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Metal Concentrations in Different Tissues of Jellyfish (*Rhopilema nomadica* Galil, 1990) in Iskenderun Bay, Northeastern Mediterranean

Onder Duysak, Ayse Bahar Yilmaz and Yavuz Mazlum
Faculty of Marine Sciences and Technology, Mustafa Kemal University,
31200 Hatay, Turkey

Abstract: In this study, the concentrations of heavy metals (Cd, Cr, Cu, Fe, Mn, Pb and Zn) were determined in gastral, tentacular and epidermal (umbrella) tissues of jellyfish *Ropilema nomadica* from 2 stations (Yumurtalik and Arsuz) in Iskenderun Bay, Turkey. Heavy metal concentrations varied significantly depending on the type of the tissue and location of stations. The average metal concentrations in gastral and tentacular were found higher than umbrella tissues in all samples. The level of Mn and Zn concentrations were significantly different among the tissues in both stations ($p<0.05$). The aim of this study was to imply potential of heavy metal accumulation in jellyfish which plays an important role in biological transfer and Summer blooms. Moreover, this is the first study of the heavy metal bioaccumulation on *R. nomadica* in Northeastern Mediterranean.

Key words: Jellyfish, *Rhopilemma nomadica*, tissues, heavy metals, bioaccumulation

INTRODUCTION

Rhopilema nomadica is active filter-feeding invertebrates and is a good bio-indicator in coastal ecosystems where they sustain life by removing suspended food particles from the water (Riisgard and Larsen, 2000). Iskenderun Bay has biological and physical activities. For example, water depth which affects the importance of wind and tidal mixing, strongly influences the grazing impact of filter-feeder populations which may be considerable in coastal waters (Cloern, 1982). *R. nomadica* had entered the Mediterranean through the Suez Canal in the 1970's. Another possibility is that a *Rhopilema* species migrated from the indo pacific by ballast waters, leading to the current proliferation of medusa in Eastern Mediterranean (Lotan *et al*., 1992).

Jellyfish are prey for numerous invertebrate and vertebrate species and as such play a central role in the tropic organization of many marine food chains. Furthermore, they are known to prey abundantly and selectively upon certain zooplankton species including fish larvae (Van der and Veer, 1985) and thereby may exert a major impact on the structure and dynamics of mesozooplankton communities as well as fish stocks. Their impact on the environment is particularly important during summer blooms when jellyfish may occur in very dense aggregations containing millions of individuals.

The mid 1980's forms large annually along the Levantine coast. *R. nomadica* was recorded in 1996 from Iskenderun Bay. Also, Ozturk and Isinibilir (2010) were reported that several blooms of *R. nomadica* in Antalya, Mersin, Iskenderun and Adana were occured and some people were hospitalized in Summer 2009.

According to Wilkerson and Dugdale (1983) wide fluctuations and proliferation of jellyfish populations in the Mediterranean have been attributed to certain climatic conditions or to pollution-induced ecological changes. Due to the high reproductive potential of *R. nomadica*, large numbers of planulae formed and the repeated in population, it has been exploded in the Eastern Mediterranean (Lotan *et al*., 1992).

Iskenderun Bay is very important for commercial and sport fishing in North-Eastern Mediterranean. In addition, in this region of the Mediterranean Sea have industries such as cement factory, iron and steel factories, power station, activities, etc. Heavy metals may enter aquatic ecosystem from different way such as natural industrial or domestic sewage, storm runoff, leaching from landfills dumpsites and atmospheric ways. It is also effected various winds, therefore, it has seen lots of currents in whole season.

According to circulation patterns inferred from earlier studies, two or more closed gyres are often found in Iskenderun Bay (Iyiduvar, 1986; Bingel *et al*., 1987). The

Corresponding Author: Onder Duysak, Faculty of Marine Sciences and Technology, Mustafa Kemal University, 31200 Hatay, Turkey

mean currents in this area of the Northeastern Mediterranean sweep the coast in an anticlockwise direction, i.e., the Northerly currents following the coasts of Lebanon and Syria then follow the Turkish coast in a westerly direction (Unluata *et al.*, 1983). Parts of this current bifurcate into Iskenderun Bay while the main flow bypasses the bay.

