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Heavy metal concentrations in marine algae from the Turkish Coast of the Black Sea, during 1979-2001

Karadeniz Kıyısal Ortamından Toplanan Deniz Alglerinde 1979-2001 yılları arasında Ağır Metal Düzeyleri

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Abstract

The heavy metal concentrations in different algae species were reviewed after collection from Black Sea and Bosphorus stations from 1979 to 2001. The results showed that the Turkish Black Sea coast and Bosphorus region faced heavy metal pollution. However, Cd, Co, Cr and Pb levels were found to be below lower limit detection in all tested Black Sea algae species collected in 1998 and 1999. On the other hand, Cd, Cr, Cu, Pb and Zn concentrations increased at the eastern Black Sea stations in 2001. As a result, it can be said that the heavy metal monitoring of marine algae species with reperesentative sampling sites along the Bosphorus and Black Sea Turkish Coast should be continued.

Keywords: Black Sea, Bosphorus, heavy metal, marine algae.

Introduction

At the present time, much attention is being focused on assessing pollution in the Black Sea. The Black Sea have been degraded by

maritime pollution, industrial activity, municipal wastewater, agricultural chemicals and airborne particles. It is well known that advances in the integrations of environmental monitoring, biokinetic and ecotoxicology with dose calculation could make it possible to eventually determine the sensitivity to pollutants of human population and marine organisms. For this purpose, Çekmece Nuclear Research and Training Center and Marine Science Institute of Istanbul University have carried out a collaborative study on heavy metal concentrations in marine algae samples since 1986.

Determination of heavy metal concentration in marine algae samples is usually preferred to the seawater and sediment samples. Heavy metal concentrations in seawater are very low and show wide fluctuations. 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 metal in the surrounding environment. Especially, macrolagae 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 as time-integrators of pollutants (Fowler, 1979). Their sedentary nature is another reason why marine algae species are well fitted as monitor organisms in heavy metal monitoring.

This review presents the concentrations of some selected heavy metals in marine algae samples collected from different stations in the Black Sea during 1979-2001. At the same time, the heavy metal levels are also presented in the Bosphorus algae samples.

The sampling stations of the marine algae at the Turkish Coast of the Black Sea and Bosphorus region are shown in Fig. 1.

Heavy metals are normal constituents of the marine environment and whether essential or not are potentially toxic to organisms when natural concentrations are exceeded. Marine algae accumulate heavy metals by two stage process, consisting first a rapid adsorption on the exterior surface area of the plant and then intracellular uptake by a slow absorption as metabolically (Granharm *et al.*, 1992).

Heavy metals are introduced into the Black Sea through rivers by direct discharge of industrial wastes, agricultural runoffs and municipal usage. In addition, levels of heavy metals in the Black Sea have increased due to oil pollution and airborne contaminants. Moreover, the western Black Sea was polluted by chemical wastes in barrels dumped irresponsibly in 1987-1988 by foreign ships (Topcuoğlu, 2000).

Fifteen species of marinealgae [*Chaetomorpha linum, Ulva rigida, Ulva lactuca, Enteromorpha linum, Enteromorpha compressa, Enteromorpha intestinalis* (green algae); *Cystoseira barbata,* , *Scytosiphon verrucosa* (brown algae); *Phyllophora nervosa, Gracilaria verrucosa, Corallina granifera, Corallina mediterranea, Corallina officinalis, Ceramium rubrum, Pterocladia capillacea* (red algae)] and a species *Zostera marina* (phanerogam) were used in the present reviewed work.

Güven *et al.*, (1992b) determined heavy metal concentrations in the Black Sea algae from 1979 to 1988 (Table 1a). Their study showed that the heavy metal pollution of the Black Sea marine algae generally increased until 1987 and remained more or less constant in 1988. The influence of the locations showed that Sinop generally was more polluted than Şile. The accumulation rate of metals were correlated with different algal taxa as follows: Al, Cr and Fe in green algae; As and Sr in brown algae and Ag, Cd, Co, Cu, Mn, Pb, Se and Zn in red algae.

Güven *et al.*, (1992a) also investigated the metal uptake by The Black Sea algae collected in 1983-1988 as shown in Table 1b. The pollution at different locations according to years were: Green algae; *Ulva rigida* at Sinop in 1986: K, in 1987 all metals except K; *Chaetomorpha linim* at Sinop in 1986: Ba, Ce, Cs, Eu, Hf, K, La, Sc, Sm, Th, Yb. Brown algae; *Cystoseria barbata* in 1987: Rb, Sb, in 1986: Cs, at Şile in 1987: Ba, Ce, Th, Sc, Sb, in 1988: Rb, K, at Sinop in 1986: Ce, Cs, Eu, Hf, K, Rb, Sc, Sm, Th, in 1987: Ba, Sb, Yb, La. Red algae; *Phyllophora nervosa*: in 1983: Ba, K, Lu, Sb, Yb, in 1987: Rb, in 1988: Ce, Eu, Hf, La, Sc, Th; *Gracilaria verrucosa*: at Sinop in 1986: K, in 1987: Ce, Cs, Eu, Hf, La, Rb, Sb, Sc, Sm, Th, Vb; *Pterocladia capillacea*: at Sinop in 1986: K, in: 1987: Hf, La, Rb, Sb, Sc, Sm, Th, Yb. When algae divisions are compared for metal

pollution, green algae was more polluted than the brown and red algae.

The metal concentrations of the algae samples in the Istanbul Region were investigated by Saygı *et al.*, (1994) collected from Sarayburnu, Sarıyer, Kilyos and R.Kavağı in 1989 (Table 2). The results showed no significant differences between the metal values in different algae species. However, Ag, Cd, Co, Cr, Cu, Fe and Mn concentrations in Sarayburnu algae were higher than other algae samples collected from the other stations. On the other hand, Pb level in the Sarayburnu algal sample was lower than the other locations in the same and different algae species. The Bosphorus had been subjected to very high levels of pollution due to industrial and municipal waste disposal. At the same time, the contaminants are introduced through water way into the Bosphorus from the top and bottom currents in the reverse direction.

Güven *et al*, (1993) investigated heavy metal concentrations in five algae and *Zostera marina* (Phanerogam) collected from seven stations in 1990 and 1991 (Table 2). *Z. marina* showed higher metal levels than the tested algae species. In that study it is indicated that the metal accumulation occurred in different algal division: Cd, Cu and Pb in green, Zn in brown and Cr, Fe and Co in red algae. A similar type of study for marine algae species of the Bosphorus stations was carried out by Kut *et al.*, (1998) after collected in 1993 (Table 3). In general, the accumulation of most of the metals showed no direct correlation with algae species. On the other hand, a comparison of the As level among the algae species in that study showed that the brown algae species could be valuable indicator organism from their ability to accumulate arsenic.

Güven *et al.*, (1998) examined heavy metal levels in different algae species after collected from the four stations on the western Black Sea coast during the period of 1991-1993 (Table 3). Their results indicated that the metal concentrations of algae increased generally (with some exception) from 1991 to 1993 in Şile and Sinop. In that study the highest amounts were found for As, Cd, Pb, Sb and Zn in Şile, Cu in Riva and Co, Cr and Fe in İğneada. The correlation of the accumulation of metals with algal divisions were found as follows: Cr,

Pb, Pb and Sb in green algae, As and Cu in brown algae and Cd, Co and Zn in red algae.

