

## LEVELS OF SOME HEAVY METALS IN WATER AND TISSUES OF CHUB MACKEREL (*SCOMBER JAPONICUS*) COMPARED WITH PHYSICO-CHEMICAL PARAMETERS, SEASONS AND SIZE OF THE FISH

N. Aktan and S. Tekin-Özan

Süleyman Demirel University, Faculty of Science and Art, Department of Biology, Isparta-TURKEY  
Corresponding author e-mail: seldaozan@sdu.edu.tr

### ABSTRACT

This study was carried out between October 2009 to July 2010 and heavy metals like Ba, As, Co, Cd, Cr, Cu, Fe, Mn, Ni and Zn were determined from water and 60 fish samples (60 in total) from Antalya Bay. Physico-chemical parameter values were also measured in the seawater from catchment area. Analysis of DORM-3 and DOLT-4, reference materials showed good accuracy with the present analytic system. The temperature varied between 17.77 - 27.76°C; pH between 7.79 - 10.52; dissolved oxygen between 7.28 - 12.83 mg l<sup>-1</sup> and salinity between 21.05‰ - 33.84‰. The seasonal variations of heavy metal levels in some tissues of *Scomber japonicus* were determined. Significant differences (P<0.05) were found in tissues in relation to the seasons. Linear regression analysis and significant associations between the metal levels in tissues and fish size were also determined. The concentrations of heavy metals in water and fish were also compared with acceptable limits given by national and international water quality guidelines. The present study revealed that the metals level in water increased during spring and decreased in autumn. Both positive and negative correlations were observed between metal contents in water and physico-chemical parameters.

**Key words:** Heavy metal; Water; *Scomber japonicus*; Antalya Bay; Turkey.

### INTRODUCTION

Heavy metals occur naturally in aquatic ecosystems in very low concentrations (Saad *et al.*, 1981) and also are considered the most important pollutants of the aquatic environment because of their toxicity and accumulation by marine organisms (Zyadah and Chouikhi, 1999). Mining of metals, geochemical structure, industrial wastes, untreated effluent, harbor activities, urban and agricultural runoff along major rivers and their tributaries, estuaries and bays create a potential source of heavy metal pollution in aquatic environments (Dalman *et al.*, 2006).

Heavy metals are potentially accumulated by marine organisms through three possible way including respiration, adsorption and ingestion (Zhou *et al.*, 2001). Metals such as iron, copper, zinc and manganese are essential metals but they may produce toxic effects when their levels exceed certain limits in organisms (Schroeder, 1973). For example, copper, although an essential metal, may produce toxic effects such as dermatitis and liver cirrhosis when consumed in excessive amounts in foods (Storelli *et al.*, 2007). Some metals like mercury, lead and arsenic are nonessential in biological systems (Schroeder, 1973). Lead exposure can cause a wide spectrum of health problems, ranging from convulsions, coma and renal failure. Cadmium can cause severe respiratory, irritation, chronic lung disease and testicular degeneration (Benoff *et al.*, 2000). Several studies have shown that the accumulation of heavy metals in fish tissues depend on

the variety in size, age, sex, feeding behaviour, ecological needs of the individuals, season of capture (Farkas *et al.*, 2003; Al-Yousuf *et al.*, 2000; Canlı *et al.*, 2001), while other environmental factors such as salinity, pH, hardness and temperature of water also contribute metal accumulation (Canlı and Atli, 2003; Kalay *et al.*, 1999).

The metal content accumulations were investigated for many organisms in the Mediterranean Sea (Canlı and Atli, 2003; Türkmen *et al.*, 2008; Türkmen *et al.*, 2010; Tepe *et al.*, 2008; Yazkan *et al.*, 2002;), for grass carps in Southeast China (Liu *et al.*, 2011), for ten fish species from Šalek lakes in Slovenis (Petrovšek *et al.*, 2011), for some edible fishes from coastal Kalpakkam, southeastern part of India (Biswas *et al.*, 2011) and for *Barbus grypus* and *Barbus xanthopterus* in Iran (Mohammadi *et al.*, 2011).

The Antalya Bay is one of the most important bay in Turkey and situated on the western Mediterranean coast of Turkey (35° 49' W- 36° 40' N; 30° 22' W - 31° 06' N). Along the coast of Antalya Bay, there are many towns, hotels and orange and lemon gardens. It covers an area of 20820 km<sup>2</sup> including Antalya city and its towns and the coast is almost 640 km long (Tuğrul-Icemer *et al.*, 2006). Antalya Bay is polluted by domestic waste water, tourist activities, pollutants brought by the Aksu and Düden streams, agricultural activities and marine transport. Total population of Antalya city and its towns in suburbs is 1.7 million in winter and 10.2 million in summer because of huge tourist activities. This increase

of population during summer has caused significant pollution in Antalya Bay (Tuğrul-Icemer *et al.*, 2006).

The aims of this study are, to assess relationships between; the metal concentration in water and physico-chemical parameters, seasonal variations of heavy metal concentrations in water and accumulation in fish tissues and heavy metal contents in fish tissues and fish size (total length and weight).

## MATERIALS AND METHODS

**Fish sampling:** Water and chub mackerel samples were collected from three different sites of Antalya Bay in autumn (October, 2009), winter (February, 2010), spring (April, 2010) and summer (July, 2010). Temperature, dissolved oxygen, pH and salinity values were measured by using YSI multiparameter equipment. Seawater samples were taken 50 cm and 1 m below the water surface and filtered through a Whatman 0.45  $\mu\text{m}$  glassfiber filter. The pH of the samples was adjusted to about 2 by adding 5 ml concentrated  $\text{HNO}_3$  and the samples were transferred 500 ml polypropylene bottle and stored in a refrigerator until the measurement process.

During each sampling month 15 fish (total 60 fish samples) were caught from the same sites. Total length and weight of fish were measured to the nearest millimeter and gram before dissection (Table 5). For analysis, 2-5 g of epaxial muscle from the dorsal surface, whole liver and four gill rakers from each fish dissected were collected, weighed and dried at 70 °C for 24-48 h until they reached a constant weight. All samples were placed in decomposition beakers and 5 ml  $\text{HNO}_3$  added to each, were kept at room temperature for 24 h. Then they were heated at 120 °C on hot plate for 2 h, until the solution evaporate slowly to near dryness. After cooling, added 1 ml  $\text{H}_2\text{SO}_4$  and diluted to 25 ml with deionized water, then added 1-2 drop  $\text{HNO}_3$ .

