KSÜ Tarım ve Doğa Derg 26 (5), 1010-1020, 2023
KSU J. Agric Nat 26 (5), 1010-1020, 2023
https://doi.org/10.18016/ksutarimdoga.vi.1201244

Determination of Metal(loid)s in Mavi Dam Lake Sediment (Ankara) and Evaluation of Health Risks Level

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ABSTRACT

This study revealed the current metal(loid) status of the Mavi Dam Lake, which is one of the important wetlands for Ankara, established the accumulation relations between metal(loid)s separately, and seek an answer to the question of whether the current metal(loid)s status poses a risk of public health. The amounts of 13 metal(loid)s were determined. Sediment quality guidelines were calculated to understand the ecological risk of metal(loid)s in the sediment and the results were compared with limit values. It was determined that Ni constitutes 51.28% of the total toxic effects of metals detected in the sediment. Ni and Cr revealed a strong correlation between cluster and correlation analyses and were involved in the same factor in the principal component analysis. Additionally, it was determined that As, Cd, Co, Cr, and Ni may pose carcinogenic risks in terms of public health by contact with the lake or ingestion. In conclusion, it was revealed that the lake being studied should be regularly monitored for all metal(loid)s, especially Ni, and Cr.

Hydrobiology

Research Article

Article History
Received : 09.11.2022
Accepted : 24.02.2023

Keywords
Ecotoxicological status
Sediment quality guidelines
Health risk assessment
Toxicity
Multivariate statistical analyses

Mavi Baraj Gölü Sedimentinde (Ankara) Metal(loid)lerin Belirlenmesi ve Sağlık Risk Düzeyinin Değerlendirilmesi

ÖZET

Bu çalışma kapsamında Ankara için önemli sulak alanlardan biri olan Mavi Baraj Göl'ün mevcut metal(loid) durumunun ortaya konması, ayrı ayrı metal(loid) arası birikim ilişkilerinin durumu, mevcut metal(loid) durumun canlılar için risk teşkil edip etmediği sorularına cevap aranmıştır. 13 metal(loid) miktarı belirlenmiştir. Sedimentteki metal(loid)lerin ekolojik riskini anlamak için sediment kalite kılavuzları hesaplanmış ve sonuçlar sınır değerlerle karşılaştırılmıştır. Sedimentte araştırılmış metallerin toplam toksik etkilerinin %51.28'ini Ni oluşturduğu tespit edilmiştir. Küme ve korelasyon analizleri ile Ni-Cr arasında güçlü bir ilişki olduğu tespit edilmiş, temel bileşen analizinde de aynı faktörde yer aldığı gözlenmiştir. Ayrıca As, Cd, Co, Cr ve Ni'in göl teması veya yutulması ile halk sağlığı açısından kanserojen risk oluşturabileceği belirlenmiştir. Sonuç olarak, çalışılan gölün başta Ni ve Cr olmak üzere tüm metal(loid)ler için düzenli olarak izlenmesi gerektiği ortaya konmuştur.

Hidrobiyoloji

Araştırma Makalesi

Makale Tarihçesi
Geliş Tarihi : 09.11.2022
Kabul Tarihi : 24.02.2023

Anahtar Kelimeler
Ekotoksikolojik durum
Sediment kalite rehberi
Sağlık risk değerlendirilmesi
Toksisite
Çok yönlü istatistiksel analiz

Atıf Şekli: Fikirdesici Ergen, Ş., Tekatlı, Ç., Altındağ, A., Kamışlı, G., Kocatürk Döngel, K. & Tunca, E., (2023) Mavi Baraj Gölü Sedimentinde (Ankara) Metal(loid)lerin Belirlenmesi ve Sağlık Risk Düzeyinin Değerlendirilmesi *KSÜ Tarım ve Doğa Derg 26* (5), 1010-1020. https://doi.org/10.18016/ksutarimdoga.vi.201244
To Cite : Fikirdesici Ergen, Ş., Tekatlı, Ç., Altındağ, A., Kamışlı, G., Kocatürk Döngel, K. & Tunca, E., (2023). Determination of Metal(loid)s in Mavi Dam Lake Sediment (Ankara) and Evaluation of Health Risks Level *KSU J. Agric Nat 26* (5), 1010-1020. https://doi.org/10.18016/ksutarimdoga.vi.201244

INTRODUCTION

Metal(loid)s (Ms) reach wetlands (Jia et al., 2019), lakes (Chen et al., 2019), rivers (Li et al., 2019), and reservoirs (Nguyen et al., 2019) through the entry of untreated wastewater from agricultural, industrial, and domestic sources. Ms that reach aquatic ecosystems via stream flow and atmospheric deposition, as well as runoff, are then deposited in the sediment through adsorption, co-precipitation, and hydrolysis (Guo et al., 2018). They cause serious concern due to their bioaccumulation, toxicity, and persistency in the environment and food webs in the aquatic ecosystems they reach (Jordanova et al., 2018; Saher et al., 2019).

