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The element concentrations and enrichment factors of sediments in West Marmara Sea Ports

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ABSTRACT

In this study, the concentration of various elements in marine sediments from Western Marmara Sea Ports has been analyzed and evaluated as well as correlated with similar studies completed earlier in the Western Marmara Sea region by using all the available data. Enrichment factor calculations made according to world average values were also calculated according to Western Marmara background values. In enrichment factor (EF) calculations EF > 3 was found in Cu and Mn calculations in M.Ereğlisi. In M.Ereğlisi, Şarköy and Menekşe the enrichment factor is 1 < EF < 3, and element enrichment is moderate or less in these regions. In the analysis EFZn > 3 in core 1–2, EfAs > 3 in core 10–13, core 14–16, core 18–19, and core 29 also EF > 3 in the enrichment factor analysis for As. In the analysis for Co is EFCo > 3 in core 8–29 samples. Ni enrichment was obtained as EFNi > 3 in core 16–29 samples and EF < 1 and 1 < EF < 3 in all other samples. In enrichment factor calculations using West Marmara Sea background values, it was calculated as EFCu > 3 in core 2 and 12, and EFMn > 3 is for core 1. In other enrichment factor calculations in ports and other locations, all elements were calculated as EF < 1 in some locations and 1 < EF < 3 in some locations. This means that there is little or moderate enrichment according to the latest data. This means that there is little or moderate enrichment in all locations. The reason for the more enrichment of Ni and Mn elements in some locations in the Western Marmara Sea is thought to be anthropogenic.

Keywords: West Marmara Sea; Heavy metals; Enrichment factor; Environmental analysis

1. Introduction

Seas constitute the largest water bodies that meet people's water need. Water sources, which were only used for the needs of households and agricultural activities when the industry was not developed, started to be consumed rapidly after the industrial revolution. Seas, apart from being water sources, have also been recipients of waste. As the receiving capacity was very high at first, the contamination in the environment and collapse of the ecological balance were not comprehended, whereas with time passing, the water sources would become scarce through time and the contamination of the existing ones has highlighted the collapse.

According to European Union legislation, aquatic environment pollutants are classified into two groups as toxic substances and substances with permanent and bioaccumulative properties (SÇO/2000/60/EC). Heavy metals, which constitute one of the most important contaminating parameters, both reveal toxicity and are accumulated while not breaking down in the recipient environment. Heavy metals, which enter the sea along with the contaminating sources, do not break down biologically but are accumulated in the sediment or living organisms [1–3]. Heavy metals can originate from natural or anthropogenic sources. The most effective sources for heavy metals to go into the recipient environment are industrial wastewater, wrong fertilizing and pesticides, mining activities, ports, and exhaust gas release [4,5]. A heavy load of contaminants is released into seas from ports. Uncontrolled ballast and bilge water released into the sea from ships, waste from freight, and petroleum leaks are the most important reasons for contamination in the ports [5].

Sediment is the most important piece in the aquatic environment. The contamination that occurs in the sediment, which is a source of food and living space for living organisms, would highly affect the living creatures in that environment. In this respect, the research on the sediment quality for the determination of aquatic environment contamination has emerged in recent years as an extremely important and stringent research subject. There has been a number of studies concerning the research about the heavy metal contamination of the sediment [6–13]. In this study, heavy metal contamination has been determined by taking nine core samples from ports which are among the most important sources of contamination in the Western Marmara Sea (Fig. 1). The sentence has been changed as "The results obtained were compared with the results of previous studies". These previous studies were done by Yümün [7]) and Topcuoğlu et al. [14]. In addition, the enrichment factor was calculated by the use of these results. World average background values were studied by Mason and Moore [15]; Islam et al. [16]; Turekian and Wedepohl [17]. In these studies, As values were used as 18, 18, and 13 ppm, respectively. Background values used by Mason and Moore [15] were also used in this study (Table 9). In addition In the West Marmara Sea, drilling samples were taken at one point by Yümün and Önce [18] and from three different points by Yümün [7], and geochemical analysis were done. In order to represent the background values of the Western Marmara Sea sediments, the average values of the values obtained from these studies are given in Table 9.

