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Evaluation of Heavy Metal and Aluminium Accumulation in a Gastropod, *Patella caerulea* L., 1758 in Iskenderun Bay, Turkey

Önder Duysak* and Kübra Azdural
Marine Sciences and Technology Faculty, Iskenderun Technical University, TR31220, Iskenderun, Hatay, Turkey.

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Both the authors conceived and designed the project, collected samples, executed all experimental work, analyzed the data and wrote the article.

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Gastropoda, *Patella caerulea*, Heavy metals, Metal accumulation.

ABSTRACT

In this study, heavy metals (*Fe, Zn, Cd, Cu, Co, Ni, Mn, Pb* and *Cr*) and aluminium (*Al*) were determined in tissue of *Patella caerulea* from various population in Iskenderun Bay, Turkey. Our study focused on seasonal variation of some heavy metals and aluminium in *Patella caerulea* L., 1758 tissues collected from eight different sampling stations of Iskenderun Bay. The concentration of heavy metal in *P. caerulea* tissues tended to vary significantly between season and stations. The distribution of heavy metals in *P. caerulea* followed in their muscular tissues in order; Çevlik > Kaleköy> Payas > Arsuz > Dörtyol > Konacık > Yumurtalık > İskenderun for spring and Kaleköy > Payas > İskenderun > Arsuz > Dörtyol > Yumurtalık > Konacık > Çevlik for autumn. It was found that the accumulation of heavy metals at different parts of *P. caerulea* changes with respect to season and the type of heavy metal.

INTRODUCTION

Water promotes the transition and dispersion of chemicals in the environment and food chain due to its carrying and solubility features. Therefore, most of the chemicals, including heavy metals, accumulate primarily in aquatic ecosystems and reach to high concentrations (Ayas *et al*., 2009). Nowadays several studies are being performed in order to determine the levels of chemical pollution in the aquatic areas. Determining the types of the chemical substances transferred into the aquatic environment, identifying their dispersion levels in water, in sediments and in living organisms are of the great importance and, therefore, several analyses are being performed at different locations of the aquatic environment (Dobrowolski and Skowronska, 2001).

Recently, very sharp increase in the level of pollutants has been observed resulting mainly from excessive population growth and intensive industrial development. Administrations of direct or indirect transfer of these contaminants into nature have caused rapid adverse deterioration of the environment with negative effects on human life.

Iskenderun Bay, with its special coastal structure having rich benthic fauna is the natural breeding and feeding grounds for various high commercial value marine organisms. Recently Iskenderun bay is exposed to very serious metal accumulation impact due to agricultural, industrial and urban wastes of expanded industrial and residential areas in the region. The presences of 'İsdemir' which is the largest iron and steel plant in the country, 'Toros Gübre' which is one of the largest Fertilizer Production Plant wide use of pesticides and synthetic fertilizers in agriculture, and influx of domestic waste directly into the bay are the main causes of marine pollution in the Gulf.

In order to determine the level of the metals on the top rung of the food chain, several studies are conducted through carnivore fish species and marine mammals (Cardellicchio *et al*., 2002; Kehrig *et al*., 2002). Gastropods are important links in the marine food chain (Wang, 2002) are considered to be indicator species (Lopez-Artiguez *et al*., 1989; Cubadda *et al*., 2001; Nakhle *et al*., 2006).

When looking at studies performed related to heavy metal deposition in mollusks in the Iskenderun Bay; it is striking that usually oysters (Türkmen and Türkmen, 2005), snails (Duysak and Ersoy, 2014), cuttlefish (Duysak *et al*., 2013) and squids (Duysak and Dural, 2015) species were investigated. It is found that only Yüzereroğlu *et al*. (2010) have studied *Patella caerulea* species in the regional waters. In the related study, researchers were able to identify the samples of 5 individuals having heavy metal accumulation levels, only in two locations of Gulf of Iskenderun namely; Iskenderun and Yumurtalık. No other study in the Gulf on related species has been observed.

This study aims at determining the status of heavy metal concentrations in three different tissues such as gill,

* Corresponding author: onderduysak@gmail.com
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muscle and hepatopancreas of *Patella caerulea* distributed in Iskenderun Bay during spring and autumn.

MATERIALS AND METHODS

This study was conducted at 8 different stations in Iskenderun Bay during the months of October 2012 and April 2013 (Fig. 1). In this study, a total of 160 *Patella caerulea* species were collected from eight different stations during spring and autumn. Specimens collected with a plastic knife, washed with clean seawater, placed in clean plastic bags, transferred to the laboratory under cooling conditions. Shell height, weight, shell width of the samples were measured and the mean average value calculated to centimeter and gram (Table I). Samples were put in different sizes of plastic zip lock bags to avoid water loss and stored at -25°C until analysis.

Table I.- The measurement of the wet weight (g), shell width (cm) and shell height (cm) of *P. caerulea* after sampling.

Seasons	n	Weight (g)	Width (cm)	Height (cm)
Spring	80	0,205±0,02	2,93±0,04	1,03±0,04
Fall	80	1,325±1,03	2,639±0,02	0,666±0,02

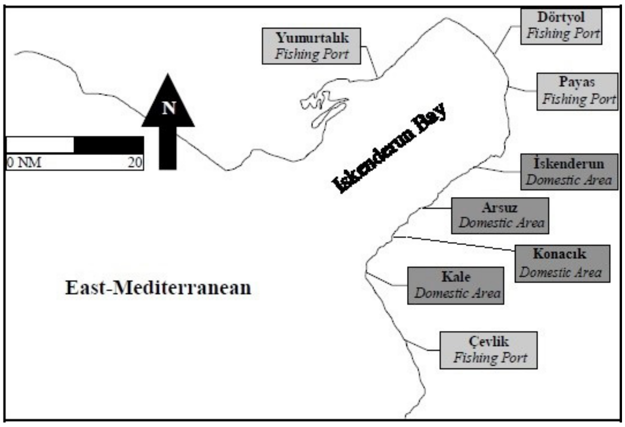

Fig. 1. Sampling area.