Şile is the main station where the investigation on the metal pollution of algae have been carried out since 1979, because it was on the route of water currents coming from the Danube and located near the metropolis of İstanbul. At the same time, the fishing potential of this region was important. For this reason, heavy metal levels were investigated in marine algae species collected from Şile during the period of 1994-1997 (Topcuoğlu *et al.*, 2001)(See Table 4). The study showed that the concentrations of Cd, Co and Cr decreased while Pb increased and Zn, Mn and Cu did not change in *C. barbata* and *Ph. nervosa* collected from Şile during this period. The highest accumulations of different heavy metals in the algal divisions were as follows: Pb and Cu in green, Fe in brown and Cd, Zn, Co, Ni, Mn and Cr in red algae.

During the period 1997-1998, marine algae samples were collected at four stations of the Turkish Black Sea coast in order to establish the level of selected heavy metals (Topcuoğlu *et al.*, 2002). The heavy metal concentrations of the algae are given in Table 4. The Cd and Cr concentrations are higher in *C. barbata* than *U. lactuca* collected from the same station. On the other hand, Co level in *U. lactuca* at Kilyos station is higher than that of the brown algae species. The study also showed that the Perşembe algae were less polluted than those at İğneada, Kilyos and Sinop. No data on the heavy metal concentrations in Pazar stations have been published in literature. Hence, the concentrations of Cd, Pb, Cu, Zn and Mn in marine algae samples at Pazar station were investigated after collected in 1998 (Topcuoğlu *et al.*,2003a). The results showed that the Pazar algae samples were less polluted (except Pb) than Perşembe, Sinop, Şile, Kilyos and İğneada algae samples collected in 1997 and 1998 (Table 4).

Topcuoğlu *et al.*, (2003b) determined heavy metal concentrations in different algae species after collection at Şile and Sinop stations from 1998 to 2000 (Table 5). In general, as regards the influence of the collection sites on the heavy metal accumulation, Sinop was considered to be more polluted than Şile. At the same time, their results showed that Cd, Co, Cr, Ni and Pb levels increased from 1998

to 2000. On the other hand, Cu, Fe, Mn and Zn concentrations decreased during this period at the two stations. Moreover, Cr and Pb concentrations in all marine algae samples tested in 1998 and 1999 were below lower limit detections. In that study it was showed that the highest accumulation of the heavy metals in the algal division were: Cr, Fe and Pb in green algae and Cd, Co, Cu, Mn, Ni and Zn in red algae.

The heavy metal concentrations in marine algae samples in two hot points (Ünye and Rize) at the eastern Black sea were determined after collected in 2001 by Topcuoğlu *et al.*, (2003 a; 2004a). In general, the Phanerogam species (*Z.marina*) showed higher metal concentrations than the tested algae species (Table 6). The Cu concentrations in Ünye algae were higher than similar algae samples collected from Rize. On the other hand, Pb concentrations were higher in Rize. A comparison of the present data in Table 6 with data reported for marine algae in the other stations suggests that the heavy metal levels at Ünye and Rize are not higher than elsewhere. However, if only Cu and Pb data are considered, some opposite trend can be observed.

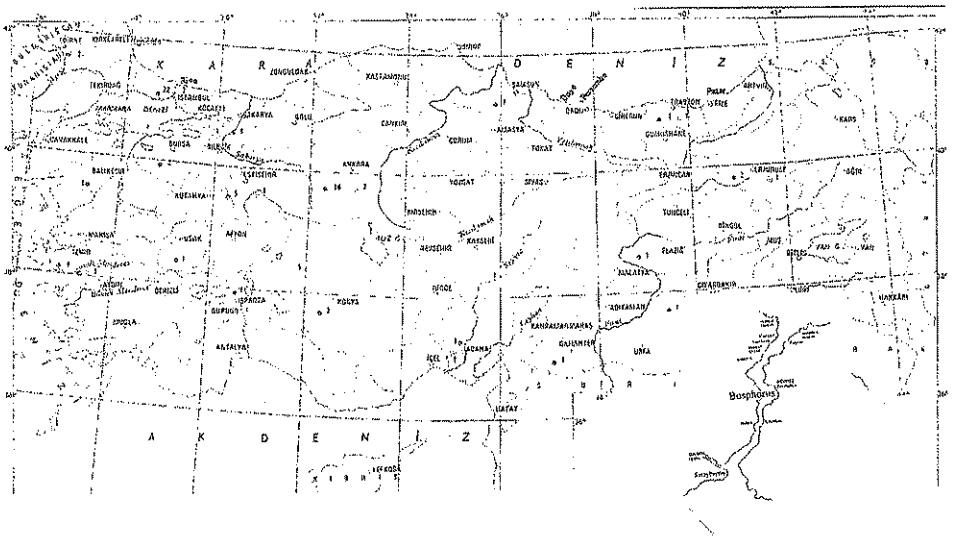

Figure 1. Sampling stations

Table 1a. Heavy metal concentrations of marine algae samples from 1979 to 1988 (µg/g dry weight) (Güven *et al.*, 1992)

Species	Station	Ag	Al	As	Cd	Co	Cr	Cu
C.granifera	Şile 1979	4.8±1.0	350±20	2.9±1.5	6.3±1.4	1.8±0.1	2.1±0.9	3.3±0.5
P.nervosa	Şile 1979	1.6±0.3	1859±105	5.1±3.8	2.6±0.6	6.8±0.2	3.0±0.9	19.5±2.8
P.nervosa	Şile 1983	2.8±0.6	1330±75	15.1±4.6	3.6±0.8	7.6±2.7	3.3±1.0	14.9±2.2
C.granifera	Şile 1984	5.0±1.0	2523±110	4.8±1.5	6.5±1.4	1.3±0.1	3.6±1.0	4.0±0.6
P.nervosa	Şile 1985	2.6±0.5	2344±132	3.2±1.4	3.8±0.8	3.9±0.2	11.5±1.4	16.5±2.4
C.linum	Sinop 1986	1.9±0.3	5906±333	12.8±3.9	3.3±0.7	4.3±1.8	18.2±3.6	6.5±0.9
U.rigida	Sinop 1986	1.7±0.3	1440±81	3.2±2.6	2.2±0.5	2.6±1.1	5.3±1.2	5.7±0.8
C.barbata	Şile 1986	<0.10	520±29	48.4±7.6	1.2±0.3	1.2±0.8	3.8±1.4	4.2±0.6
C.barbata	Sinop 1986	1.8±0.4	4500±254	43.0±7.0	2.4±0.5	5.3±1.7	14.3±1.9	7.9±1.2
P.nervosa	Şile 1986	2.4±0.5	1944±97	0.9±3.8	4.2±1.1	6.6±1.7	8.2±1.7	17.7±3.0
C.granifera	Sinop 1986	4.5±0.9	892±50	2.7±1.5	6.1±1.4	2.3±0.2	4.7±1.3	8.0±1.2
G.verrucosa	Sinop 1986	1.2±0.2	918±52	12.3±5.9	1.0±0.2	1.2±0.5	9.1±1.0	9.1±1.3
P.capillacea	Sinop 1986	1.5±0.3	476±27	2.7±1.6	2.8±0.6	3.4±1.2	2.8±0.9	3.8±0.6
C.linum	Sinop 1987	1.4±0.3	4809±270	5.6±2.6	2.3±0.5	3.2±1.4	14.5±2.8	5.5±0.8
U.rigida	Sinop 1987	1.6±0.3	2007±113	6.4±3.2	2.1±0.5	2.3±1.0	5.9±1.7	4.5±0.7
C.barbata	Şile 1987	1.3±0.3	2214±125	35.8±6.8	2.0±0.5	2.4±1.6	8.5±2.0	879±1.3
C.barbata	Sinop 1987	0.7±0.2	747±254	34.8±4.6	1.4±0.3	2.5±1.1	4.8±1.5	5.7±0.8
P.nervosa	Şile 1987	2.2±0.4	1526±86	7.1±4.0	3.3±0.7	8.2±2.9	6.7±1.2	14.6±2.1
C.granifera	Şile 1987	4.6±0.9	2251±127	2.4±1.4	5.9±1.3	2.6±0.2	6.1±2.4	3.6±0.5
C.granifera	Sinop 1987	3.9±0.8	2521±142	3.6±1.3	5.1±1.1	3.1±0.2	4.9±1.4	3.3±0.5
G.verrucosa	Sinop 1987	1.3±0.3	4003±225	18±12	2.1±0.5	4.7±1.5	10.8±2.4	4.8±0.7
P.capillacea	Sinop 1987	1.3±0.3	1183±67	7.8±2.8	2.5±0.6	3.0±0.9	6.1±1.2	7.8±1.1
C.barbata	Şile 1988	0.6±0.1	541±31	28.0±3.9	2.2±0.5	2.0±0.9	4.8±1.6	3.2±0.5
P.nervosa	Şile 1988	1.3±0.3	1959±110	6.2±2.9	1.8±0.4	6.9±0.9	9.2±0.9	17.2±2.5