**Analytical procedures:** All samples were analyzed three times for Ba, As, Co, Cd, Cr, Cu, Fe, Mn, Ni and Zn by using ICP-AES Vista. Two standard materials DORM-3 and DOLT-4 (National Research Council Canada) were analyzed for all ten metals. The absorption wavelength was 455.403 nm for Ba, 188.979 nm for As, 238.892 nm for Co, 214.438 nm for Cd, 267.716 nm for Cr, 324.753 nm for Cu, 259.94 nm for Fe, 257.61 nm for Mn, 231.604 nm for Ni and 213.856 nm for Zn.

**Statistical procedures:** All metal concentrations were determined as milligrams per liter for water and milligrams per gram dry weight for fish tissues. While results are expressed as milligrams as per kilogram ( $\text{mg kg}^{-1}$ ) Statistical analysis of data was carried out using SPSS 15 statistical package programs. One-Way ANOVA and Duncan's Multiple Comparison Test were used to compare the data among seasons at the level of

0.05. Pearson correlation matrix was used to test the significant relationship between heavy metal concentration in water and physico-chemical parameters. Linear regression analyses were applied to compare the relationships between fish size (total length and weight) and heavy metal concentrations.

## RESULTS AND DISCUSSION

In this study, to check the validity of the measurements reference materials (DORM-3 and DOLT-4) provided by National Research Council of Canada was used. The recovery was replicate analysis of these reference materials showed good accuracy, with recovery rates between 86% and 100% for DORM-3, between 85% and 99% for DOLT-4.

Physico-chemical parameters measured in the water samples from the Antalya Bay during the study period are presented in Table 1. Temperature ranged between 17.77°C and 27.76°C, was highest in autumn. pH value were between 7.79 and 10.52, was highest in summer and lowest in winter.  $\text{CO}_2$  and pH values have negative correlations each other. When  $\text{CO}_2$  levels decrease pH value increase (Tanyolaç, 1993). This can be due to photosynthesis which increase in summer. Dissolved oxygen varied from 7.28 mg l<sup>-1</sup> to 12.83 mg l<sup>-1</sup>. It reached the highest level in winter. Because temperature effects the solubility of gases in water (Tanyolaç, 1993). Generally, the dissolved oxygen level is decreasing in summer owing to increasing of temperature (Tanyolaç, 1993). Salinity value ranged between 21.05 ‰ and 33.84 ‰. The highest value measured in autumn, while the lowest in spring.

The concentrations of some heavy metals in Antalya Bay's water were given in Table 2. As seen Table 2, Ba, Cu and Zn were detected in all seasons, while Co, Cd, Cr, Fe and Mn in autumn, As, Co, Cd, Cr and Ni in winter were below the detection limit (ppm, <0.001). As was the highest in summer with 0.43 mg l<sup>-1</sup> and lowest in autumn with 0.0013 mg l<sup>-1</sup>. Ba reached the highest levels in spring (1.57 mg l<sup>-1</sup>) and the lowest level in winter (0.033 mg l<sup>-1</sup>). Co and Cd have the highest levels in summer (0.114 mg l<sup>-1</sup>, 0.036 mg l<sup>-1</sup>) and lowest in spring (0.07 mg l<sup>-1</sup>, 0.029 mg l<sup>-1</sup>). Cr level was the highest in spring with 0.034 mg l<sup>-1</sup> and lowest in summer with 0.026 mg l<sup>-1</sup>. The highest mean of Cu in water was detected in spring (0.20 mg l<sup>-1</sup>) and the lowest in autumn (0.003 mg l<sup>-1</sup>). The highest value of Fe was measured in spring (6.61 mg l<sup>-1</sup>) and lowest in winter (1.47 mg l<sup>-1</sup>). The highest Mn concentrations in water recorded in summer (0.134 mg l<sup>-1</sup>) and the lowest levels in winter (0.071 mg l<sup>-1</sup>). The maximum concentration of Ni in water was measured in spring (6.06 mg l<sup>-1</sup>) and the minimum level in autumn (0.04 mg l<sup>-1</sup>). Zn concentration reached the highest level in spring (2.44 mg l<sup>-1</sup>) and minimum level in autumn (0.033 mg l<sup>-1</sup>). As, Ba, Co, Cu,

Fe, Mn, Ni and Zn levels varied significantly ( $<0.05$ ), whereas Cd and Cr levels don't vary significantly ( $>0.05$ ) from season to season. Generally, the metal concentrations increased in spring and decreased in autumn. The increasing of metal levels in spring can be caused by increasing the air temperature and evaporation. Because Antalya is situated the north of the Turkey and the air is getting warmer early. The decrease of metal concentrations caused by heavy rain in autumn.

Usero *et al.* (2003) investigated levels of heavy metals in water of Atlantic coast of Spain. They studied four seawater reservoirs (Bacuta, Liebre, San Carlos, San Juan) and found the following concentrations: 1.3-60 mg l<sup>-1</sup> for As, 13-87 mg l<sup>-1</sup> for Mn, 12-33 mg l<sup>-1</sup> for Zn, 8-32 mg l<sup>-1</sup> for Fe, 1.6-11 mg l<sup>-1</sup> for Cu, 2.3-3.8 mg l<sup>-1</sup> for Ni, 0.1-3.4 mg l<sup>-1</sup> for Cd and 0.4-0.6 mg l<sup>-1</sup> for Cr. Akbulut and Akbulut (2010) investigated concentrations of heavy metals in Kızılırmak River basin's water (Turkey) and found following concentrations (in mg l<sup>-1</sup>) as 6.36-84.31 for Zn and 1.42-31.46 for Cu. They showed that Zn, Co and Cr displayed the highest values during the February-2008, others during the August-2008.

