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Research Article

Anthropogenically-Induced Ecological Risks in Lake Gala, Thrace, NW Turkey

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Abstract

The aim of this study is to determine the anthropogenic effects in Lake Gala in the Trakya Region and to make an ecological risk analysis as a result of these effects. Based on the multi-element analyzes of the samples collected from the lake by grab and core method, using ICP-MS, which is frequently used in the calculation of ecological risk in sediment pollution studies; ecological risk analysis of lakes with statistical analyzes such as Enrichment Factor (EF), Contamination Factor (CF), Geoaccumulation Index (I_{geo}), Ecological Risk Index (ERi), Potential Ecological Risk Index (PER), Pollution Load Index (PLI), Factor Analysis, Spearman's Correlation Analysis and Cluster Analysis has been made. According to the analysis results, very high contamination observed in Hg and high contamination values observed in Mn pose a remarkable threat to the ecosystem. We conclude that the lake is exposed to intense anthropogenic pressure due to industrial pollutants, agricultural wastes, domestic wastes and pollutants from transportation vehicles.

Keywords: Ecological Risk, Pollution, Lake Gala, Trakya, NW Turkey

Introduction

Heavy metals are expressed as elements in a large area from group 2A to group 6A in the periodic table and are metals with a density higher than 5 g/cm³. There are more than 60 metals in this group, mainly Pb, Cd, Cr, Fe, Cu, Ni, Hg, As, Al and Zn. These elements are mostly found in the form of carbonate, oxide, silicate and sulfide in the form of fixed compounds or complexes with silicates (Haktanır and Arcak 1998). Heavy metals can undergo geological and biological transformation in nature. Heavy metals can accumulate further away from their current locations as a result of their disintegration and transport, and their concentrations can increase. For example, the increase in lead concentration in Greenland glaciers compared to previous years is a sign that this metal has been redistributed and transported (Karakaş 2000).

Lakes and ponds are habitats of great importance as they provide water for domestic, industrial and agricultural use, as well as food sources. Freshwater lakes, whose water can be used for agricultural irrigation, are also important in this respect. Although of fundamental importance to humans, freshwater systems are affected by multiple anthropogenic factors that cause serious adverse effects on the structure and function of these ecosystems. However, population growth and global warming create a negative pressure on lake ecosystems.
The biodiversity of lake and pond ecosystems is threatened by a range of human influences, including increased nutrient loads, pollution, acid rain and the invasion of exotic species. Analysis of changes over time suggests that older and well-known threats to biodiversity, such as eutrophication, acidification and contamination by metals, will be less of a problem in developed countries in the future. New threats such as global warming, ultraviolet (UV) radiation, endocrine disruptors and especially the invasion of exotic species will increase in importance. In addition, the threat of eutrophication, acidification and pollution by toxic substances is expected to continue to increase in developing countries where priorities other than environmental protection are present. Although the future of biodiversity in lakes and ponds is seriously threatened, increasing concern about environmental problems, implementation of new environmental strategies and administrations and international agreements triggers people's sensitivity to nature and lake ecosystems.

In this study, it was aimed to determine the metal levels accumulated at the bottom of the Lake Gala to perform ecological risk analyze (Figure 1). For this purpose, metal concentrations of the sediments of the lakes, which have not been studied on sediment quality before and which have been selected as examples within the scope of this study, have been tried to be determined? Heavy metals, due to its toxic effect by accumulating in the tissues and increasing heavy metal pollution, it causes more effects than the effects of organic pollutants in the environment alone. Many different analytical methods are used in regional ecological risk studies from potentially toxic element (PTE) in lakes, rivers, dams etc. (Fural and Kükrer, 2021). In recent years, many studies have been published on the different risks posed by toxic elements enriched by anthropogenic sources for ecosystem and human health in lakes, dams and rivers of Turkey (Kükrer, 2017, 2018; Kükrer et al., 2015, 2019; Kaya et al., 2017; Kükrer, 2018; Kırış and Baltaş 2020; Fural et al., 2021a,b; Tokatlı et al., 2021; Ustaoğlu and Tepe, 2018; Ustaoğlu and Islam, 2020; Ustaoğlu et al., 2020; Ustaoğlu, 2021). This study aims to determine the ecological risks of anthropogenic origin in Lake Gala.

Materials and Methods

Study Area

Lake Gala, located between Enez and Ipsala districts of Edirne province, is a freshwater/limnic lake established on the alluvial bottom of the Meriç River. There is the Meriç river in the west of Lake Gala and the Hisarlıdağ volcanic mass in the south. It is located between 40o 77' 24" north latitudes and 26o 19' 02' east longitudes. Lake Gala emerged as a product of the period when the Meriç River flowed on the Paşaköy-Karpuzlu-Bıyıklı Farm line. (Figure 1).