2. Material and method

Nine sediment samples were taken from the ports in the study area (Tekirdağ Barbaros Port, Tekirdağ Marmara Ereğlisi Port, Tekirdağ Süleymanpaşa Port, Çanakkale Municipality Yacht Port, Çanakkale Lapseki Port, Çanakkale Gelibolu Port, İstanbul Silivri Port, Erdek Port and Balıkesir Bandırma Yacht Port) (Table 1).

For comparison with the samples obtained from the ports of the West Marmara Sea, the samples of the cores between Bandırma (Balıkesir) and Çanakkale-Silivri (İstanbul) were taken from Yümün [7] and in Şarköy (Tekirdağ), M.Ereğlisi (Tekirdağ) and Menekşe (Fatih/İstanbul) locations were taken from Topcuoğlu et al. [14]. Sampling methods from the sea are core sampler, drilling sampler, and grap sampler methods. The core sampling method (Grap Sampler Method) was used because it is a practical and economical method. The enrichment factors were calculated by using heavy metal concentrations of all locations. Thus, heavy metal contamination in the ports and other coasts of the West Marmara Sea was examined comparatively. The location map and coordinates of sediment samples taken in this study are given in Fig. 1, Table 1, and the Coordinates of Yümün [7] are given in Table 2.

In order to perform the geochemical analysis, the samples were first milled. The geochemical analysis of these ground samples (Fe, Zn, Al, Mn, As, B, Cd, Co, Cr, Cu, Ni, Na, Mg, K, Ca, P, Bi, Mo, Pb, Pt, Sb, Sn, Se, Hg and etc.) was carried out using the SPECTROBLUE Model induced matched plasma-optic emission spectrometer (ICP-OES) device. In ICP-OES typical detection limit is between 1–10 ppb. Using the results of the heavy metal analysis, the enrichment factor (EF) of the metals (Zn, As, Co, Cu, Ni, Pb, and Mn) has been calculated. The enrichment factor is a widely used value in the evaluation of different environments over time and in the calculation of anthropogenic additives in metal pollution [19–21].

The enrichment factor is calculated using the following formula:

$$\mathrm{EF} = \left(\frac{C_n / C_{\mathrm{ref}}}{B_n / B_{\mathrm{ref}}} \right) \tag{1}$$

In this formula, EF is the enrichment factor, C_n is the metal value measured in the study, C_{ref} is the value of the working metal in the reference medium (sediment), B_n is the measured value of the reference element in operation and B_{ref} is the value of the reference element in the reference environment (shell). The calculated EF value result is close to 1 (EF < 1) depending on the shell origin. There is a small amount of enrichment from 1 to 3 crustal origin. The fact that

Table 1
Depth and coordinates of core samples obtained from the study area

Core sample number	Depth (m)	Geographic position (WGS-84)	
		Y	*X*
(LM-1) Tekirdağ (Barbaros) Port	15	539546.14	4527947.89
(LM-2) Tekirdağ (M.Ereğlisi) Port	22	582550.33	4537387.45
(LM-3) Tekirdağ (Süleymanpaşa) Port	19.5	542704.65	4534548.40
(LM-4) Çanakkale Belediyesi Port	22.5	449276.29	4444854.67
(LM-5) Çanakkale (Lapseki) Port	18.5	473040.03	4466504.92
(LM-6) Çanakkale (Gelibolu) Port	20.5	471826.01	4472819.58
(LM-7) Bandırma Port	18.5	582270.28	4468063.95
(LM-8) Silivri Port	15.5	604130.38	4547597.85
(LM-9) Erdek Port	17.5	567029.42	4471806.49