Relationships of metal in water with some physico-chemical parameters were studied using Pearson correlation matrix (Table 3). Positive and insignificant correlations ( $>0.05$ ) were determined between water temperature and all the studied metals. Negative correlations were determined between some metals (As, Ni, Cu and Zn) and pH value. Significant correlations at  $p<0.01$  level were found between Ba, Co, Cd, Mn and pH value. Negative correlations were found only between As, Co, Cd, Ni and Zn and dissolved oxygen. No significant correlations were found between all the studied metals and dissolved oxygen ( $>0.05$ ). All the studied metals showed negative correlations with salinity. As, Co, Cu and Ni showed significant relationships with salinity at 0.01 level, while Cr at 0.05 level. Türkmen *et al.* (2004) found similar results. Hellowell (1988) determined that heavy metal toxicity is affected by dissolved oxygen, pH and temperature. In present study that is determined; some metal levels increase with decreasing of temperature and dissolved oxygen.

The minimum, maximum and mean length and weight of each fish species were measured and given in Table 4. The total length of fish ranged between 23.40-29.60 cm, while weight between 64 and 229 g. The seasonal variations of metal levels (mg kg<sup>-1</sup> dry mass) are, in muscle, liver and gill of *Scomber japonicus* from Antalya Bay, summarized in Table 5. Mean As concentrations varied from 0.68 to 26.09 in the muscle, from 0.68 to 24.89, from 5.20 to 29.86, with the highest levels in winter. As concentrations in muscle, liver and gill were significant season to season ( $<0.05$ ). Mean Ba levels were between 0.20-0.40 in muscle, with the highest level in summer, 1.89-12.77 in liver and 4.57-15.60 in gill, with the highest levels in winter. In relation to

season, close correlations ( $<0.05$ ) were found in tissues. Mean Co levels varied from BDL-0.06 in muscle, below detection limit in liver in all seasons and BDL-0.06 in gill, with the highest levels in summer in muscle and gill. No significant ( $>0.05$ ) correlations were found in tissues from season to season. Mean cadmium concentrations ranged between BDL-0.04 in muscle, BDL-0.06 in liver, with the highest levels in summer, between 0.05-0.12 in gill, with the highest level in spring. Significant relationships ( $<0.05$ ) were found in tissues related to seasons. Mean Cr levels changed between 0.13-0.73 in the muscle, with the highest level in winter, between BDL-0.33 in liver, with the highest level in spring, between 0.65-1.95 in gill, with the highest level in winter. Significant correlations ( $<0.05$ ) were found in muscle from season to season. Mean level of Cu ranged from 1.70 to 24.69 in muscle, with the highest level in winter, from 0.90 to 85.43 in liver, with the highest level in autumn, from 2.16 to 9.79 in gill, with the highest level in spring. In relation to season, Cu levels varied significantly ( $<0.05$ ) in muscle, while not significant ( $>0.05$ ) in liver and gill. Mean Fe levels changed between 17.31-109.22 in muscle, with the highest level in spring, between 136.50-4021 in liver, with the highest level in winter, between 182.23-283.30 in gill with the highest level in summer. Significant correlations ( $<0.05$ ) were found in muscle and liver from season to season. Mn levels varied from 0.11 to 1.29 in muscle, with the highest level in spring, below detection limit in liver in all seasons, from 7.96 to 10.57 in gill, with the highest level in autumn. There was significant differences ( $<0.05$ ) in muscle, while not significant differences ( $>0.05$ ) in gill from season to season. Ni concentrations changed between 0.13-0.70 in muscle, with the highest level in autumn, between BDL-6.67 in liver, with the highest level in summer. Mean Zn levels varied from 12.07 to 89.56 in muscle, from 65.06 to 90.44 in gill, with the highest level in spring, from 22.00 to 98.15 in liver, with the highest level in winter. Significant differences ( $<0.05$ ) were found in tissues in relation to seasons. Yazkan *et al.* (2002), studied the accumulation of Cu, Zn, Pb and Cd in muscle and liver of different fish species from Antalya Bay. They have reported that Cu level in the muscle of fish specimens was 1.58 mg kg<sup>-1</sup>, while in liver 1.90 mg kg<sup>-1</sup>. Zn levels were found as 11.36 mg kg<sup>-1</sup> in muscle and 6.85 mg kg<sup>-1</sup> in liver of *Mullus barbatus*. These results are lower than our studies results. The Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn levels in *Sparus auratus* inhabiting in Antalya Bay have been measured by Türkmen *et al.* (2008). They found the following concentrations in muscle as 0.16 mg kg<sup>-1</sup> for Cd, 0.18 mg kg<sup>-1</sup> for Co, 0.65 mg kg<sup>-1</sup> for Cr, 1.36 mg kg<sup>-1</sup> for Cu, 22.3 mg kg<sup>-1</sup> for Fe, 0.49 mg kg<sup>-1</sup> for Mn, 2.03 mg kg<sup>-1</sup> for Ni, 0.72 mg kg<sup>-1</sup> for Pb and 6.34 mg kg<sup>-1</sup> for Zn. Generally, these results were similar to our results. Seasonal variations of metal levels in fish tissues are

**Table 1** Some physico-chemical parameters of Antalya Bay's water.

	Temperature (°C)	pH	Dissolved Oxygen (mg l <sup>-1</sup> )	Salinity (‰)
Autumn	26.76±0.15	8.33±0.05	9.34±0.46	32.70±1.49
Winter	18.2±0.35	7.85±0.04	11.25±1.08	30.64±1.40
Spring	23.87±0.91	8.31±0.11	11.06±0.71	27.25±3.65
Summer	25.53±1.10	10.40±0.12	9.62±1.55	30.84±2.63

**Table 2.** The concentrations of some heavy metals in Antalya Bay's water (mg l<sup>-1</sup>)

Season	As	Ba	Co	Cd	Cr	Cu	Fe	Mn	Ni	Zn
Autumn	0.013±0.0124 <sup>a**</sup>	0.053±0.067 <sup>a</sup>	BDL*	BDL	BDL	0.003±0.002 <sup>a</sup>	BDL	BDL	0.04±0.0484 <sup>a</sup>	0.01-0.190.033±0.060 <sup>a</sup>
Winter	BDL	0.033±0.016 <sup>a</sup>	BDL	BDL	BDL	0.0044±0.0032 <sup>a</sup>	1.476±2.174 <sup>a</sup>	0.071±0.088 <sup>a</sup>	BDL	0.004-0.170.062±0.063 <sup>a</sup>
Spring	0.398±0.268 <sup>b</sup>	1.57±1.257 <sup>b</sup>	0.07±0.03 <sup>b</sup>	0.029±0.014 <sup>b</sup>	0.034±0.0184 <sup>a</sup>	0.20±0.242 <sup>b</sup>	6.612±3.766 <sup>b</sup>	0.113±0.106 <sup>ab</sup>	6.066±4.931 <sup>b</sup>	0.08-12.252.448±4.152 <sup>b</sup>
Summer	0.43±0.262 <sup>b</sup>	0.32±0.09 <sup>a</sup>	0.114±0.0398 <sup>c</sup>	0.036±0.015 <sup>b</sup>	0.026±0.017 <sup>a</sup>	0.048±0.0478 <sup>a</sup>	3.10±2.24 <sup>ab</sup>	0.134±0.126 <sup>b</sup>	0.14±0.093 <sup>a</sup>	0.05-0.730.46±0.36 <sup>a</sup>