Metals such as iron, copper, zinc and manganese are essential metals since, they play an important role in biological systems whereas non-essential metals such as Cr, Ni, Pb and Cd are toxic even in trace amounts (Unak *et al.*, 2007). The essential metals can also produce toxic effects at high concentrations. Only a few metals, of proven hazardous nature are to be completely excluded in food for human consumption. Thus, only three metals, namely lead, cadmium and mercury have been included in the regulations of the European Union for hazardous metals (EC, 2001) while the USFDA has included further three elements, namely, chromium, arsenic and nickel in the list (Sivaperumal *et al.*, 2007; USFDA, 1993). Jellyfish is not consume as a food in Turkey but in the world especially in Asian countries has consumed and also in the treatment of many diseases, loosing weight and skin beauty (Liu *et al.*, 2012). According to Jiang and Zhang (1994), jellyfish can use for cure effects to hyper tension, asthma, gastric ulcer, etc.

Jellyfish which are key representatives of the gelatinous plankton community, constitute an important biomass and also efficient metal bioaccumulators in the oceans. Jellyfish plays an important role in biological transfer and recycling of heavy metal contaminants in the marine environment. A variety of organisms have been investigated to evaluate their potential as biological indicators of different forms of pollution in the aquatic environment. Despite the well-known ecological importance of jellyfish, earlier studies are extremely rare on the accumulation of metals and other contaminants (Fowler *et al.*, 2004).

The objective of this study was to determine the potential of heavy metal accumulation in jellyfish and also to compare various heavy metals concentrations cadmium, chromium, copper, manganese, iron, lead and zinc (Cd, Cr, Cu, Mn, Fe, Pb and Zn) in different tissues (gastral, tentacular and umbrella) of *R. nomadica*, collected from Iskenderun Bay.

MATERIALS AND METHODS

Sample preperation: This study was performed in the Iskenderun Bay in September 2011 by using fish net. Jellyfish sampling was collected from two stations (Fig. 1). Yumurtalik (station 1) is in the Northern and Arsuz

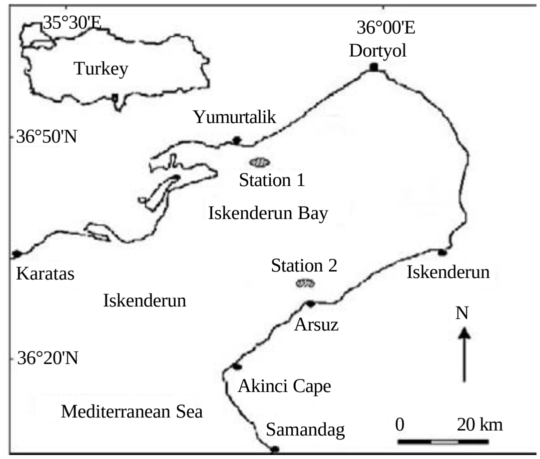

Fig. 1: The map of sampling stations in Iskenderun Bay

(station 2) which is representing enter of Iskenderun Bay in the Southern part (Yilmaz, 2003). Ten jellyfish samples from each station were collected for analysing of tentacular, gastral and umbrella tissue. Samples were labeled and they were preserved on ice and transported to the laboratory. All the samples were stored at -25°C until dissection for analysis. In the laboratory, jellyfish umbrella length (cm) and total weight (g) were measured before dissection (station 1: 43.9±4.1 cm and 3554±0.814 g; station 2: 48.45±4.45 cm and 5592±1.086 g).

Digestion procedures: This approach was modified from UNEP. Approximately, 5 g tissue was accurately weighed and digested in 5 mL of concentrated nitric acid. Samples were digested 15 days at room temperature. The completely digested samples were allowed, filtered (glass wool) and made up to 50 mL double distilled water. A blank digest was carried out in the same way. All metals were determined againist aqueous standards. Digested samples were analyzed three replicates for each metal.