Then the individuals were dissected and their gill, hepatopancreas and muscular tissue samples for taken. The samples are placed in Petri dishes and dried in the oven at 105ºC for 36 h and completely dried tissue samples are weighed. Nitric acid and perchloric acid (2:1 v/v-mg/kg) were added on the scaled samples in a digestion flask and digested at 120ºC for 3 h in order to have their contents completely dissolved (Liang *et al*., 1999). The contents of the were filtered through 45 mm thick blue Whatman Filter Paper their volume adjusted to 5 ml by the addition of deionized water and then analyzed for heavy metals (Canlı and Atlı, 2003) with inductively coupled plasma atomic emission spectrometry (ICP-AES) (Varian Model, Liberty Series II; Palo Alto, USA). For calibration ICP-AES was used as a High Purity Multi Standard. Metal concentrations were calculated as µg/g dry weight. The quality of data was checked against the analysis of standard reference material DORM-2 (National Research Council of Canada; dogfish muscle and liver MA-A-2/TM fish flesh). Replicate analysis of reference materials showed good accuracy with recovery rates for metals between 96% and 106%. The results showed good agreement between the certified and the analytical values (Table II).

In order to have a correlation between the metal levels calculated in the tissues as per the locations of the stations; ANOVA and t-test Statistical Methods were performed by using the SPSS 17.0 Statistical Software Package.

Table II.- Observed and certified values of elemental concentrations as micrograms per gram wet weight in Standard reference materials DORM-2 from the Nationals Research Council, Canada (*n* = 2).

DORM-2	Certified values (µg/g)	Measured values	Recovery (%)
Cd	0.043 ± 0.008	0.045 ± 0.009	104
Cr	0.200 ± 0.01	0.199 ± 0.009	99
Cu	2.34 ± 0.16	2.26 ± 0.17	96
Co	0.21±0.01	0.20±0.009	96
Ni	17.20±1.8	18.00±1.6	104
Fe	142 ± 10	137 ± 11	96
Mn	0.050 ± 0.006	0.0485 ± 0.007	97
Pb	0.065 ± 0.007	0.069 ± 0.008	106
Zn	25.6 ± 2.3	24.9 ± 2.4	97

RESULTS

Metal levels in *P. caerulea* samples collected from the eight sites in Iskenderun Bay are given in Table III for spring and for autumn in Table IV. The results of statistical comparisons of metal levels between tissues and stations are also given in Tables III and IV.

Fe

In spring season the highest iron concentration (3302.1±505.5 µg/g) was observed in Dörtyol, whereas the lowest level (854.8±31.6 µg/g) was observed in Kaleköy on gill tissue (Table III). For liver tissue the highest iron

Table III.- Mean heavy metal concentrations (± standard deviation) (µg/g dry weight) in tissues of *P. caerulea* for Spring.