Sediments are like a sink of Ms in aquatic environments and the metal concentration is always higher than in the water above it (Liu et al., 2018; Levent et al., 2019). However, Ms in the sediment can be released back into the water through a changes in the surrounding chemical (dissolved oxygen, pH, redox potential, etc.) and physical (salinity, degradation, flood, temperature, etc.) factors (Islam et al., 2015). Therefore, it would be appropriate to suggest that the secondary source of Ms in aquatic ecosystems is sediments. For all these reasons, sediments play a vital role in maintaining the ecological conditions of the water bodies (Pal & Mandal, 2019).

Ms can bioaccumulate not only in aquatic ecosystems but also in the tissues of living organisms that benefit from water. Therefore, they have toxic effects on aquatic organisms, terrestrial organisms, and eventually humans (Li et al., 2018). For this reason, it is significant to examine the level of contamination and toxicity of Ms in aquatic ecosystems and sediments for protecting both ecosystems and human health (Fang et al., 2017). Therefore, the Sediment Quality Standards (SQGs) have been developed and used by many researchers to evaluate the current Ms status in sediments (Yoo et al. 2015; Fikirdeşici-Ergen et al., 2021).

The Mavi Dam Lake is one of the important lakes for Ankara. A large part of the area, which is now under protection, is used as a picnic area. Around the lake, there are streams that fill with rain water in winter and dry up in summer. Saray, Bayındır, Yunuslar, and Karanlık streams feed the lake water. Many roads pass through the area, and a highway runs through the middle of the lake (Yeni, 1995).

In this study, 13 heavy Ms (Al, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, and Zn) in the sediment of the Mavi Dam Lake were investigated. The amounts of these Ms were compared with the limit values, such as probable effect level (PEL), threshold effect level (TEL), effects range low (ERL), effects range median (ERM), reported using the Sediment Quality Guidelines (SQGs). The effects of Ms were evaluated with sediment evaluation methods including degree of contamination (Cd), modified degree of contamination (mCd), contamination factor (CF) and enrichment factor (EF), Geoaccumulation index (Igeo), toxic unit (TU), Pollution Load Index (PLI), mean ERM quotients (m-ERM-q), and mean PEL quotients (m-PEL-q). Additionally, risk indices developed and modeled by the USEPA (2004) were used to determine possible carcinogenic risks to public health due to exposure to Ms in the sediment. Some researchers have also used these indices (Kusin et al., 2018; Song et al., 2019; Ustaoğlu & Islam, 2020). The accumulation relations of the Ms were also evaluated statistically.

MATERIAL and METHODS

Sampling and Analyses

In this study, surface sediment and water samples were taken from 17 sampling sites in the Mavi Dam Lake were collected in April 2021 (Figure 1, Table 1). Surface sediment was taken from 1-2 cm using plastic materials (1-2 cm) and transported to the laboratory in polyethylene storage containers. They were stored in a refrigerator at +4 degrees until analysis. The samples were digested and analyzed according to the MA270 method by Bureau Veritas Mineral Laboratoires Canada (ACME LAB.). Concentrations of elements were determined by ICP-MS. Samples were studied and analyzed by Bureau Veritas Mineral Laboratoires Canada (ACME LAB.) according to the AQ270 method.