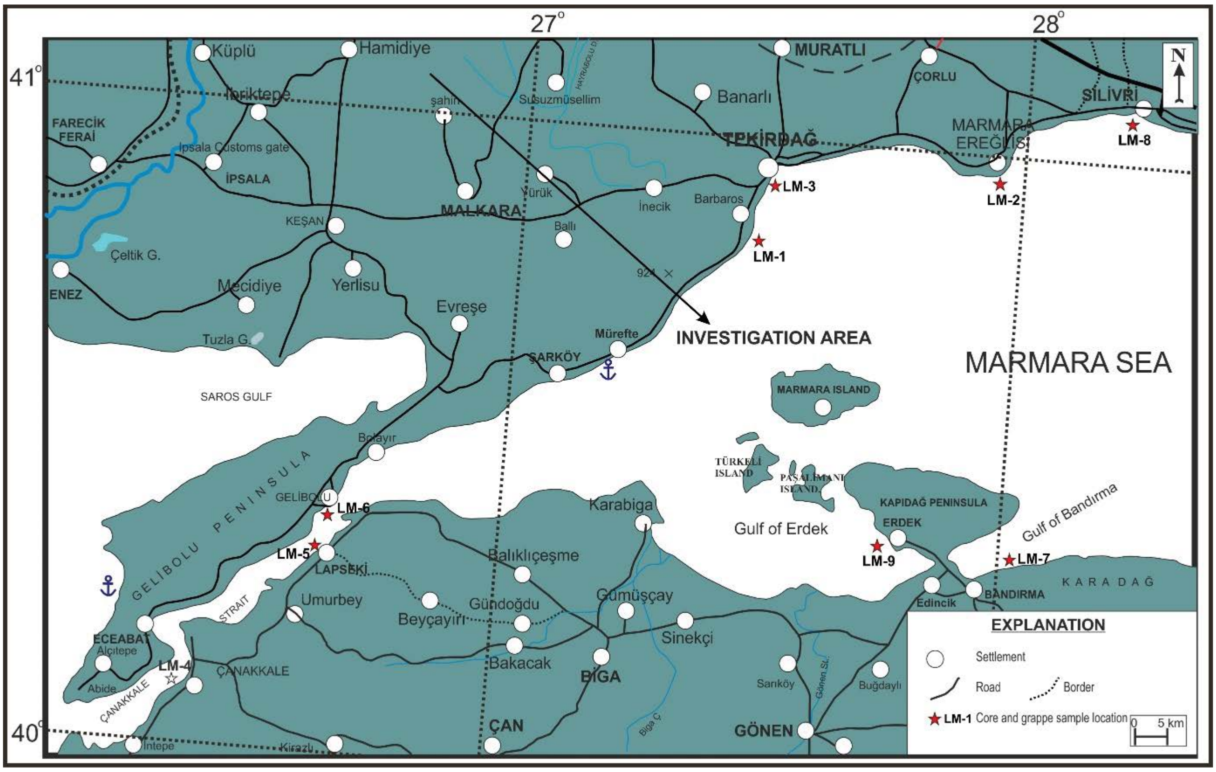

Fig. 1. Location map of investigation area and sample locations.

Table 2
Depth and coordinates of 29 core samples between Marmara Sea Silivri and Bandırma [7]

Core sample number	Depth (m)	Geographic position (WGS-84)		Core sample number	Depth (m)	Geographic position (WGS-84)	
		Y	*X*			*Y*	*X*
Core 1	30	0581459	4474677	Core 16	43	0472908	4472487
Core 2	29	0584985	4476692	Core 17	26	0488099	4481025
Core 3	30	0588105	4481639	Core 18	41	0511008	4494809
Core 4	30	0582393	4483551	Core 19	30	0540197	4522435
Core 5	38	0577401	4485335	Core 20	33	0542591	4530386
Core 6	40	0566840	4486334	Core 21	32	0546815	4533986
Core 7	48	0562101	4486810	Core 22	30	0560139	4536953
Core 8	39,5	0558197	4484862	Core 23	32	0569767	4535792
Core 9	28	0558282	4480129	Core 24	33	0580368	4533824
Core 10	19	05562 81	4463687	Core 25	33	0588549	4541739
Core 11	26	0542436	4464634	Core 26	32	0596782	4544493
Core 12	18	0528796	4470648	Core 27	30	0603222	4545684
Core 13	46	0514452	4478784	Core 28	31	0540197	4522435
Core 14	29	0490282	4473347	Core 29	25	0540095	4541896
Core 15	36	0473914	4469971				