	Tissues	Çevlik	Konacık	Kaleköy	Arsuz	İskenderun	Payas	Dörtyol	Yumurtalık
Fe	Gill	1360.6±150.3^{x,a}	1589.3±233.8^{x,a}	854.8±31.6^{y,a}	1108.0±134.3^{x,a}	1587.5±188.4^{x,a}	1384.8±90.1^{x,a}	3302.1±505.5^{y,a}	1682.1±746.3^{y,a}
	Muscle	467.8±20.8^{x,b}	265.0±24.5^{x,b}	463.3±27.1^{y,b}	310.0±15.7^{x,b}	221.8±12.7^{x,b}	343.8±19.2^{x,b}	271.2±16.6^{x,b}	121.3±15.2^{y,b}
	Liver	259.7±12.0^{x,b}	1635.8±161.7^{y,a}	2903.6±400.2^{y,c}	1935.4±215.5^{y,c}	2097.6±132.9^{y,c}	1372.6±177.9^{y,a}	1356.9±163.1^{y,c}	1623.5±191.8^{y,a}
Zn	Gill	1684.9±100.8^{x,a}	1612.6±356.8^{x,a}	2329.8±282.9^{y,a}	1363.2±235.6^{y,a}	254.9±35.3^{y,a}	375.4±48.8^{y,a}	478.2±53.1^{y,a}	278.4±62.8^{y,a}
	Muscle	440.2±31.8^{x,b}	238.0±41.0^{y,b}	252.5±32.0^{y,b}	64.3±6.9^{z,b}	55.4±6.9^{z,b}	22.7±2.9^{z,b}	25.5±3.8^{z,b}	24.9±3.1^{z,b}
	Liver	249.8±31.8^{x,c}	225.3±6.0^{x,b}	458.4±34.3^{y,c}	475.3±13.6^{y,c}	104.5±7.9^{z,b}	177.2±19.3^{x,c}	64.1±6.2^{z,b}	73.0±4.3^{z,b}
Cd	Gill	65.2±16.0^{x,a}	121.9±13.9^{y,a}	163.4±33.5^{z,a}	17.4±2.8^{t,a}	37.8±6.5^{q,a}	52.0±5.0^{r,a}	40.1±9.5^{q,a}	29.6±3.4^{q,a}
	Muscle	10.3±1.6^{x,b}	18.5±3.6^{x,b}	16.1±2.9^{x,b}	3.9±1.0^{y,b}	6.2±0.9^{y,b}	6.0±1.1^{y,b}	7.0±1.6^{y,b}	7.7±2.0^{y,b}
	Liver	8.3±1.6^{x,b}	24.6±3.6^{y,b}	26.7±3.3^{z,b}	9.6±2.4^{x,a}	12.3±1.58^{x,b}	19.8±2.6^{t,c}	6.5±1.9^{x,b}	8.8±2.1^{x,b}
Cu	Gill	39.5±2.3^{x,a}	47.7±10.2^{y,a}	58.2±14.9^{z,a}	21.5±3.3^{t,a}	12.0±3.0^{q,a}	12.7±2.2^{q,a}	15.7±1.8^{q,a}	51.2±8.4^{y,a}
	Muscle	9.0±1.4^{x,b}	7.5±0.6^{x,b}	8.3±1.2^{x,b}	8.9±2.6^{x,b}	4.6±2.0^{x,b}	6.2±1.3^{x,b}	1.9±0.6^{y,b}	1.6±0.5^{y,b}
	Liver	9.9±2.2^{x,b}	13.1±2.2^{x,b}	20.7±2.0^{y,c}	16.7±2.7^{y,a}	12.5±2.8^{x,a}	6.2±1.3^{z,c}	4.7±2.4^{x,b}	4.3±1.2^{x,b}
Co	Gill	25.6±17.2^{x,a}	120.9±14.3^{y,a}	181.7±21.4^{z,a}	86.6±9.5^{t,a}	57.4±7.0^{q,a}	45.6±3.5^{r,a}	23.8±2.9^{x,a}	43.4±3.8^{r,a}
	Muscle	7.9±2.6^{x,b}	16.4±2.0^{x,b}	17.2±2.1^{y,b}	12.9±2.0^{y,b}	8.0±0.5^{z,b}	2.0±0.8^{z,b}	1.9±0.5^{z,b}	8.1±1.4^{z,b}
	Liver	6.8±1.6^{x,b}	15.6±3.3^{y,b}	16.5±1.2^{y,b}	24.7±3.4^{y,c}	16.9±3.0^{y,c}	5.6±2.4^{x,b}	4.6±0.9^{x,b}	8.1±1.8^{x,b}
Ni	Gill	14.5±4.5^{x,a}	32.9±7.7^{y,a}	24.3±2.2^{z,a}	17.7±3.7^{x,a}	20.2±2.6^{t,a}	23.8±4.7^{z,a}	14.9±1.4^{x,a}	6.7±1.3^{q,a}
	Muscle	2.0±0.5^{x,b}	2.4±0.6^{x,b}	4.4±1.2^{x,b}	4.5±0.4^{x,b}	3.7±1.1^{x,b}	2.8±0.6^{x,b}	3.4±1.3^{x,b}	2.3±0.3^{x,b}
	Liver	3.4±1.3^{x,b}	25.3±2.9^{y,c}	16.4±3.7^{z,c}	24.0±1.8^{y,c}	13.9±1.9^{z,c}	15.5±3.1^{z,b}	5.1±1.7^{x,b}	6.8±1.4^{x,a}
Al	Gill	110.1±6.4^{x,a}	61.0±12.8^{y,a}	58.1±6.0^{y,a}	69.6±9.1^{z,a}	79.1±10.7^{z,a}	125.3±18.9^{t,a}	35.4±14.4^{q,a}	157.8±14.1^{r,a}
	Muscle	32.5±1.9^{x,b}	20.4±3.4^{y,b}	16.5±1.8^{y,b}	24.7±3.3^{y,b}	22.9±2.3^{y,b}	30.5±3.8^{x,b}	46.1±2.9^{z,b}	35.1±3.3^{x,b}
	Liver	15.3±1.5^{x,c}	58.3±5.2^{y,a}	37.4±4.9^{z,c}	73.5±2.0^{t,a}	16.8±2.8^{x,b}	77.8±5.1^{t,c}	97.7±8.7^{q,c}	77.7±9.5^{t,c}
Mn	Gill	11.2±5.0^{x,a}	34.1±9.4^{y,a}	13.2±1.5^{x,a}	12.1±3.6^{x,a}	20.3±6.2^{z,a}	12.9±2.7^{x,a}	10.0±3.1^{x,a}	7.5±2.1^{t,a}
	Muscle	3.9±0.6^{x,b}	2.0±0.7^{x,b}	2.3±0.6^{x,b}	2.9±0.9^{x,b}	2.9±0.5^{x,b}	7.8±1.0^{y,b}	5.3±0.9^{x,b}	3.1±1.5^{x,b}
	Liver	5.7±3.3^{x,b}	5.3±1.3^{x,b}	5.5±1.6^{x,b}	7.3±1.9^{x,c}	5.3±1.3^{x,b}	2.1±0.5^{x,c}	7.0±2.1^{x,a}	4.6±2.2^{x,a}
Pb	Gill	48.7±2.4^{x,a}	45.2±1.3^{x,a}	56.2±11.5^{y,a}	46.1±6.5^{x,a}	47.3±5.8^{x,a}	54.8±7.1^{y,a}	36.1±4.0^{z,a}	27.4±3.6^{t,a}
	Muscle	11.2±1.5^{x,b}	10.2±1.7^{x,b}	10.7±1.3^{x,b}	13.0±2.1^{x,b}	12.9±1.5^{x,b}	12.6±1.5^{x,b}	14.0±2.01^{x,b}	9.7±2.1^{x,b}
	Liver	5.9±2.2^{x,c}	3.6±1.3^{x,c}	7.1±0.6^{x,b}	18.1±2.1^{y,c}	17.6±4.0^{y,b}	20.0±3.7^{y,c}	17.1±3.5^{y,b}	10.5±1.9^{x,b}
Cr	Gill	10.5±1.9^{x,a}	12.7±2.4^{x,a}	15.2±2.547^{y,a}	9.6±1.1^{x,a}	11.0±1.7^{x,a}	19.8±9.1^{z,a}	18.2±5.0^{y,a}	7.5±2.1^{x,a}
	Muscle	2.1±0.3^{x,b}	1.9±0.5^{x,b}	7.9±0.9^{y,b}	3.0±0.9^{x,b}	5.0±0.5^{x,b}	3.5±1.5^{x,b}	2.2±0.5^{x,b}	2.0±0.6^{x,b}
	Liver	2.2±0.9^{x,b}	13.2±2.1^{y,a}	14.8±1.7^{y,a}	15.4±2.9^{y,c}	4.5±2.3^{x,b}	3.8±0.8^{x,b}	4.7±2.5^{x,b}	3.6±1.7^{x,b}

