

Element Contamination and Probable Ecological Concern in Surface Sediments of the Black Sea's İğneada Coasts

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Abstract

Enrichments of metals in surface sediments from İğneada shores of the Black Sea were analysed to define the level of contamination in the region. For this purposes, Cd, Hg, Pb, Cu, Cr, Ni, Zn, Mn, Al and Fe levels in surface sediments were studied from 6 stations. Sediment samples were collected using a Van Veen grab. Elemental analyses in sediments were measured by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). The concentrations of metals varied from 0.031 to 0.091 for Cd; 0.025 to 0.064 for Hg; 3.32 to 7.88 for Pb; 5.75 to 13.42 for Cu; 25.63 to 40.07 for Cr; 14.8 to 28.2 for Ni; 18.29 to 33.21 for Zn; 268 to 377 for Mn; 10,987 to 17,101 for Al; and 11,521 to 20,700 mg·kg⁻¹ for Fe mg·kg⁻¹ dry wt. Metal levels were found to be much lower than recommended levels when compared to Sediment Quality Criteria for surface sediments. Enrichment Factors (EF), Geo-Accumulation Index (I_{geo}) and Pollution Load Index (PLI) were applied to the data for assessing the sediment quality. EF values were nearly between 0.33 and 2.4. Mostly EF for metals were less than 2, may be come from natural weathering processes or crustal substances, indicate no enrichment. However, some results of EF values slightly exceeding 2 indicate moderate enrichment. These rates aren't thought to be important. I_{geo} values for all metals were less than 0 at all stations, suggesting that the İğneada shores was uncontaminated by these studied metals. PLI values ranged from 0.410 in station I to 0.747 in station IV, indicating that İğneada shores in the Black Sea were less impacted by these metals. PLI value for zone was found as 0.553665002. The I_{geo} and PLI values also suggest that surface sediments in İğneada shores of the Black Sea is uncontaminated.

Keywords: İğneada, Black Sea, Metal, Sediment quality guidelines, Enrichment factor, Geoaccumulation index, Pollution load index

Introduction

İğneada is located on the Black Sea coast in North-Western Turkey, close to the Turkish-Bulgarian national border. It is a small town in Turkey's Kırklareli Province, located in the Demirköy district. It is positioned on the Black Sea shore, about 5 km South of the Rezovo River, which forms the Bulgarian boundary. The region has been designated as one of Turkey's maximal significant flora and fauna areas. Different ecosystems and a diverse range of biodiversity can be found in Turkey [1,2], it is now 1 of Turkey's most significant regions. This region and its surroundings have distinct characteristics; the different types of wild forests that can be met in the İğneada have been affected by human activities in other parts of Turkey and Europe. It is an international level Important Bird Area since it is situated on major bird migration routes between Europe and Africa. The key occupations of the town's residents are forestry, fishing and tourism. On the other side of the line, there are parallels [3,4].

Tok *et al.* [5] pointed out that cross-border cooperation at the local level between 2 or more countries has been established, especially in the last 2 decades, with the goal of supporting the further growth of economic potential. Until now, border regions have been extremely sensitive. This new approach, as well as the financial support it receives from the European Union and other global organizations, emphasizes the long-term sustainable use of natural resources and the preservation of biological diversity. It is the case of the long-term use of the trans-border possible biosphere reserve area in Stranja Mountain between Bulgaria and Turkey. The Seville Strategy for Biosphere Reserves is considered to include the legal structure of Bulgaria and Turkey in the sense of trans-border nature

conservation, the importance of the Acquis in the field of natural habitat conservation, and the protection of wild fauna and flora [5].

The great biological and ecological diversity of the İğneada area is extremely significant in terms of natural conservation. Ecologists, scientists and administrators face a major challenge in reducing human impact on natural resources. The most significant negative effect on habitats in the İğneada area is that forest work and fishing are the primary sources of income for locals [5]. A comprehensive study is expected to be more realistic to obtain more details about the environment. Furthermore, residents started to sell their land to people who wanted to build holiday residences in the area, resulting in a new origin of contamination [5].

The absence of contamination indicator species among the species known from the region, particularly the presence of Syllidae (Polychaeta) species that have a distribution in clear waters and the dominance of *Pisidia longimana* (Crustacea), suggests that the area is free of contamination stress. On Turkey's Black Sea coast Öztürk *et al.* [6], proposed 5 Marine Protected Areas. The İğneada seaside region, as well as a terrestrial part, Strandja, which is found between Turkey and Bulgaria, is 1 of the proposed potential areas. The terrestrial portion of İğneada is so far preserved on account of its special wetlands on alluvial soils, floodplain forests and beaches [6].