\* Below Detection Limit; \*\* Means with the same superscript in the same row are not significant different according to Duncan's multiple range test (p<0.05)

**Table 3.** Pearson correlation matrix showing the correlation coefficients between physico-chemical parameters of water and metal levels

	Temp.	pH	Dissolved Oxygen	Salinity	As	Ba	Co	Cd	Cr	Cu	Fe	Mn	Ni	Zn
Temperature	1	0.482 <sup>**</sup>	-0.293	0.227	0.127	0.314	0.281	0.294	0.094	0.07	0.079	0.146	0.064	0.089
pH		1	-0.049	0.076	-0.013	0.526 <sup>**</sup>	0.686 <sup>**</sup>	0.650 <sup>**</sup>	0.275	-0.004	0.080	0.424 <sup>**</sup>	-0.172	-0.062
Dissolved Oxygen			1	-0.087	-0.054	0.031	-0.108	-0.032	0.128	0.012	0.085	0.206	-0.054	-0.036
Salinity				1	-0.444 <sup>**</sup>	-0.261	-0.330 <sup>**</sup>	-0.312	-0.351*	-0.539 <sup>**</sup>	-0.213	-0.115	-0.454 <sup>**</sup>	-0.192
As					1	0.462 <sup>**</sup>	0.293	0.344*	0.604 <sup>**</sup>	0.520 <sup>**</sup>	0.276	0.212	0.721 <sup>**</sup>	0.871 <sup>**</sup>
Ba						1	0.635 <sup>**</sup>	0.664 <sup>**</sup>	0.421*	0.379*	0.553 <sup>**</sup>	0.574 <sup>**</sup>	0.486 <sup>**</sup>	0.300
Co							1	0.784 <sup>**</sup>	0.250	0.279	0.342*	0.296	0.254	0.073
Cd								1	0.259	0.239	0.359*	0.376*	0.295	0.186
Cr									1	0.460 <sup>**</sup>	0.036	0.451 <sup>**</sup>	0.276	0.558 <sup>**</sup>
Cu										1	0.254	0.369*	0.440 <sup>**</sup>	0.306
Fe											1	0.492 <sup>**</sup>	0.631 <sup>**</sup>	-0.037
Mn												1	0.000	0.207
Ni													1	0.403*
Zn														1

\* and \*\* indicate the correlation coefficients were significant at 0.05 and 0.01 probability levels, using two-tailed test.

Table 4. Minimum, maximum and mean total length and weight of the species examined in the present study

	Length±SE (cm)	Weight±SE (g)
Autumn	25.43±0.65	87.60±14.19
Winter	26.84±1.32	174.8±17.46
Spring	28.19±0.75	198.67±17.46
Summer	26.41±1.86	157.07±26.6

Table 5. Heavy metal concentrations in different tissues of *Scomber scombrus* from the Antalya Bay (mg kg<sup>-1</sup>)