Table 1a (Continued)

Species	Station	Fe	Hg	Mn	Pb	Se	Sr	Zn
C.granifera	Şile 1979	443±25	2.6±0.2	35.0±5.2	20.8±0.8	<0.2	1685±290	33.2±1.47
P.nervosa	Şile 1979	882±6.0	3.7±1.4	94.7±14.2	15.3±0.6	<0.2	882±178	83±8.0
P.nervosa	Şile 1983	921±64	<1.5	96.0±14.4	15.5±0.6	<0.2	879±170	85.4±4.3
C.granifera	Şile 1984	206±24	0.4±0.1	16.6±2.5	22.6±0.8	<0.2	1230±213	59.3±2.2
P.nervosa	Şile 1985	1008±150	3.2±1.2	115.4±17.3	21.5±0.8	0.3±0.2	1147±192	71±11
C.linum	Sinop 1986	3506±119	5.6±1.3	55.4±8.3	9.3±0.4	<0.2	230±49	32.4±3.1
U.rigida	Sinop 1986	1021±59	2.5±0.3	25.8±3.9	8.8±0.3	<0.2	147±51	6.0±2.6
C.barbata	Şile 1986	348±15	3.1±1.2	17.4±2.6	5.8±0.2	<0.2	875±152	55.1±11.6
C.barbata	Sinop 1986	3414±744	5.1±1.1	73.3±11	12.8±0.5	0.4±0.2	1727±472	85.8±19.6
P.nervosa	Şile 1986	1127±173	1.9±0.6	92.1±13.3	17.6±0.7	<0.2	677±141	87.7±5.5
C.granifera	Sinop 1986	592±23	2.2±0.2	42.0±6.3	24.6±0.9	<0.2	1177±204	36.8±1.5
G.verrucosa	Sinop 1986	781±68	4.1±1.8	40.4±6.1	6.8±0.2	0.5±0.3	77±40	73.4±16.1
P.capillacea	Sinop 1986	529±44	<1.5	33.2±5.0	6.4±0.2	<0.2	265±58	48.9±3.1
C.linum	Sinop 1987	2578±87	6.2±0.4	48.0±7.2	8.0±0.3	<0.2	76±19	23.9±2.3
U.rigida	Sinop 1987	1298±61	1.9±0.5	28.4±4.2	6.0±0.2	<0.2	242±48	11.9±2.4
C.barbata	Şile 1987	474±55	2.7±0.6	81.6±12.2	8.7±0.3	<0.2	2115±574	69.1±27.9
C.barbata	Sinop 1987	654±39	1.8±0.7	21.7±3.3	6.8±0.3	0.3±0.2	1452±282	64.4±4.7
P.nervosa	Şile 1987	817±49	2.4±0.6	98.3±14.7	12.8±0.5	0.5±0.4	476±77	76.7±3.9
C.granifera	Şile 1987	1395±39	10±6	71.5±10.8	22.1±0.8	<0.2	985±181	55.2±1.5
C.granifera	Sinop 1987	2203±85	<1.5	69.0±10.4	18.4±0.7	0.3±0.2	1240±163	43.2±1.9
G.verrucosa	Sinop 1987	2777±105	<1.5	149.9±22.5	8.0±0.3	<0.2	345±61	31.4±2.6
P.capillacea	Sinop 1987	881±55	10±4	34.7±5.2	9.7±0.4	<0.2	304±71	68.7±3.6
C.barbata	Şile 1988	317±50	<1.5	14.4±2.2	5.3±0.2	<0.2	673±133	36.9±9.3
P.nervosa	Şile 1988	1336±205	<1.5	107.7±16.2	9.5±0.4	<0.2	531±102	98±7

Table 1b. Heavy metal concentrations of marine algae samples from 1979 to 1988 (µg/g dry weight) (Güven *et al.*, 1992)

Algae, Location	Ulva rigida		Chaetomorpha linum	
Date	Sinop		Sinop	
Metal	July 1986	Oct. 1987	July 1986	Oct. 1987
Ba	<20	64±43	44±21	<20
Ce	1,34±0,42	2,88±0,33	4,93±0,42	2,95±0,42
Cs	0,10±0,05	0,13±0,09	0,42±0,14	0,28±0,13
Eu	0,04±0,01	0,05±0,01	0,09±0,02	0,06±0,02
Hf	0,13±0,08	0,22±0,09	0,32±0,09	0,28±0,09
K(%)	2,02±0,41	1,72±0,43	4,93±0,63	3,97±0,67
La	<0,5	1.17±0,63	2,07±0,79	<0,5
Lu	<0,02	0,03±0,02	0,03±0,02	0,03±0,02
Rb	7,0±4,9	11,1±4,9	14,9±4,5	19,2±4,6
Sb	<0,03	0,09±0,02	0,07±0,03	0,08±0,03
Sc	0,36±0,01	0,55±0,03	1,39±0,05	0,88±0,03
Sm	<0,05	0,22±0,12	0,41±0,15	0,23±0,17
Tb	<0,08	<0,08	<0,08	<0,08
Th	0,22±0,09	0,35±0,08	0,69±0,09	0,48±0,08
Yb	<0,06	0,12±0,07	0,22±0,11	0,10±0,05

Table 1b. (Continued)