A project has also been suggested for the designation of a Black Sea Transboundary Protected Area between Turkey and Bulgaria. It will count in the Strandja preserved area on the Bulgarian side, and the İğneada protected area on the Turkish side. The region is part of the NATURA 2000 network on the Bulgarian side. It is largely free of direct pollution from major land-based sources on the Bulgarian side and is still thought to have well-saved ecosystems in well environment condition [7]. The area is known for its abundance of fish, mammals, invertebrates, birds and plants. There are a variety of species there that are vital to the conservation of the Black Sea. The region is scientifically significant, and it can also be used as a reference zone since it is still relatively undisturbed. Furthermore, if the region is held in its natural state, environmentally sustainable tourism, scuba diving, non-commercial fishing, aquatic sports, photography and other activities could be of interest to the public [3,4].

The proposed area in Turkish waters has never been thoroughly studied, and no preserved region in marine waters or coastal have ever been designated or proposed here. It is inevitable to investigate the ecological quality of such an important region. However, the Black Sea is still under pressure from multiple contaminants. Increased quantities of land-based nutrients and other contaminants have increased the human activities on these ecosystems as coastal areas of the Black Sea have grown. Undoubtedly, metals are among the most important of these [8]. Metals continue to be reach into coastal ecosystems in the Black Sea through major rivers, land-based sources and runoff [9]. This has resulted to accumulation of contaminants especially metals in shore waters. In line with international commitments at the universal and areal levels, 1 of the principal goals of the MSFD (Marine Strategy Framework Directive) is to prevent and lessen loads to the oceanic environment with the aim of phased-out contamination. The aim of the GES (Good Environmental Status) assessment under the MSFD 2008/56/EC Descriptor 8 is to make that the amounts of contaminants in oceanic environments must not cause contamination [10].

The part of the marine environment most susceptible to metal accumulation is commonly thought to be sediment [11,12]. The ability to accumulate these substances is affected by the sediment's form, chemical and physical properties, especially the content of silt and clay fractions and organic content, as well as the nature of the individual element. Metals are normally not biodegradable or leachable and have a high environmental resilience. Metals in sediment may come from both natural and man-made sources. Both direct and indirect human activities are related to metal accumulation in sediment surface layers. Metals that are anthropogenically produced can be transported through the air, deposited on the sediment surface, and then penetrate deep into the sediment profile. Metals in sediment could be connected to the location of manufacturing plants or transportation routes [8]. Especially through rivers metals reach the seas and eventually sediments and accumulate there. Metals in sediment are almost definitely influenced by land-based waste [9].

The amounts of metals in surface sediments of the İğneada shores of the Black Sea were investigated in this study. The study's goals were to: (a) determine metal levels (Cd, Hg, Pb, Cu, Cr, Ni, Zn, Mn, Al and Fe); (b) determine the degree of contamination with these metals; and (c) equate metal levels to SQGs (Sediment Quality Guidelines). Various environmental indices can be used to assess the distribution of metals in various compartments and the severity of contamination in marine systems. In this current study Enrichment Factors (EF), Geo-Accumulation Index (I_{geo}) and Pollution Load Index (PLI) were applied to the data for assessing the sediment quality.

Materials and methods

Study area

Field sampling was performed out in the frame of the MSFD Guiding Improvements in the Black Sea Integrated Monitoring System (MISIS) project. Six sampling stations in İğneada shores in the Black Sea were selected (**Figure 1**), coordinates, depths and substrate type of sampling stations were presented in **Table 1**.

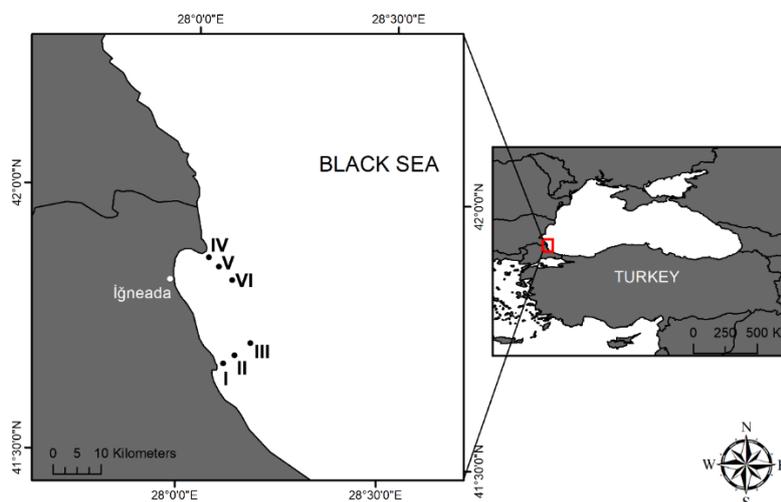


Figure 1 Study region.