Season	Tissue	As	Ba	Co	Cd	Cr	Cu	Fe	Mn	Ni	Zn
Autumn	Muscle	0.77-6.27 4.05±1.26 <sup>a*</sup>	0.15-0.28 0.20±0.03 <sup>a</sup>	BDL <sup>**</sup>	BDL	0.02-0.41 0.13±0.09 <sup>a</sup>	0.88-2.61 1.70±0.46 <sup>a</sup>	4.75-39.63 17.31±8.73 <sup>a</sup>	0.04-0.22 0.11±0.06 <sup>a</sup>	0.004-5.36 0.7±1.65 <sup>a</sup>	4.85-16.33 12.07±2.72 <sup>a</sup>
	Liver	5.19-29.37 13.36±7.73 <sup>a</sup>	1.30-40.69 9.59±12.43 <sup>b</sup>	BDL	BDL	BDL	0.67-1059.58 85.43±292.75 <sup>a</sup>	105.08-1345.6 739.38±443.48 <sup>a</sup>	BDL	BDL	30.41-458.6 89.9±106.84 <sup>b</sup>
	Gill	2.19-8.67 5.20±1.67 <sup>a</sup>	7.70-16.05 12.11±2.62 <sup>b</sup>	BDL	BDL	0.52-0.76 0.65±0.05 <sup>a</sup>	1.54-2.5 2.16±0.28 <sup>a</sup>	121.25-263.67 182.23±40.71 <sup>a</sup>	7.45-16.16 10.57±2.26 <sup>a</sup>	0.03-1.43 0.32±0.41 <sup>a</sup>	61.61-92.58 79.22±8.62 <sup>b</sup>
Winter	Muscle	26.09-35.8 30.39±2.84 <sup>c</sup>	0.17-0.35 0.21±0.05 <sup>a</sup>	BDL	BDL	0.16-2.34 0.73±0.6 <sup>a</sup>	2.18-75.96 24.69±23.2 <sup>b</sup>	24.31-68.03 37.54±10.95 <sup>a</sup>	0.09-0.38 0.2±0.07 <sup>a</sup>	0.04-2.27 0.47±0.62 <sup>a</sup>	15.53-50.3 25.24±10.26 <sup>a</sup>
	Liver	24.89-285.66 83.12±71.98 <sup>b</sup>	1.6-35.2 12.77±11.64 <sup>b</sup>	BDL	BDL	BDL	2.29-461.6 70.44±142.71 <sup>a</sup>	116.09-9584.09 4021.44±2914.84 <sup>b</sup>	BDL	BDL	60.91-175.45 98.15±32.93 <sup>b</sup>
	Gill	24.62-37.86 29.86±4.08 <sup>c</sup>	9.20-24.04 15.60±4.68 <sup>c</sup>	BDL	0.004-0.22 0.1±0.07 <sup>ab</sup>	0.93-4.29 1.95±1.14 <sup>b</sup>	2.52-13.22 4.63±3.34 <sup>a</sup>	202.71-379.59 264.57±50.65 <sup>a</sup>	5.79-9.8 7.96±1.24 <sup>a</sup>	0.39-2.14 1.05±0.59 <sup>a</sup>	72.89-105.48 89.79±8.56 <sup>b</sup>
Spring	Muscle	2.16-48.12 27.43±11.28 <sup>c</sup>	0.08-0.58 0.26±0.14 <sup>ab</sup>	0.01-0.1 0.05±0.03 <sup>b</sup>	0.02-0.06 0.03±0.01 <sup>b</sup>	0.004-1.06 0.67±0.27 <sup>b</sup>	0.31-50.64 17.68±15.21 <sup>b</sup>	47.72-203.29 109.22±40.75 <sup>b</sup>	0.38-4.52 1.29±1.36 <sup>b</sup>	0.02-0.73 0.28±0.18 <sup>a</sup>	4.02-183.35 89.56±42.79 <sup>b</sup>
	Liver	0.70-33.75 5.15±8.72 <sup>a</sup>	0.07-9.85 1.89±3.20 <sup>a</sup>	BDL	0.01-0.07 0.03±0.01 <sup>b</sup>	0.007-0.73 0.33±0.30 <sup>b</sup>	0.07-30.31 2.77±7.96 <sup>a</sup>	13.92-342.08 136.50±91.58 <sup>a</sup>	BDL	0.03-0.38 0.19±0.11 <sup>a</sup>	0.17-122.49 25.79±40.5 <sup>a</sup>
	Gill	6.34-15.93 11.17±2.58 <sup>b</sup>	4.57-7.93 6.25±1.03 <sup>a</sup>	0.01-0.1 0.05±0.03 <sup>b</sup>	0.04-0.31 0.12±0.10 <sup>b</sup>	0.54-3.09 0.89±0.63 <sup>a</sup>	1.42-111.75 9.79±28.21 <sup>a</sup>	130.93-324.58 207.2±55.81 <sup>a</sup>	5.93-16.11 9.24±2.56 <sup>a</sup>	0.17-1.10 0.42±0.24 <sup>a</sup>	64.08-172.25 90.44±27.76 <sup>b</sup>
Summer	Muscle	0.68-19.95 9.33±6.05 <sup>b</sup>	0.06-1.47 0.40±0.38 <sup>b</sup>	0.01-0.13 0.05±0.03 <sup>b</sup>	0.01-0.08 0.03±0.01 <sup>b</sup>	0.04-0.52 0.37±0.12 <sup>b</sup>	0.07-10.71 4.62±3.17 <sup>a</sup>	47.23-176.27 96.24±43.2 <sup>b</sup>	0.06-1.07 0.55±0.29 <sup>b</sup>	0.03-0.43 0.13±0.11 <sup>a</sup>	1.48-146.82 50.98±42.17 <sup>c</sup>
	Liver	0.68-6.55 2.25±1.96 <sup>a</sup>	0.07-8.22 2.09±3.28 <sup>a</sup>	BDL	0.01-0.36 0.06±0.08 <sup>c</sup>	BDL	0.05-5.40 0.90±1.38 <sup>a</sup>	8.24-3612.58 397.69±895.22 <sup>a</sup>	BDL	0.01-46.05 6.67±14.82 <sup>a</sup>	0.24-93.42 22.00±33.87 <sup>a</sup>
	Gill	2.77-17.81 5.93±3.86 <sup>a</sup>	0.12-7.98 4.57±3.00 <sup>a</sup>	0-0.20 0.06±0.05 <sup>b</sup>	0.01-0.10 0.05±0.02 <sup>a</sup>	0.24-4.78 0.96±1.12 <sup>a</sup>	1.09-7.79 3.06±2.29 <sup>a</sup>	57.41-1440.88 283.30±356.01 <sup>a</sup>	0.40-45.94 9.82±11.15 <sup>a</sup>	0.01-37.58 5.91±9.69 <sup>b</sup>	25.09-96.52 65.06±18.55 <sup>a</sup>

\* Means with the same superscript in the same row are not significant different according to Duncan's multiple range test (p<0.05)

\*\* Below Detection Limit

**Table 6. The relationships between weight and heavy metal concentrations in various tissues of *Scomber japonicus* caught from the Antalya Bay<sup>a</sup>.**

Tissue		As	Ba	Co	Cd	Cr	Cu	Fe	Mn	Ni	Zn
Muscle	Equation	$Y = -11.833 + (0.192) X$	$Y = 0.288 + (0.123) X$	BDL <sup>c</sup>	BDL	$Y = -(0.144 + (0.004) X)$	$Y = -7.607 + (0.128) X$	$Y = -0.051 + (0.421) X$	$Y = -0.100 + (0.003) X$	$Y = -0.879 + (-0.003) X$	$Y = -3.448 + (0.265) X$
	R value	0.679	-0.023			0.463	0.358	0.399	0.152	-0.201	0.292
	R value	00 <sup>c</sup>	NS <sup>b</sup>			**	**	* <sup>d</sup>	NS	NS	*
Liver	Equation	$Y = -78.285 + (-0.357) X$	$Y = -6.782 + (-0.001) X$	BDL	BDL	BDL	$Y = -78.423 + (-0.256) X$	$Y = -668.764 + (13.142) X$	BDL	BDL	$Y = -84.398 + (-0.161) X$
	R value	-0.378	-0.006				-0.077	0.279			-0.107
	R value	NS	NS				NS	*			NS
Gill	Equation	$Y = -9.019 + (-142) X$	$Y = -9.741 + (-0.001) X$	BDL	BDL	$Y = -0.047 + (-0.008) X$	$Y = -2.808 + (-0.050) X$	$Y = -195.490 + (-0.251) X$	$Y = -13.591 + (-0.027) X$	$Y = -3.299 + (-0.009) X$	$Y = -69.694 + (-0.074) X$
	R value	0.639	-0.006			0.356	0.163	0.064	-0.217	-0.078	0.170
	R value	**	NS			**	NS	NS	NS	NS	NS

<sup>a</sup> Y is metal concentrations (mg/kg) X is total fish weight (g).