Location and Collection date	Şile			Sinop	
Metal	Sept. 1985	May. 1986	Juin 1987	Jan. 1988	July 1986	Oct. 1987
Ba	39±15	68±24	96±16	59±42	113±24	137±41
Ce	0,43±0,33	0,77±0,31	0,88±0,31	0,47±0,35	2,99±0,34	1,18±0,31
Cs	<0,10	0,11±0,05	<0,10	<0,10	0,31±0,15	0,11±0,06
Eu	<0,03	<0,03	<0,03	<0,03	0,10±0,03	<0,03
Hf	<0.1	<0,1	<0,1	<0,1	0,24±0,10	<0,1
K(%)	5,68±0,70	4,46±0,52	4,61±0,55	6,56±1,16	5,25±0,63	3,59±0,68
La	<0,5	<0,5	<0,5	<0,5	<0,5	0,79±1,06
Lu	<0,02	<0,02	<0,02	<0,02	0,03±0,02	<0,02
Rb	12,7±4,1	15,7±4,3	16,5±4,9	24,0±5,1	18,7±4,4	12,4±4,0
Sb	0,04±0,02	0,04±0,02	0,08±0,03	0,03±0,02	0,07±0,04	0,10±0,02
Sc	0,02±0,01	0,15±0,01	0,18±0,01	0,07±0,01	1,27±0,07	0,31±0,01
Sm	<0,05	<0,05	<0,05	<0,05	0,40±0,24	<0,05
Tb	<0,08	<0,08	<0,08	<0,08	<0,08	<0,08
Th	<0,05	0,05±0,03	0,07±0,04	<0,05	0,30±0,06	0,15±0,07
Yb	<0,06	0,06±0,04	<0,06	<0,06	0,13±0,06	0,14±0,07

Table 1b. (Continued)

Algae, Location and Collection date / Metal	Phyllophora nervosa				
	Şile Sept. 1979	Şile Sept. 1983	Şile Sept. 1985	Şile Juin 1987	Şile Dec. 1988
Ba	<20	34±17	24±13	<20	23±13
Ce	3,43±0,42	3,62±0,46	2,70±0,30	2,69±0,36	5,03±0,44
Cs	<0,10	<0,10	0,12±0,05	<0,1	<0,10
Eu	0,07±0,02	0,06±0,02	0,08±0,01	0,04±0,01	0,11±0,02
Hf	0,18±0,10	0,43±0,11	0,27±0,07	0,14±0,03	1,14±0,11
K	%1,99±0,42	%2,59±0,40	%0,47±0,13	%1,84±0,39	%1,75±0,30
La	1,02±0,94	2,04±1,41	1,79±0,36	1,00±0,60	2,27±0,44
Lu	0,03±0,02	0,05±0,02	0,02±0,01	0,02±0,01	0,04±0,02
Rb	15,9±5,2	11,2±3,9	3,9±2,7	11,6±4,2	8,0±3,9
Sb	0,33±0,06	0,36±0,08	0,07±0,02	0,07±0,02	0,10±0,02
Sc	0,37±0,01	0,43±0,02	0,31±0,01	0,25±0,02	0,57±0,02
Sm	0,27±0,17	0,37±0,21	0,24±0,15	0,19±0,16	0,43±0,16
Tb	<0,08	<0,08	<0,08	<0,08	0,08±0,04
Th	0,24±0,08	0,39±0,10	0,26±0,06	0,18±0,07	0,46±0,08
Yb	0,20±0,09	0,22±0,15	0,15±0,08	0,09±0,07	0,16±0,06

Table 1b. (Continued)

Algae, Locations and collection date	Gracilaria verrucosa Sinop		Pterocladia capillacea Sinop	
Metal	July 1986	Oct. 1987	July 1986	Oct. 1987
Ba	<20	<20	<20	<20
Ce	0,69±0,22	3,54±0,45	0,60±0,29	2,30±0,33
Cs	<0,10	0,46±0,12	<0,10	<0,10
Eu	<0,03	0,06±0,01	0,03±0,01	0,06±0,01
Hf	<0,1	0,49±0,10	<0,1	0,24±0,09
K(%)	5,35±0,62	3,91±1,09	2,52±0,40	2,42±0,47
La	<0,5	2,56±0,86	<0,5	2,50±1,15
Lu	<0,02	<0,02	<0,02	<0,02
Rb	17,4±6,6	20,7±5,6	8,5±2,9	10,8±4,5
Sb	0,09±0,05	0,10±0,02	<0,03	0,07±0,02
Sc	0,20±0,02	1,20±0,04	0,22±0,01	0,42±0,01
Sm	<0,05	0,25±0,20	<0,05	0,31±0,17
Tb	<0,08	<0,08	<0,08	<0,08
Th	0,07±0,03	0,60±0,10	0,09±0,05	0,21±0,06
Yb	<0,06	0,13±0,06	<0,06	0,09±0,07

Table 1b. (Continued)

Algae, Location and collection date Metal	Corallina granifera Şile May 79	Şile Sept. 1984	Şile Oct. 1987	Sinop July 1986	Sinop Oct. 1987
Ba	<20	<20	25±17	<20	41±31
Ce	1,39±0,20	0,99±0,22	1,75±0,21	0,82±0,16	2,88±0,22
Cs	<0,1	<0,1	0,14±0,07	<0,1	0,18±0,06
Eu	0,05±0,01	0,06±0,01	0,05±0,01	0,03±0,01	0,07±0,02
Hf	<0,1	<0,1	<0,1	<0,1	0,22±0,05
K(%)	0,54±0,15	0,69±0,13	0,28±0,10	0,41±0,11	0,49±0,12
La	0,50±0,46	1,20±0,46	0,96±0,42	0,33±0,23	1,55±0,51
Lu	<0,02	<0,02	0,02±0,01	<0,02	0,02±0,01
Rb	3,6±2,3	<2,7	<2,7	2,7±2,0	5,7±2,3
Sb	0,07±0,02	0,03±0,02	0,03±0,02	0,03±0,01	0,08±0,02
Sc	0,16±0,01	0,10±0,04	0,41±0,01	0,16±0,06	1,03±0,04
Sm	0,21±0,09	0,23±0,08	0,18±0,06	0,13±0,08	0,31±0,09
Tb	<0,08	<0,08	<0,08	<0,08	<0,08
Th	0,13±0,04	0,08±0,04	0,19±0,04	0,10±0,04	0,38±0,05
Yb	0,06±0,04	0,06±0,03	0,11±0,06	0,06±0,03	0,20±0,07

Table 2. Heavy metal concentrations of marine algae samples from 1989 t0 1991 (µg/g dry weight) (1)Saygı *et al.*, 1994; (2) Güven *et al.*,1993;

