

was carried out at depths between 1 and 14 meters (Table I).

The Karşıyaka study area featured a 0.0 to 11.0 m waterbed, and in its blackish-gray, sandy clay parts, towards the lower levels from 12.5 to 13.5 m, it is made up of mud layers containing high amounts of water.

In the Bayraklı location, the waterbed starts at 0.0 to 4.0 m,

and in its sandy clay parts towards the lower levels from 6.5 to 7.5 m, it contains blackish-gray mud layers containing high amounts of water. In the Inciraltı region, the waterbed starts at 0.0 to 10.0 m, and it is made up of greenish-gray sediments from 10.0 to 12.0 m towards the lower levels with the clay parts containing low levels of sand.

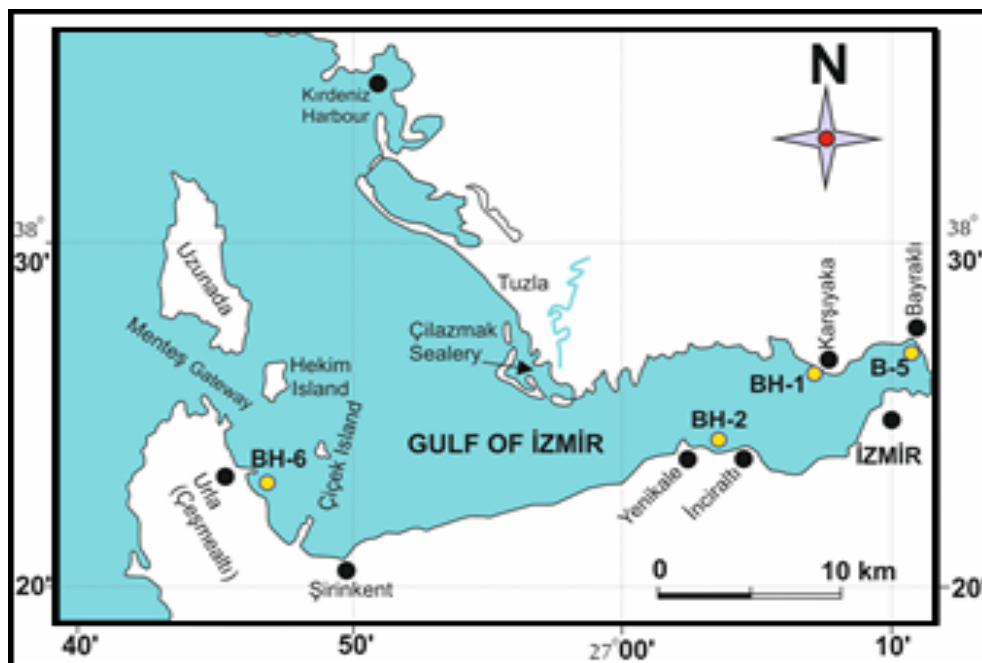


Fig. 2 Location map of the drill hole zones in the Gulf of İzmir (BH-1: Sample location)

TABLE I
PROPERTIES OF CORE SEDIMENTS [14]

Sample No	Depth of Sample (m)	Quantity of Sample (gr)	Sample Coordinates (WGS-84, 6 th)	
			X	Y
Karsiyaka DH-1	12,50-13,50	1047	4255697	510456
Bayrakli DH-5	6,50-7,50	1021	4258790	513920
Inciralti DH-2	10,00-12,00	1023,5	4253810	502590
Cesmealti DH-6	4,50-5,00	1035,7	4249770	478170

As in the other regions, towards the lower levels of the Çeşmealtı region, there are sediments with high water content in the blackish-gray, caked, sandy clay parts. Core sediments were collected to a depth of 1.5 meters and aligned in core boxes. At the end of drilling, sediment samples were put in secure plastic bags and immediately sent to the laboratory where they were dried at room temperature and sieved with a polyurethane sieve in preparation for heavy metal analysis in their powder form.

