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Use of marine algae as biological indicator of heavy metal pollution in Turkish marine environment

Türkiye denizel ortamlarında ağır metal kirliliğinin denizel alg türleri ile araştırılması

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Abstract

The heavy metal concentrations were reviewed in marine algae species collected from Turkish marine environment and the new data also given in the marine algae samples at some stations at the Turkish coast of the Mediterranean Sea. Some data also reviewed at the neighbors countries of the Black Sea, Aegean Sea and Mediterranean Sea.

Keywords: Heavy metals, marine algae, Turkish marine environment.

Introduction

Marine algae accumulate heavy metal by means two stages process, consisting first of rapid and reversible physico-chemical process of adsorption on the surface of the algae and then of a slower metabolically arranged intracellular uptake (Garnham et al. 1992).

Therefore, heavy metal concentrations are generally dependent both on the external factors (pH, salinity, inorganic and organic complex

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molecules) and on physico-chemical parameters which control the metabolic rate (temperature, light, oxygen and nutrients). The accumulation of heavy metals in the marine algae is a continuous processes their life span after binding on the external wall, older tissues usually contains higher levels of some heavy metals (Barreiro et al. 1993).

Determination of heavy metal concentrations in marine algae samples is usually preferred in the seawater and sediment samples. Heavy metal concentrations in seawater are very low and show wide fluctuation. At the same time, heavy metal levels in the sediment samples can be changed by organic matter content, grain size composition, pH and oxidation-reduction potential, etc. (Förstner 1985). On the other hand, marine organisms can be used as monitors to give information on concentrations of heavy metals in the surrounding environment. Especially, marine algae species are usually used to indicate heavy metal levels in both estuarine and coastal waters throughout the world. In benthic food webs, marine algae are key links and they act time-integrators of pollutants (Fowler 1979).

Some papers have been published concerning heavy metal levels observed in algae species collected at different stations of the Turkish marine environment at various time after 1979 (Güven et al. 1992a, 1992b, 1993, 1998, Kut et al. 2000, Topcuoğlu 2000, Topcuoğlu et al. 2001, 2002, 2003a,b).

This review presents the concentration of some heavy metals in marine algae samples were generally collected from different stations in Turkish marine environment after 2001. At the same time, the aim of the study is to compare the present results with the similar study which has been carried out in the neighbors countries. Moreover, the unpublished results on the level of Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn also were given in marine algae samples collected from different Turkish Mediterranean coast during 2004.

Eleven different marine algae species: *Cystoseira barbata, Padina pavonia* (brown algae); *Ulva lactuca, Enteromorpha compressa, Cladophora vagabunda, Chaetomorpha gracilis* (green algae);

Antithamnion cruciatum, Corallina mediterranea, Corallina officinalis, Jania rubens, Pterocladia capillacea (red algae) were used in the present study.

A study was published on heavy metal concentrations of marine algae in collected from Turkish Black Sea coast and Bosphorus stations between 1979 and 2001 (Topcuoğlu et al. 2003c). The results of the previous study showed that Cd, Co, Pb, Cu and Mn concentrations of the brown algae in western Black Sea stations showed peak values during 1986 and 1987. Similarly, Pb, Ni, Cu and Mn in the same algae species of the region also showed peak values in 1997 and 1998. The results also showed that the Perşembe brown algae at the eastern Black Sea region were less polluted than the same species collected from the western Black Sea in 1997. On the other hand, Cd, Cu and Zn in Ünye and Pb in Rize algae samples of the eastern Black Sea are higher than western Black Sea region during 2001.

The Cd, Co. Cr, Cu, Fe, Mn, Ni, Pb and Zn concentrations in the some algae species are given from different region of the Black Sea marine environment in the period of 2001-2005 (Table 1). The highest metal accumulation in different marine algae species were: Co, Cr, Cu, Fe, Mn, Ni and Zn in *A. curicuatum*, Cd in *C. gracilis* and Pb in *P. capillacea.* Regarding the areas the highest amounts of Co, Cr, Cu, Fe, Mn, Ni and Zn were found in Sinop, Cd in Bulgarian Black Sea coast and Pb in İğneada. In general, as regards the influence of the collection sites on the whole metal accumulation, Sinop considered to be more polluted than other sites of the Black Sea. The concentrations of the tested heavy metals in *C. barbata* and *U. lactuca* algae species when compared with the previous study in the same species (Topcuoğlu et al. 2004), the results showed that all metal levels gradually decreased during the past years.