the enrichment values are between 3 and 5 is controversial depending on the shell origin. EF > 5 values are considered to be non-shell origin [22,23]. In the calculation and evaluation of this factor, unlike other pollution indices, normalization is performed by selecting a reference element. Although there is no definite acceptance in the selection of the element to be applied for normalization, it is generally used in geochemically inactive materials such as aluminum, iron, lithium, zirconium, and titanium, which can be easily encountered in fine-grained materials [22] and [24–28].

Table 3
Element analysis results of West Marmara Sea Ports

Samples	Element Concentrations (ppm)															
	Zn	Mn	As	B	Co	Cr	Cu	Ni	Sb	P	Al	Fe	Na	Mg	K	Ca
LM-1	115	651	18.4	45.6	54.5	80.4	18.9	250.4	2.30	490	28,940	37,881	4,891	3,941	2,971	50,960
LM-2	85.6	695	22.5	48.9	64.7	92.8	20.5	225.6	2.10	416	30,255	45,761	5,064	4,160	2,571	48,650
LM-3	96.7	581	14.8	39.6	52.5	75.8	16.7	195.6	1.70	426	35,620	42,981	4,533	4,221	2,691	45,961
LM-4	109.5	613	16.7	40.9	51.9	82.6	17.9	210.6	1.50	399	38,650	41,890	4,261	4,063	2,790	45,621
LM-5	92.7	591	12.7	41.6	49.7	84.8	19.7	230.5	1.90	373	40,560	39,651	4,366	3,871	3,261	43,901
LM-6	88.9	498	18.8	43.8	53.7	79.5	20.6	226.3	1.60	410.8	41,564	40,598	4,051	3,966	3,565	42,651
LM-7	82.7	471	15.7	46.3	61.5	72.5	22.5	230.7	1.90	388	42,561	41,651	3,971	4,051	2,961	49,871
LM-8	88.9	457	19.8	42.6	62.7	75.9	23.6	250.8	2.00	397	4,357	43,621	3,897	3,679	2,880	47,908
LM-9	85.3	462	15.7	41.6	60.9	72.6	21.4	249.3	1.90	387	4,266	41,562	4,057	3,547	2,568	45,632
Earth crust (Mason and Moore [15])	70.0	–	18.0	–	25.0	–	55.0	75.0	–	–	–	50,000	–	950	–	–