Letters x,y,z,t,q and r Show differences among stations; a,b and c among tissues.
Data shown with different letters are statistically significant at the differences $p<0.05$ level.

Table IV.- Mean heavy metal concentrations (± standard deviation) (µg/g dry weight) in tissues of *P.* caerulea for Autumn.

	Tissues	Çevlik	Konacık	Kaleköy	Arsuz	İskenderun	Payas	Dörtyol	Yumurtalık
Fe	Gill	1717.6±103.2^{x,a}	1879.6±208.8^{y,a}	4726.7±168.0^{z,a}	1600.3±166.3^{x,a}	2012.7±207.7^{y,a}	1715.9±127.1^{x,a}	1571.5±122.2^{x,a}	1261.9±70.7^{t,a}
	Muscle	306.2±14.0^{x,b}	513.6±26.9^{y,b}	1274.0±159.7^{z,b}	668.8±30.8^{y,b}	635.4±25.9^{y,b}	893.1±110.2^{t,b}	548.3±26.5^{y,b}	523.0±32.1^{y,b}
	Liver	1471.0±128.9^{x,c}	1682.9±146.0^{a,y}	4404.6±295.5^{y,c}	1473.9±182.4^{x,a}	1926.3±164.4^{z,a}	1481.4±316.7^{x,c}	2108.6±156.3^{z,c}	1887.9±227.9^{z,c}
Zn	Gill	78.0±13.7^{x,a}	99.4±18.4^{x,a}	3409.3±190.5^{y,a}	3607.7±163.6^{z,a}	3497.3±174.4^{y,a}	3452.4±210.5^{y,a}	2518.9±174.5^{t,a}	2382.1±1415.8^{q,a}
	Muscle	34.0±2.2^{x,a}	44.4±3.6^{x,a}	451.1±49.7^{y,b}	475.1±15.9^{y,b}	756.8±31.3^{z,b}	627.5±22.1^{t,b}	455.1±38.1^{q,b}	436.2±254.6^{z,b}
	Liver	73.5±9.9^{x,a}	58.3±5.8^{x,a}	137.9±8.6^{x,c}	80.4±6.8^{x,c}	80.3±9.2^{x,c}	63.7±3.6^{x,c}	36.5±4.2^{x,c}	71.7±30.3^{x,c}
Cd	Gill	127.5±17.9^{x,a}	122.1±24.2^{x,a}	121.2±21.6^{x,a}	164.0±16.7^{y,a}	223.3±17.3^{z,a}	138.5±16.1^{x,a}	175.5±11.9^{y,a}	156.0±22.4^{y,a}
	Muscle	5.7±1.4^{x,b}	16.3±3.1^{x,b}	14.9±2.0^{x,b}	20.5±3.5^{y,b}	25.7±3.4^{y,b}	80.0±16.4^{z,b}	34.3±4.8^{y,b}	41.5±3.5^{t,b}
	Liver	27.3±5.6^{x,c}	28.3±3.6^{x,b}	40.5±3.5^{x,c}	43.5±4.9^{y,c}	39.7±5.4^{x,b}	46.5±3.1^{y,c}	24.9±2.1^{x,b}	27.3±1.7^{x,b}
Cu	Gill	16.5±1.6^{x,a}	22.7±8.4^{x,a}	77.3±19.2^{y,a}	16.0±1.7^{x,a}	85.3±11.9^{y,a}	47.8±8.7^{z,a}	158.1±10.5^{t,a}	64.8±47.5^{q,a}
	Muscle	8.1±2.2^{x,b}	9.5±2.0^{x,b}	10.3±2.2^{x,b}	14.3±2.0^{x,a}	18.3±1.2^{y,b}	24.0±4.0^{y,b}	25.0±2.0^{y,b}	17.6±8.3^{z,b}
	Liver	26.1±1.0^{x,c}	14.9±0.9^{y,a}	12.7±3.5^{y,b}	29.5±2.8^{x,b}	19.8±3.7^{x,b}	20.0±6.5^{x,b}	13.8±4.0^{y,c}	21.2±7.8^{x,b}
Co	Gill	67.7±7.5^{x,a}	28.9±11.7^{y,a}	25.3±5.0^{y,a}	241.5±19.4^{z,a}	221.3±13.0^{t,a}	174.2±18.2^{q,a}	163.9±15.7^{q,a}	148.0±14.4^{r,a}
	Muscle	4.4±2.0^{x,b}	3.3±0.6^{x,b}	5.7±2.4^{x,b}	7.4±1.0^{x,b}	15.2±2.3^{y,b}	29.5±2.9^{z,b}	29.5±3.8^{z,b}	33.5±3.8^{z,b}
	Liver	6.3±2.2^{x,b}	4.3±1.0^{x,b}	26.1±3.8^{y,a}	8.2±1.0^{x,b}	5.9±1.6^{x,b}	6.4±1.8^{x,c}	8.7±1.5^{x,c}	5.4±2.0^{x,c}