Species	Station	Ag	Cd	Co	Cr	Cu
E.linza (1)	Sarayburnu 1989	1.4±0.3	2.4±0.5	5.1±1.6	6.7±1.7	13.1±1.9
E.linza (1)	Sarıyer 1989	1.2±0.2	2.0±0.4	4.0±1.1	3.3±0.8	12.2±1.8
U.lactuca (1)	Sarıyer 1989	0.5±0.1	1.6±0.4	3.0±0.8	1.5±0.4	12.2±1.8
E.linza (1)	Kilyos 1989	1.0±0.2	1.9±0.4	4.4±1.2	4.0±1.0	7.0±1.0
E.linza (1)	R.Kavağı 1989	1.0±0.2	1.7±0.4	4.2±1.2	3.4±0.9	7.3±1.1
C.barbata (1)	R.Kavağı 1989	1.0±0.2	1.6±0.4	3.4±0.9	2.1±0.5	6.1±0.9
U.lactuca (2)	Poyraz 1990	0.8 ±0.2	1.0±0.2	2.6±0.6	4.9±1.2	13.1±1.9
C.barbata (2)	Poyraz 1990	0.5±0.1	1.2±0.3	1.1±0.2	2.2±0.6	10.7±1.5
C.rubrum (2)	Garipçe 1990	1.1±0.2	1.6±0.4	4.0±0.9	4.0±1.0	10.8±1.5
U.lactuca (2)	Küçüksu 1990	0.9±0.2	1.3±0.3	4.0±0.8	7.8±2.0	19.8±2.9
U.lactuca (2)	Bebek 1990	0.6±0.1	1.1±0.2	4.1±0.9	3.3±0.8	19.0±2.8
C.barbata (2)	Bebek 1990	0.7±0.1	1.5±0.3	2.6±0.6	3.9±1.0	8.7±1.3
C.rubrum (2)	Bebek 1990	0.9±0.2	2.4±0.5	5.4±1.2	5.4±1.4	22.4±3.7
Z.marina (2)	Altınkum 1990	1.2±0.2	1.9±0.4	5.5±1.2	8.3±2.1	23.4±3.8
Z.marina (2)	Paşabahçe 1990	1.3±0.3	2.3±0.5	7.9±1.8	13.6±3.4	39.8±5.8
U.lactuca (2)	Beykoz 1991	0.6±0.1	1.4±0.3	4.0±1.0	3.0±1.0	13.5±2.0
E.compressa(2)	Beykoz 1991	1.4±0.3	2.5±0.5	4.3±1.0	9.8±2.4	26.8±3.9
C.barbata (2)	Beykoz 1991	0.9±0.2	1.7±0.4	3.3±0.7	4.4±1.1	12.6±1.8
S.lomentaria (2)	Beykoz 1991	0.7±0.1	2.4±0.5	3.5±0.8	5.8±1.5	7.4±1.1
C.rubrum (2)	Beykoz 1991	1.4±0.3	1.3±0.3	6.9±1.6	14.3±3.6	17.0±2.5
U.lactuca (2)	Haliç 1991	0.9±0.2	1.5±0.3	4.0±0.9	4.4±1.1	24.8±3.5
C.barbata (2)	Haliç 1991	0.8±0.2	1.9±0.4	5.6±1.3	6.8±1.7	26.1±3.8
U.lactuca (2)	Sarayburnu 1991	0.8±0.2	1.4±0.3	3.6±0.8	4.1±1.0	21.3±3.1
C.barbata (2)	Sarayburnu 1991	0.6±0.1	1.8±0.4	5.5±1.2	4.0±1.0	12.8±1.9

Table 2.(Continued)

Species	Station	Fe	Mn	Ni	Pb	Zn
E.linza (1)	Sarayburnu 1989	5978±71	33.1±4.1	11.1±1.5	6.1±0.2	40.1±6.8
E.linza (1)	Sarıyer 1989	1847±22	20.9±3.1	6.4±0.9	12.8±0.5	40.7±6.8
U.lactuca (1)	Sarıyer 1989	317±4	9.4±1.4	6.0±0.8	9.7±0.4	20.8±3.5
E.linza (1)	Kilyos 1989	1284±15	17.2±2.6	11.6±1.6	9.6±0.4	24.0±4.0
E.linza (1)	R.kavağı 1989	810.9±10	24.4±3.7	8.8±1.2	10.3±0.4	31.1±5.2
C.barbata (1)	R.Kavağı 1989	742±9	23.2±3.5	7.7±1.0	7.1±0.3	26.2±4.8
U.lactuca (2)	Poyraz 1990	410±5	21.5±3.2	9.0±1.2	6.6±0.2	31.2±2.7
C.barbata (2)	Poyraz 1990	366±4.5	9.0±1.4	12.4±1.7	9.4±0.4	38.0±3.3
C.rubrum (2)	Garipçe 1990	1750±19	14.0±2.1	12.1±1.6	10.4±0.5	31.4±2.8
U.lactuca (2)	Küçüksu 1990	750±8	24.4±3.7	9.1±1.2	11.5±0.5	65.4±5.7
U.lactuca (2)	Bebek 1990	850±10	11.4±1.7	12.4±1.7	9.8±0.4	66.9±5.9
C.barbata (2)	Bebek 1990	855±10	14.6±2.2	13.3±1.8	12.0±0.4	61.9±5.4
C.rubrum (2)	Bebek 1990	1832±21	16.2±2.4	19.8±1.7	15.9±0.6	77.6±6.8
Z.marina (2)	Altınkum 1990	2513±30	38.6±5.8	12.9±1.7	26.1±1.0	48.7±3.6
Z.marina (2)	Paşabahçe 1990	2590±31	45.1±6.8	17.5±2.4	32.1±1.2	91.3±8.0
U.lactuca (2)	Beykoz 1991	436±5	19.3±2.9	16.8±2.3	15.4±0.6	51.3±4.5
E.compressa(2)	Beykoz 1991	1441±17	31.7±4.8	22.8±3.1	18.4±0.6	68.5±6.2
C.barbata (2)	Beykoz 1991	733±9	13.4±2.0	11.5±1.6	14.7±0.6	51.3±4.5
S.lomentaria (2)	Beykoz 1991	1035±12	14.5±2.2	25.1±3.4	16.7±0.6	81.7±7.1
C.rubrum (2)	Beykoz 1991	2879±34	28.8±4.3	25.8±3.5	7.8±0.3	72.8±0.3
U.lactuca (2)	Haliç 1991	785±9	12.5±1.9	13.2±1.8	11.2±0.4	66.9±5.9
C.barbata (2)	Haliç 1991	609±7	8.3±1.2	12.6±1.7	17.4±0.6	78.6±6.9
U.lactuca (2)	Sarayburnu 1991	502±6	11.6±1.3	9.9±1.3	7.7±0.3	51.1±4.5
C.barbata (2)	Sarayburnu 1991	428±5	8.9±1.3	13.2±1.8	9.9±0.4	59.4±15.2

Table 3. Heavy metal concentrations of marine algae samples from 1992 to 1993 (µg/g dry weight)
(1)- Güven *et al.*,1998; (2)-Kut *et al.*,2000