Table 1. Coordinates of the study area
Çizelge 1. Çalışma alanı koordinatları

Stations	Coordinates (WGS84)	
	X	Y
1.Station	32.989903°	39.910116°
2. Station	32.988849°	39.910343°
3. Station	32.989762°	39.911543°
4. Station	32.988363°	39.913525°
5. Station	32.989764°	39.911542°
6. Station	32.990846°	39.908893°
7. Station	32.993886°	39.911145°
8. Station	32.994752°	39.908854°
9. Station	32.995603°	39.910948°
10. Station	32.998064°	39.911984°
11. Station	33.001869°	39.912092°
12. Station	32.993973°	39.915223°
13. Station	32.995627°	39.914055°
14. Station	32.998089°	39.916232°
15. Station	32.999867°	39.919461°
16. Station	33.000849°	39.918541°
17. Station	33.000675°	39.915639°

Sediment Quality Assessment Methods

In this study, Turekian and Wedepohl data were used as reference data (Turekian & Wedepohl, 1961). These reference data are the most preferred data (PEL (Smith et al., 1996), ERL and ERM (Long & Morgan, 1991).

Contamination factors (C_f^i) (Hakanson, 1980)

$$C_f^i = C^i / C_n^i \quad (1)$$

C^i= Amount of metal

C_n^i= Reference values

Figure 1. Stations sampled in the Mavi Dam Lake
Şekil 1. Mavi Baraj Gölü örnekleme istasyonları

Degree of contamination (C_d) (Hakanson, 1980)

$$C_d = \sum_{i=1}^{n} C_f^i \quad (2)$$

C_f^i= Contamination factors

Modified degree of contamination (mC_d) (Abrahim & Parker, 2008)

$$mC_d = \frac{\sum_{i=1}^{n} C_f^i}{n} \quad (3)$$

C_f^i= Contamination factors

n= Number of metals studied

Pollution load index (PLI) (Tomlinson et al., 1980)

$$PLI = (C_{f1} \times C_{f2} \times C_{f3} \ldots . \times C_{fn})^{1/n} \quad (4)$$

C_{f1}= Contamination factors

n= Number of metals studied

Enrichment factor (EF) (Hasan et al., 2013)

$$EF = \frac{C_n/C_{ref}}{B_n/B_{ref}} \quad (5)$$

C_n= Amount of metal

C_{ref}= Amount of metal in reference sample

B_n= Amount of reference elements in the sample

B_{ref}= Value of reference Ms in reference sample

Al was chosen as the reference Ms.

Geoaccumulation Index (I_{geo}) (Müller, 1969)

$$I_{geo} = \log_2 \frac{C_n}{1.5 \times B_n} \quad (6)$$

C_n= number of metals

B_n= Amount of metal in reference sample

1.5= natural fluctuation coefficient

Mean effect range median quotients (m-ERM-Q) (Long & Morgan, 1991), and mean probable effect-level quotients (m-PEL-Q) (Carr et al., 1996).

$$m - ERM - Q = \frac{\sum_{i=1}^{n} C_i/ERM_i}{n} \quad (7)$$

$$m - PEL - Q = \frac{\sum_{i=1}^{n} C_i/PEL_i}{n} \quad (8)$$

C_i= number of metals

n= Number of metals studied

Total toxic unit (Σ TU) and relative toxic unit

$$\Sigma TUs = \sum_{i=1}^{n} C_i/PEL_{C_i} \quad (9)$$

$$\text{Relative TU} = \frac{C_i/PEL_{C_i}}{\Sigma TUs} X100 \quad (10)$$

Σ TU is the sum of the values obtained with the ratio of the number of metals detected in the samples to the PEL value of these Ms. The relative toxic unit is the percentage ΣTU of the toxic unit value of each Ms.

Potential Public Health Risk Calculation

In this study, dermal and ingestion routes to the body were used as the basis for public health risk calculation. The formula used to calculate the exposure values is as follows (USEPA, 2004; Song et al., 2019; Ustaoğlu & Islam, 2020).

$$Exp_{ing} = \frac{C_{sed} \times IR \times CF \times EF \times ED}{BW \times AT} \quad (11)$$

Exp_{ing} defines the risk of exposure to metals in the sediment through ingestion (mg/kg/day); IR is the amount of daily intake (IR=114 mg/day); The unit conversion factor is CF (CF = 10^{-6} kg/mg); EF refers to the frequency of exposure from sediment (EF = 350 days/year); The exposure time is expressed in ED. (ED = 30 years), BW used for body weight of an adult (BW = 70 kg); AT means the total number of days in 30 years (AT = 10,950 days) (Iqbal et al. 2013).

$$Exp_{derm} = \frac{C_{sed} \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT} \quad (12)$$

Exp_{derm} defines the risk of dermal exposure to metals in sediment; SA is the exposed skin area (SA = 5700 cm^2); the adhesion index of Ms per unit skin area is defined as AF (AF = 0.07 mg/cm^2); the dermal adsorption rate from the sediment is ABS (ABS = 0.001) (Kusin et al., 2018; Song et al. 2019).

