Turkish Journal of Science & Technology
Volume 4, No 1,7-15, 2009

# The Comparison of Heavy Metal Concentrations (Cd, Cu, Mn, Pb, and Zn) in Tissues of Three Economically Important Fish (*Anguilla anguilla*, *Mugil cephalus* and *Oreochromis niloticus*) Inhabiting Köycegiz Lake-Mugla (Turkey)

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**(Received: 10.08.2008; Accepted: 17.12.2008)**

### Abstract

In this study, some heavy metals were analyzed in liver, muscle and gills of 127 fish samples of three fish species (*Anguilla anguilla*, *Mugil cephalus*, *Oreochromis niloticus*) caught from the Köyceğiz Lake between June–2005 and May–2006. The highest concentrations were found in liver (Cd: 3.32 µg $g^{-1}$, Cu: 749.76 µg $g^{-1}$ and Zn: 402.61 µg $g^{-1}$) and in gills (Mn: 430.22 µg $g^{-1}$ and Pb: 1.96 µg $g^{-1}$) of *A. anguilla*. The lowest metal contents were determined in edible parts (muscle) of all species. Hovewer, Pb and Zn for *O. niloticus*; Pb, Zn and Cd for *A. anguilla*; and Cd and Zn for *M. cephalus* were found higher than the Turkish Food Codex, European Units and World Health Organization limits for human consumption in edible parts of the fish samples and posed a risk for human health. Metal concentration differences among the fish species were statistically significant ($p< 0.05$) and various degrees of correlations coefficient were found between the elements.

**Key Words:** Heavy metal, fish, Köyceğiz Lake, *A. Anguilla, M. cephalus, O. niloticus.*

# Köyceğiz Gölü (Muğla-Türkiye)'nde Yaşayan Ekonomik Öneme Sahip Üç Balığın (*Anguilla anguilla*, *Mugil cephalus* ve *Oreochromis niloticus*) Dokularındaki Ağır Metal Konsantrasyonlarının Karşılaştırılması

### Özet

Bu çalışmada, Köyceğiz Gölünden, 2005-Haziran ve 2006-Mayıs tarihleri arasında yakalanan üç türe ait (*Anguilla anguilla*, *Mugil cephalus*, *Oreochromis niloticus*) 127 adet balık örneğinin karaciğer, kas ve solungaç dokularındaki bazı ağır metaller analiz edildi. En yüksek konsantrasyonlar; *A. anguilla*'nın karaciğer (Cd: 3.32 µg $g^{-1}$, Cu: 749.76 µg $g^{-1}$ ve Zn: 402.61 µg $g^{-1}$) ve solungaçlarında (Mn: 430.22 µg $g^{-1}$ ve Pb: 1.96 µg $g^{-1}$) bulunmuştur. Bu üç ekonomik balığın yenilebilir kısımlarında (kas), diğer dokulara gore daha düşük metal miktarları tesbit edilmiştir. Bununla birlikte *O. niloticus* için Pb ve Zn; *A. anguilla* için Pb, Zn ve Cd ve *M. cephalus* için Cd ve Zn seviyeleri insan tüketimi için Türk Gıda Kodeksi, Avrupa Birliği ve Dünya Sağlık Örgütü tarafından belirlenen limitlerin üstünde olup, sağlık açısından risk oluşturmaktadır. Balık türleri arasında metal konsantrasyonları arası fark istatistiki açıdan önemli olup ($p<0.05$), metaller arasında değişen oranlarda korelasyon katsayıları bulunmuştur.

**Anahtar Kelimeler:** Ağır metal, balık, Köyceğiz Gölü, *A. Anguilla, M. cephalus, O. niloticus.*

## 1. Introduction

Heavy metal contamination of aquatic ecosystems has been recognised as a serious pollution problem. All heavy metals are potentially harmful to most organisms at some level of exposure and adsorption. Contamination of aquatic environments with potentially harmful subtances, in particular non-degradable heavy metals, and its subsequent impact on organisms, is more dramatic within estuaries and semiclosed coastal zones, especially when they are near highly populated or industrial areas. Heavy metals may enter an estuary from different natural and anthropogenic sources, including industrial or domestic sewage, storm runoff, leaching from landfills, shipping and harbour activities, and atmospheric deposits [1,2].