For heavy metal analysis, sediments were firstly dissolved in an acid mixture containing nitric (HNO₃), hydrofluoric (HF), perchloric (HClO₄) and hydrochloric (HCl) acids and then placed in a microwave digestion system [15]-[17]. The presence of Cd, Co, Cr, Cu, Mn, Ni, Pb and Zn heavy metals was determined by using a Perkin Elmer® Optima™ 7000 DV model using a charge-coupled device (CCD) detector. For the investigated heavy metals, data were stored and processed by

WinLab32, ICP Version 4.0 software. All data were obtained with axial imaging, a nebulizer and a cyclonic spraying chamber with a 10 second integration time.

Standard calibrated solutions of Cd, Co, Cr, Cu, Mn, Ni, Pb and Zn were prepared from a stock primer standard solution, and a calibration curve with an 0.999 correlation coefficient was obtained with three study standards over a range of 0.25 µg L⁻¹ to 1.0 µg L⁻¹. In the calibration space, ultrapure water acidified with Suprapur® nitric acid (HNO₃) was used. An empty solution, study standards and samples were kept under acidic conditions at 2.5% (v/v) volume.

IV. RESULTS AND DISCUSSION

The average concentrations of heavy metals detected in the sediment samples from the Gulf of İzmir were, respectively, Cd < LOD; Co 14.145 ± 0.13 µg g⁻¹; Cr 112.8618 ± 0.89 µg g⁻¹; Cu 34.045 ± 0.53 µg g⁻¹; Mn 481.43 ± 7.65 µg g⁻¹; Ni 76.538 ± 3.81 µg g⁻¹; Pb 11.059 ± 0.53 µg g⁻¹ and Zn 140.133 ± 1.37 µg g⁻¹ (Table II).

The Cd, Co, Cr, Cu, Mn, Ni, Pb and Zn heavy metals in µg/g units found in the sampling locations show a tendency to increase and decrease in parallel with each other (Fig. 3). The comparison of the samples to the average abundances of these elements in the Earth's crust [18] revealed that Cd, Mn and Pb values in all sediments were lower than the reference values, except for Çeşmealtı where the Pb value was similar to the

reference value. In Inciraltı, Co and Ni levels were high, while Ni and Cu levels were high in Karşıyaka. Çeşmealtı was the only location in which Cr and Zn levels were low. In summary, Cr, Cu, Ni and Zn were high in Karşıyaka; Co, Cr, Ni and Zn were high in Inciraltı; Cu and Zn were high in Bayraklı. In the samples from Çeşmealtı, levels of all elements, except for Pb, were lower than the samples from other locations. This is attributable to heavy metals entering

into the water environment, the absorptive capacity and textural composition of sediments, the chemical structure of metals and their ability to accumulate on the seabed by bonding to other compounds [19]. In this study, the Çeşmealtı core sample was collected from a region that was closer to the surface compared to the other locations. Furthermore, Karşıyaka and Inciraltı were determined to be more polluted due to the intense industrial activities in the Inner Gulf [20].

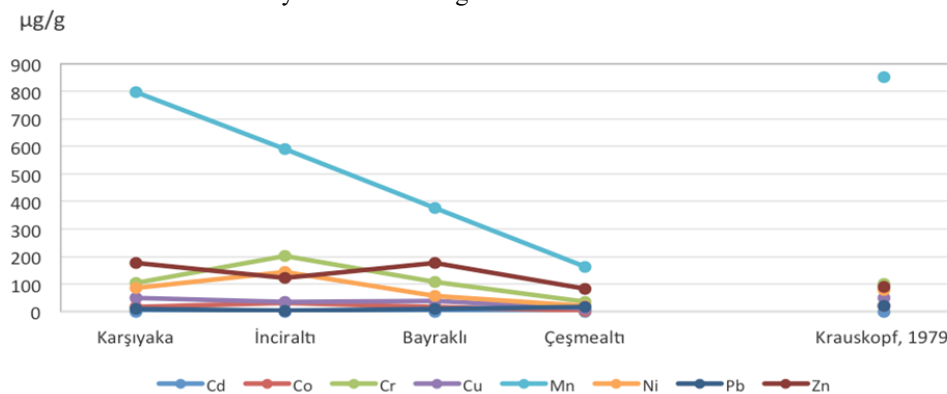


Fig. 3 Distribution of Cd, Co, Cr, Cu, Mn, Ni, Pb and Zn heavy metals by investigated regions [18]