Temperature, salinity, pH and dissolved oxygen using a multiparameter device (YSI-6600V) were obtained as physicochemical parameters during the study. Secchi Disc depths were measured at the stations.

Sediment samples were collected using a Van Veen grab. At each station, 3 surface sediment (0 - 5 cm) samples were taken by scraping the surface layer by using a clean plastic spoon. All sample's surface sediments were put in polyethylene plastic bags and held preserved in a box with ice. The samples for assessment were dried by using an air-circulating oven at 105 °C for a day and kept in an acid-washed containers for future use.

Table 1 Coordinates, depths and substrate type of sampling stations.

Stn.	Latitude (N)	Longitude (E)	Depths (m)	Substrate type
I.	41°52'10"	27°59'10"	5	fine sand + coarse sand
II.	41°52'05"	27°59'24"	10	fine sand + coarse sand + shells
III.	41°52'13"	28°00'15"	20	fine sand + coarse sand
IV.	41°52'50"	28°02'43"	5	fine sand + silt
V.	41°52'39"	28°02'40"	10	fine sand + coarse sand + shells
VI.	41°52'14"	28°02'44"	20	fine sand + coarse sand

Metal analysis

The contents of Cd, Hg, Pb, Cu, Cr, Ni, Zn, Mn, Al and Fe was determined in the surface sediments of İğneada shores in the Black Sea. Accredited ACME Analytical Laboratories Ltd used 4 acid digestion and ultra-trace ICP-MS (Inductively Coupled Plasma-Mass Spectrometry) method to perform metal assay (apart from Hg) in all subsampling crushed to 85 % crossing 200 mesh (Vancouver, Canada). For Hg

research, the ultra-trace Aqua Regia digestion method was used. For each determination, the mean values of triplicates were analyzed.

The quality control was used to examine sediment samples. Background noise, accuracy and precision are measured using blanks (analytical and procedure), duplicates and standard reference materials put into the sequences of client samples. Quartz sample-prep blank(s) are carried through all steps of preparation and analysis as the first sample(s) in the job, according to the QA/QC protocol. As a control for analytical procedures, a reagent blank was employed to measure background and an aliquot of Certified Reference Material (STD OREAS24P) was utilized to evaluate accuracy.

Pollution indices

Three indices, Enrichment Factor (EF), Geoaccumulation Index (I_{geo}) and Pollution Load Index (PLI) were estimated to evaluate the degree of sediment contamination at the area of Iğneada shores.

Enrichment factor (EF)

To distinguish natural from anthropogenic components in this analysis, Fe was used as a reference metal, and EF was estimated using the below equation;

$$EF = \frac{\left(\frac{Me}{Fe}\right)_{\text{sample}}}{\left(\frac{Me}{Fe}\right)_{\text{background}}}$$

The ratio of metal and Fe amounts in the sample is $\left(\frac{Me}{Fe}\right)_{\text{sample}}$, and the ratio of background metal and Fe amounts is $\left(\frac{Me}{Fe}\right)_{\text{background}}$. In addition, the average crust element concentrations were used as a background [13].

For EF, Sutherland [14] proposes a system of preliminary 5 categories: $EF < 2$ indicates no enrichment, $2 \leq EF \leq 5$ is moderate enrichment, $5 \leq EF \leq 20$ is significant enrichment, $20 \leq EF \leq 40$ is very highly enriched, $EF \geq 40$ is extremely enrichment.