Fish are often at the top of the aquatic food chain and may concentrate large amounts of some metals from the water. In addition, fish are most indicative factors in fresh water systems, for the estimation of trace metal pollution and risk potential of human consumption [3]. For the normal metabolism of fish, the essential metals like copper and zinc must be taken up from water, food or sediment. However, similar to the route of essential metals, non-essential ones are also taken up by fish and accumulate in their tissues [4,5].

*Anguilla anguilla*, European eel, is an amphihaline species, which migrates to the depths of the Sargasso Sea to spawn. Its food includes virtually the whole aquatic fauna occurring in the eel's area, augmented with animals living out of water, e.g. worms. Utilized fresh, dried or salted, smoked and frozen; can be fried, boiled and baked. They live on the bottom, under stones, in the mud or in crevices [6].

*Mugil cephalus,* Flathead mullet, is a cosmopolitan in coastal waters of the tropical and subtropical zones of all seas that often enters estuaries and rivers. Mainly diurnal, feed on zooplankton, benthic organisms and detritus. Adult fish tend to feed mainly on algae while inhabiting fresh waters. Marketed fresh, dried, salted, and frozen; or sold fresh or smoked. They are very important commercial species in many parts of the world [7].

*Oreochromis niloticus,* Nile tilapia, occurs in a wide variety of freshwater habitats like rivers, lakes, sewage canals and irrigation channels. Herbivorous, feeds on water plants and epiphyton, and some invertebrates and phytoplankton or benthic algae [8]. These fish species are considered to be important part of the diet, around the estuaries study area, Köyceğiz Lake.

This area has also an economic importance for fishery, especially for Mugilidae sp. But, on the other hand, the region is under the effect of pressure of pollution originating from touristic activities, boat and shipping traffic, agriculture and similar industries, gradually degrading the highly suitable environmental factors for the survival and growth of these commercial fishes. The contaminated fish from this area may become a public health concern. Therefore, in order to assess the metal contamination of the aquatic environment of lagoon system, information on elemental concentration in fish species in Köyceğiz Lake and Lagoon System becomes of great importance.

The present study has been conducted to determine cadmium, copper, manganese, lead and zinc concentrations in the gill, muscle and liver of the three fish (*A. anguilla, M. cephalus, O. niloticus*) from the study area, Köyceğiz Lake. Gills and liver are chosen as target organs for assessing metal accumulation.

## 2. Material and Method

### 2.1. Study area

The Köyceğiz Lake estuary is a system of vital importance in South-West of Turkey, not only from the physical viewpoint but also because of its ecological significance (Figure 1). Because of its special ecological value and the natural beauty of the region, this area is among the most attractive tourist sites on the Mediterranean coast of Turkey. Touristic development which took place by and after 1988, especially with case of Iztuzu and marine turtles *Caretta caretta* seemed to mobilize economic demand in the area. This area designated as a national reservation area to be administrated by the Authority of Specially Protected Areas [9].

### 2.2 Sampling and analysis

During the study period, four fishing expeditions were carried out in the Köyceğiz Lake between June–2005 and May–2006. Ten or twelve fish samples were transported to the laboratory in a thermos-flask with ice on the same day in each study period. The main characterisrics of the fish species are given in Table 1. Approximately 5 g of muscle, two gill racers and entire liver from each sample were dissected, washed with deionized water, weighed, packed in polyethylene bags, and stored at -20 $^{0}$C prior to analysis.

The tissue samples were digested with conc. nitric acid. Dissected samples were transferred to a 100 mL Teflon beaker. Thereafter, 10 mL ultrapure conc. $HNO_3$ (Merck) was added, and the sample heated at 100, 150, 210, and 280 $^0$C on a hot plate for 0.5, 0.5, 0.5 and 2 hours with a DK-20 Heating Digester respectively. Two mL of 1 N $HNO_3$ was added to the residue, and the solution continuously evaporated on the hot plate, until it was digested in every sample. After cooling, a further 10 mL of 1 N $HNO_3$ was added. The solution was transferred, diluted and filtered through 0.45 µm nitrocellulose membrane filter [10].

All samples were analysed two times for Cd, Cu, Mn, Pb and Zn by ICP/AES (Optima 2000-Perkin Elmer), which is a fast multi-element technique with a dynamic linear range and moderate-low detection limits [11].

Standard solutions were prepared from stock solutions (Merck, multi element standard). Standard reference materials, DORM-2 (for muscle) and DOLT-2 (for liver) - National Research Council Canada, were analysed for each of the eight elements.