The results for heavy metal concentrations in marine algae of the Marmara Sea are shown in Table 2. The highest accumulation in marine algae species were: Cd, Fe, Mn, Ni, Pb and Zn in *U. lactuca* and Co, Cr and Cu in *C. barbata.* Regarding the areas the highest amounts of Co, Cr, Ni and Zn were found in Şarköy, Cd and Pb in Menekşe, Fe and Mn in

Dil İskelesi Station 2, and Cu in M. Ereğli. No comparison could be made regarding heavy metal concentrations of marine algae of Marmara region for different times since these areas had not been investigated before.

The heavy metal concentrations of the marine algae in the Aegean Sea marine environment are shown in Table 3. In general, the heavy metal levels in Thermaikos Gulf of Greece agree well the present data of the Marmara Sea. However, Cd level in the Thermaikos Gulf 4 sample is significantly higher than Marmara Sea algae but lower than at the Sinop algae in the present work.

The results of the heavy metals in two marine algae species in the South Eastern Mediterranean Sea of Egypt are given in Table 4. As it seen, Cd, Fe and Mn concentrations are higher at the EL-Mex Bay than Eastern Harbour. On the other hand, Co, Cu and Zn levels are lower in this Bay than the Eastern Harbour station of the Egypt.

The results for heavy metals concentrations in marine algae samples at the Turkish Mediterranean coast are shown in Table 5. The concentrations of the Cd, Co, Cr, Cu, Fe, Ni, Pb and Zn in the Yumurtalık algae sample are significantly higher than in Fethiye, Iskenderun and Alanya algae samples. The wide variation of heavy metal concentrations among the tested algae species showed that oil pollution and other kinds of pollutants in the Yumurtalık station are significantly higher than that the other stations. On the other hand, Cd and Pb levels in Fethiye, Iskenderun and Alanya and Co in Fethiye and Alanya algae samples were found to be below lower limit detection. At the same time, Cd, Co,Cu and Mn concentrations in Fethiye, Iskenderun and Alanya algae are lower than in the South Eastern coast of Mediterranean Sea (Abdullah and Abdullah 2008). However, Fe and Zn levels in Alanya *U. lactuca* sample are higher than their study but lower than at the Marmara algae that is same species (Topcuoğlu et al. 2004, Ergül et al. 2010).

Table 1. Heavy metal concentrations in marine algae at Black Sea marine environment (μg g^{-1} dry weight).

Station/region and species	Collection date and reference	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
İğneada (*C. barbata*)	2001-2003 Güven et al. 2007	0.13±0.06		2.5±0.3	6.9±0.1		57.2±3		<0.2	8.3±0.1
" (*P.capillacea)*	"	0.03±0.02		2.5±0.4	8.8±0.2		41.7±2		14±2	18±0.2
Bulgarian Black Sea Coast (*C. vagabunda*)	1992-2004 Strezov and Nonova 2009	1.0±0.3		7±1	6±1	1500±310	170±20		3.5±0.7	19±4
" (*C. gracilis)*	"	1.3±0.3		7±1	5±1	520±80	180±20		2.7±0.3	12±2
" (*C. barbata*)	"	0.32±0.03		2.3±0.6	5±1	440±90	47±9		1.4±0.2	17±2
" (*C. officinalis*)	"	0.73±0.24		4.8±0.3	15±2	600±40	55±9		1.4±0.1	13±2
Rize (*U. lactuca*)	2005 Tuzen et al. 2009*	5.00±0.42	2.91±0.16	1.04±0.10	9.52± 0.55	425±24	17.2±1.2	2.16±0.13	1354±50	15.6±1.3
Trabzon (*U. lactuca*)	"	4.04±0.20	6.63±0.47	0.50±0.05	4.95±0.15	277±20	9.98±0.67	2.06±0.11	1.54±0.10	6.50±0.32
Sinop (*U. lactuca*)	"	21.8±1.9	32.2±2.5	1.02±0.10	6.78±0.42	306±25	11.7±1.1	2.72±0.14	22.2±2.1	19.1±1.6
Rize (*A. cruciatum*)	"	17.9±1.4	27.6±2.2	4.13±0.32	6.83±0.34	1524±75	43.5 ± 3.3	2.45±0.17	2768±100	16.2±1.4
Trabzon (*A. cruciatum*)	"	4.63±0.23	4.42±0.32	3.00±0.14	7.74±0.26	2823±150	78.1±4.5	2.80±0.23	146±10	11.6±0.8
Sinop *(A. cruciatum)*	"	44.6±3.5	81.9±5.3	11.6±0.9	17.1±0.9	3949±200	285±10	10.3±0.9	3969±250	48.9±2.8

*Cd, Co and Pb levels are given as μg kg^{-1} by Tüzen et al. (2009).