Geoaccumulation index (I_{geo})

The geo-accumulation index is a standard criterion for assessing metal contamination in sediments [15]. Since the late 1969s, the geo-accumulation index (I_{geo}) has been used extensively in European metal studies [16,17]. The geoaccumulation index is determined using the following equation to assess metal toxicity in sediments from the Iğneada shores;

$$I_{geo} = \log_2 \left| \frac{C_{\text{sample}}}{1.5 \times C_{\text{background}}} \right|$$

where C_{sample} denotes the calculated concentration of samples, $C_{\text{background}}$ denotes the background level of sediments, and factor 1.5 denotes the potential for anthropogenic impacts on background data. From unpolluted to extremely contaminated, the geo-accumulation index (I_{geo}) scale has 7 grades from 0 to 6 [18]; Grade 0 (uncontaminated, $I_{geo} \leq 0$), grade 1 (uncontaminated to moderately contaminated, $0 < I_{geo} \leq 1$), grade 2 (moderately contaminated, $1 < I_{geo} \leq 2$), grade 3 (moderately to heavily contaminated, $2 < I_{geo} \leq 3$), grade 4 (heavily contaminated, $3 < I_{geo} \leq 4$), grade 5 (heavily to extremely contaminated, $4 < I_{geo} \leq 5$) and grade 6 (extremely contaminated), $I_{geo} > 5$.

Pollution load index (PLI)

The quality of the sediment samples is determined using the pollution load index, which is defined as the n^{th} root of the multiplicity of the presumed contaminants. The PLI shows how contaminated the sediment is an indication of the overall toxicity of the sediment [19]. PLI is estimated using the formula below;

$$PLI = \sqrt[n]{CF_1 \times CF_2 \times \dots \times CF_n}$$

where CF is the ratio of the measured metals' mean concentrations to their background concentrations in the sediment. n is the total number of CF values. n , which stands for number of metals in this analysis, is 9. Pollution Load Index for zone is calculated as the following equation;

$$PLI = \sqrt[n]{\text{Station}_I \times \text{Station}_{II} \times \dots \times \text{Station}_n}$$

Contamination factors for Cd, Hg, Pb, Cu, Cr, Ni, Zn, Mn and Al are used to produce 6 stations and zone indices, and these indices are then multiplied and 9 rooted to give the Pollution Load Index for İğneada shores. The 0 value of the index indicates perfection, only a fundamental value is contaminant levels, and values above one (1) indicate that the quality is getting worse [19].

Results and discussion

Physicochemical parameters in waters of İğneada shores in the Black Sea

The obtained values of physicochemical values in İğneada coastal waters of the Black Sea are given in **Table 2**.

Table 2 Physicochemical variables of the İğneada coastal waters.

Seasons	Temp (°C)	Salinity (ppt)	pH	DO (mg·L ⁻¹)
Winter	15.04 ± 0.22	17.93 ± 0.11	8.28 ± 0.03	8.71 ± 0.63
Spring	15.55 ± 0.15	16.51 ± 0.44	8.51 ± 0.11	9.91 ± 0.65
Summer	23.8 ± 1.28	15.61 ± 0.64	6.93 ± 0.06	8.03 ± 0.63
Autumn	18.5 ± 0.17	18.26 ± 0.02	6.87 ± 0.02	8.01 ± 0.17

The maximum temperature values were 24.36 °C recorded in July. The water temperatures of İğneada coast were within Water Pollution Control Regulations of 25687 the Official Gazette Environment Law (< 25 °C) for water [20]. Salinity values were particularly low during summer, and high in autumn. The maximum salinity value (18.26 ± 0.02) was obtained in October. pH value measured at stations ranged between 6.87 ± 0.02 and 8.51 ± 0.11. The pH values were below the standards maximum above 80 % of oxygen saturation set by the Turkish Environmental Regulation [20], for General Quality Criteria of Marine Water for pH levels. The maximum dissolved oxygen value obtained in the sampling period was found to be as 9.91 ± 0.65 mg·L⁻¹ (May) and the minimum oxygen value was found as 9.91 ± 0.65 mg·L⁻¹ (October). To Quality Criteria of Recreational Coasts and Marine Water, since dissolved oxygen levels measured in each season are higher than 8, it is class 1 [20].

Secchi Disc (SD) depth graphs of the sampling stations were given in **Figure 2**. The biggest Secchi Disc depth was found at station III in winter (November). The lowest Secchi Disc depth was found at station V in autumn (October). Secchi Disc depths are measured low, which means the waters are turbid.