Ni	Gill	11.9±4.1^{x,a}	23.6±4.5^{a,y}	48.7±8.7^{z,a}	21.7±5.4^{y,a}	22.6±2.7^{y,a}	16.1±2.2^{x,a}	195.5±20.3^{t,a}	160.3±13.8^{q,a}
	Muscle	2.1±0.9^{x,b}	3.8±1.3^{x,b}	54.2±3.0^{y,a}	8.5±1.6^{x,b}	14.9±2.1^{z,b}	13.5±4.1^{z,a}	22.9±1.0^{t,b}	37.8±3.6^{q,b}
	Liver	6.4±2.5^{x,a}	10.0±1.6^{x,b}	42.1±5.5^{y,b}	9.0±2.4^{x,b}	15.9±2.8^{z,a}	7.6±1.8^{t,b}	15.6±2.7^{z,c}	16.7±2.9^{z,c}
Al	Gill	146.6±33.4^{x,a}	136.8±16.5^{x,a}	124.6±14.4^{y,a}	113.3±4.3^{y,a}	123.1±9.9^{y,a}	128.3±8.6^{y,a}	114.5±7.5^{y,a}	145.5±23.3^{x,a}
	Muscle	36.9±5.0^{x,b}	24.0±4.5^{x,b}	53.0±4.7^{y,b}	44.2±4.6^{x,b}	45.5±5.1^{x,b}	24.3±3.9^{x,b}	18.4±2.7^{z,b}	39.9±4.4^{y,b}
	Liver	51.6±3.1^{x,c}	35.0±2.4^{y,b}	63.1±3.0^{x,b}	64.9±6.3^{x,c}	32.6±6.1^{y,b}	70.0±10.2^{z,c}	80.9±4.7^{z,c}	49.0±4.0^{x,b}
Mn	Gill	21.5±4.6^{x,a}	24.7±5.9^{x,a}	24.7±6.5^{x,a}	25.7±1.4^{y,a}	22.7±3.6^{x,a}	15.5±2.1^{z,a}	18.9±2.9^{x,a}	17.4±1.6^{z,a}
	Muscle	2.1±0.9^{x,b}	2.9±0.3^{y,b}	8.3±1.9^{z,b}	9.9±1.7^{t,b}	4.5±1.4^{x,b}	10.4±3.0^{t,b}	3.1±0.4^{x,b}	5.0±1.3^{x,b}
	Liver	5.7±1.9^{x,c}	6.2±1.3^{x,b}	4.5±0.9^{y,c}	9.1±1.7^{z,b}	8.2±3.8^{t,c}	7.0±0.9^{x,c}	4.2±1.6^{x,b}	7.5±1.3^{x,b}
Pb	Gill	52.8±9.9^{x,a}	122.8±11.5^{y,a}	102.4±5.4^{z,a}	180.5±13.2^{t,a}	128.0±10.9^{y,a}	21.6±2.3^{q,a}	15.5±1.8^{q,a}	18.7±3.7^{q,a}
	Muscle	19.8±1.6^{x,b}	26.1±2.1^{x,b}	24.0±2.7^{x,b}	7.3±1.7^{y,b}	8.8±1.4^{y,b}	5.3±2.6^{y,b}	4.9±1.5^{y,b}	8.3±1.2^{y,b}
	Liver	24.3±3.5^{x,b}	13.9±2.5^{y,c}	53.9±9.0^{z,c}	24.7±3.7^{x,c}	15.5±2.4^{y,b}	24.8±5.1^{x,a}	16.7±5.5^{y,a}	25.8±2.3^{x,a}
Cr	Gill	19.9±4.0^{x,a}	23.2±3.8^{y,a}	26.3±6.0^{y,a}	30.7±2.5^{z,a}	22.7±3.6^{y,a}	14.5±2.7^{t,a}	16.1±1.4^{t,a}	16.0±2.6^{t,a}
	Muscle	2.6±1.5^{x,b}	2.6±0.6^{x,b}	4.1±1.0^{x,b}	4.5±1.4^{x,b}	4.5±1.4^{x,b}	5.3±2.6^{x,b}	3.8±1.5^{x,b}	5.8±2.1^{x,b}
	Liver	4.4±1.4^{x,b}	4.9±0.9^{x,b}	28.5±3.8^{y,a}	14.3±1.7^{z,c}	13.1±2.6^{t,c}	16.9±2.2^{z,a}	19.8±2.4^{z,c}	7.4±1.4^{x,b}

Letters x,y,z,t and q Show differences among stations; a,b and c among tissues.
Data shown with different letters are statistically significant at the differences $p<0.05$ level.

metal level (2903.6±400.2 µg/g) was observed in Kaleköy, whereas the lowest level (259.7±12 µg/g) was observed in Çevlik (Table III). Iron accumulation in muscular tissues was calculated as highest in Çevlik and the lowest in Yumurtalık in this season. For this metal, significant differences were observed for every kind of tissue in Kaleköy, Arsuz, Iskenderun and Dörtyol stations in spring ($p<0.05$).