Table 4
Element analysis results of 29 core samples in West Marmara Sea

Samples	Element concentrations (ppm)															
	Zn	Mn	As	B	Co	Cr	Cu	Ni	Sb	P	Al	Fe	Na	Mg	K	Ca
Core-1	90.0	1,974	23.1	36.1	84.1	89.6	25.5	223	2.23	469	24,522	38,779	2,657	5,104	3,217	62,475
Core-2	95.0	509	20.4	40.5	89.2	95.1	28.3	237	3.94	425	26,694	39,821	3,465	5,367	3,913	22,870
Core-3	105	511	19.2	44.3	91.4	98.6	28.1	244	2.68	469	27,784	41,544	3,912	5,691	4,324	16,987
Core-4	191	400	22.9	42.8	48.8	49.9	22.9	112	2.33	407	15,697	28,392	3,042	3,717	1,892	93,491
Core-5	226	443	20.1	43.8	54.7	60.6	21.2	134	2.82	403	19,561	29,171	3,396	4,115	2,751	78,906
Core-6	205	505	24.0	52.3	65.6	80.5	24.7	159	3.91	437	20,416	35,742	3,891	4,659	3,627	90,173
Core-7	99.4	386	19.8	80.8	62.9	48.7	15.6	78.5	2.79	408	26,954	34,743	7,956	5,753	7,055	38,647
Core-8	97.5	339	20.4	66.6	71.4	57.1	18.5	72.8	3.41	533	27,589	36,833	6,214	5,592	6,899	44,717
Core-9	62.9	294	23.8	63.8	44.6	28.5	11.6	45.0	2.14	324	19,592	24,426	6,789	4,395	4,337	82,889
Core-10	126	369	81.0	65.8	74.4	49.7	31.2	72.8	6.33	727	27,511	41,733	7,557	4,844	5,030	14,280
Core-11	200	339	67.9	104	80.2	67.7	31.4	93.7	4.98	606	29,108	45,093	10,660	5,846	6,046	13,938
Core-12	321	690	91.4	101	109	116	52.5	171	7.34	685	31,749	58,647	10,227	7,802	6,719	15,253
Core-13	112	414	42.1	81.1	61.8	66.4	22.5	117	2.89	376	24,851	34,352	9,376	5,661	5,582	61,444
Core-14	79.6	308	47.2	80.1	53.1	44.0	22.0	87.0	3.89	401	21,585	29,664	8,261	6,054	4,341	116,603
Core-15	98.5	359	81.1	86.5	63.3	69.1	24.3	121	7.51	414	24,322	34,765	8,745	5,594	4,781	42,405
Core-16	83.8	465	46.6	102.4	60.9	78.9	22.2	155	3.69	440	23,653	31,169	8,759	7,161	5,537	65,945
Core-17	59.2	321	31.8	113	45.9	61.9	15.9	121	2.90	372	20,963	25,975	12,385	9,569	5,283	194,094
Core-18	92.6	581	44.2	88.1	78.6	112	22.5	217	3.04	515	24,236	37,398	7,615	8,993	5,653	66,032
Core-19	94.7	508	39.8	88.4	77.7	106	21.6	213	2.89	454	23,723	36,989	8,130	8,579	5,653	54,287
Core-20	87.4	332	23.9	82.4	61.7	81.0	21.2	172	2.62	460	23,368	33,355	7,893	6,352	5,172	49,661
Core-21	76.4	416	29.9	69.7	65.9	79.2	18.4	176	2.90	398	21,551	31,759	6,606	6,908	4,407	51,711
Core-22	74.7	387	26.9	73.8	64.2	81.5	17.1	168	1.94	397	21,896	31,733	6,605	6,617	4,755	55,815
Core-23	54.1	229	29.7	91.5	41.1	52.1	11.4	113	2.36	330	20,515	24,098	8,513	6,869	4,534	154,577
Core-24	69.2	304	20.8	92.1	54.1	67.8	14.5	147	3.31	371	22,557	29,658	10,340	6,681	5,004	68,214
Core-25	51.8	223	23.1	74.8	42.9	51.5	11.2	107	2.05	330	20,183	23,867	7,063	5,033	4,046	84,885
Core-26	49.1	160	17.6	65.2	32.7	32.9	8.83	82.6	2.64	208	15,939	19,381	6,420	4,595	3,116	99,718
Core-27	77.3	327	27.1	117.8	55.5	80.6	18.2	157	2.92	330	25,266	31,778	15,359	7,385	6,893	77,610
Core-28	46.9	194	22.6	88.3	37.1	42.5	10.3	98.6	2.59	308	18,610	21,509	8,902	6,010	4,042	157,686
Core 29	36.0	156	20.5	85.7	32.6	41.6	8.60	97.6	1.9.0	281	19,756	22,546	7,626	5,242	4,550	12,697

3. Results

Table 3 shows the results of the heavy metal analysis of the sediment samples taken from the seabed in ports in the West Marmara Sea. Yümün [7] from the West Marmara Sea sediment samples taken from the analysis results are given in Table 4.