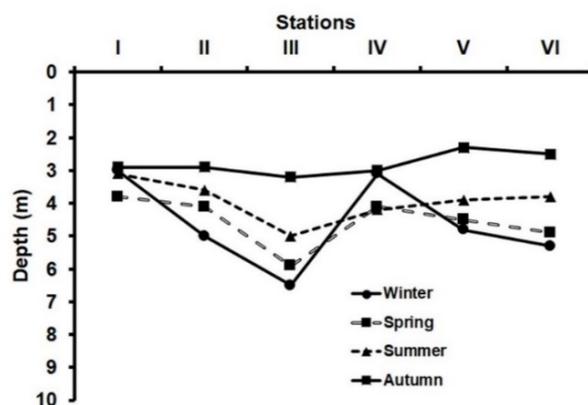


Figure 2 Depths of the Secchi Disc (m) at sampling stations during sampling seasons.

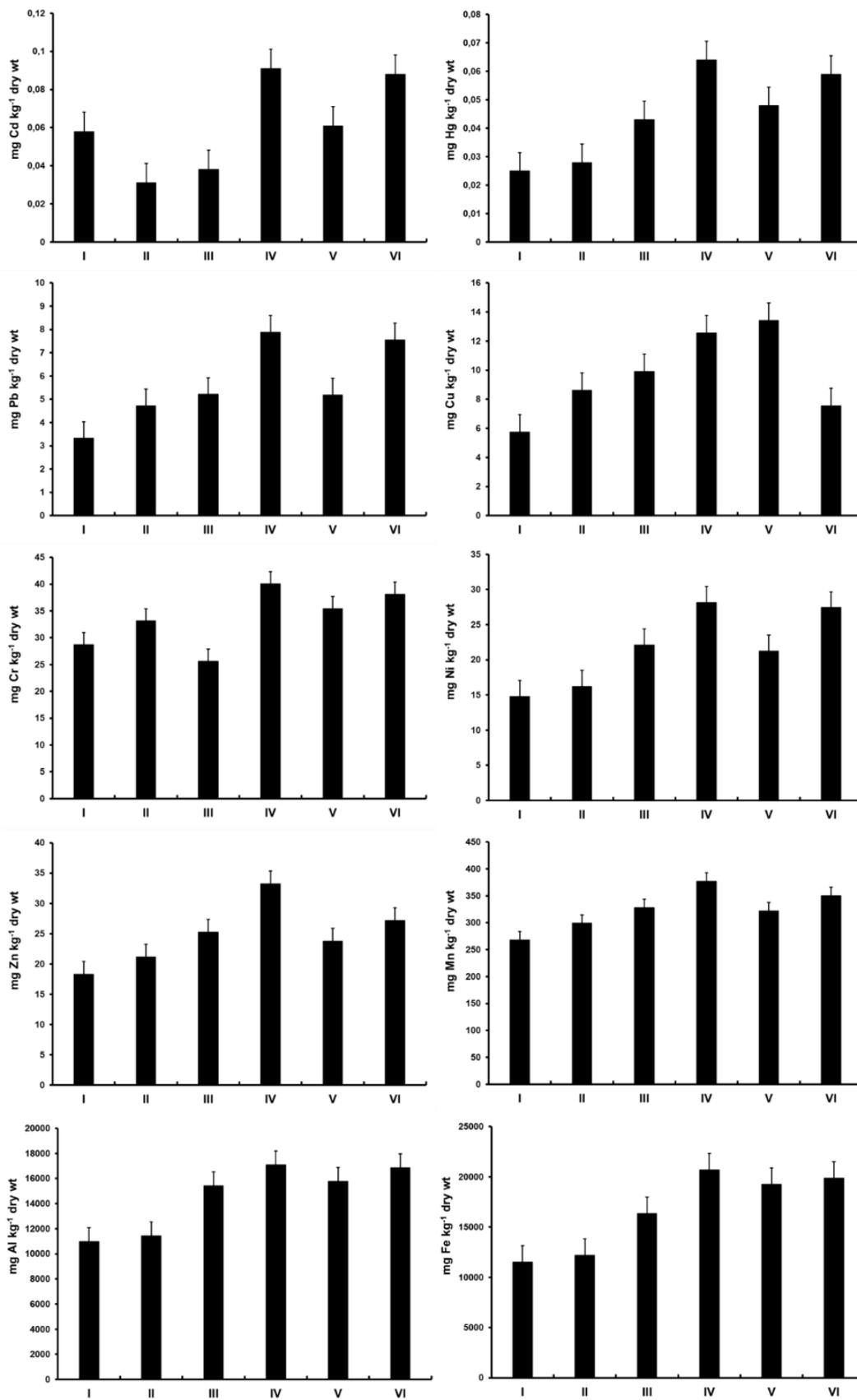


Figure 3 Mean concentrations of elements in sediments of İğneada shores in the Black Sea.