Species	Station	As	Cd	Co	Cr	Cu
P.capillacea (3)	Şile 1991	16.3±4.1	-	13.2±0.8	4.9±2.1	-
C.barbata (1)	Sinop 1993	44.8±8.9	1.3±0.02	0.6±0.1	<1.0	4.2±0.03
C.granifera (1)	Sinop 1993	3.4±2.0	1.0±0.01	1.4±0.1	1.1±0.9	5.5±0.08
P.capillacea (1)	Sinop 1993	4.0±3.3	1.4±0.02	0.6±0.1	<1.0	3.7±0.02
C.linum (1)	Şile 1993	<3.0	0.7±0.02	0.6±0.2	~1.3	6.0±0.1
E.intestinalis (1)	Şile 1993	7.1±4.9	1.0±0.03	0.2±0.1	8.0±2.3	9.6±0.1
U.rigida (1)	Şile 1993	<3.0	0.5±0.02	0.3±0.1	<1.0	3.2±0.04
C.barbata (1)	Şile 1993	77.2±13.9	1.0±0.01	0.7±0.1	<1.0	11.8±0.1
C.officinalis (1)	Şile 1993	2.7±2.0	1.1±0.01	1.3±0.1	1.6±1.0	2.78±0.1
P.capillacea (1)	Şile 1993	9.4±3.8	2.0±0.01	1.2±0.3	<1.0	6.7±0.2
P.nervosa (1)	Şile 1993	<3.0	0.6±0.01	4.7±0.3	2.6±1.8	8.0±0.1
E.intestinalis (1)	Riva 1993	9.2±5.3	0.2±0.01	0.3±0.04	1.4±0.7	4.1±0.05
C.barbata (1)	Riva 1993	67.6±11.9	1.1±0.02	1.1±0.2	3.7±1.1	12.3±0.2
C.officinalis (1)	Riva 1993	4.2±2.4	1.0±0.03	0.6±0.08	<1.0	2.4±0.1
P.capillacea (1)	Riva 1993	4.3±1.3	2.7±0.03	1.6±0.2	<1.0	6.0±0.1
C.linum (1)	İğneada 1993	3.3±2.9	-	4.6±0.3	74.7±7.6	-
E.intestinalis (1)	İğneada 1993	5.3±4.1	-	4.8±0.3	84.7±8.4	-
C.barbata (1)	İğneada 1993	38.5±6.4	-	0.5±0.1	<1.0	-
E.linza (2)	Garipçe 1993	<3.0	0.8±0.01	0.4±0.1	4.7±2.1	8.0±0.1
U.lactuca (2)	Garipçe 1993	<3.0	1.1±0.02	0.3±0.1	<1.0	3.6±0.1
C.barbata (2)	Garipçe 1993	69.1±17.2	0.6±0.01	3.6±0.3	<1.0	5.2±0.1
E.intestinalis (2)	R.Feneri 1993	4.6±3.0	1.1±0.02	1.1±0.2	5.2±2.6	8.4±0.1
U.lactuca (2)	R.Feneri 1993	<3.0	1.1±0.01	0.7±0.1	~1.1	8.8±0.2
C.barbata (2)	R.Feneri 1993	52.6±10.7	1.4±0.02	2.5±0.3	<1.0	4.6±0.3
C.rubrum (2)	R.Feneri 1993	16.4±5.1	0.6±0.02	1.3±0.3	2.1±1.0	7.0±0.01
E.linza (2)	Poyraz 1993	8.8±3.0	0.4±0.01	0.2±0.1	<1.0	6.0±0.02
U.lactuca (2)	Poyraz 1993	5.7±2.4	0.4±0.01	0.2±0.1	<1.0	4.0±0.06
C.barbata (2)	Poyraz 1993	83.5±14.9	0.6±0.01	2.0±0.2	~0.3	6.1±0.02
C.rubrum (2)	Poyraz 1993	4.2±1.8	1.1±0.02	0.8±0.1	~1.3	8.5±0.1

Table 3 (Continued)

Species	Station	Fe	Pb	Zn	Sb
P.capillacea (1)	Şile 1992	866±117	-	48.7±7.5	0.08±0.05
P.nervosa (1)	Şile 1992	878±127	-	69.8±9.5	0.10±0.05
U.lactuca (1)	Sinop 1993	669±148	6.5±0.2	34.2±8.5	~0.03
C.barbata (1)	Sinop 1993	446±88	5.3±2.4	12.1±5.1	<0.03
C.granifera (1)	Sinop 1993	2100±100	4.8±0.4	25.5±4.2	~ 0.04
P.capillacea (1)	Sinop 1993	140±95	<0.5	39.9±5.7	<0.03
C.linum (1)	Şile 1993	631±108	<0.5	35.1±9.4	0.07±0.06
E.intestinalis (1)	Şile 1993	580±98	9.3±1.9	10.1±3.2	0.20±0.08
U.rigida (1)	Şile 1993	122±72	<0.5	<7	<0.03
C.barbata (1)	Şile 1993	124±47	5.5±2.9	18.1±8.0	<0.03
C.officinalis (1)	Şile 1993	520±72	5.8±2.5	21.9±5.3	<0.03
P.capillacea (1)	Şile 1993	194±136	4.3±3.2	98.8±12.5	<0.03
P.nervosa (1)	Şile 1993	748±92	7.5±1.3	38.4±6.6	0.08±0.06
E.intestinalis (1)	Riva 1993	495±65	4.0±1.1	14.4±2.3	<0.03
C.barbata (1)	Riva 1993	604±101	8.3±1.2	7.0±2.8	<0.03
C.officinalis (1)	Riva 1993	188±54	3.8±1.6	10.8±3.8	<0.03
P.capillacea (1)	Riva 1993	~102	5.5±1.0	30.3±6.4	~0.04
C.linum (1)	İğneada 1993	12241±280	-	29.2±7.2	0.12±0.08
E.intestinalis (1)	İğneada 1993	12640±276	-	35.8±6.5	0.18±0.09
C.barbata (1)	İğneada 1993	<100	-	<7	<0.03
E.linza (2)	Garipçe 1993	281±90	7.8±1.8	16.9±5.5	~0.05
U.lactuca (2)	Garipçe 1993	175±78	6.0±0.7	8.5±4.4	<0.03
C.barbata (2)	Garipçe 1993	210±101	4.2±0.5	35.6±6.8	0.11±0.06
E.intestialis (2)	R.Feneri 1993	1064±137	5.3±2.8	12.9±6.2	0.09±0.06
U.lactuca (2)	R.Feneri 1993	475±104	6.5±2.8	<7	<0.03
C.barbata (2)	R.Feneri 1993	216±111	7.3±1.9	12.4±4.2	<0.03
C.rubrum (2)	R.Feneri 1993	702±139	8.7±0.4	14.1±7.5	<0.03
E.linza (2)	Poyraz 1993	241±99	2.0±1.3	15.8±4.5	<0.03
U.lactuca (2)	Poyraz 1993	154±64	2.1±0.1	8.3±5.7	<0.03
C.barbata (2)	Poyraz 1993	615±114	7.5±3.3	27.9±7.7	0.15±0.06
C.rubrum (2)	Poyraz 1993	833±91	5.5±1.7	90.8±11.0	0.19±0.12

Table 4. Heavy metal concentrations of marine algae samples from 1994 to 1998 (µg/g dry weight)
(1) Topçuoğlu *et al.*, 2001; (2) Topçuoğlu *et al.*, 2002; (3) Topçuoğlu *et al.*, 2003a