Analytical procedures: Determination of all metals (Cd, Cu, Cr, Pb, Zn, Fe and Mn) was used for Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) (Varian Model-Liberty Series II; Palo Alto, USA) equipment located at Mustafa Kemal University. For the calibration of the ICP-AES as a high multistandard was used. Following absorbtion lines are given in Table 1.

Metal concentrations were calculated in micrograms per gram wet weight (μg/g w.w.). The quality of data was checked by the analysis of standard reference material DORM-2 (National Research Council of Canada; dogfish muscle and liver MA-A-2/TM Fish Flesh) (Table 2). Replicate analyses of reference materials showed good

Table 1: Absorption line and detection limit of metals

Elements	Absorbsiyon line (nm)	Detection limit (ppm)
Cd	226.502	0.015-750
Cr	267.716	0.040-2000
Cu	324.754	0.020-1000
Fe	259.940	0.015-750
Mn	257.610	0.003-150
Pb	220.353	0.14-7000
Zn	213.856	0.009-450

Table 2: 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^{-1})	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
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

accuracy with recovery rates for metals between 96 and 106%. The results showed good agreement between the analytical and the certified values.

Statistical analysis: One-way Analysis of Variance (ANOVA) and Duncan multiple comparison test ($p \leq 0.05$) were used to access whether heavy metal concentrations varied among tissues. A paired t-test is used to compare two stations. The $p<0.05$ were considered to indicate statistical significance. All statistical calculations were performed with SPSS 17.0 for Windows.

RESULTS AND DISCUSSION

The mean values of heavy metals (Cd, Cu, Cr, Pb, Zn, Fe and Mn) in *R. nomadica* tissues (gastral, tentacular and umbrella) from two stations were given in Table 3.

The present study showed that mean concentrations of Cd for all samples ranged from 0.571-1.042 μg metal g^{-1} w.w. The highest Cd concentrations were found in gastral tissue of Arsuz (Table 3). No significant differences were found among tissues within stations ($p>0.05$) whereas the same tissues varied significantly among stations ($p<0.05$).

Data on chromium concentrations in tentacular and umbrella were found same among stations, except gastral tissue in Yumurtalik ($p<0.05$). The chromium concentrations in tentacular tissues of individuals in Arsuz and Yumurtalik were calculated higher than the other tissues.

In this study, the patterns of copper in the selected tissues can be listed as follows in descending order: Copper: Gastral>Tentacular>Umbrella (Table 3). The mean copper concentrations in jellyfish ranged from 2.104-2.841 μg metal g^{-1} w.w. for Arsuz and from

Table 3: Mean concentrations (μg metal g^{-1} w.w.) and Standard Deviations (Mean±SD) of heavy metals (Cd, Cr, Cu, Fe, Ni, Pb and Zn) in the tentacular, gastral and umbrella of *R. nomadica* from two stations

		Tissue metal concentrations, Mean±SD^{a} (μg g^{-1} w.w.)		
Metals	Stations	Tentacular	Gastral	Umbrella
Cd	Arsuz*	0.907±0.106^{ax}	1.042±0.123^{ax}	0.773±0.065^{ax}
	Yumurtalik*	0.600±0.031^{ay}	0.597±0.022^{ay}	0.571±0.025^{ay}
Cr	Arsuz	1.964±0.246^{ax}	1.799±0.355^{ax}	1.882±0.223^{ax}
	Yumurtalik	0.930±0.171^{ax}	0.515±0.132^{ay}	0.840±0.195^{ax}
Cu	Arsuz	2.383±0.279^{ax}	2.841±0.203^{ax}	2.104±0.156^{ax}
	Yumurtalik	2.491±0.177^{ay}	2.739±0.234^{ax}	2.392±0.250^{ay}
Fe	Arsuz	5.481±1.649^{ax}	2.553±0.612^{ax}	2.930±0.474^{ax}
	Yumurtalik	3.779±1.784^{ax}	5.175±1.700^{ay}	1.258±0.856^{ay}
Mn	Arsuz	0.933±0.088^{ax}	1.132±0.127^{bx}	0.770±0.053^{ax}
	Yumurtalik	0.863±0.957^{ax}	0.741±0.649^{ax}	0.257±0.047^{ax}
Pb	Arsuz	1.544±0.235^{ax}	2.039±0.336^{ax}	1.736±0.232^{ax}
	Yumurtalik	0.759±0.132^{ay}	0.792±0.164^{ay}	0.529±0.107^{ay}
Zn	Arsuz	3.761±0.478^{ax}	2.130±0.468^{ax}	5.142±0.496^{bx}
	Yumurtalik	5.701±0.681^{ay}	3.066±0.724^{bx}	6.062±0.241^{ay}