Metals in sediment of Iğneada shores in the Black Sea

The metals' analytical concentrations were within the range of reference values and repeat analysis of samples revealed that the analytical precision variability was always within acceptable limits.

The concentrations of metals varied from 0.031 to 0.091 for Cd; 0.025 to 0.064 for Hg; 3.32 to 7.88 for Pb; 5.75 to 13.42 for Cu; 25.63 to 40.07 for Cr; 14.8 to 28.2 for Ni; 18.29 to 33.21 for Zn; 268 to 377 for Mn; 10,987 to 17,101 for Al; and 11,521 to 20,700 $\text{mg}\cdot\text{kg}^{-1}$ for Fe $\text{mg}\cdot\text{kg}^{-1}$ dry wt. (**Figure 3**). According to the results, the concentrations of these metals in sediments differ depending on where they are sampled ($p < 0.05$). SQGVs (sediment quality guideline values) are valuable and useful tools for protecting and evaluating the marine environment. The outcomes were compared to the SQGV's predictions [21]. The findings were contrasted with SQGV to see information on metal amounts in sediments from the Iğneada shores in the Black Sea in this analysis. Except for Ni, the metal levels were quite below than the quantities indicated by the sediment content. SQGV for Cd, Hg, Pb, Cu, Cr, Ni and Zn are 1.5, 0.15, 50, 65, 80, 21 and 200 $\text{mg}\cdot\text{kg}^{-1}$ dry wt., respectively [21]. Ni values (14.8 - 28.2 $\text{mg}\cdot\text{kg}^{-1}$ dry wt.) were slightly above the recommended value (21 $\text{mg}\cdot\text{kg}^{-1}$ dry wt.) except for the 1st and 2nd stations. However, recommended SQGV-high for Ni is 52 $\text{mg}\cdot\text{kg}^{-1}$ dry wt. The value found for Ni is considerably lower than the recommended value.

Pollution indices

Enrichment factor (EF)

In **Figure 4**, EFs for the sediments taken from all the stations are presented. Metal enrichment factors for metals in Iğneada shore sediments range from: 0.70291 to 1.5246 for Cd, 1.19696 to 1.70545 for Hg, 0.4899 to 0.70236 for Pb, 0.82159 to 1.52312 for Cu, 1.38165 to 2.39381 for Cr, 1.8333 to 2.29182 for Ni, 0.7329 to 1.0289 for Zn, 0.98047 to 1.43525 for Mn and 0.32686 to 0.3804 for Al.

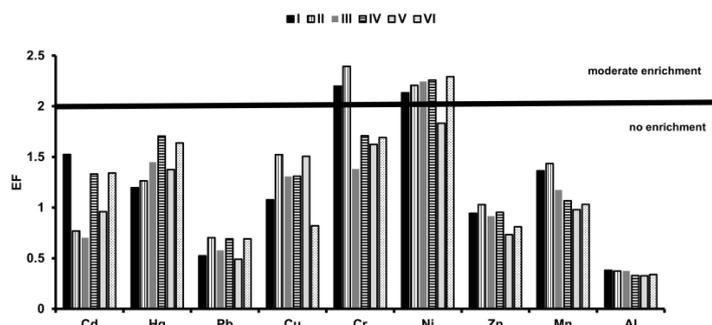


Figure 4 Mean values of enrichment factor (EF) for 9 elements in the sediments of Iğneada shores in the Black Sea.

For measuring metal levels due to anthropogenic activities, normalizing metal concentrations to Al or Fe has become standard practice in environmental science [22]. Fe is a common element in clay minerals, as well as on particle surfaces like oxide coatings. Normal weathering processes are the primary source of Fe in estuarine or coastal sediments. EF may be used to determine if the metals in response came from natural weathering processes in rocks or from anthropogenic sources, as well as the extent of pollution in the environment. The EF values are commonly used as evaluation parameters. The EF is a method for calculating the rate of anthropogenic heavy metal pollution in marine sediments. Calculating the enrichment factor to determine anthropogenic influences in sediments is quite prevalent. In this study EF values were nearly between 0.33 and 2.4. In this study, EF values of Cd, Hg, Pb, Cu, Zn, Mn and Al in all of stations were found to be less than 2 ($EF < 2$) that indicated these metals had no enrichment. It may be said that these come from crustal materials or natural weathering processes. However, some the results of EF values were slightly higher than 2, indicate is moderate enrichment ($2 \leq EF \leq 5$). The high EF values were determined in Cr for stations I and II and Ni for all stations except station V, could be classified as moderate enrichment.

