88± 31.60	5.87 ± 2.87	6.95 ± 15.16	12.68 ± 10.82

Conclusion

The results of the present study reveal the accumulation levels of Pb, Cd, Cu and Zn in different tissues (gonads and fillets) of Horse mackerel collected from Ghazaouet Bay. The metal concentrations in the fish fillets and gonads decreased in the order of Zn >Cd >Pb >Cu and Zn >Cd >Cu >Pb, respectively. It is worth noting that most of the time, metal accumulations were different between the target organs. For both organs, copper levels, except for June, comply with the recommended value for fish[22]. Zinc levels in the fillets also comply with the recommended value for fish by WHO[22] and are slightly above this value in the gonads. Further, the levels of essential metals (zinc and copper) are higher in the gonads than in the fillets. Moreover, it is also important to note here that the levels of non-essential metals (cadmium and lead), greatly exceed the recommended values in both the target organs, the gonads and fillets, which is ascribed mainly to the industrial pollution in the Ghazaouet area. Therefore, it can be concluded that these heavy metals in different tissues (gonads and fillets) of Horse mackerel, which is highly consumed in the Algerian coastal regions, could pose adverse health effects for the consumers. Hence, effective legislation and proper implementation of appropriate industrial waste treatment measures can help reduce heavy metal pollution and the toxic levels of ambient fishery in the Ghazaouet Bay.

Acknowledgements

The authors would like to thank the Algerian DGRSDT-MESRS, and the University of Tlemcen for funding this work.

Conflict of Interest

The authors declare that they have no conflict of interest.

Ethical Statement

This is to certify that the reported work in the paper entitled “Heavy metals levels in tissues of Horse mackerel collected from Ghazaouet Bay, Algeria” submitted for publication is an original one and has not been submitted for publication elsewhere. We further certify that proper citations to the previously reported work have been given and no data/table/figure has been quoted verbatim from other publications without giving due acknowledgement and without the permission of the author(s). The consent of all the authors of this paper has been obtained for submitting the paper to the “Indian Journal of Geo-Marine Sciences”.

Author Contributions

MC: Investigation, writing - review & editing; WBR: Supervision; MB: Statistical analysis; and FZM: Atomic absorption analysis.

References

1 Tewari P K & Singh A K, Amberlite XAD-7 impregnated with Xylenol Orange: a chelating collector for preconcentration of Cd (II), Co (II), Cu (II), Ni (II), Zn (II) and Fe (III) ions prior to their determination by flame AAS, *Fresenius J Anal Chem*, 367 (2000) 562-567.

2 Baral A & Engelken R D, Chromium-based regulations and greening in metal finishing industries in the USA, *Environ Sci Policy*, 5 (2002) 121-133.

3 Demirbas A, Pehlivan E, Gode F, Altun T & Arslan G, Adsorption of Cu (II), Zn (II), Ni (II), Pb (II), and Cd (II) from aqueous solution on Amberlite IR-120 synthetic resin, *J Colloid Interface Sci*, 282 (2005) 20-25.

4 Abramson S, Beaunier P, Borensztajn S, Dupuis V, Perrigaud L, *et al*., Magnetic silica nanocomposites prepared by green methods: synthesis, properties and application in water-treatment, *Matér Tech*, 100 (3) (2012) 221-239.

5 Mason A & Jenkins K, Metal detoxification in aquatic organisms, *Metal Speciation and Bioavailability in Aquatic Systems*, 3 (1995) 479-578.

6 Behera P, Bharti V, Ahirwal S, Purushothaman C & Vennila A, Assessment of heavy metals distribution in a coastal environment of Versova coast, Mumbai, India, *Indian J Geo-Mar Sci*, 50 (2021) 1058-1065.

7 Mamatchi M, Rajaram R & Ganeshkumar A, Toxic metals (Cd and Pb) induced dysfunctioning of antioxidant system in marine fish Sphyraena barracuda (Edwards, 1771) collected from Kpeme, South of Togo, *Indian J Geo-Mar Sci*, 50 (2021) 44-51.