Species	Station	Cd	Co	Cr	Cu	Fe
P.capillacea (1)	Şile 1994	2.0±0.01	1.2±0.2	1.2±0.01	7.3±0.1	275.4±0.6
P.nervosa (1)	Şile 1994	0.5±0.06	6.3±0.3	-	10.9±0.1	324.1±0.7
E.linza (1)	Şile 1994	0.9±0.08	<0.05	-	7.6±0.01	440.7±0.4
C.barbata (1)	Şile 1995	0.7±0.04	0.9±0.1	-	6.2±0.03	166.6±6.7
P.capillacea (1)	Şile 1995	1.5±0.04	1.6±0.4	-	8.7±0.5	351.7±0.4
P.nervosa (1)	Şile 1995	0.5±0.04	3.6±0.5	-	16.5±0.1	481.8±0.1
C.rubrum (1)	Şile 1995	0.8±0.02	1.4±0.5	-	16.0±0.2	709.5±2.2
U.lactuca (1)	Şile 1995	0.5±0.03	0.9±0.1	-	24.1±0.1	501.5±2.5
C.barbata (1)	Şile 1996	0.3±0.02	0.6±0.5	0.8±0.03	4.8±0.04	526.6±0.5
P.capillacea (1)	Şile 1996	1.3±0.04	0.9±0.2	1.1±0.08	5.4±0.03	258.5±0.5
P.nervosa (1)	Şile 1996	0.5±0.03	3.4±0.1	1.2±0.03	14.5±0.1	448.7±0.5
C.barbata (1)	Şile 1997	0.4±0.01	0.7±0.3	1.0±0.05	6.9±0.1	1066±14.9
P.capillacea (1)	Şile 1997	0.9±0.01	0.8±0.2	1.1±0.11	7.1±0.03	403.3±0.4
P.nervosa (1)	Şile 1997	0.4±0.09	5.0±0.2	0.9±0.07	13.1±0.02	372.1±0.7
C.rubrum (1)	Şile 1997	0.5±0.01	0.6±0.1	1.5±0.08	6.1±0.02	664±0.7
U.lactuca (1)	Şile 1997	0.5±0.01	0.7±0.4	0.5±0.03	5.9±0.04	147.3±0.7
C.barbata (2)	Sinop 1997	<0.02	<0.05	7.8±0.6	8.6±0.1	427±3
U.lactuca (2)	Sinop 1997	<0.02	<0.05	<0.06	9.9±0.1	1127±6
C.barbata (2)	Perşembe 1997	<0.02	<0.05	<0.06	7.3±0.04	310±1
C.barbata (2)	İğneada 1998	6.4±0.1	<0.05	<0.06	12.7±0.1	869±9
U.lactuca (2)	İğneada 1998	<0.02	<0.05	<0.06	10.5±0.1	1929±9
C.barbata (2)	Kilyos 1998	<0.02	2.1±0.3	5.4±0.5	8.9±0.03	511±3
U.lactuca (2)	Kilyos 1998	<0.02	4.0±1.8	<0.06	8.9±0.1	494±16
U.lactuca (3)	Pazar 1998	0.6±0.03	-	-	5.5±2.3	-
C.barbata (3)	Pazar 1998	0.6±0.03	-	-	4.1±2.3	-

Table 4 (Continued)

Species	Station	Mn	Ni	Pb	Zn
P.capillacea (1)	Şile 1994	46.7±0.3	5.3±0.5	6.0±0.8	107.9±0.1
P.nervosa (1)	Şile 1994	296.4±1.2	67.3±0.1	20.0±2.0	95.8±0.2
E.linza (1)	Şile 1994	49.7±0.3	7.0±0.5	3.4±1.7	9.0±0.02
C.barbata (1)	Şile 1995	23.0±0.1	5.9±0.6	1.0±0.1	59.3±0.1
P.capillacea (1)	Şile 1995	71.1±0.1	3.6±0.2	3.0±0.3	82.6±0.1
P.nervosa (1)	Şile 1995	154.0±0.3	83.8±0.3	3.0±1.7	81.9±0.3
C.rubrum (1)	Şile 1995	58.6±0.3	4.3±0.8	10.8±4.4	61.6±0.3
U.lactuca (1)	Şile 1995	49.7±0.3	8.1±0.3	<0.1	24.1±0.1
C.barbata (1)	Şile 1996	22.2±0.1	2.2±0.5	1.0±0.3	50.4±0.2
P.capillacea (1)	Şile 1996	66.8±0.3	4.1±0.2	3.0±0.5	75.7±0.2
P.nervosa (1)	Şile 1996	111.1±0.1	83.2±0.2	4.0±0.7	107.6±0.2
C.barbata (1)	Şile 1997	24.9±0.1	4.5±0.01	14.0±0.8	65.1±0.06
P.capillacea (1)	Şile 1997	72.1±0.3	3.9±0.9	9.5±1.08	97.9±0.3
P.nervosa (1)	Şile 1997	95.4±0.3	64.9±0.5	12.0±0.9	83.7±0.3
C.rubrum (1)	Şile 1997	23.8±0.1	1.9±0.5	10.0±0.11	41.7±0.1
U.lactuca (1)	Şile 1997	12.8±0.1	3.9±0.4	23.5±3.6	35.2±0.1
C.barbata (2)	Sinop 1997	79.9±0.3	10.4±0.1	<0.5	11.4±0.1
U.lactuca (2)	Sinop 1997	82.2±0.6	9.0±0.4	<0.5	72.75±0.2
C.barbata (2)	Perşembe 1997	19.4±0.1	8.4±0.3	<0.5	44.3±0.1
C.barbata (2)	İğneada 1998	46.8±0.2	10.7±0.8	<0.5	94.9±0.2
U.lactuca (2)	İğneada 1998	46.0±0.1	7.9±0.2	<0.5	76.6±0.2
C.barbata (2)	Kilyos 1998	71.9±0.3	8.2±0.3	<0.5	105.5±0.2
U.lactuca (2)	Kilyos 1998	54.0±0.1	8.8±0.1	<0.5	122.9±0.2
U.lactuca (3)	Pazar 1998	5.9±1.7	-	6.9±1.4	12.7±2.3
C.barbata (3)	Pazar 1998	5.4±2.1	-	6.7±1.9	12.0±2.6

Table 5. Heavy metal concentrations of marine algae samples from 1998 to 2000 (µg/g dry weight) (Topçuoğlu et al., 2003b)

Species	Station	Cd	Co	Cr	Cu	Fe
U.lactuca	Şile 1998	<0.02	<0.05	<0.06	13.8±0.05	778
C.barbata	Şile 1998	<0.02	<0.05	<0.06	5.7±0.1	427±3
P.capillacea	Şile 1998	1.5±0.3	<0.05	<0.06	10.3±0.05	158±1
C.mediterranea	Şile 1998	<0.02	<0.05	<0.06	3.1±0.1	595±3
U.lactuca	Sinop 1998	<0.02	<0.05	<0.06	11.3±0.1	902±1
E.linza	Sinop 1998	<0.02	4.5±0.2	<0.06	18.2±0.1	8821±18
C.barbata	Sinop 1998	<0.02	<0.05	<0.06	5.7±0.05	593±4
C.mediterranea	Sinop 1998	<0.02	<0.05	<0.06	4.0±0.04	626±3
C.rubrum	Sinop 1998	1.6±0.1	4.4±0.1	<0.06	16.8±0.1	4988±10
U.lactuca	Şile 1999	<0.02	<0.05	<0.06	3.9±0.05	550±2
C.barbata	Şile 1999	<0.02	<0.05	<0.06	2.2±0.1	130±1
P.capillacea	Şile 1999	1.4±0.1	<0.05	<0.06	5.3±0.2	288±1
P.nervosa	Şile 1999	<0.02	<0.05	<0.06	11.9±0.1	743±5
C.mediterranea	Şile 1999	<0.02	<0.05	<0.06	<0.03	173±1
U.lactuca	Sinop 1999	<0.02	<0.05	<0.06	7.7±0.1	357±1
C.barbata	Sinop 1999	<0.02	<0.05	<0.06	6.0±0.01	590±3
P.capillacea	Sinop 1999	<0.02	<0.05	<0.06	<0.03	407±5
P.nervosa	Sinop 1999	<0.02	9.08±0.5	<0.06	20.1±0.1	1359±26
C.mediterranea	Sinop 1999	<0.02	<0.05	<0.06	3.9±0.1	1508±2
U.rigida	Şile 2000	0.10±0.1	0.3±0.06	1.1±0.2	2.5±0.1	235±15
C.barbata	Şile 2000	0.8±0.1	<0.05	<0.06	3.4±0.1	133±11
P.nervosa	Şile 2000	0.12±0.1	3.1±0.3	1.1±0.1	5.5±0.1	359±37
C.granifera	Şile 2000	0.08±0.1	1.9±0.2	0.9±0.1	0.8±0.01	231±21
C.linum	Sinop 2000	0.03±0.1	0.4±0.1	2.1±0.2	3.4±0.5	1044±15
E.linza	Sinop 2000	0.06±0.1	0.9±0.2	2.3±0.2	2.6±0.2	2656±22
C.barbata	Sinop 2000	0.09±0.1	1.8±0.1	1.2±0.1	1.7±0.02	463±2