<sup>b</sup> NS, Not significant at the p<0.05 level.

<sup>c</sup> Significant at the level p<0.01 level

<sup>d</sup> Significant at the level p<0.05 level

<sup>e</sup> Below Detection Limit

**Table 7. The relationships between total length and heavy metal concentrations of the *Scomber japonicus* caught from the Antalya Bay<sup>a</sup>.**

Tissue		As	Ba	Co	Cd	Cr	Cu	Fe	Mn	Ni	Zn
Muscle	Equation	$Y = -59.751 + (2.903) X$	$Y = -0.435 + (0.006) X$	BDL <sup>c</sup>	BDL	$Y = -(0.342 + (0.031) X)$	$Y = -34.054 + (1.730) X$	$Y = -352.681 + (15.637) X$	$Y = -0.380 + (0.034) X$	$Y = -1.359 + (-0.007) X$	$Y = -204.535 + (9.320) X$
	R value	0.349	-0.044			0.117	0.164	0.503	0.063	-0.070	0.349
	R value	** <sup>c</sup>	NS <sup>b</sup>			NS	NS	**	NS	NS	**
Liver	Equation	$Y = -197.923 + (-0.523) X$	$Y = -29.638 + (-0.864) X$	BDL	BDL	BDL	$Y = -277.986 + (-8.950) X$	$Y = -819.700 + (81.502) X$	BDL	BDL	$Y = -228.102 + (-6.316) X$
	R value	-0.201	-0.139				-0.089	0.058			-0.142
	R value	NS	NS				NS	*			NS
Gill	Equation	$Y = -15.686 + (1.070) X$	$Y = -34.8351 + (-0.943) X$	BDL	BDL	$Y = -0.965 + (0.078) X$	$Y = -50.856 + (2.087) X$	$Y = -777.764 + (-0.20.341) X$	$Y = -30.640 + (-0.795) X$	$Y = -10.991 + (-0.338) X$	$Y = -2.641 + (3.136) X$
	R value	0.164	-0.006			0.356	0.163	0.064	-0.217	-0.078	0.170
	R value	NS	* <sup>d</sup>			NS	NS	NS	NS	NS	NS

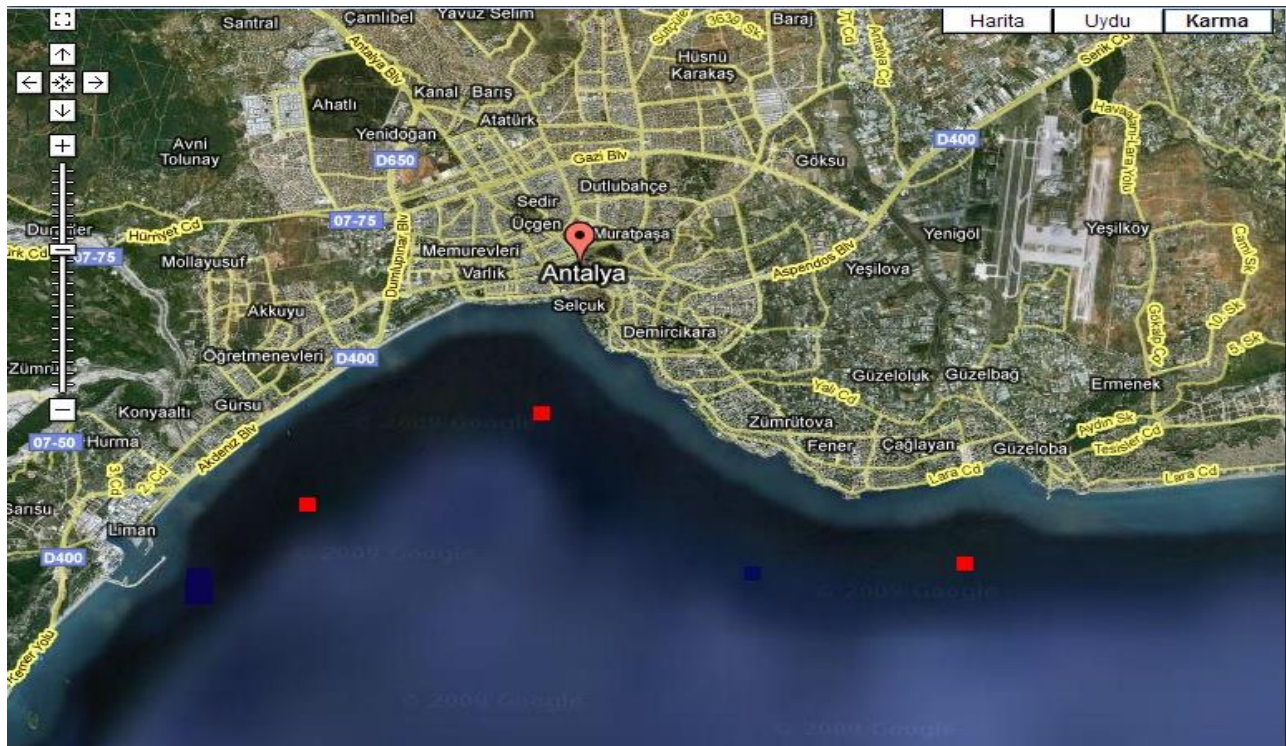
<sup>a</sup> Y is metal concentrations (mg/kg) X is total length (cm).

<sup>b</sup> NS, Not significant at the p<0.05 level.

<sup>c</sup> Significant at the level p<0.01 level

<sup>d</sup> Significant at the level p<0.05 level

<sup>e</sup> Below Detection Limit



**Figure 1. Map of Antalya Bay (Mediterranean Sea, Turkey) (Taken from maps.google.com) and different localities from where the samples were taken.**

depend on different factors like ecological needs of fish, metabolism, feeding habit, their life cycle and physico-chemical parameters as salinity, temperature and pH value (Philips, 1990; Newman and Doubet, 1989). Generally, the metal levels increased in winter and summer, and decreased in spring and autumn. This can be due to biological activity and feeding habits of *Scomber japonicus*.