*Each station has 10 jellyfish; [a]Horizontally, letters a-c show differences among tissues. Means with the same letter are not statistically significant, $p>0.05$. [x]Vertically, letters x and y show differences among stations. Means with the same column are not statistically significant, $p>0.05$

2.392-2.739 for Yumurtalik. The highest mean concentration was 2.841 μg metal g^{-1} w.w. in the gastral tissue in Arsuz. The results of the analyses indicated that there were significant differences tentacular and umbrella tissues among stations ($p<0.05$).

Iron levels were observed higher in the tentacular and umbrella tissues than in the gastral in Arsuz whereas lower concentrations of this metal were noted in the umbrella in Yumurtalik (Table 3). The highest iron concentrations (5.481±1.649 μg metal g^{-1} w.w.) were observed in tentacular tissue in Arsuz station. There were significant differences between gastral and umbrella tissues among stations ($p<0.05$) except tentacular tissues of jellyfish between stations ($p>0.05$).

Manganese concentrations varied among tissues ($p<0.05$) and its levels in tentacular, gastral and umbrella of jellyfish were found 0.933, 1.132 and 0.770 μg metal g^{-1} w.w. in Arsuz, respectively. Higher concentrations of Mn were observed in the tentacular than gastral tissue but umbrella was the lowest in Yumurtalik (Table 3).

The highest lead concentrations were found in both Arsuz (2.039 μg metal g^{-1} w.w.) and Yumurtalik (0.792 μg metal g^{-1} w.w.) in the gastral of jellfish. The results indicated that the gastral accumulated more lead than the other tissues (Table 3). Pb levels were significantly different among stations ($p<0.05$) but no statistical differences found between the tissues in Arsuz and Yumurtalik ($p>0.05$).

The zinc content varied from 2.130-6.062 μg metal g^{-1} w.w. In addition, the level of zinc concentrations showed significant differences among the tissues for each station. The highest level of Zn was observed 5.142 and 6.062 μg metal g^{-1} w.w. Arsuz and Yumurtalik in umbrella tissue of jellyfish, respectively.

Table 4: Heavy metal concentration in tissues of scyphozoan jellyfish from literature. Results are mean for tissue type. Indicates concentration as μg metal g^{-1} w.w. Results from present study are the means from all locations (Templeman and Kingsford, 2010)

Species	Location collected	Tissue type	Cd	Cr	Cu	Fe	Mn	Pb	Zn	Source
Pelagia noctiluca	Straits of Messina, Sicily, Italy	Tentacles	0.055	-	0.190	33.000	1.150	0.330	3.010	Cimino *et al.* (1983)
Cassiopea sp.	Gold and Sunshine coasts, Queensland and Darwin, Northern Territory Australia	Umbrella (Bell)	0.008	0.114	0.077	7.120	0.340	-	1.993	Templeman and Kinsford (2010)
		Tentacle (Oral arm)	0.016	0.128	0.146	16.330	0.686	-	4.344	
R. esculentum	Yellow sea	Umbrella	0.020	0.040	0.030	0.060	0.020	0.080	0.610	Liu *et al.* (2012)
		Tentacle (Oral arm)	0.020	0.020	0.030	0.070	0.030	0.090	1.040	
R. nomadica	Arsuz Station (Iskenderun Bay, NE Mediterranean)	Umbrella	0.773	1.882	2.104	2.930	0.770	1.736	5.142	Current study
		Tentacle	0.907	1.964	2.383	5.481	0.933	1.544	3.761	
	Yumurtalik Station (Iskenderun Bay, NE Mediterranean)	Umbrella	0.571	0.840	2.392	1.258	0.257	0.529	6.062	Current study
		Tentacle	0.600	0.930	2.491	3.779	0.863	0.759	5.701	