Table 5 (Continued)

Species	Station	Mn	Ni	Pb	Zn
U.lactuca	Şile 1998	45.1	9.7±0.2	<0.1	21.2±0.1
C.barbata	Şile 1998	32.1±0.2	9.1±0.1	<0.1	35.1±0.3
P.capillacea	Şile 1998	91.1±0.4	10.8±0.5	<0.1	119.8±0.5
C.mediterranea	Şile 1998	64.7±0.2	<0.1	<0.1	43.4±0.7
U.lactuca	Sinop 1998	41.1±0.1	9.0±0.4	<0.1	13.5±0.1
E.linza	Sinop 1998	192.4±0.2	7.7±0.8	<0.1	43.2±0.2
C.barbata	Sinop 1998	27.3±0.1	7.2±0.1	<0.1	43.9±0.1
C.mediterranea	Sinop 1998	48.5±0.5	<0.1	<0.1	39.3±0.6
C.rubrum	Sinop 1998	249.5±1.0	11.2±0.3	<0.1	58.0±0.1
U.lactuca	Şile 1999	21.8±0.2	<0.1	<0.1	9.6±0.1
C.barbata	Şile 1999	6.7±0.1	<0.1	<0.1	13.9±0.3
P.capillacea	Şile 1999	52.1±0.2	<0.1	<0.1	86.2±0.5
P.nervosa	Şile 1999	88.3±0.3	47.4±1.1	<0.1	71.8±0.4
C.mediterranea	Şile 1999	22.2±0.1	<0.1	<0.1	22.5±0.1
U.lactuca	Sinop 1999	12.5±0.1	<0.1	<0.1	394.4±1.6
C.barbata	Sinop 1999	22.7±0.1	5.7±0.7	<0.1	191.5±0.4
P.capillacea	Sinop 1999	10.8±0.7	<0.1	<0.1	176.8±1.1
P.nervosa	Sinop 1999	364.6±1.8	70.6±1.8	<0.1	54.4±0.3
C.mediterranea	Sinop 1999	56.7±0.2	<0.1	<0.1	19.1±0.1
U.rigida	Şile 2000	9.5±0.3	31.0±1.5	1.3±0.1	3.9±0.3
C.barbata	Şile 2000	12.0±0.2	5.7±0.1	1.4±0.2	21.7±0.1
P.nervosa	Şile 2000	75.8±1.1	70.0±0.3	1.9±0.1	24.0±1.2
C.granifera	Şile 2000	17.9±2.4	4.1±0.2	2.2±0.1	8.9±0.3
C.linum	Sinop 2000	17.2±1.9	12.3±1.6	2.1±0.1	7.7±0.3
E.linza	Sinop 2000	50.1±1.1	24.4±3.5	9.1±0.2	7.1±0.5
C.barbata	Sinop 2000	33.5±3.0	4.7±0.5	3.5±0.4	6.5±0.9

Table 6. Heavy metal concentrations of marine algae samples in 2001 (µg/g dry weight)
(1) Topçuoğlu *et al.*, 2003a; (2) Topçuoğlu *et al.*, 2004a

Species	Station	Cd	Co	Cr	Cu	Fe
U.lactuca (1)	Rize 2001	0.5±0.1	-	-	21.4±0.2	-
C.barbata (1)	Rize 2001	0.7±0.1	-	-	6.3±0.04	-
C.barbata (2)	Ünye 2001	0.8±0.02	<0.05	<0.06	19.2±0.4	0.08%
U.lactuca (2)	Ünye 2001	2.7±0.02	<0.05	2.4±0.3	25.7±0.5	0.2%
Z.marina (2)	Ünye 2001	0.6±0.06	<0.05	<0.06	5.5±0.3	0.03%
Z.marna (2)	Ünye 2001	5.1±0.10	7.8±0.7	<0.06	27.1±0.03	0.1%

Species	Station	Mn	Ni	Pb	Zn
U.lactuca (1)	Rize 2001	20.6±2.6	-	7.7±1.3	36.1±2.3
C.barbata (1)	Rize 2001	22.2±1.3	-	14.1±1.2	61.2±1.1
C.barbata (2)	Ünye 2001	38.5±0.1	6.7±0.2	<0.1	76.03±0.2
U.lactuca (2)	Ünye 2001	80.2±0.3	4.3±0.2	<0.1	349.7±27.6
Z.marina (2)	Ünye 2001	99.76±0.5	5.3±0.4	<0.1	14.0±0.1
Z.marina (2)	Ünye 2001	436.1±4.0	17.2±0.1	15.8±0.6	109.8±0.3

Conclusion

The present results on heavy metal concentrations in marine algae samples have provided information on the interaction of these metals with algae species, which is the key question in reviewing the fate of the pollution in Black Sea and Bosphorus region during past twenty years. In the light of the results the following conclusions can be drawn :

1. In general, Cd, Co, Pb, Cu and Mn concentrations of the brown algae (C. Barbata) in the 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 high heavy metal levels in the C. Barbata samples gradually decreased after 1997 or 1998. The results also showed that the Perşembe algae (C.barbata) were less polluted than the same species collected from the western Black Sea in 1997. On the other hand, Cd, Cr, Cu, and Zn in Ünye and Cu and Pb in Rize algae samples increased in 2001. That meant that the data in the eastern Black Sea were limited in space and time and further sampling would be needed to follow annual changes in the eastern Black Sea.

2. The collection sites had influenced the accumulation of metals in marine algae. Sinop station was more polluted than Şile. The results also showed that the metal concentrations of the Black Sea algae were higher than Bosphorus and Marmara Sea algae. On the other hand, Cu and Mn in C.barbara and Cr in U.lactuca species at the Black Sea and Bosphorus

stations were lower than Marmara Sea algae collected in 2000 (Topcuoğlu et al., 2004b).

3. The presented results indicated that the heavy metal uptakes in marine algae species were irregular. However, the concentration of As in C. barbata was found to be regular.

4. This review shows that determination of heavy metal concentrations of marine algae samples through the years is a good indicator of the contamination of the Turkish marine environment. The phanerogam species (Z.marina) has also been a subject of pollution surveys and could be considered as an alternative species.

Özet

1979-2001 yılları arasında Karadeniz ve Boğaziçi'nden toplanan deniz alg örneklerinde saptanan ağır metal bulguları bu makalede verilmiştir. Bu sonuçlara gore Karadeniz ve Boğaziçi ağır metal kirliliğine maruzdur. Bu arada Cd, Co, Cr ve Pb düzeyleri 1998 ve 1999 yıllarında analizi yapılan tüm Karadeniz deniz alglerinde tayin limiti altında bulunmuştur. Buna karşılık, Cd, Cr, Cu, Pb ve Zn konsantrasyonları 2001 yılı Doğu Karadeniz örneklerinde giderek artmıştır. Zira midyeler belli sürelerde metali tutup sonra salıverirler, algler ise ağır metali yığıştırırlar, bu sebebten bu tayinlerde alglerin kullanılması uygundur.

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