Geoaccumulation Index (I_{geo})

In this study I_{geo} values were estimated using geochemical background values for all stations of Iğneada shores and given in **Figure 5**. I_{geo} values for all metals were less than 0 at all stations, suggesting that the Iğneada shores was uncontaminated by these studied metals.

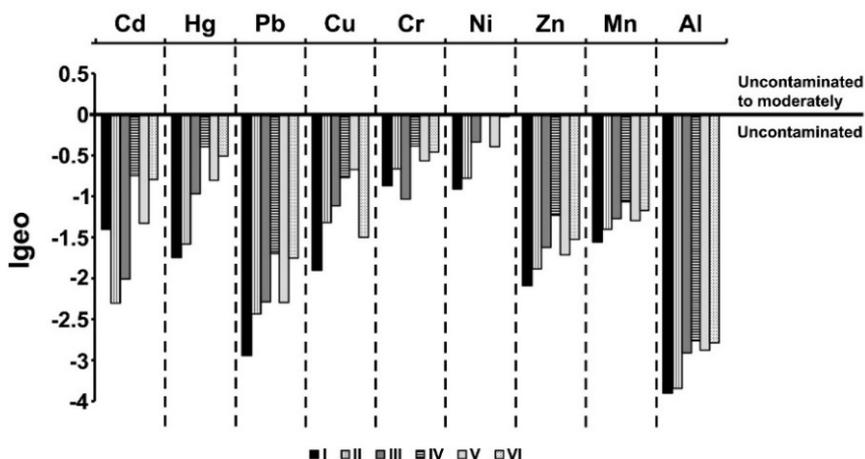


Figure 5 Mean values of Geoaccumulation index for 9 elements in the sediments of İğneada shores in the Black Sea.

Pollution load index (PLI)

In this study, upper continental crust values were used [13] as background value for those metals. The PLI is presented as a standardized method for detecting contaminants that allows pollution levels to be compared between different stations. PLI assesses a sample's overall toxicity status by determining how far it exceeds the amounts of heavy metals found in natural environments. Based on [19], PLI value of 0 advice absence of background metals, a value of 1 advice that only background levels of metals are present, and value larger than one (1) would advice progressive deterioration of quality. In this study PLI values were given in **Figure 6**. PLI values ranged from 0.410 in station I to 0.747 in station IV, indicating that İğneada shores in the Black Sea were less impacted by these metals. PLI value for zone was found as 0.553665002.

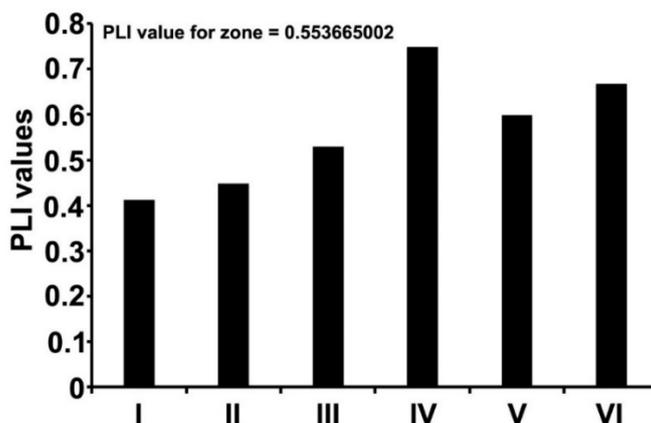


Figure 6 Pollution load index values for 9 elements in the sediments of İğneada shores in the Black Sea.

Comparison with literature values

The determination of metal amounts in sediments on the Turkish coast of the Black Sea has been implemented about 30 years [23]. However, studies on the coasts of İğneada are much less than other places in the Black Sea [11,23]. Studies on the coasts of İğneada and in areas close to it have been compared with literature in the Black Sea (**Table 3**). Metal concentrations in this study were significantly lower than those locations that situated in industrialized areas and densely populated regions. Despite everything, metal amount in the sediments of the Black Sea is at normal levels and is not faced with metal pollution. Similarly, a comparison with the sediment quality guidelines in the study conducted on the R/V Academic cruise in the Western Black Sea within the MISIS project revealed that most metal concentrations in Constanta sediments, Romanian waters, Galata, Bulgarian waters and Turkish waters off İğneada were below the recommended limits [7]. Ni and Cu levels were found to exceed limits, but a

further analysis showed that this was mostly the result of a higher natural background. Based on these results, it was emphasized that metal contamination of the sediments was not a problem for the investigated areas [7].