Previous studies have pointed out that jellyfish are capable of absorbing heavy metals from the environment (Hanaoka *et al*., 2001; Fowler *et al*., 2004; Templeman and Kingsford, 2010; Liu *et al*., 2012). Until now, most of the bioaccumulation studies have done on *Pelagia noctulica*, *Chrysaora melanester*, *Mastigias papua* and *Stromolophus nomurai* in Japon (Hanaoka *et al*., 2001), China (Liu *et al*., 2012), *Cassiopea* sp. in Australia (Templeman and Kingsford, 2010) but a few studies on heavy metal accumulation of jellyfish has been limited whole Mediterranean especially in Northeastern Mediterranean. Romeo *et al*. (1987) and Caurant *et al*. (1999) were studied on whole body of *Pelagia noctulica* and unknown jellyfish species, respectively. Hanaoka *et al*. (2001) were reported only arsenic accumulation by different species in some tissues of jellyfish (Table 4).

Cimino *et al*. (1983) pointed out that cadmium, zinc, copper, lead, manganese and iron concentrations in tentacular tissue of *Pelagica noctiluca* on Mediterranean Sea (Italy) 0.055, 3.01, 0.19, 0.33, 1.15 and 33 μg metal g^{-1} w.w., respectively. The study showed that cadmium and zinc accumulation on tentacular tissue of *R. nomadica* were found similar to compare earlier study. While manganese and iron levels were lower, copper and lead levels were higher than earlier study (Table 4).

Templeman and Kingsford (2010) found that accumulation of heavy metals (Cd, Cr, Cu, Fe, Mn, Pb and Zn) in tentacular tissue of *Pelagia noctiluca* almost two times greater than umbrella (bell) tissue. In present study, there was no significant difference the accumulation of heavy metals on tentacular and umbrella tissues ($p>0.05$), except zinc ($p<0.05$). In the study, concentrations of heavy metals (Cd, Cr, Cu, Mn, Pb and Zn) in all tissues on *R. nomadica* were found higher than *P. noctiluca* but the iron levels were lower than their study. Although, *R. nomadica* and *P. noctiluca* are both jellyfish, the accumulation of heavy metal differences in both jellyfish could be reason for living regions and feeding behaviors (Table 4). Liu *et al.* (2012) showed that all metal concentrations in umbrella and tentacular tissues of *R. esculentum* on yellow sea were lower than present study. This situation can be explained by low levels of heavy metals and discharges in yellow sea.

Aquatic animals may accumulate large amounts of certain metals from water, food or sediment and also it is well known that target organs such as the liver, gonads, kidney and gills are metabolically active tissues and accumulate heavy metals. Some other environmental factors such as the salinity, pH, hardness and temperature play significant roles in metal accumulation (Yilmaz, 2003).

Jellyfish is an aquatic invertabrate which does not have organs and systems. Therefore, it is hard to say this animal could be accumulation of high heavy metals in tissue. But in the study indicated that gastral tissue accumulated high heavy metals (Cd, Cu, Fe, Mn, Pb and Zn) than tentacular and umbrella tissues. The high metal concentrations in the gastral tissue could be reason the metal complexion with the undigested preys that were impossible to remove completely from the tissue.

CONCLUSION

There are many studies about ecological importance and distribution of lessepsian jellyfish *R. nomadica* but the accumulation of heavy metals in this gelatinous organisms studies have been limited in this area. The major findings of this study were that heavy metals concentrations in the tentacular, gastral and umbrella tissues of *R. nomadica* were showed significant variations in both stations (Arsuz and Yumurtalik) in Iskenderun Bay. This study also has shown that *R. nomadica* is capable of accumulating heavy metals according tissues.

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