Heavy metal analyzes of sediments taken from the Western Marmara Sea (Şarköy (Tekirdağ), M.Ereğlisi (Tekirdağ) and Menekşe (Fatih/İstanbul)) by Topcuoğlu et al. [14] were also compiled and interpreted (Table 5). The enrichment factors of the study area were calculated using the element concentration values given in Tables 3–5. The calculated enrichment factors are given in Tables 6–8. Background values suggested by Mason and Moore [15] are given in the calculation of enrichment factors. The crust values used in the enrichment factor calculations are given in Table 9. Enrichment factor calculations made according to world average values were also calculated according to Western Marmara background values (Table 9). The enrichment factors obtained according to these calculations are given in Tables 8 and 9.

4. Conclusion and discussion

The founding of the present study points out that due to the intensive agricultural activities carried out in the vicinity of the sea, the surface waters rich in element flowing into the sea caused pollution of the sea. The obtained results of EFCo and EFNi values to vary between 1 to 3 and 3 to 5, respectively, in the Western Marmara Sea samples show that both elements are in the enrichment level. Nickel is a very abundant element in the structure of some nitrogenous and phosphorus fertilizers such as arsenic. Furthermore, the interfusion rate to the environment via industrial activities is high.

The enrichment of Mn and Ni in Şarköy, M.Ereğlisi and Menekşe was found out to be of 1 < EFMn < 3, which is at a moderate level. The Co, N, Zn, and Co enrichment in Şarköy was determined to be at a moderate level of 1 < EF < 3, whereas that of Cu was found out to have a low-level enrichment factor. In M.Ereğlisi, the enrichment factor was found out as 3 < EFMn, were Zn, Co, and Cu were determined to have a high-level enrichment, and in Menekşe a low-level of Co, a moderate level of Cu, and a high level of Zn enrichment was observed. In enrichment factor calculations using West Marmara Sea background values, EF > 3 was found in Cu and Mn calculations in M.Ereğlisi. Here, enrichment was determined according to both methods. However, in other locations (M.Ereğlisi, Şarköy, and Menekşe) the enrichment factor is 1 < EF < 3, and element enrichment is little or moderate observed in these regions.

In the analyzes made using the ground shell data as background, it is seen that different reconstitutions occur in Marmara Sea samples (core 1–29). In the analysis made for Zn EFZn > 3 in core 1–2, core 10–13, core 14–16, core 18–19 and core 29 also EFAs > 3 in the analysis for As; in the analysis for Co, EFCo > 3 in core 8–29 samples. Ni enrichment was obtained as EFNi > 3 in core 16–29 samples and EFNi < 1 and 1 < EFNi < 3 in all other analyzes.

Table 5
Element analysis results of sediment samples taken from Şarköy (Tekirdağ), M.Ereğlisi (Tekirdağ) and Menekşe (Fatih/İstanbul) locations [14]

Sample	Zn (ppm)	Mn (ppm)	Cd (ppm)	Co (ppm)	Cr (ppm)	Cu (ppm)	Ni (ppm)	Pb (ppm)	Fe (ppm)
Şarköy	43.6	373	<0.02	11.1	61.5	12.7	53.9	22.7	14,896
M.Ereğlisi	34.1	274	<0.02	10.5	27.2	30.6	20.5	31.9	5,956
Menekşe	50.9	384	0.50	4.30	54.5	16.8	41.3	21.6	11,875

Table 6
Enrichment factor calculations for sediment samples taken from West Marmara Sea Ports