Replicate analysis of these reference materials showed good accuracy, with recovery rates for metals between 92-107 % for fish. The absorption wavelengths and detections limits were 228.804 nm and 0.001 ppm for Cd, 324.75 nm and 0.01 ppm for Cu, 257.61 nm and 0.0014 ppm for Mn, 220.35 nm and 0.0042 ppm for Pb, and 206.20 nm and 0.0059 ppm for Zn, respectively.

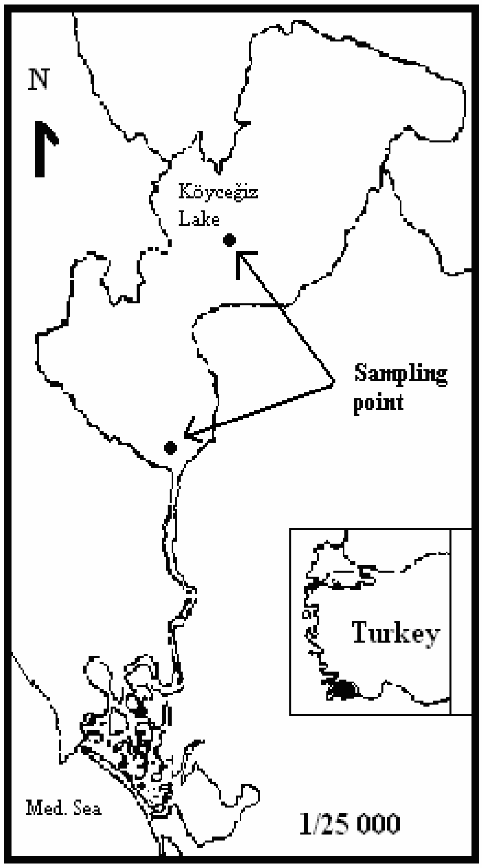


**Figure 1.** Sampling points and studying area

**Table 1.** Main characteristics of the fish species *O. niloticus*, *A. anguilla* and *M. cephalus* from Köyceğiz Lake

| Fish species | Number of species | Length (cm) | Weight (g) | Age |
|---|---|---|---|---|
| ***Oreochromis niloticus*** | 42 | 13.51±2.34 | 67.31±5.84 | 2-3 |
| ***Anguilla anguilla*** | 41 | 46.78±7.53 | 141.23±14.72 | 5-8 |
| ***Mugil cephalus*** | 44 | 24.35±3.78 | 85.29±12.81 | 3-4 |

### 2.3. Statistically analysis

Statistical analysis of data was carried out using SPSS 9.0 statistical package program. One-way analysis of variance (ANOVA) was used to assess whether metal concentrations varied as sigificantly among tissues. Also, to determine the correlation between the element pairs in tissues, the Pearson's correlation coefficient matrix for the elements was done.

## 3. Results and Discussion

### 3.1. Metal bioaccumulation in fish species and differences among tissues

Mean concentrations of cadmium, copper, manganese, lead and zinc in muscle, gill and liver of *A. anguilla, M. cephalus,* and *O. niloticus* from the Köyceğiz Lake is shown in Table 2. The results confirm the differences of heavy metal accumulation in the different tissues. The highest concentrations were found in liver, except for Mn, and Pb which is found in gills to be highest. The lowest levels were detected in the muscle, except for Pb. Liver is a target organ of accumulation for many metals, because of its strong irrigation and excretion function. Target organs, such as liver, gonads, kidney, and gills, are metabolically active tissues and accumulate heavy metals of higher levels, as was observed many experimental and field studies. The liver is often considered a good monitor of water pollution with metals since their concentrations are proportional to those present in the environment. The reason for high metal concentrations in the gills could be due to the metal complexing with the mucus that is impossible to remove completely from the lamellae before analysis [12].

In this study, heavy metal accumulation order was, Zn>Mn>Cu>Pb>Cd in the muscles and in the gills of *A. anguilla, O. niloticus,* whereas Mn>Zn>Cu>Pb>Cd in gills of *M. cephalus.* Heavy metal accumulation order in the liver was Zn>Cu>Mn>Pb>Cd for *A. anguilla, O. niloticus* and Cu>Zn>Mn>Pb>Cd for *M. cephalus.* It is generally accepted that heavy metal uptake occurs mainly from water, food, and sediment. Hovewer, the efficiency of metal uptake from contaminated water and food may differ in relation to ecological needs, metabolism, and the contamination gradients of water, food, and sediment, as well as other factors such as salinity, temperature, and interacting agents [13].