The health risks caused by the metal(loids) in the sediment were evaluated together with the hazardous ratios (HQs) as to the health risk calculation guidelines (USEPA, 2004; Wang et al., 2015).

$$HQ = \frac{Exp_{ing}/Exp_{derm}}{RfD_{ing}/RfD_{derm}} \quad (13)$$

$$HI = \sum(HQ_{ing} + HQ_{derm}) \quad (14)$$

Hazardous ratios below the exposure concentration detected by ingestion or skin contact are HQ. RFD is accepted as the reference value for negative health effects caused by Ms contamination. The reference values for exposure through skin contact and ingestion are considered the same (Iqbal et al., 2013; Wang et al., 2015). If the value is below 1 (HI < 1), no significant risk of non-carcinogenic effects is expected. However, if the HI value is above 1 (HI > 1), non-carcinogenic risk effects may arise, which tend to increase with increasing HI value (USEPA, 2004).

$$CRing = Exp_{ing} \times CSF \quad (15)$$

$$CRderm = Exp_{derm} \times CSF \quad (16)$$

$$\sum LCR = CR_{ing} + CR_{derm} \quad (17)$$

As, Cd, Cr, and Pb are the Ms that can create carcinogenic risks. Lifetime cancer risk (LCR) is used to calculate the public health risk caused by carcinogenic Ms (Ustaoğlu & Islam, 2020). The values for cancer slope factor (CSF) of As, Cd, Cr, and Pb were defined by USEPA (2012) as 1.5, 6.3, 0.5, 0.0085, and mg kg^{-1} day^{-1}, respectively. The range of 1.0×10^{-6}–1.0×10^{-4} was considered the acceptable LCR range, and 1.0×10^{-4} was considered the tolerable threshold for cancer risk (Wang et al., 2015).

RESULTS and DISCUSSION

Distribution and Contamination Status of Ms in the Surface Sediment of the Lake

The findings and limit values of 13 Ms (Al, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, and Zn) obtained from 17 selected stations are presented in Table 2. The amount of Hg, which has a highly toxic effect, was also examined, but it was found below the analytical detection limit (0.05 mg kg-1). Moreover, the same Ms were investigated in water samples and all of them were found below the detection limits.

Table 2. Amount of detected metal(loid) (mg kg^{-1}) and limit values
Çizelge 2. Tespit edilen metal(loid) miktarı (mg kg^{-1}) ve limit değerler

	Al	As	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Zn
Mean	10285.7	5.0	0.1	10.3	31.1	23.3	13899.9	484.0	0.3	41.3	11.4	56.3
Min	2882	1.34	0.053	3.28	10.3	5.53	4564	134	0.059	12.5	1.73	12.3
Max.	16490	7.75	0.208	14.3	54.9	57.6	23619	1995	0.4450	70.8	30.99	92.0
Std. Dev.	±239.14	±0.095	±0.003	±0.19	±0.59	±0.75	±297.68	±23.83	±0.005	±0.85	±0.37	±1.27
PEL		17.00	3.53		90.00	197.00				36.00	91.30	315.00
ERM		85.00	9.00		145.00	390.00				50.00	110.00	270.00
TEL		5.9	0.60		37.30	35.70				18.00	35.00	123.00
ERL	X	33.00	5.00	X	80.00	70.00	X	X	X	30.00	35.00	120.00
Earth crust	80000	13.00	0.30	19.00	90.00	45.00	47200	850.00	2.6	68.00	20.00	95.00

Al (10285.7±239.14 mg kg^{-1}), Fe (13899.9±297.68 mg kg^{-1}) and Mn (484.0±23.83 mg kg^{-1}) were in the highest amounts among the elements detected in the sediment (Iqbal & Shah, 2014; Diami et al., 2016; Ustaoğlu & Islam, 2020). This was an expected result because most of these metals are abundant in the upper and lower parts of the Earth's crust (Turekian & Wedepohl, 1961) and many studies support this result (Yaroshevsky, 2006; Ravisankar et al., 2015; Fikirdeşici-Ergen et al., 2021). In the study, the concentrations of all Ms did not exceed the average shale values.