Linear regression analysis and significant associations between the metal levels of tissues and the size (total length and weight) also given in Table 6 and 7. Negative relationships were found between fish weight and Ba and Ni in the muscle, between fish weight and As, Ba, Cu and Zn in the liver and between fish weight and Ba, Mn and Ni in the gill (Table 6). All the other relationships were positive and significant at 0.01 and 0.05 level. Negative correlations were found between total length and Ba and Ni in muscle, between total length and As, Ba, Cu and Zn in liver and between total length and Ba (<0.05), Fe, Mn and Ni in gill. All the other relationships were positive. The positive and negative relationships between heavy metal levels in the tissues and fish size (total length and weight) generally supported in the literature. Nussey *et al.* (2000) found that levels of metals increased with the decrease in the length of *Labeo umbratus*. In the other research, it was found that the concentrations of Cu, Fe, Mn and Zn in some tissues of *Capoeta capoeta umbla* increased with

the increase in length. The metabolic activity is the most important factor that play a significant role in heavy metal accumulation (Elder and Collins, 1991). Canlı and Atli (2003) reported that the negative correlations between metal levels and size may be the difference in metabolic activity between younger and older fish. Heath (1987) found that the presence of heavy metals in water affect the fish development and juveniles are sensitive in the early life stages like larval development and juvenile growth. Canpolat and Çalta (2003) expressed that smaller fish are more active and need more oxygen to supply more energy.

**Conclusions:** In this study, we also compared our results with permissible levels in water and fish tissues for heavy metals given by some different institutes. The water of Antalya Bay was included to the first category accordance to with Republic of Turkey Ministry of Environment and Forest (Anonymous, 2004). The levels of As, Cd, Ni, Zn, Cr, Cu, Fe and Mn in the seawater are lower than WHO (WHO, 1993; 1998), European Commission (EC, 1998), United States Environmental Protection Agency (US EPA, 1999) standards. As, Cd, Cr, Cu, Fe in summer and spring, Ni in spring and Zn in all seasons were found to be above for permissible levels given by Republic of Turkey, Ministry of Agriculture and Rural Areas (Anonymous, 2002a).

Turkish legislation establishes maximum levels for four of the metal studied, above which human consumption is not permitted: 1.0 mg kg<sup>-1</sup> for As, 0.1 mg kg<sup>-1</sup> for Cd, 50 mg kg<sup>-1</sup> for Zn and 20 mg kg<sup>-1</sup> for Cu (Anonymous, 1997; 2002a). The levels of As in all tissues were higher than these maximum levels, while Zn levels were higher than in muscle in spring and summer. Turkish Food Codex (Anonymous, 2002b) limits the levels at 1.0 mg kg<sup>-1</sup> for As, 0.5 mg kg<sup>-1</sup> for Cd, 20 mg kg<sup>-1</sup> for Cu and 50 mg kg<sup>-1</sup> for Fe. As concentrations in muscle in all seasons, Cu concentrations in muscle in winter and Fe concentrations in muscle except in autumn were higher than permissible limits given by Turkish Food Codex (Anonymous, 2002b). In spite of these, the levels of all studied metals were below the legal values for fish and fishery products proposed by European Commission (EC, 2006). The acceptable levels given by World Health Organization reported as Zn: 30, Cr: 1.0, Fe: 2.0 and Mn: 1.0 mg kg<sup>-1</sup> (UNESCO, WHO, UNEP, 1992). Our results were lower than these limits given by World Health Organization except Zn in muscle in spring and summer, Fe in all tissues in all seasons and Mn in muscle in spring.

**Acknowledgements:** This work supported by Süleyman Demirel University, SDÜBAP 2053-YL-09 project. I would like to thank Süleyman Demirel University – Scientific Research Project Management for their financial support.

## REFERENCES

- Akbulut, A. and N. E. Akbulut (2010). The study of heavy metal pollution and accumulation in water, sediment and fish tissue in Kızılırmak River Basin in Turkey. *Environmental Monitoring and Assessment*. 167 (1-4): 387-395.
- Al-Yousuf, M. H., M. S. El-Shahawi, and S. M. Al-Ghais (2000). Trace elements in liver, skin and muscle of *Lethrinus lentjan* fish species in relation to body length and sex. *The Sci. Total Environment*. 256: 87-94.
- Anonymous (1997). Institution of Turkish Standards, Annual Progress Report.
- Anonymous (2004). Çevre ve Orman Bakanlığı, Su Kirliliği Kontrolü Yönetmeliği, Resmi Gazete, 31.12.2004, No: 25687.
- Anonymous (2002a). Republic of Turkey Ministry of Agricultural and Rural Areas. Su ürünleri kanunu ve su ürünleri yönetmeliği, 63 p, Ankara.
- Anonymous (2002b). Türk Gıda Kodeksi Gıda maddelerinde belirli bulaşanların maksimum seviyelerinin belirlenmesi hakkında tebliğ, ek 2: Metal ve metaloidler, Resmi gazete, 23.09.2002, No: 24885.
- Benoff, S., A. Jacop, and I.R. Hurley (2000). Male infertility and environmental exposure to lead and cadmium. *Human Reproduction Update*. 6: 107-121.
- Biswas, S., R. K. Rrabhu, K. J. Hussain, M. Selvanayagam, and K. K. Satpathy (2011). Heavy metal concentration in edible fishes from coastal region of Kalpakkam, southeastern part of India. *Environmental Monitoring and Assessment*. (Online published).
- Canlı, M. and G. Atli (2003). The relationships between heavy metal (Cd, Cr, Cu, Fe, Pb, Zn) levels and the size of six mediterranean fish species. *Environmental Pollution*. 121:129-136.
- Canpolat, Ö. and M. Çalta (2003). Heavy metals in some tissues and organs of *Capoeta capoeta umbra* (Heckel, 1843) fish species in relation to body size, age, sex and seasons. *Fresenius Environmental Bulletin*. 12: 961-966.
- Dalman, Ö., A. Demirak, and A. Balcı (2006). Determination of heavy metals (Cd, Pb) and trace elements (Cu, Zn) in sediments and fish of the Southeastern Aegean Sea (Turkey) by atomic absorption spectrometry. *Food Chemistry*. 95: 157-162.
- Elder, J. F. and J. J. Collins (1991). Freshwater molluscs as indicators of bioavailability and toxicity of metals in surface systems. *Rev. Environ. Contam. Toxicol*. 122: 37-79.
- European Commission (EC) (1998). Council directive 98/83 Ec of 3 November 1998/ on the quality of water intended for human consumption. L 330/32, 3.12.1998.2006. Maximum levels for certain contaminants in foodstuffs. No: 1881/2006.
- European Commission (EC) (2006). Maximum levels for certain contaminants in foodstuffs. No: 1881/2006.
- Farkas, A., J. Salánki, and A. Specziár (2003). Age- and size specific of heavy metals in the organs of freshwater fish *Abramis brama* L. populating a low-contaminated site. *Water Research*. 37, 959-964.
- Heath, A. G. (1987) *Water Pollution and Fish Physiology*. CRP Press Inc., Florida, 245 pp.
- Hellawell, M. J. (1988). Toxic substances in rivers and streams. *Environmental Pollution*. 50: 61-85.
- Kalay, M., O. Ay, and M. Canlı (1999). Heavy metal concentrations in fish tissues from the Northeast Mediterranean Sea. *Bulletin Environmental Contamination and Toxicology*. 63: 673-981.
- Liu, F., H. G. Ni, F. Chen, Z. X. Lou, H. Shen, L. Liu, and P. Wu (2011) Metal accumulation in the tissues of grass carps (*Ctenopharyngodon idellus*) from fresh water around a copper mine