The liver tissue is highly active in the uptake and storage of heavy metals. It is well known that large amount of metallothionein induction occurs in the liver tissue of fishes. The gills are uptake site of waterborne ions, where metal concentrations increase especially at the beginning of exposure, before the metal enters other parts of organism [12].

Analysis of heavy metal levels in tissues of three species showed that, highest values of Cd, Cu and Zn in liver and Mn and Pb in gills of *M. cephalus.* Among the values mean copper (749.96 $\mu$ $g^{-1}$) and mean zinc (402,61 $\mu$ $g^{-1}$) concentrations appear considerably higher in the liver such as mean Mn (430.32 $\mu$ $g^{-1}$) in the gills. Our results showed that different fish species contained different metal levels in their tissues. This is perhaps due to the heavy metal levels in different species depend on feeding habits, age, size and length of fish [14,5]. Due to variations in feeding habits and habitats, the levels of metals found in tissues of the *M. cephalus* were generally higher than those found in other fish species throughout the study period. Studies carried out with various fish species have shown that heavy metals accumulate mainly in metabolic organs, such as liver and kidney, and those stored are detoxificated by producing metallothioneins [15]. Our results show that metal accumulation is highest in liver and in gills, whereas it is low in muscle in all species, except Pb.

On the other hand, high levels of metals in tissues of fishes could be originated from different sources around the study area. These sources are; i) for Pb and Cd, boat traffic, motor oil and ballasts water, also Cd can be occuring from phosphorus-fertilizer used in agriculture, ii) for Zn, compossed fertilizer enriched with Zn, iii) for Mn, micro-elements fertilizer and iv) for Cu, conservative fungicides that contains Cu used for citrus fruits plantations and green-houses around Köyceğiz Lake.

Many studies reported that on a number of fish species, which show that muscle is not an active tissue in accumulating heavy metals. Heavy metal analysis in edible parts (muscle) of three commercial fish, *A. anguilla, M. cephalus, O. niloticus,* indicated that, all metals had the lowest values in muscle. Hovewer, Pb and Zn for *O. niloticus*, Pb, Zn and Cd for *A. anguilla* and Cd and Zn for *M. cephalus* were higher than the limits for human consumption in edible parts of the fish samples from the Köyceğiz Lagoon System [16-18].

**Table 2**. Mean concentrations (µg $g^{-1}$ metal/ wet w) with standard deviations and min. and max. values of metals in muscle, gills and liver of *O. niloticus*, *A. anguilla* and *M. cephalus* in Köyceğiz Lake

| Fish species | Tissues | Cd | Cu | Mn | Pb | Zn |
|---|---|---|---|---|---|---|
| ***Oreochromis*** | Muscle | 0.12± 0.02 | 3.91±1.76 | 12.65±3.21 | 1.12±1.10 | 84.76±12.76 |
| ***niloticus*** | | (0.04-0.15) | (1.34-5.61) | (5.34-18-97) | (0.78-1.32) | (34-76-120.45) |
| | Gills | 0.11± 0.03 | 7.34±2.34 | 63.44±8.71 | 0.96±0.02 | 104.82±18.90 |
| | | (0.01-0.16) | (2.36-9.80) | (34.78-96.85) | (0.23-1.12) | (45.78-134.63) |
| | Liver | 0.44±0.01 | 114.25±23.45 | 9.64±3.24 | 1.02±0.95 | 136.95±22.31 |
| | | (0.11-0.56) | (58.91-145.65) | (4.12-14.78) | (0.67-1.18) | (98.34-167.12) |
| ***Anguilla anguilla*** | Muscle | 0.16±0.02 | 2.21±1.12 | 3.14±2.76 | 1.16±0.93 | 106.71±15.82 |
| | | (0.08-0.23) | (1.45-2.89) | (2.34-3.78) | (0.98-1.45) | (65.43-134.76) |
| | Gills | 0.15±0.02 | 2.54±1.23 | 8.62±3.56 | 0.35±0.01 | 147.84±34.78 |
| | | (0.10-0.19) | (1.89-3.12) | (4.39-11.23) | (0.23-0.46) | (83.49-169.87) |
| | Liver | 0.43±0.23 | 73.91±8.97 | 11.04±2.54 | 1.63±0.97 | 199.32±45.72 |
| | | (0.32-0.54) | (49.23-92.36) | (8.76-15.39) | (0.98-2.10) | (1.28-2.34) |
| ***Mugil cephalus*** | Muscle | 0.12±0.01 | 6.34±2.56 | 8.89±3.59 | 0.43±0.03 | 98.6±10.38 |
| | | (0.09-0.14) | (5.45-7.09) | (6.78-11.25) | (.021-0.63) | (68.90-124.72) |
| | Gills | 0.37±0.03 | 5.68±2.65 | 430.22±54.78 | 1.96±0.76 | 176.93±16.78 |
| | | (0.21-0.52) | (3.68-7.32) | (214.12-753.74) | (1.17-2.36) | (1.28-1.99) |
| | Liver | 3.32±1.23 | 749.76±123.45 | 18.43±7.54 | 0.78±0.09 | 402.61±68.91 |
| | | (2.41-4.19) | (367.90-981.34) | (12.45-23.81) | (0.56-0.98) | (259.12-587.23) |