When the results of all Ms were analyzed according to the limit values, all of them except Ni were found below the limit values (Table 2). The resulting Ni value was above the PEL, and ERM. The effects of amounts of Ms obtained below the TEL and ERL values on living organisms are rare. The amounts of Ms obtained above the PEL and ERM are likely to have toxic effects on living organisms. At concentrations below ERL means that it can be affect less than 10% of the population (Hakanson, 1980). At concentrations above ERM, means it can be affect more than 50% of the population (Hakanson, 1980). Therefore, the amount of Ni (41.3±0.85 mg kg^{-1}) in the sediment is likely to have a toxic effect on the living organisms in the environment (Table 2).

Ni is of great importance for today's technology due to its use in petroleum, stainless steel, metal alloys, batteries, coins, and galvanic coatings (Mudd & Jowitti, 2014). Ni, Hg, Pb, and Cd are on the list of priority pollutants (Environmental Quality Standards (EQS) Directive 105/EC 2008). Although in fresh waters, Ni is predominantly in the soluble form of Ni^{2+}, it is more commonly found in complexes with chloride and sulfate (Binet et al., 2018). Ni in anaerobic freshwater sediments can precipitate as Ni sulfide, which reduces the bioavailability of living organisms in the sediment. Furthermore, Mn and Fe oxides can bind to Ni in both aerobic and anaerobic sediments (Schlekat et al., 2016). Ni is considered to be one of the toxic metals for living organisms other than plants (Bocca et al., 2019).

Evaluation of Results Using Sediment Assessment Methods

Contamination factor (CF) gives information about the distribution of Ms. The CF value was calculated below one for all Ms, indicating low contamination. PLI is a comparative and simple empirical index used to determine the level of Ms contamination (Hossain et al., 2014). The PLI result of the concentrations of Ms in the lake sediment was less than 1, indicating that the lake sediment is not polluted. The degree of contamination (C_d) and modified degree of contamination (mCd) values also showed that the pollution level of the lake is at a minimum (Table 3-4).

EF was used to analyze potential Ms sources in the surface sediment of the lake. The EF value helps understand the degree of contamination of the sediment by Ms by comparing it with the background rate. If the EF result is 1, it can be explained that Ms originated in the earth's crust. If the EF result is greater than 1, it can be explained that significant amount of Ms resulting from unnatural-weathering processes and anthropogenic effects (Zhang & Liu, 2002). In this study, EF results were found to be from 2 to 5 for the average Ms in the lake, excluding Mo (Table 4). EF values of Cu, Co, Mn, Ni, Pb, and Zn were remarkable. Especially, Ni and Zn are very close to the level of significant enrichment, indicating anthropogenic activity (Islam et al., 2015).

TU values are based on total concentrations. This value is a pre-indicator of the effects of Ms (Niu et al., 2020). Ni constitute 51.28% of the total toxic effects of metals detected in the sediment. This is followed by Cr constituting 15.45% and As constituting 13.15% of the total toxic effect. Therefore, it was determined that Ni, Cr, and As, which can demonstrate high toxic effects, have a high-risk level. Some studies in the literature support this result (Tunca et al., 2018, Fikirdeşici-Ergen et al., 2021).

When the m-ERM-Q result was evaluated, it was determined that the Ms accumulated in the lake was at the second level (21%) according to the scale. A rate of 21% indicates that the Ms accumulated in the lake has a 21% toxic effect on living organisms The m-PEL-Q result shows that the lake is moderately affected by the tested Ms (Table 3,4).

Potential Public Health Risk Calculation

In the literature, there are many studies including the human health risk assessment methods applied for sediment-induced Ms exposure (Khalil et al., 2011; Kusin et al., 2018; Ustaoğlu & Islam, 2020). Three methods are commonly used to assess human health risk. These are ingestion, skin contact, and inhalation. Ingestion and dermal contact routes were used in this study to assess human health risk.