TABLE II
ICP-OES ANALYSIS RESULTS OF THE SEDIMENT SAMPLES FROM THE GULF OF İZMİR

Heavy Metals	Wavelength (nm)	Unit	Karşıyaka (DH-1)	Inciraltı (DH-2)	Bayraklı (DH-5)	Cesmealti (DH-6)	Limit of Detection (LOD) µg/L	µg/g
Cd	228.802	µg/g	< LOD	< LOD	< LOD	< LOD	0,584	0,096
Co	228.616	µg/g	16,17 ± 0,27	20,62 ± 0,04	16,34 ± 0,18	3,448 ± 0,046	0,808	0,133
Cr	267.716	µg/g	104,9 ± 1,9	203,8 ± 0,8	106,7 ± 0,6	36,07 ± 0,26	1,54	0,254
Cu	327.393	µg/g	51,55 ± 0,75	35,46 ± 0,41	37,65 ± 0,35	11,52 ± 0,60	0,761	0,125
Mn	257.610	µg/g	795,9 ± 19,9	590,0 ± 6,6	376,4 ± 2,9	163,4 ± 1,2	1,23	0,202
Ni	231.604	µg/g	85,78 ± 0,73	143,8 ± 2,1	56,12 ± 0,81	20,45 ± 0,17	2,05	0,339
Pb	220.353	µg/g	10,53 ± 0,44	3,685 ± 0,558	11,30 ± 0,54	18,72 ± 0,57	5,79	0,955
Zn	206.200	µg/g	176,8 ± 1,9	123,2 ± 1,1	177,2 ± 1,3	83,33 ± 1,18	0,66	0,109

V. CONCLUSION

Heavy metal concentrations (Cd, Co, Cr, Cu, Mn, Ni, Pb and Zn) of the core samples collected from four different locations in the Gulf of İzmir (Karşıyaka, Bayraklı, Inciraltı and Çeşmealtı) were analyzed with ICP-OES. The results showed that pollution gradually decreased from the Inner Gulf to the outer regions and, moreover, there was not significant pollution in Çeşmealtı (Urla). The geochemical structure of sediments can become deformed as a result of natural and anthropogenic factors. However, when seas reach a point where they cannot eliminate the accumulated anthropogenic pollution by their own means, the pollution starts to harm humans and organisms living in the seas. This leads to the emergence of diseases that necessitate long-term treatments. Researching the particles that gradually settle on the seabed through various ways is of great importance in controlling heavy metal pollution.

REFERENCES

[1] Bergin F., Kucuksezgin F., Uluturhan E., Barut I.F., Meric E., Avsar N., Nazik A. (2006). "The response of benthic foraminifera and ostracoda to heavy metal pollution in Gulf of Izmir (Eastern Aegean Sea)", *Estuarine,*

Coastal and Shelf Science 66, 368-386.
[2] Effendi H., Wardiatno Y., Kawaroe M., Mursalin, Lestari D.F. (2017). "Spatial distribution and ecological risk assessment of heavy metal on surface sediment in west part of Java Sea", *IOP Conf. Series: Earth and Environmental Science* 54, 012088.
[3] Canadian Council of Ministers of the Environment. 2001. Canadian sediment quality guidelines for the protection of aquatic life: Introduction. (Canada: Winnipeg).
[4] Bastami K. D., Bagheri H., Kheirabadi V., Zaferani G. G., Teymori M. B., Hamzehpoor A., Soltani F., Haghparast S., Harami S. R. M., Nasrin Ghorghani F., Ganji S. (2014). "Distribution and ecological risk assessment of heavy metals in surface sediments along southeast coast of the Caspian Sea", *Marine Pollution Bulletin* 81, 262-267.
[5] Lin Y., Chang-Chien G., Chiang P., Chen W. (2013). "Multivariate analysis of heavy metal contaminations in seawater and sediments from a heavily industrialized harbor in Southern Taiwan", *Marine Pollution Bulletin* 76, 266-275.
[6] Alkarkhi A. F. M., Ismail N., Ahmed A., Easa A. (2009). "Analysis of heavy metal concentrations in sediments of selected estuaries of Malaysia—a statistical assessment". *Environ Monit Assess* 153:179-185.
[7] Yuan C., Shi J., He B., Liu J., Liang L., Jiang G. (2004). "Speciation of heavy metals in marine sediments from the East China Sea by ICP-MS with sequential extraction", *Environment International* 30: 769-783.
[8] Kucuksezgin F., Kontas A., Altay O., Uluturhan E., DarNlmaz E. (2006). "Assessment of marine pollution in Izmir Bay: Nutrient, heavy metal and total hydrocarbon concentrations", *Environment International* 32: 41 - 51.
[9] Nolting R. F., Ramkema A., Everaarts J.M. (1999). "The geochemistry