### 3.2. Comparison With Published Data and Estabilished Guidelines

Our copper values ranged from 2.21 to 749.76 µg $g^{-1}$ and were similar to those detected in Southern Sri Lanka [19] and Northeast Mediterranean [5] but higher than those reported in other study areas (Table 3). The liver of *M. cephalus* showed enormously high copper concentrations (749.76 µg $g^{-1}$). High copper concentrations of *M. cephalus* were also found in previous studies and this was related to its swimming activity. The highest accumulation of copper can be explained by its relation to low-molecular-weight proteins (metallothionein-like), which are concentrated in hepatic tissue.

Our manganese values ranged from 3.14 to 430.32 µg $g^{-1}$, and were always higher than those in fish species of in other study areas (Table 3). Zinc values ranged from 84.76 to 402.61 µg $g^{-1}$ and were similar to Tuzla Lagoon [25], Northeast Mediterranean [5] and Kolleru Lake [28] and were higher than those from other studies. Zinc concentrations found in edible muscle tissue of *O. nilotica, A. anguilla* and *M. cephalus* were higher than the local and internationally standards, accepted values for human consumption [16-18]. One of the interesting results was the high manganese concentrations in the gills of *M. cephalus* and this may be related to their feeding behaviour. *M. cephalus* feeding on benthic organisms and detritus on bottom and filter particles in waters with their gill rakers and active swimning. Metal concentrations in the gills could be due to element-complexing with the mucus, which is impossible to be removed completely between the lamellae, before tissue is prepared for analysis. Thus, high concentrations of various metals can be observed there. The gills of a fish constitute a multifunctional organ (respiration, ion-regulation, acid-base regulation, nitrogenous waste exretion) accounting for over 50% of the total surface area of the animal [32]. Another intersting result was the enormously high zinc concentration in liver of eel and this may be related the trophic level of this species.

Copper, manganese and zinc are essential, with considerably higher concentrations in metabolic organs, such as liver and kidney than in muscle tissue, presumably due to their function as co-factor for the activation of a number of enzymes. Copper is involved in electron transport. In addition, the activity of numerous enzymes (Cu-Zn- superoxide dismutase, catalase, tyrosinase etc.) depends on the presence of Cu. The main role of Zn is that as a co-factor in many enzymatic systems, involved in the utilization of almost all nutrients. Manganese acts either as an integral part of enzymes (private carboxylase, lipase) or as a co-factor for numerous enzymes involved in nitrogen, lipid and carbohydrate metabolism [32]. Like copper, zinc is both a micro-nutrient and toxicant, which is released diffusely from industrial and domestic sources (e.g. galvanized metals). However, zinc is about five-fold less toxic than copper, and zinc uptake at the gills appears to be a normal branchial function, occurring via the chloride cells.

Our Cd values ranged from 0.11 to 3.32 µg $g^{-1}$, were similar to those from Tuzla Lagoon [25], wild ecosystems in Spain [26] and northeast Mediterranean [5], but higher than those detected in fish species of other areas (Table 3). Cadmium has a high potential for bioconcentration in fish and is accumulated in multiple organs. Liver tissues of *O. niloticus* and *A. anguilla* have a higher capacity to accumulate Cd compared to muscle tissues. But liver tissue of *M. cephalus* showed a considerably highest accumulation than other species.