HQ and HI values greater than 1 indicate adverse health effects due to the presence of Ms in the sediment (Table 5). Because of this study, it was determined that the Hqing, Hqderm, and HI values of As, Cd, Co, Cr, and Ni, which was the Ms tested in the sediment, were above 1. This suggested a carcinogenic health risk and showed that there are risks that may arise with ingestion Ms or skin contact. Moreover, it was determined that the risk of carcinogens caused by the ingestion of Ms is higher than the risk of skin contact. The lifetime cancer risk (LCR) results of As, Cd, Cr, and Pb are given in Table 5. The LCR value of Cr (Cr>As>Cd>Pb) was higher than the values of other Ms. This means that the risk of carcinogens caused by Cr is higher than other Ms. Moreover, the fact that the calculated LCR values for As, Cd, Cr, and Pb were in the range of 1.00E-06 to 1.00E-04, which is suggested by the USEPA, explains the importance of monitoring these Ms in the sediment (USEPA, 2004).

Multivariate Statistical Analyses

To understand the Ms-Ms interactions in the Mavi Dam Lake sediment, various analyses (correlation, cluster, and principal component analyses) were performed. Three factors were found to explain 72.55% of the total variance. Al, Cr, Fe, Co, Ni, and As were associated with 48.19% of the total variance explained by the first factor (F1). The second factor (F2) is 13.87% of the total variance explained in relation to Cu, Zn, Cd and Pb; the third factor (F3) was found to explain 10.48% of the total variance and was associated with Mn and Mo metals.

Table 3. Sediment assessment scale
Çizelge 3. Sediment değerlendirme ölçeği

Contamination factor (Hakanson, 1980)	
Cf<1	low contamination
1≤Cf<3	moderate contamination
3≤Cf<6	considerable contamination
Cf≥6	high contamination
Degree of contamination (C_d)(Hakanson, 1980)	
Cd≤8	low degree of contamination
8≤Cd<16	moderate degree of contamination
16≤Cd<32	considerable degree of contamination
Cd≥32	very high degree of contaminations
Modified degree of contamination (mCd)(Abrahim & Parker, 2008)	
mCd < 1.5	nil to very low degree of contamination
1.5 ≤ mCd < 2	low degree of contamination
2 ≤ mCd < 4	moderate degree of contamination
4 ≤ mCd < 8	high degree of contamination
8 ≤ mCd < 16	very high degree of contamination
16 ≤ mCd < 32	extremely high degree of contamination
mCd ≥ 32	ultra high degree of contamination
Pollution load index (PLI) (Tomlinson et al., 1980)	
PLI <1	no pollution
PLI is >1	deterioration
Enrichment factor (EF) (Hasan et al., 2013)	
<1	no enrichment
1 to 3	minor enrichment
3 to 5	moderate enrichment
5 to 10	moderately severe enrichment
10 to 25	severe enrichment
25 to 50	very severe enrichment
>50 extremely	severe enrichment
Geoaccumulation index (Igeo) (Müller, 1969)	
Igeo≤0	practically uncontaminated
0<Igeo<1	uncontaminated to moderately contaminated
1<Igeo<2	moderately contaminated
2<Igeo<3	moderately to strongly contaminated
3<Igeo<4	strongly contaminated
4<Igeo<5	strongly to extremely contaminated
Igeo≥5	extremely contaminated
Ratio of average effects range median (m-ERM-Q) (Long et al., 2000)	
m-ERM-q<0.1	9%
0.11<m-ERM-q<0.5	21%
0.51 <m-ERM-q <1.5	49%
m-ERM-q>1.50	76% probability of being toxic
Ratio of average probable effect level (m-PEL-Q) (Carr et al., 1996)	
m-PEL-Q<0.1	unimpacted
0.1< m-PEL-Q<1	moderately impacted
m-ERM-Q>1	highly impacted

The correlation between Ni-Cr-Fe-Co-Cu is significant. The highest correlation was observed between Ni-Cr (.860**) and Ni-Fe (.843**) (Table 6). These findings were also supported by PCA and CA results (Table 7–8). According to the PCA, these three are included in component number 1 (Table 7, Figure 2). When the CA analysis results were examined, it was seen that these 3 elements were in the same cluster (Table 8, Figure 3). Furthermore, the closest distance in the proximity matrix, that is, the strongest correlation, was between Ni-Cr (1.61) and Ni-Fe (1.65). The high correlation between Fe and Ni indicates the affinity of Ni with Fe oxide in the sediment (Taghipour et al. 2011, Ghorbani et al. 2015, Paoli et al. 2017). The correlation between Ni-Cr (.860**) and Ni-Co (.840**), which were among those with the highest correlations, can be attributed to the same geogenic origin from the parental material (Dankoub et al., 2012; Otari & Dabiri, 2015; Salmanpour et al., 2018).