EF analysis	Zn		As		Co		Cu		Ni		Mn	
	*	**	*	**	*	**	*	**	*	**	*	**
LM-1	2.10	1.15	1.34	0.50	2.80	1.07	0.50	1.02	4.40	2.64	0.90	1.48
LM-2	1.30	0.71	1.37	0.50	2.90	1.53	0.40	1.87	3.30	1.97	0.80	1.31
LM-3	1.60	0.85	0.95	0.35	2.40	1.22	0.40	1.61	3.10	1.82	0.70	1.16
LM-4	1.80	0.99	1.1	0.41	2.40	1.26	0.40	1.74	3.40	2.01	0.70	1.26
LM-5	1.70	0.88	0.9	0.33	2.50	0.93	0.50	1.01	3.90	2.32	0.80	1.28
LM-6	1.60	0.83	1.3	0.47	2.70	0.98	0.50	1.04	3.70	2.23	0.70	1.06
LM-7	1.40	0.75	1	0.39	2.90	1.09	0.50	1.10	3.70	2.21	0.60	0.97
LM-8	1.50	0.77	1.26	0.46	2.90	1.06	0.50	1.10	3.80	2.30	0.60	0.90
LM-9	1.40	0.78	1.05	0.39	2.90	1.09	0.50	1.05	4.00	2.40	0.60	0.96

*According to Earth background value of Earth [15] and **Earth background value of Marmara Sea [7,18].

Table 7
Element enrichment factors of sediment samples taken from Şarköy (Tekirdağ), M.Ereğlisi (Tekirdağ) and Menekşe (Fatih/İstanbul) locations

EF analysis	Zn		Co		Cu		Ni		Mn	
	*	**	*	**	*	**	*	**	*	**
Şarköy	2.10	1.11	1.50	0.55	0.80	1.74	2.40	1.45	1.30	2.16
M.Ereğlisi	4.10	2.16	3.50	1.31	4.60	10.48	2.30	1.38	2.40	3.96
Menekşe	3.10	1.62	0.70	0.27	1.30	2.89	2.30	1.39	1.70	2.78

*According to Earth background value of Earth [15] and **Earth background value of Marmara Sea [7,18].

Table 8
Enrichment factor values of 10 core samples (core 1–29) from the Marmara Sea