Our lead values ranged from 0.35 to 1.96 µg $g^{-1}$ and were similar to that reported in Spain [26] and were higher than those from Camargue [27], from Raine Island [28] and from Bolti Lake [21] and lower than those reported in other studies. Cadmium and lead concentrations found in edible muscle tissue of *O. nilotica, A. anguilla* and *M. cephalus* were always higher than the local and internationally standards accepted as for human consumption (Table 3).

Cd and Pb belong to the group of non-essential and toxic metals, implying no known function in biochemical processes. Usually Pb levels in teleost liver and kidney are considerably higher than that in the corresponding muscle tissue, though the specific mechanism for the highly elevated Pb levels in liver remains unknown. In contrast to the metals Cu, Zn and Cd, there is no evidence of Pb in metallothioneins. The overall results for liver emphasise trace metal exposure. Indeed, higher accumulation of metals in the liver may be considered a primary signal of metal exposure [12,32].

### 3.3. Statistically evaluation

Statistically, significance analysis (p values from the ANOVA) was performed among the fish species and our results showed that, the concentration differences among the fish species were very high ($p<0.05$). This may be related to swimming activity and trophic levels of fishes. Various degrees of correlations were found between the elements. There were highly positive relationships between some elements ($p<0.05$) (Cd and Cu; Cu and Pb; Cu and Mn; Mn and Zn), between some elements, the relationships were low ($p > 0.05$) (Cd and Mn; Cd and Zn; Mn and Pb), while other elements had no significant relationships in the study area. These results can show some elements have similar sources that can be related to geological structure and similar anthropogenic activities around the study area.

In addition the results showed that, there are more metals with high corelation coefficients in livers and in gills than in muscle. Especially, the flathead mullet presents the greatest number of metals with correlations between liver and gills, while the Nile tilapia shows the lowest number of metals. Consequently, according to the results of metal concentrations in the liver and gills of flathead mullet, we can conclude this species can be useful as bioindicator of the degree of pollution in estuarine ecosystems.

**Table3.** Trace metal concentrations (µg $g^{-1}$) in the gills, liver and muscle in other studies and guidelines.

| **Habitat/fish/tissue** | | Cd | Cu | Mn | Pb | Zn |
|---|---|---|---|---|---|---|
| Southern Sri Lanka | Flesh | 0.0 - 0.5 | 0.3 – 1.2 | 0.1- 1.2 | - | 2.9. – 5.7 |
| (*O. mossambicus*) (19) | Liver | 0.0 – 2.0 | 8.3 - 554 | 0.6 – 13.3 | - | 7.8. – 26.4 |
| Raine Island (20) | Muscle | 0.13 | 3.6 | | 0.04 | 2.6 |
| (*T.niloticus*) | | | | | | |
| Bolti Lake (*Tilapia* sp.) (21) | Flesh | 0.23 | 1.65 | 3.67 | 0.16 | 7.89 |
| Bacuta, Spain (22) | Muscle | 0.032 | 0.7 | 14.1 | 0.09 | 11.4 |
| (*A. anguilla*) | Liver | 0.48 | 23.4 | 4.50 | 0.60 | 37.0 |
| (*Liza aurata*) | Muscle | 0.030 | 0.5 | 2.33 | 0.03 | 6.07 |
| | Liver | 0.51 | 88.9 | 4.61 | 0.32 | 49.6 |
| Chi-kou Lagon, Taiwan | Liver | 0.072 | 26.3 | 1.19 | <0.07 | 46.8 |
| (23) (*M.cephalus*) | Muscle | | 0.36 | 0.20 | - | 2.31 |
| Dhanmondi Lake (24)(*O. niloticus*) | | - | 4.80-6.12 | 15.9-19.6 | 1.97-2.70 | 52.8-64.3 |
| Tuzla lagoon | Muscle | 0.11 | 0.62 | | 1.19 | 60.86 |
| (*M. cephalus*) (25) | Gill | 1.59 | 7.82 | | 6.75 | 60.50 |
| | Liver | 0.35 | 12.03 | | 3.12 | 99.80 |
| Wild ecosystems, Spain | Liver | 1.41 | 10.50 | | 1.90 | |
| (*A.anguilla*) (26) | Muscle | 0.06 | 0.29 | | 0.10 | |
| Camargue,France (27) | Liver | 0.11 | 19.00 | 1.93 | 0.16 | 53.75 |
| (*A.anguilla*) | Muscle | - | 0.14 | 0.11 | 0.26 | 19.3 |
| Northeast-Mediterranean | Muscle | 0.66 | 4.42 | - | 5.32 | 26.66 |
| (5)(*M. cephalus*) | Liver | 1.64 | 202.80 | - | 12.59 | 110.03 |
| | Muscle | 2.08 | 13.48 | - | 8.95 | 71.21 |
| Kolleru Lake | Muscle | 0.38 | 91 | - | 4.21 | 96 |
| (*O.niloticus*) (28) | Liver | 0.20 | 59 | - | 3.0 | 72 |
| | Gills | 0.12 | 28 | - | 1.90 | 37 |
| Nasser Lake | Muscle | | 0.26 | 0.026 | | 0.630 |
| (*T nilotica*) (3) | Gill | | 0.33 | 0.218 | | 1.372 |
| | Liver | | 7.50 | 0.26 | | 2.28 |
| Turkish Guidelines (18) | | 0.1 | 20 | 20 | 1 | 50 |
| FAO/WHO limits (16) | | 0.5 | 30 | - | 0.5 | 40 |
| EU limits (17) | | 0.1 | 10 | - | 0.1 | - |
| Range of International Standards (29) | | 0.0-2 | 10-100 | - | 0.5-10 | 40-100 |