of Cu, Cd, Zn, Ni and Pb in sediment cores from the continental slope of the Banc d'Arguin (Mauritania)", *Continental Shelf Research* 19: 665—691.

- [10] Duman, M., Küçüksezgin, F., Atalar, M. ve Akçalı, B., (2011). "Geochemistry of the northern Cyprus (NE Mediterranean) shelf sediments: Implications for anthropogenic and lithogenic impact", *Marine Pollution Bulletin*, 64: 2245 - 2250.
- [11] Kucuksezgin, F., Uluturhan, E., Konaş, A. ve Altay, O. (2002). "Trace metal concentrations in edible fishes from İzmir Bay, Eastern Aegean", *Marine Pollution Bulletin*, 44: 816 - 832.
- [12] Kucuksezgin, F., Konaş A. ve Uluturhan E (2011). "1997 - 2009 döneminde İzmir Körfezi (Doğu Ege Denizi) gelen tortu ve *Mullus barbatus* ağır metal kirliliğinin Değerlendirmeleri", *Marine pollution Bulletin* 62: 1562 - 157.
- [13] Yümün Z. Y., Meriç E., Aşar N., Nazik A., Barut I. F., Yokes B., Sagular E. K., Yıldız A., Eryılmaz M., Kam E., Başarı A., Sonuvar B., Diçer F., Baykal K., Kaya S. (2016). "Meiofauna, microflora and geochemical properties of the late quaternary (Holocene) core sediments in the Gulf of İzmir (Eastern Aegean Sea, Turkey)", *Journal of African Earth Sciences* 124: 383-408.
- [14] Kurt D., Yümün Z. U., Barut I. F., Kam E. (2016). "Distribution of Gamma Radiation Levels in Core Sediment Samples in Gulf of İzmir: Eastern Aegean Sea, Turkey", *World Academy of Science, Engineering and Technology, International Science Index 111, International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering*, vol. 10 no: 3, 375 - 379.
- [15] UNEP/IAEA, 1986. Determination of Total Iron in Marine sediments by Flame Atomic Absorption spectrophotometry. Reference Methods for Marine Pollution Studies. No. 37-39, Vienna.
- [16] Loring, D. H., Rantala, R. T. T., 1988. An intercalibration exercise for trace metals in marine sediments. *Mar. Chem.* 24, 13e28.
- [17] UNEP. Determination of total cadmium in marine sediments by flameless AAS. Reference Methods for Marine Pollution Studies, vol. 27; 1985c.
- [18] Krauskopf, K. B., 1979. Introduction to geochemistry. In: *International Series in the Earth and Planetary Sciences*. McGraw-Hill, Tokyo, 617 pp.
- [19] Kuriata-Potasznik A., Szymczyk S., Skwierawski A., Glinska-Lewczuk K., Cymes I. (2016). "Heavy Metal Contamination in the Surface Layer of Bottom Sediments in a Flow-Through Lake: A Case Study of Lake Symsar in Northern Poland", *Water*, MDPI, 8, 358; doi: 10.3390/w8080358.
- [20] Akçalı İ., Küçüksezgin F. (2009). "Bioaccumulation of heavy metals by the brown alga *Cystoseira* sp. along the Aegean Sea", *E.U. Journal of Fisheries & Aquatic Sciences*, Volume 26, Issue 3: 159-163.