Table 4. Evaluation of mean concentrations of Ms with a sediment assessment guide
Çizelge 4. Sediment değerlendirme kılavuzu ile ortalama Ms konsantrasyonlarının değerlendirilmesi

	Al	**As**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mn**	**Mo**	**Ni**	**Pb**	**Zn**
Cf	0.13	0.38	0.33	0.54	0.35	0.52	0.29	0.57	0.12	0.61	0.57	0.59
Cd						5						
mCd						0.50						
EF	1.00	2.99	2.59	4.22	2.69	4.03	2.29	4.43	0.90	4.72	4.43	4.61
Igeo	-3.54	-1.96	-2.17	-1.47	-2.12	-1.53	-2.35	-1.40	-3.70	-1.30	-1.40	-1.34
PLI						0.302						
m-ERM-Q						0.21						
m-PEL-Q						0.32						
TTU						2.24						
TU		13.15	1.27		15.45	5.29				51.28	5.58	7.99

Table 5. Health risk assessment of Ms in sediment
Çizelge 5. Sedimentte Ms'nin sağlık riski değerlendirmesi

		Exposure assessment		Non-carcinogenic risk			Carcinogenic risk		
	RfD	Exping	Expderm	HQing	HQderm	HI	CRing	CRderm	LCR
Al	1.00E+00	1.33E-02	4.65E-05	1.33E-02	4.65E-05	1.33E-02			
As	0.30E-03	1.77E-02	6.20E-05	5.91E+01	2.07E-01	5.93E+01	4.28E-03	1.50E-05	4.29E-03
Cd	1.00E-03	0.59E+01	2.05E-02	5.86E+03	2.05E+01	5.88E+03	3.59E-04	1.26E-06	3.60E-04
Co	3.00E-04	2.76E-01	9.66E-04	9.20E+02	3.22E+00	9.23E+02			
Cr	3.00E-03	6.50E-03	2.27E-05	2.17E+00	7.58E-03	2.17E+00	8.86E-03	3.1E-05	8.89E-03
Cu	4.00E-02	2.90E-03	9.98 E-06	7.13E-02	2.49E-04	7.15E-02			
Fe	7.00E-01	2.35E-02	8.24E-05	3.36E-02	1.18E-04	3.37E-02			
Mn	1.40E-01	3.21E-02	1.12E-04	2.29E-01	8.02E-04	2.30E-01			
Mo	5.00E-03	2.00E-04	5.99E-07	3.42E-02	1.20E-04	3.43E-02			
Ni	2.00E-02	0.79E+01	2.77 E-02	3.96E+02	1.39E+00	3.98E+02			
Pb	3.00E-03	1.00E-04	1.99E-07	1.90E-02	6.65E-05	1.91E-02	5.52E-05	1.93E-07	5.54E-05
Zn	3.00E-01	5.90E-03	2.05E-05	1.96E-02	6.85E-05	1.96E-02			

Table 6. Ms correlations
Çizelge 6. Ms korelasyonları

	Al	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Mo	Cd	Pb
Al	1											
Cr	.551*	1										
Mn	.262	.203	1									
Fe	.537*	.721**	.466	1								
Co	.437	.804**	.492*	.619**	1							
Ni	.373	.860**	.336	.843**	.840**	1						
Cu	.465	.813**	.325	.554*	.645**	.690**	1					
Zn	.228	.485*	.309	.495*	.387	.502*	.650**	1				
As	.259	.482	.018	.558*	.357	.535*	.336	.396	1			
Mo	.078	-.076	.230	.110	-.069	-.066	.184	.392	.260	1		
Cd	-.441	-.218	-.228	-.571*	-.287	-.419	-.185	.100	-.085	.103	1	
Pb	.488*	.480	.338	.377	.489*	.424	.525*	.485*	.609**	.426	.142	1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

CONCLUSION

The sediment quality was evaluated by investigating the Ms found in the sediment of the Mavi Dam Lake. Additionally, the possible toxic effects of the current accumulation of the sediment on living organisms were also examined. According to the results, it was determined that 51.28% of the total toxic effects of the Ms in the sediment were caused by Ni. When evaluated according to the sediment quality guideline, the accumulation of Ni was found to be significant. In this study, the possible health risks of the lake sediment to humans were assessed. It was seen that exposure to As, Cd, Co, Cr, and Ni in the sediment through ingestion or skin contact may be carcinogenic. Although it is thought that the sediment contamination will not directly threaten human life, the water-sediment relationship and the sedimentation-release mechanism draw attention to the extent of the danger. In the long term, anthropogenic pressure will also increase this risk. In conclusion, all data show that it would be correct to monitor lake sediment regularly.