- in Southeast China. Environmental Monitoring and Assessment. (Online published).
- Mohammadi, M, A. A. Sary, and M. Khodadadi (2011). Determination of heavy metals in two barbs, *Barbus grypus* and *Barbus xanthopterus* in Karoon and Dez Rivers, Khoozestan, Iran. Bulletin of the Environmental Contamination and Toxicology. 87: 158-162.
- Newman, M. C. and D. K. Doubet (1989). Size-dependence of mercury (II) accumulation kinetics in the mosquitofish, *Gambusia affinis* (Baird and Girard). Archives of Environmental Contamination and Toxicology. 18: 819-825.
- Nussey, G., J. H. J. Van Vuren, and H. H. Du Preez (2000). Bioaccumulation of chromium, manganese, nickel and lead in the tissues of the moggel, *Labeo umbratus* (Cyprinidae), from Witbank Dam, Mpumalanga. Water SA. 26: 269-284.
- Petrovšek, A. A. S., Z. M. Grudnik and B. Porkony (2011). Heavy metals and arsenic concentrations in ten fish species from the Šalek lakes (Slovenia): assessment of potential human health risk due to fish consumption. Environmental Monitoring and Assessment. (Online published).
- Phillips, D. J. H. (1990) Arsenic in aquatic organisms: A review, emphasizing chemical speciation. Aquatic Toxicology. 16: 151-186.
- Saad, M. A. H., A. A. Ezzat, O. A. El-Rayis, and H. Hatez (1981). Occurrence and distribution of chemical pollutants in Lake Mariut, Egypt II Heavy metals. Water, Air and Soil Pollution. 16: 401-407.
- Schroeder, H. A. (1973). The trace elements and nutrition. London: Faber and Faber.
- Storelli, M., M. Barone, G. Garofalo, and G.O. Marcotrigiano (2007). Metals and organochlorine compounds in eel (*Anguilla anguilla*) from the Lesina Lagoon, Adriatic Sea (Italy). Food Chemistry. 100: 1337-1341.
- Tanyolaç, J (1993) Limnoloji. Hatipoğlu Yayınevi, Ankara, 263pp.
- Tepe, Y., M. Türkmen, and A. Türkmen (2008). Assessment of heavy metals in two commercial fish species of four Turkish seas. Environmental Monitoring and Assessment. 146: 277-284.
- Tuğrul-İçemer, G., C. Keles, and H. Karaca (2006) Influence of inter annual variations on total and fecal coliform levels in Antalya Bay. 10<sup>th</sup> International specialized conference on diffuse pollution and sustainable basin management. 18-22 September, İstanbul.
- Türkmen, A., M. Türkmen, and M. Naz (2004). İskenderun Körfezi deniz suyu ağır metal konsantrasyonları ile sıcaklık, pH, oksijen ve tuzluluk değerleri arasındaki korelasyonlar. Turkish Journal of Aquatic Life. 2 (3): 400-407.
- Türkmen, A., M. Türkmen, Y. Tepe, and M. Çekiç (2010). Metals in tissues of fish from Yelkoma Lagoon, northeastern Mediterranean. Environmental Monitoring and Assessment. 168: 223-230.
- Türkmen, M., A. Türkmen, Y. Tepe, A. Ateş, and G. Kutalmış (2008). Determination of metal contaminations in sea foods from Marmara, Aegean and Mediterranean seas: Twelve fish species. Food Chemistry. 108: 794-800.
- Unesco/Who/Unep (1992). Water quality assessments, pp.10-13. Chapman and Hall Ltd., London.
- United States Environmental Protection Agency (US EPA) (1999). National recommended water quality criteria correction office of water, EPA 822-Z-99-001, 25 pp.
- Usero, J., C. Izquierdo, J. Morillo, and I. Gracia (2003). Heavy metals in fish (*Solea vulgaris*, *Anguilla anguilla* and *Liza aurata*) from Salt Marshes on the Southern Atlantic Coast of Spain. Environmental International. 1069: 1-8.
- WHO (1993). 41 st report of the joint expert committee on food additives (JEFCA).
- WHO (1998). Guidelines for drinking-water quality. Second Edition, volume I Geneva.
- Yazkan, M., F. Özdemir, and M. Gölükçü (2002). Antalya Körfezinde avlanan bazı balık türlerinde Cu, Zn, Pb ve Cd İçeriği. Türk. J. Vet Anim. Sci. 26: 1309-1313.
- Yılmaz, A. B. (2005). Comparison of heavy metal levels of grey mullet (*Mugil cephalus* L.) and sea bream (*Sparus aurata* L.) caught in İskenderun Bay (Turkey). Turkish J. Vet. Anim. Sci. 29: 257-262.
- Zhou, J. L., S. M. Salvador, Y. P. Liu, and M. Sequeria (2001). Heavy metals in the tissues of dolphins (*Delphinus delphis*) stranded on the Portuguese coast. Sci. Total Environment. 273: 61-76.
- Zyadah, M. and A. Chouikhi (1999). Heavy metal accumulation in *Mullus barbatus*, *Merluccius merluccius* and *Boops boops* fish from the Aegean Sea, Turkey. Intl. J. Food Sciences and Nutr., 50: 429-434.