In autumn season, for gill and liver tissues the highest ferrous metal level were observed in Kaleköy, whereas the lowest level for gill tissue was observed in Yumurtalık (Table IV). Iron accumulation in muscular tissues was calculated as highest in Kaleköy and the lowest in Çevlik station. Significant differences was observed between Çevlik, Kaleköy, Payas, Dörtyol and Yumurtalık stations in autumn ($p<0.05$).

Zn

In spring season the highest zinc level (475.3±13.6 µg/g) for liver tissue was observed in Arsuz, whereas the lowest level was observed in Dörtyol (Table III).

In spring for gill tissue the highest zinc metal level (2329.8±282.9 µg/g) was observed in Kaleköy, whereas, the lowest level (254.9±35.3 µg/g) was observed in Iskenderun (Table III). Zn accumulation in muscular tissues was calculated as highest (440.2±31.8 µg/g) in Çevlik and the lowest (22.7±2.9 µg/g) in Payas. For Zn levels in tissues, significant differences were observed in Çevlik, Kaleköy, Arsuz, and Payas stations in spring ($p<0.05$) (Table III).

In autumn season, for gill tissue highest Zn level was observed in Arsuz, whereas the lowest level was observed in Çevlik (Table IV). Zn deposition in liver tissue in this season was determined as highest in Kaleköy and the lowest in Dörtyol. Zn deposition in muscular tissues in this season was calculated as highest in Iskenderun and the lowest in Çevlik. Significant differences were observed in all stations between the tissues in autumn ($p<0.05$). No significant differences were observed in the tissues from Çevlik and Konacık in autumn ($p<0.05$) (Table IV).

Cd

In spring season; for gill tissue the highest cadmium metal level (163.4±33.5 µg/g) was observed in Kaleköy, whereas the lowest level (17.4±2.8 µg/g) was observed in Arsuz (Table III). For liver tissue the highest Cd level was observed in Kaleköy (26.7±3.3 µg/g), whereas the lowest level was observed in Dörtyol (6.5±1.9 µg/g). In this season Cd accumulation in muscular tissues was the highest (18.5±3.6 µg/g) in Konacık and the lowest (3.9±1.0 µg/g) in Arsuz. No significant differences have been observed in the Cd accumulation levels in muscular tissues and liver except for those in Arsuz and Payas samples in this season ($p>0.05$). Significant differences have been observed in the values for gill, comparing with the values observed in muscular tissues and liver ($p<0.05$).

In autumn season, the highest cadmium level (223.3±17.3 µg/g) was observed in gill tissue in İskenderun; whereas the lowest level (121.2±21.6 µg/g) was observed in Kaleköy (Table IV). Cd deposition in liver tissue in this season was observed as the highest (46.5±3.1 µg/g) in Payas and the lowest (24.9±2.1 µg/g) in Dörtyol (Table IV). Cadmium deposition in muscular tissues in this season was calculated as highest in Payas and the lowest in Çevlik.

The measurements taken in autumn did not show statistically significant differences for Cd levels among Çevlik, Kaleköy and Konacık stations; whereas significant differences have been observed for the other stations' metal levels ($p<0.05$).

Cu

In spring season, for gill tissue the highest copper level (58.2±14.9 µg/g) was observed in Kaleköy, whereas the lowest level (12.0 ±3.0 µg/g) was observed in Iskenderun (Table III). For liver tissue the highest copper level was observed in Kaleköy, whereas the lowest level was observed in Yumurtalık (Table III). In this season, copper accumulation in muscular tissues was calculated as the highest in Çevlik and the lowest in Yumurtalık (Table III).

In autumn season, the highest copper level (158.1±10.5 µg/g) for gill tissue was observed in Dörtyol, whereas the lowest level (16.0±1.7 µg/g) was observed in Arsuz as (Table IV). Cu deposition in liver tissue was observed as the highest in Arsuz and the lowest in Kaleköy (Table IV). Cu deposition in muscular tissues in this season was calculated as highest in Dörtyol and the lowest in Çevlik station (Table IV).

In spring and autumn Cu concentration in showed statistically significant differences ($p<0.05$) gill and muscular tissues. The highest Cu levels were measured in Kaleköy and Konacık in both seasons. Also, in both seasons, Cu levels of gill tissue were higher compared to the muscular tissue Cu metal levels.

Co

In spring season, the highest cobalt level (181.7±21.4 µg/g) for gill tissue was observed in Kaleköy, whereas the lowest level (23.8±2.9 µg/g) was observed in Dörtyol (Table III). The highest cobalt level for liver tissue was observed in Arsuz, whereas the lowest level was observed in Dörtyol (Table III). In this season, Co accumulation in muscular tissues was calculated as the highest in Kaleköy and the lowest in Dörtyol (Table III).

In spring and autumn, Co concentrations in all tissues showed statistically significant differences ($p<0.05$). When the results were examined again, it was found that there were statistically significant differences for the gill tissues between stations in both seasons ($p<0.05$), but in autumn, the results obtained from liver tissues showed no statistically significant differences ($p>0.05$).

In autumn season, the highest Co level (241.5±19.4 µg/g) for gill tissue was observed in Arsuz, whereas the lowest level (25.3±5.0 µg/g) was observed in Kaleköy (Table IV). Cobalt deposition in muscular tissue was observed as the highest (33.5±3.8 µg/g) in Yumurtalık and the lowest (3.3±0.6 µg/g) in Konacık (Table IV). Co deposition in liver tissues was determined as the highest in Kaleköy and the lowest in Konacık (Table IV).

Ni

In spring season, for gill tissue the highest nickel level was observed in Konacık, whereas the lowest level was observed in Yumurtalık (Table III). For liver tissue the highest Ni level was observed in Konacık, whereas the lowest level was observed in Çevlik (Table III). In this season, Ni accumulation in muscular tissues was calculated as the highest in Arsuz and the lowest in Çevlik (Table III).