Table 2. Heavy metal concentrations in marine algae samples at the Marmara Sea (μg g^{-1} dry weight).

Station and Species	Collection date and references	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Şarköy *(C.barbata)*	May 2000, Topçuoğlu et al. 2004	<0.02	1.76±0.20	8.63±0.07	5.2±0.1	1511±1.5	143.6±0.6	12.36±0.14	3.7±0.2	113.5±0.2
Marmara Ereğli *(C.barbata)*	"	<0.02	<0.05	<0.06	164.3±0.8	114±0.1	23.8±0.1	<0.1	<0.1	41.8±0.1
Şarköy *(U.lactuca)*	"	<0.02	<0.05	<0.06	13.7±0.1	189±0.6	13.6±0.1	16.91±0.32	<0.1	151.9±0.6
Marmara Ereğli *(U.lactuca)*	"	<0.02	<0.05	<0.06	8.3±0.1	116±0.1	15.0±0.1	<0.1	<0.1	78.9±0.2
Menekşe *(U.lactuca)*	"	1.10±0.02	1.01±0.21	4.90±1.12	29.1±1.6	2197±7.5	105.2±1.8	8.11±0.12	15.4±1.5	286.4±8.3
Dil İskelesi 1.station *(U.lactuca)*	Spring 2009, Ergül et al. 2010					3351.1±0.10	434.1±0.01		8.8±0.01	214.9±0.01
2.station *(U.lactuca)*	"					1635.6±17.7	78.9±0.01		2.5±0.01	100.4±0.01
1.station *(U.lactuca)*	Summer 2009, Ergül et al. 2010					2305.7±0.60	92.8±0.01		1.6±0.01	98.4±0.01
2.station *(U.lactuca)*	"					732.1±1.10	50.3±0.01		0.5±0.01	153.5±0.10
1.station *(U.lactuca)*	Autumn 2009, Ergül et al. 2010					5229.5±1.10	294.5±0.10		0.5±0.01	149.7±0.01
2.station *(U.lactuca)*	"					5270.1±0.20	219.2±0.10		3.4±0.01	223.4±0.01

Table 3. Heavy metal concentrations in marine algae samples at the Aegean Sea (μg g^{-1} dry weight).

Station and Species	Collection date and references	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Thermaikos Gulf 1(*Ulva sp.*)	1997-1998 Fytianos et al. 1999	4.1±0.93	4.3±2.65	0.5±0.42	373.5±110.7	36.6 ±25.29		40.7±3.12	34.5±10.10
Thermaikos Gulf 2(*Ulva sp.*)	"	4.8±2.31	5.3±3.31	0.5±0.25	362.5±152.9	29.1±14.23		14.5±6.97	35.8 ±20.03
Thermaikos Gulf 3(*Ulva sp.*)	"	6.2±1.93	5.1±2.69	0.5±0.14	479.9±205.7	16.7±10.55		12.0±3.32	49.7±16.12
Thermaikos Gulf 4(*Ulva sp.*)	"	10.7±4.14	9.0±262.17	0.7±0.17	262.2±80.5	31.5±32.97		21.5±10.55	43.6±31.78
Chalkidiki-Kalandra (*C.barbata*)	Sawidis et al. 2001*	0.83		0.80		40.5	14.2	2.5	16.4
Thermaikos-A. Tria (*C.barbata*)	"	0.06		1.70		22.2	9.7	<0.02	29.8
Thermaikos-N. Krini (*U.lactuca*)	"	0.42		7.40		33.3	9.2	<0.02	43.7
Chalkidiki-Kalochor (*U.lactuca*)	"	0.76		11.1		132.3	5.1	<0.02	88.0
Pagastikos-Lohonia *(C.barbata*)	"	2.60		3.20		181.3	28.5	<0.02	58.1
Pagastikos-Lohonia (*U.lactuca*)	"	0.54		9.0		182.0	52.6	<0.02	79.9
Chania *(C.barbata)*	"	2.70		1.70		34.0	16.0	<0.02	27.5
Crete-Chania *(U.lactuca)*	"	1.10		14.5		137.0	13.7	<0.02	56.3

* The collection date and SD not given by Sawidis et al. (2001).