EF analysis	Zn		As		Co		Cu		Ni		Mn	
	*	**	*	**	*	**	*	**	*	**	*	**
Core-1	0.90	0.88	0.99	0.61	2.60	1.61	0.35	1.34	2.30	2.30	1.60	4.38
Core-2	1.10	0.90	0.903	0.52	2.80	1.63	0.41	5.49	2.50	2.38	0.42	1.10
Core-3	1.20	0.96	0.89	0.47	3.20	1.58	0.43	7.35	2.70	2.35	0.45	1.06
Core-4	1.55	2.54	0.72	0.83	1.1.0	1.29	0.23	1.09	0.85	1.58	0.23	1.21
Core-5	1.90	2.93	0.652	0.71	1.30	1.39	0.22	1.48	1.04	1.84	0.27	1.31
Core-6	2.10	2.17	0.954	0.69	1.90	1.36	0.32	1.41	1.52	1.78	0.38	1.22
Core-7	0.98	1.08	0.76	0.58	1.75	1.34	0.19	0.92	0.73	0.90	0.28	0.96
Core-8	1.90	1.00	1.54	0.57	3.90	1.44	0.46	1.02	1.32	0.79	0.48	0.79
Core-9	1.84	0.97	2.7	1.00	3.70	1.35	0.43	0.97	1.23	0.74	0.63	1.04
Core-10	2.16	1.14	5.39	1.99	3.60	1.32	0.68	1.53	1.16	0.70	0.46	0.76
Core-11	3.17	1.68	4.19	1.54	3.55	1.32	0.63	1.42	1.40	0.83	0.39	0.65
Core-12	3.90	2.07	4.33	1.59	3.72	1.37	0.81	15.28	1.94	1.17	0.62	1.01
Core-13	2.30	1.23	3.4	1.25	3.60	1.07	0.59	1.63	2.30	1.36	0.63	1.04
Core-14	1.90	1.01	4.42	1.63	3.60	0.86	0.67	0.84	1.96	1.17	0.55	0.89
Core-15	2.02	1.07	6.47	2.39	3.60	1.35	0.64	1.43	2.32	1.39	0.54	0.89
Core-16	1.90	1.02	4.15	1.53	3.90	1.45	0.64	1.45	3.30	1.99	0.78	1.28
Core-17	1.60	0.86	3.4	1.25	3.50	1.31	0.56	1.25	3.10	1.86	0.65	1.06
Core-18	1.70	0.94	3.28	1.21	4.20	1.56	0.54	1.23	3.80	2.32	0.81	1.34
Core-19	1.80	0.97	3.93	1.10	4.20	1.56	0.53	1.19	3.90	2.30	0.72	1.18
Core-20	1.80	0.99	1.99	0.73	3.70	1.37	0.58	1.30	3.43	2.06	0.52	0.86
Core-21	1.70	0.91	2.61	0.96	4.10	0.94	0.52	1.58	3.70	2.21	0.69	1.13
Core-22	1.70	0.89	2.36	0.87	4.00	0.95	0.50	1.36	3.53	2.12	0.64	1.05
Core-23	1.60	0.85	3.42	1.26	3.40	0.59	0.43	0.33	3.13	1.87	0.50	0.82
Core-24	1.70	0.88	1.95	0.72	3.70	1.35	0.44	1.00	3.30	1.98	0.54	0.88
Core-25	1.60	0.82	2.68	0.99	3.60	1.33	0.43	0.96	3.20	1.79	0.50	0.80
Core-26	1.80	0.96	2.52	0.93	3.40	1.25	0.41	0.93	2.80	1.70	0.43	0.71
Core-27	1.73	0.92	2.37	0.87	3.50	1.29	0.50	1.17	3.30	1.97	0.54	0.89
Core-28	1.60	0.82	2.9	1.08	3.50	1.28	0.43	0.98	3.10	1.83	0.50	0.78
Core-29	1.40	0.60	3.17	0.93	3.70	1.07	0.40	0.78	3.40	1.73	0.40	0.60

*According to Earth background value of Earth [15] and **Earth background value of Marmara Sea [7,18].

In enrichment factor calculations using West Marmara Sea background values, it was calculated as EF > 3 in core 2 and 12 for Cu and core 1 for Mn. In other enrichment factor calculations, all elements were calculated as EF < 1 in some locations and 1 < EF < 3 in some locations. This means that there is little or moderate enrichment according to the latest data.

In the enrichment factor calculations for samples taken in 9 ports in the Western Marmara Sea, calculations were made using both the Earth's crust and the background data of the Western Marmara Sea (Table 9). In enrichment factor calculations made according to the background values of the Earth crust in all ports, it was found to be EF > 3 for Ni. In enrichment factor calculations using West Marmara

Table 9
Background value of Earth crust [15], background value of Marmara Sea [7,18]

	Fe(%)	Mn (ppm)	Co (ppm)	Ni (ppm)	Cu (ppm)	Zn (ppm)	As (ppm)
Earth crust (Mason and Moore [15])	50,000	950	25	75	55	70	18
Yümün [7] and Yümün and Önce [18]	27,844.32	323.42	37.6	69.67	13.65	73.67	27.21

Sea background values, all elements were calculated as EF < 1 in some locations and 1 < EF < 3 in some locations. This means that there is little or moderate enrichment in all locations.

The enrichment factor of the sediment of some harbors being higher than 3 does not mean that the element is enriched by anthropogenic sources. Elements can get into the environment through industrial wastewater as well as through intense agricultural activities. Ni is thought to occur as provided by the ship and industrial wastes and also by natural resources. In addition, the probability of entering this element into nature through industrial activities is also high.

In the enrichment factor calculations made in this study, it is important for the sensitivity of the study that the enrichment factors obtained by using West Marmara and Earth crust background values are close to each other.

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