8 Shaabani Z, Esmaili-Sari A, Moradi A M, Taghavi L & Farsad F, Possible health risk assessment for heavy metal concentrations in water, sediment, and fish species and Turkmen pregnant women's biomonitoring in Miankaleh Peninsula, Iran, *Environ Sci Pollut Res*, 29 (2022) 37187-37203.

9 Benguedda W, DaliYoucef N & Amara R, Heavy Metals in the three fish species from Honaine Bay in western part of Algerian coast, *Int J Curr Eng Technol*, 5 (3) (2015) 2198-2205.

10 Benguedda W & Amara R, Trace metals in sediments, macroalgae and benthic species from the western part of Algerian coast, *J Environ Sci Eng*, 5 (3) (2011) 2198-2205.

11 Reboa A, Mandich A, Cutroneo L, Carbone C, Malatesta A, *et al*., Baseline evaluation of metal contamination in teleost fishes of the Gulf of Tigullio (north-western Italy): histopathology and chemical analysis, *Mar Pollut Bull*, 141 (2019) 16-23.

12 Walker T R & Grant J, Metal (loid) s in sediment, lobster and mussel tissues near historical gold mine sites, *Mar Pollut Bull*, 101 (2015) 404-408.

13 Vikas M & Dwarakish G, Coastal pollution: a review, *Aquatic Procedia*, 4 (2015) 381-388.

14 Gupta S K & Singh J, Evaluation of mollusc as sensitive indicator of heavy metal pollution in aquatic system: a review, *The IIOAB J*, 2 (2011) 49-57.

15 Montaser M, Mahfouz M E, El-Shazly S A, Abdel-Rahman G H & Bakry S, Toxicity of heavy metals on fish at Jeddah coast KSA: Metallothionein expression as a biomarker and histopathological study on liver and gills, *World J Fish Mar Sci*, 2 (2010) 174-185.

16 Derrag Z & Dali Youcef N, Bioaccumulation of heavy metals in the *Cyprinus carpio* organs of the El Izdihar dam (Algeria), *Desalin Water Treat*, 52 (2014) 2293-2300.

17 Dali Youcef N, Benguedda W & Youbi F, Levels of heavy metals (Zn, Pb, Cu, Cd, Ni) in tissues of *Sarpa salpa* from Honaine bay in the Western part of the Algerian Coast, *Desalin Water Treat*, 52 (2014) 2850-2855.

18 Belhadj H, Aubert D & Dali Youcef N, Geochemistry of major and trace elements in sediments of Ghazaouet Bay (western Algeria): an assessment of metal pollution, *Comptes Rendus Geosci*, 349 (2017) 412-421.

19 Smith-Vaniz W F, Carangidae, In: *Fish of the Northeastern Atlantic and the Mediterranean*, Vol II, edited by Whitehead P J P, Bauchot M-L, Hureau J-C, Neilsen J & Tortonese E, Paris, 1986.

20 Touahri H G, Boutiba Z, Benguedda W & Shaposhnikov S, Active biomonitoring of mussels *Mytilus galloprovincialis* with integrated use of micronucleus assay and physiological indices to assess harbor pollution, *Mar Pollut Bull*, 110 (2016) 52-64.

21 Malaiyandi M & Barrette J, Wet oxidation method for the determination of submicrogram quantities of mercury in cereal grains, *J Assoc Official Anal Chem*, 55 (1972) 951-959.

22 FAO & WHO, World Health Organization, 1989. https://apps.who.int/iris/handle/10665/41268

23 Casas S, *Modélisation de la bioaccumulation de métaux traces (Hg, Cd, Pb, Cu et Zn) chez la moule, Mytilus galloprovincialis en milieu méditerranéen*, Thèse de Doctorat, Université du Sud Toulon Var, Toulon, 2005.

24 Malik D, Sastry K & Hamilton D, Effects of zinc toxicity on biochemical composition of muscle and liver of murrel (*Channa punctatus*), *Environ Intern*, 24 (1998) 433-438.

25 Çelik E Ş, Kaya H, Yilmaz S, Akbulut M & Tulgar A, Effects of zinc exposure on the accumulation, haematology and immunology of Mozambique tilapia, *Oreochromis mossambicus*, *African J Biotech*, 12 (2013) 744-753.