### 3.4. Guidelines and human consumption

Unfortunately, there is no uniform source of guidance or standards for most metal residues in aquatic ecosystems, especially in fish tissue. We could not find single references for acceptable levels of most metals in marine or fresh water fish, self-caught or commercial ones. Information was compiled from documents of the Codex Alimentarius Commission assembled under the aegis of the United Nations Food and Agriculture Organization and the World Health Organization [16] European Commission Regulation Directives [17], and national sources [18].

From the public health perspective, people are faced with making choices in fish markets, based on available knowledge. Usually, this has to include identification of species or, at least, the type, and knowledge of fish with low levels of contaminants, such as metals, but this information is generally unavailable [4].

*A. anguilla, M. cephalus, O. niloticus* are important sources of protein for human nutrition in the region. Therefore, the presence of heavy metals in posed a risk for food contamination. The data in this study suggest that some tissues have relatively high levels of contaminants of concern, such as Cd, Pb and Zn in muscle (edible parts). On the other hand, in the gill, Cd, Pb and Zn levels were upper the limits. This situation could be due to element complexing with mucus, which is impossible to remove, before tissue analysis.

Human beings have been exposed to heavy metal toxins for an immeasurable amount of time. These toxins contribute to a variety of adverse health effects. Knowledge of heavy metal concentrations in fish is important both with respect to nature management and human health. An individual with metal toxicity, even if high dose and acute, typically has very general symptoms, such as weakness or headache. But main toxicity involves the brain and the kidney and some metals capable of causing cancer [25].

## 4. Conlusions

The metal content in the livers and gills of fish was considerably higher than that in muscle of fish. A comparison of the species analysed showed that the *M. cephalus* accumulates the most of the metals in the liver (Cd, Cu and Zn) and in the gills (Mn and Pb).

The highest concentration of trace metals was found in the tissues of *M.cephalus* from the Köyceğiz Lake. This is probably related with the trophic characteristics of this species, which being iliophagous fish [2] reflect the metal concentrations in surface and suspended particulate matter, showing high metal concentrations.

Considering the results of this study, *M. cephalus* is adequate and most suitable species for use as bio-monitors of trace metals pollution in the Köyceğiz Lake. Consequently, we recommend the use of these species as biological indicators as a tool for future monitoring programs, to evaluate the evolution of heavy metal pollution in this area.

Consequently, the results indicated that, Köyceğiz Lake have been polluted by heavy metals due to anthropogenic activities and from the legal standpoint, the muscle of all the fish caught was not suitable for human consumption and posed a risk for human health.

## Acknomledgments

The author is grateful to Dr. Nedim ÖZDEMİR for the assistance in collection and preparation of the samples, to Dr. A. Levent Tuna, and Dr. Ahmet Demirak for their skillful and persistent technical assistance throughout the study, and to Mustafa Demirkollu for analysis in the laboratory of the Ministry of Agriculture, Government of Mugla, Turkey. In addition, the author would like to thank Huseyin Yucel, Department of English Language Teaching, Mugla University, for his English editing of the paper.

## 5. References

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