In autumn season, the highest nickel level (195.5±20.3 µg/g) for gill tissue was observed in Dörtyol, whereas the lowest level (11.9±4.1 µg/g) was observed in Çevlik (Table IV). Ni deposition in liver tissues was calculated as the highest in Kaleköy and the lowest in Çevlik (Table IV). In this season, Ni deposition in muscular tissue was observed as the highest in Kaleköy and the lowest in Çevlik (Table IV). There were statistically significant differences for all tissues between stations in spring season ($p<0.05$), though, the results showed no statistically significant differences in muscular tissue ($p>0.05$).

Al

In spring season, the highest aluminum level (157.8±14.1 µg/g) for gill tissue was observed in Yumurtalık, whereas the lowest level (35.4±14.4 µg/g) was observed in Dörtyol. The highest aluminum level (97.7±8.7 µg/g) for liver tissue was observed in Dörtyol, whereas the lowest level (15.3±1.5 µg/g) was observed in Çevlik (Table III). Al accumulation in muscular tissues was calculated as the highest in Dörtyol and the lowest in Kaleköy in spring season (Table III).

In autumn season, the highest Al level (146.6±33.4 µg/g) for gill tissue was observed in Çevlik station, whereas the lowest level (113.3±4.3 µg/g) was observed in Arsuz station (Table IV). Al deposition in liver tissues was calculated as the highest (80.9±4.7 µg/g) in Dörtyol station and the lowest (32.6±6.1 µg/g) in Iskenderun station (Table IV). In this season, Al deposition in muscular tissue was observed as the highest in Kaleköy station; and the lowest in Dörtyol station (Table IV).

There were statistically significant differences for gill and muscular tissues between stations in spring and autumn seasons ($p<0.05$); whereas evaluation as per station in gill tissue, showed statistically significant difference ($p>0.05$).

Mn

In spring season, the highest Mn level (34.1±9.4 µg/g) for gill tissue was observed in Konacık, whereas the lowest level (7.5±2.1 µg/g) was observed in Yumurtalık. The highest Mn level (7.3±1.9 µg/g) deposited for liver tissue was calculated in Arsuz, whereas the lowest level (2.1±0.5 µg/g) was calculated in Payas (Table III). In this season, Mn accumulation in muscular tissues was calculated as the highest in Payas and the lowest in Konacık (Table III). In spring, the mean values of Mn accumulation levels in liver and muscular tissues did not show any statistically significant value according to the stations ($p>0.05$).

In autumn season, the highest Mn level (25.7±1.4 µg/g) for gill tissue was observed in Arsuz station, whereas the lowest level (15.5±2.1 µg/g) was observed in Payas station (Table IV). Mn deposition in liver tissue was observed as the highest (9.1±1.7 µg/g) in Arsuz and the lowest (4.2±1.6 µg/g) in Dörtyol. In this season, Mn deposition in muscular tissues was calculated as the highest (10.4±3.0 µg/g) in Payas and the lowest (2.1±0.9 µg/g) in Çevlik. In autumn, Mn concentration measurements calculated from all tissues showed statistically significant differences ($p<0.05$).

Pb

In spring season, the highest Pb level (56.2±11.5 µg/g) for gill tissue was observed in Kaleköy, whereas the lowest level (27.4±3.6 µg/g) was observed in Yumurtalık (Table III). The highest Pb level (20.0±3.7 µg/g) for liver tissue was found in Payas, whereas the lowest level (3.6±1.3 µg/g) was found in Konacık. In this season, Pb metal accumulation in muscular tissues was observed as the highest (14.0±2.1 µg/g) in Dörtyol and the lowest (9.7±2.1 µg/g) in Yumurtalık. In spring, the mean values of Pb accumulation levels in muscular tissues did not show any statistical differences according to the stations ($p>0.05$).

In autumn season, for gill tissue the highest Pb level (180.5±13.2 µg/g) was observed in Arsuz, whereas the lowest level (15.5±1.8 µg/g) was observed in Dörtyol (Table IV). Pb deposition in liver tissue was observed as the highest (53.9±9.0 µg/g) in Kaleköy, and the lowest (13.9±2.5 µg/g) in Konacık. Pb deposition in muscular tissues in this season was calculated as highest in Konacık and the lowest in Dörtyol (Table IV). In both seasons Pb concentration measurements calculated from gill and muscular tissues showed statistically significant differences ($p<0.05$).

Cr

In spring season, for gill tissue the highest Cr level (19.8±9.1 µg/g) was observed in Payas, whereas the lowest level (7.5±2.1 µg/g) was observed in Yumurtalık. For liver tissue the highest Cr level (15.4±2.9 µg/g) was observed in Arsuz, whereas the lowest level (2.2±0.9 µg/g) was observed in Çevlik. All the end of this study we observed that Cr accumulation in muscular tissues was calculated as the highest in Iskenderun and the lowest in Konacık (Table III).

In autumn, for gill tissue the highest Cr level (30.7±2.5 µg/g) was observed in Arsuz, whereas the lowest level (14.5±2.7 µg/g) was observed in Payas. Cr deposition in liver tissue was observed as the highest (28.5±3.8 µg/g) in Kaleköy and the lowest (4.4±1.4 µg/g) in Çevlik. Cr deposition in muscular tissues was calculated as the highest in Yumurtalık and the lowest in Çevlik for fall season (Table IV). When seasonal comparison of the tissues was made, Cr concentration showed statistically significant differences between gill and muscular tissues ($P<0.05$).