26 Fletcher G & King M, Seasonal dynamics of Cu^{2+}, Zn^{2+}, Ca^{2+}, and Mg^{2+} in gonads and liver of winter flounder (*Pseudopleuronectes americanus*): evidence for summer storage of Zn^{2+} for winter gonad development in females, *Canadian J Zool*, 56 (1978) 284-290.

27 Dara S S, *Environmental Chemistry and Pollution Control*, (S. Chand Publishers, India), 1998.

28 Levit S M, A literature review of effects of cadmium on fish, *Nat Conser*, 15 (2010) pp. 16.

29 Lee J-W, Choi H, Hwang U-K, Kang J-C, Kang Y J, *et al*., Toxic effects of lead exposure on bioaccumulation, oxidative stress, neurotoxicity, and immune responses in fish: A review, *Environ Toxico Pharmaco*, 68 (2019) 101-108.

30 Malhotra N, Ger T-R, Uapipatanakul B, Huang J-C, Chen K H-C, *et al*., Review of copper and copper nanoparticle toxicity in fish, *Nanomaterials*, 10 (2020) p. 1126.

31 Yılmaz A B & Yılmaz L, Influences of sex and seasons on levels of heavy metals in tissues of green tiger shrimp (*Penaeus semisulcatus* de Hann, 1844), *Food Chem*, 101 (2007) 1664-1669.

32 Alzieu C, Abamou A, Bassoullet P & Boutier B, Dragage et environnement marin: état des connaissances. Plouzane: Edition Ifremer, 1999, pp. 223.

33 Yilmaz A B, Levels of heavy metals (Fe, Cu, Ni, Cr, Pb, and Zn) in tissue of *Mugil cephalus* and *Trachurus mediterraneus* from Iskenderun Bay, Turkey, *Environ Res*, 92 (2003) 277-281.

34 Jovanović D A, Marković R V, Teodorović V B, Šefer D S, Krstić M P, *et al*., Determination of heavy metals in muscle tissue of six fish species with different feeding habits from the Danube River, Belgrade—public health and environmental risk assessment, *Environ Sci Pollut Res*, 24 (2017) 11383-11391.

35 Tuzen M, Toxic and essential trace elemental contents in fish species from the Black Sea, Turkey, *Food Chem Toxicol*, 47 (2009) 1785-1790.

36 Tüzen M, Determination of heavy metals in fish samples of the middle Black Sea (Turkey) by graphite furnace atomic absorption spectrometry, *Food Chem*, 80 (2003) 119-123.

37 Tuzen M & Soylak M, Determination of trace metals in canned fish marketed in Turkey, *Food Chem*, 101 (2007) 1378-1382.

38 Mendil D, Demirci Z, Tuzen M & Soylak M, Seasonal investigation of trace element contents in commercially valuable fish species from the Black Sea, Turkey, *Food Chem Toxicol*, 48 (2010) 865-870.

39 Mingant V, Drava G, De Pellegrini R & Siccardi C, Trace elements in farmed and wild gilthead seabream, *Sparus aurata*, *Mar Pollut Bull*, 60 (2010) 2022-2025.

40 Nisbet C, Terzi G, Pilgir O & Sarac N, Determination of heavy metal levels in fish samples collected from the Middle Black Sea, *Kafkas Univ Vet Fak Derg*, 16 (2010) 119-125.

41 Gundogdu A, Culha S T, Kocbas F & Culha M, Heavy metal accumulation in muscles and total bodies of *Mullus barbatus*, *Trachurus trachurus* and *Engraulis encrasicolus* captured from the coast of Sinop, Black Sea, *Pak J Zool*, 48 (2016) pp. 25-34.

42 Alkan N, Alkan A, Gedik K & Fisher A, Assessment of metal concentrations in commercially important fish species in Black Sea, *Toxicol Ind Health*, 32 (2016) 447-456.

43 Aydın D & Tokalıoğlu Ş, Trace metals in tissues of the six most common fish species in the Black Sea, Turkey, *Food Addit Contam: Part B*, 8 (2015) 25-31.