Table 3 Metal levels in sediments of the Black Sea.

Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn	Ref.
< 0.02	74.7	13.57	29,000		519.1	31.57	< 0.05	119.3	[24]
0.07 - 0.35				Bld - 0.06			0.86 - 16		[25]
0.057 - 0.386	38 - 88	13.76 - 50.31			349 - 1,425	15.7 - 57.8	9.21 - 45.18	26.1 - 85.6	[7]
	13 - 224	15 - 87	2,000 - 49,000		112 - 1,064	11 - 202	12 - 66	24 - 138	[26]
	32 - 171	29 - 68	13,000 - 43,000		355 - 751	38 - 130	14 - 35	50 - 108	[27]
0.01 - 19.5		2 - 8580					5 - 2920	12 - 345	[28]
0.6 - 0.9	22 - 122	23 - 75	26,000 - 49,000		354 - 902	2.2 - 69.1	11 - 30	57 - 127	[29]
							2.9 - 617.8		[30]
	51 - 135	20 - 47	19,000 - 39,000		312 - 995	34 - 88	19 - 51	50 - 111	[31,32]
0.18 - 0.53	54 - 147	39.8 - 72.46	33,800 - 50,100	0.03 - 0.13	383 - 763	49.5 - 140.6	18.13 - 44.33	82.8 - 183.9	[33]
0.02 - 1.04		2.87 - 407.93		0.47 - 2.86			2.51 - 79.78		[34]
			12,223.5						[35]
0.031 - 0.091	25.63 - 40.07	5.75 - 13.42	11,521 - 20,700	0.025 - 0.064	268 - 377	14.8 - 28.2	3.32 - 7.88	18.29 - 33.21	This study

Conclusions

The concentration ranges of Fe and Al in the surface sediment was found to be the highest at 20,700 and 17,101 mg·kg⁻¹ dry wt., respectively among the studied metals followed by Mn, Cr, Zn, Ni, Cu, Pb, Cd and Hg. In this study, the accumulated studied metal levels except Ni in sediment from Iğneada shores did not exceed the standard maximum limits [21]. However, Ni was below the recommended SQGV-high value.

The degrees of sediments contamination were computed by using an Enrichment Factor (EF), Geoaccumulation index (I_{geo}) and Pollution Load Index (PLI). The EF may reflect the real impact of anthropogenic activities on the marine environment. EF is a useful method for distinguishing between anthropogenic and natural sources of the metals [33]. In this study, EF values less or equal to 2, show that there is no contamination at all, the concentration is within the prediction range for the natural background. However, only EF values of Cr and Ni showed between 2 and 5, indicated as moderate enrichment. Although there is not an industry in Iğneada, it is known that these high values are carried to these shores via large rivers such as the Danube [8].

I_{geo} values for all measured metals were calculated to be less than 0 at all 6 stations. The I_{geo} analyses showed that Iğneada shores sediments for all studied metal levels at all stations were classed as unpolluted; however, in the PLI calculations made using Iğneada coasts in the Black Sea metal concentration means, contamination is observed in the stations. All PLI values in the stations (I-IV) were between 0 and 1, indicated that Iğneada shores were less impacted by these metals. It may be because of direct outer sources such as agricultural flows, industrial activities uploaded from the major rivers and other anthropogenic resources. The PLI values cannot provide data on the effect of the combination of metals, it can give the public a similar understanding of the quality of a part of their ecosystem, as well as show patterns over time and across regions [19]. In this study, metals were not significantly enriched in the surface sediments of Iğneada shores and did not show an important hazard to the marine coastal environment. Overall indices revealed that the Iğneada sediments are not contaminated, and that the quantities of elements discovered are geogenic in origin. Although Ni and Cr levels were slightly high in some stations at Iğneada, the levels of the rest metals were not enriched in these surface sediments and did not show a significant threat to the environment. Further research and monitoring were recommended in order to determine the long-term impact of anthropogenic inputs on the Iğneada shores in the Black Sea.

Acknowledgements

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