DISCUSSION

Ayas *et al*. (2009) reported Cr at the highest level and Pb at the lowest level in the muscular tissues of *Patella caerulea* and *Patella rustica* species in Mersin Bay. In our study, Cd was found to be at the highest level and Cr at the lowest level in muscular tissues of *Patella caerulea*. Besides that, the concentrations measured in the muscular tissues of the Gulf of Mersin *Patella caerulea* species was lower than that of Gulf of Iskenderun which indicated different pollution load levels of the bays even for the same type of species. Yüzereroğlu *et al*. (2010) indicated in their study which was conducted in Yumurtalık and Iskenderun districts of Gulf of Iskenderun, that the concentration of the muscular tissues of Co, Pb, Cd, Ni, Cu, Zn and Fe *Patella caerulea* was respectively 0.33±0.02, 0.66±0.01, 0.60±0.01, 0.60±0.09, 5.58±0.18, 11.2±0.60 and 83.36±0.52 in (µg/g dry weight) during Spring. The same metals for Yumurtalık district showed the concentration of 0.12±0.05, 0.14±0.05, 0.44±0.08, 0.53±0.27, 2.12±0.06, 7.80±0.06 and 68.00±1.15 in µg/g dry weight, respectively. In our study the heavy metal contamination levels for Co, Pb, Cd, Ni, Cu, Zn and Fe for muscular tissues of *Patella caerulea* were 8.0±0.5, 12.9±1.5, 6.2±0.9, 3.7±1.1, 4.6±2.0, 55.4±6.9, 221.8±12.7 µg/g dry weight for Iskenderun and 8.1±1.37, 9.7±2.07, 7.7±2.0, 2.3±0.3, 1.6±0.5, 24.9±3.1, 121.3±15.2 µg/g dry weight for Yumurtalık. When these two studies were compared, the muscular tissues of *Patella caerulea* from Iskenderun station had higher concentration than that of Mersin. Ni and Cu levels in Yumurtalık were found almost similar, while other metals were found in higher concentrations than Mersin. The differences in these concentrations may be because of gap period between the two studies and the capacity increase, qualitatively and quantitatively, of the wastes discharged to bays due to various additional industries and population growth within this period.

Duysak and Ersoy (2014) determined heavy metals levels in the muscular tissues of *M. turbinata* in spring and autumn in Iskenderun Bay. In spring, they found the highest metal concentration (3176.85±1232.55 µg/g dry weight) in muscular tissues in Kaleköy, and the lowest metal concentration (0.46±0.39 µg/g dry weight) Cr in Yumurtalık. In autumn the highest Fe concentration (450.12±106.84 µg/g dry weight) was found in muscular tissue in Dörtyol, and the lowest metal concentration (1.74±0.32 µg/g dry weight) of Cr in Konacık. In our study, the highest concentration of Fe was found in muscular tissues (467.8±20.8 µg/g dry weight) in Çevlik and the lowest concentration of Cu (1.6±0.5 µg/g dry weight) was found in in spring. In fall, the highest metal deposition in muscular tissues was found to be Fe (1274.0±159.7 µg/g dry weight) in Kaleköy, and the lowest metal concentrations was found to be Ni and Mn (2.1±0.9 µg/g dry weight) in Çevlik. It was concluded that even though there were seasonal differences, the most deposited heavy metal in the tissues was Fe in both the studies.

Although the two species of gastropods were living in the same water column (upper littoral zone), the heavy metal concentrations in the muscular tissues of these two species should have shown differences due to the induced physiological differences in their moving ability. Alyakrinskaya (2010) in his study with gastropods has shown that more moving gastropods, compared to the relatively less moving species deposited 4 times more Cu in their muscular tissues. The reason for finding seasonally relatively low levels of Cu in the *P. caerulea* individuals in our study compared with that of Duysak and Ersoy's conducted in 2014 with more moving *M. turbinata* species, could be explained in similar way.

When distribution of *P. caerulea* having deposition of heavy metal concentrations are examined in muscles in the Gulf of Iskenderun, in spring, they are in the order Çevlik > Kaleköy> Payas > Arsuz > Dörtyol > Konacık > Yumurtalık > İskenderun, in gills in the order Dörtyol >

Kaleköy > Çevlik > Yumurtalık > Konacık > İskenderun > Payas > Arsuz, in liver in order; Kaleköy> İskenderun> Arsuz > Konacık> Yumurtalık > Payas > Dörtyol > Çevlik. For autumn they are calculated as in their muscular tissues in the order: Kaleköy > Payas > İskenderun > Arsuz > Dörtyol > Yumurtalık > Konacık > Çevlik, in gills in the order Kaleköy > Arsuz> İskenderun > Payas > Dörtyol > Yumurtalık > Konacık > Çevlik, in liver in the order Kaleköy> Dörtyol > İskenderun > Yumurtalık > Konacık > Payas > Arsuz > Çevlik. The highest metal accumulations were observed in Kaleköy station for both seasons. The high metal concentrations in Kaleköy in the spring season are thought to have originated from the increased household wastes.

When heavy metals and aluminium accumulations in the tissues are seasonally analyzed the deposition in spring and autumn were similarly calculated as gills> liver> muscles.

CONCLUSION

In Iskenderun Bay, different types of molluscan species are used as bio-monitors for the determination of heavy metal concentrations deposited in the tissues. *Patella caerulea* type species were observed in almost every part and in every season in the Iskenderun Bay. Therefore, it can be utilized as bio-monitoring species to determine the heavy metal level in the bay.

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Statement of conflict of interest

Authors have declared no conflict of interest.

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