Table 7. PCA rotated component matrix
Çizelge 7. PCA döndürülmüş bileşen matrisi

	1	2	3
Al	.763		
Cr	.760	.570	
Mn			.894
Fe	.925		
Co	.800		
Ni	.864		
Cu		.573	
Zn		.671	.554
As	.603		
Mo			.611
Cd		.514	
Pb		.784	

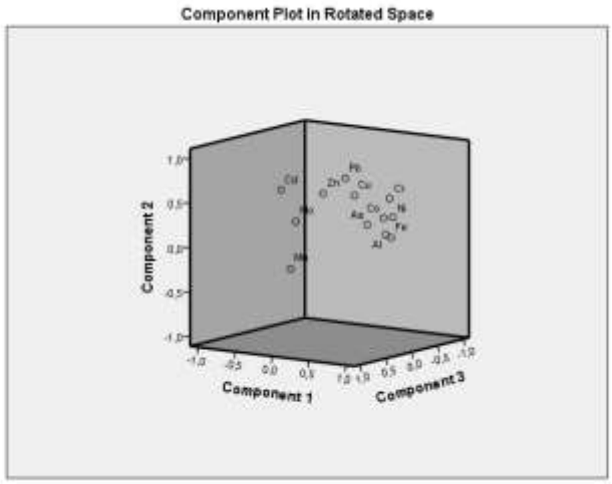

Figure 2. PCA analysis of Ms in the sediment of the Mavi Dam Lake
Şekil 2. Mavi Baraj Gölü sedimentinde Ms'nin PCA analizi

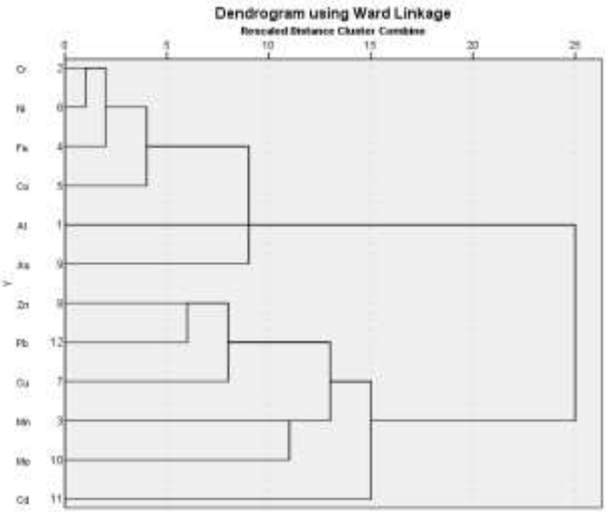

Figure 3. Cluster analysis of Ms in the sediment of the Mavi Dam Lake
Şekil 3. Mavi Baraj Gölü sedimentinde Ms'nin kümeleme analizi

Çizelge 8. CA yakınlık matrisi
Table 8. CA proximity matrix

	Al	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Mo	Cd	Pb
Al	0.000	3.537	5.806	3.304	3.409	3.558	4.384	4.722	4.396	4.856	6.982	4.295
Cr		0.000	5.860	2.344	2.466	1.610	3.774	3.477	3.679	5.349	6.201	3.759
Mn			0.000	5.182	5.029	5.421	5.624	4.173	5.325	4.974	6.064	5.568
Fe				0.000	2.666	1.655	4.478	3.972	3.426	5.294	7.027	4.462
Co					0.000	1.958	4.222	4.059	3.978	5.449	6.495	3.563
Ni						0.000	4.479	3.826	3.337	5.543	6.518	3.860
Cu							0.000	3.896	5.058	5.322	6.039	4.109
Zn								0.000	4.498	4.352	5.436	3.487
As									0.000	5.167	6.190	4.239
Mo										0.000	5.529	4.633
Cd											0.000	5.457
Pb												0.000

Contribution Rate Statement Summary of Researchers

The authors contributed equally to the article.

Author's Contributions

The authors declare that they have contributed equally to the article.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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