Table 4. Heavy metal concentrations in marine algae samples at the Mediterranean Sea (μg g^{-1} dry weight).

Station and species	Collection date and reference	Cd	Co	Cu	Fe	Mn	Zn
Eastern Harbour, Egypt (*E. compressa*)	2005 and 2008, Abdallah	0.77±1.1	3.08±1.6	20.07±3.2	449.64±36.1	134.89±8.7	37.78±5.8
EL-Mex Bay, Egypt (*E. compressa*)	"	1.61±1.4	15.43±5.5	13.77±7.4	1,628.09±44.4	165.65±36	47.24±3.8
Eastern Harbour, Egypt (*U. lactuca*)	"	1.84±0.93	7.08±1.3	14.52±4.7	514.55±2.1	73.95±4.8	63.10±3.2
EL-Mex Bay, Egypt (*U. lactuca*)	"	0.73±0.24	6.58±1.4	7.24±2.30	709.23±12.7	33.20±3.9	27.38±8.3
Eastern Harbour, Egypt (*J. rubens*)	"	0.63±1.2	16.60±5.1	6.16±1.60	466.65±23.8	71. 43±11.2	28.72±10.4

Table 5. Heavy metal concentrations in marine algae at the Turkish coast of the Mediterranean (μg g^{-1} dry weight).

Station and Species	Collection date	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
Fethiye *(C.officinalis)*	30.12.2004	<0.02	<0.05	3.34±0.41	4.25±0.10	70.07±0.56	43.40±1.15	2.50±0.31	<0.1	31.50±0.59
İskenderun *(J.rubens)*	02.12.2004	<0.02	1.66±0.09	8.80±0.25	3.16±0.04	990.5±54.8	34.26±0.36	21.33±0.04	<0.1	30.17±1.91
Yumurtalık *(C.mediterranea)*	02.12.2004	0.95±0.01	12.96±0.14	94.25±6.35	54.51±1.24	10961.8±179.9	39.33±0.96	157.39±2.57	4.98±2.14	248.97±2.76
Alanya *(P.pavonia)*	01.12.2004	0.57±0.11	<0.05	4.14±0.55	2.50±0.11	520.3±20.6	21.50±0.10	2.38±0.39	<0.1	31.34±5.80
Alanya *(Corralina sp.)*	01.12.2004	<0.02	<0.05	3.39 ±0.63	2.76±0.11	698.6±31.8	47.93±0.55	1.31±0.21	<0.1	41.92±2.25
Fethiye *(U.lactuca)*	30.11.2004	<0.02	<0.05	16.41±1.27	8.06±0.35	474.9±3.4	39.13±0.40	7.54±1.23	<0.1	62.88±3.38
Alanya *(U.lactuca)*	01.12.2004	<0.02	1.69±0.10	6.85±0.48	7.93±0.11	3195.1±12.3	68.02±0.51	5.33±0.24	<0.1	76.37±1.68

Conclusion

The use of marine algae could conveniently be taken for monitoring of heavy metal contamination of coastal marine environment. At the same time, the given results could be useful for comparing these sites of the region with future data of heavy metal pollution. However, the presented results and new data are limited in space and time and further sampling would be needed to follow the seasonal and annual changes.

Özet

Bu çalışmada Türkiye denizel ortamlarından toplanmış olan deniz alg türlerindeki ağır metal konsantrasyonlarını içeren bulgular bir derleme olarak verilmektedir. Ayrıca, Karadeniz, Ege ve Akdeniz kıyılarımıza komşu olan ülkelerdeki bazı veriler de çalışma içine alınmıştır. Diğer taraftan, Akdeniz kıyılarımızdaki bazı istasyonlardan toplanan deniz alg türlerindeki ağır metal düzeyleri de ilk defa bu çalışma ile ortaya konmuştur.

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