The Meriç River flowed between İpsala and Karpuzlu, located at the eastern end of the flood plain, before settled in its current bed. During this flow, the floods of the Meriç River formed crevasses. Micro-basins have settled behind the sets formed by these crevasses. Lake Gala has formed on these crevasses. The crevass deposits draw the western border of the lake basin formed by the eastern branch of the Meriç River before it enters the delta. Lake Gala remained behind the levees left behind by the Meriç delta's progress towards the sea, and its formation was completed by the alluvium brought by the Meriç River (Figure 1).

The lake consists of two parts, the Big Gala, and the Small Gala. The surface area of Lake Gala is 556 ha, and it is located at an altitude of 2 m above sea level. The water level of the lake varies according to the seasons. Lake Gala is an area where marine influences are seen due to its location close to the Saros Gulf and the Aegean Sea. There is a temperate climate type around the lake. The mean of the winter temperatures does not fall below 0oC. Due to this situation, precipitation falls in the form of rain. It is stated that the most precipitation is seen in winter and autumn seasons (Topgül, 2012). Hisarlıdağ located in the southeastern part of the lake, has a non-calcareous brown forest soil around it. There are alluvial soils, which are azonal soil type, around the lake. Paddy is cultivated largely in these lands.

There are 55 species of plant plankton, 31 species of animal plankton (zooplankton), 42 species of aquatic plants and 15 different tree species such as oak, willow and elm around the lake in Lake Gala. Reeds and swamps surround the lake (Topgül, 2012).

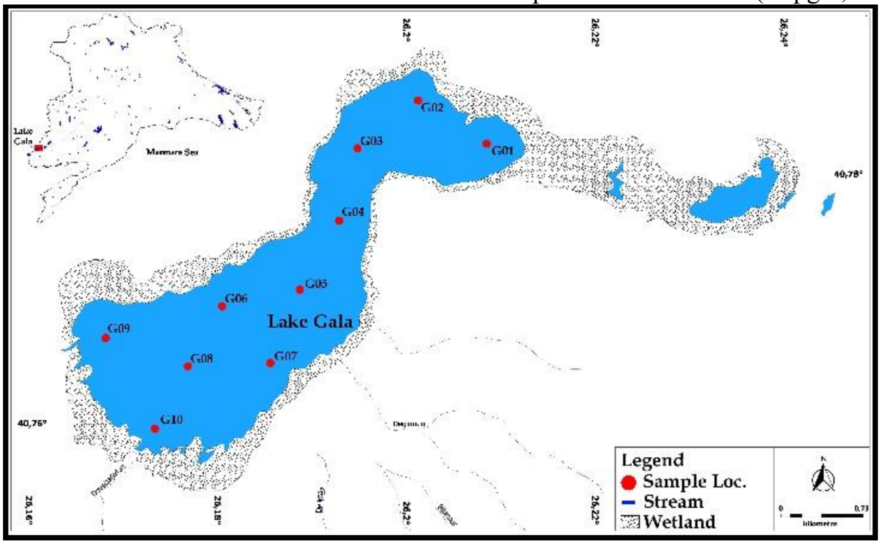

Fig. 1. Location map of Lake Gala and sampling sites.

Sampling and Analyses

Within the scope of the study, sediment samples were taken from selected stations in Lake Gala using Van Veen Grab. In addition, approximately 45 cm long surface sediment core samples were taken. Sampling was carried out in 2016 and 2017.

Chlorophyll degradation products, organic carbon and carbonate analyzes

While some of the samples taken were dried and stored for organic carbon analysis, the part to be used for chlorophyll degradation products was weighed less than 2 grams and was extracted with acetone in wet form and kept overnight. At the end of 24 hours, sediment and acetone were separated from each other by filtration method and the obtained liquid was read at 667 and 750 nanometer wavelengths in the spectrophotometer and chlorophyll degradation products were determined with the following formula (Lorenzen 1971).

CDP = K. OD 667.V/g.l

In formula *CDP; chlorophyll degradation products.

The sediment samples, which were dried and stored for organic carbon, were thinned by pounding in a mortar before analysis, and the analyzes were carried out according to the Wakley-Black Titration method. The amount of organic carbon in the sediments evaluated with the help of this method was calculated on a percentage (%) scale (Gaudette et al. 1974). For this, 0.2-0.5 grams of sample was taken and placed in a 500 ml flask, 10 ml of 1 N K2Cr2O7 was added and mixed. 20 ml of concentrated sulfuric acid was added and shaken for about 1 minute, blank and samples were left for 30 minutes. At the end of the period, the sample volume was diluted to 200 ml with distilled water, 10 ml of 85% H3PO4, 0.2 grams of NaF and 15 drops of diphenylamine indicator were added. The solution was back titrated with 0.5 N ammonium iron sulfate solution and the color was changed to brilliant green.

In the determination of carbonate in the sediment, a calcimeter device is generally used and the % lime content is expressed in terms of CaCO3. The metals in the sediment are stored in lake sediments by binding to other particles, especially CaCO3, decomposition products, chlorophyll and organic carbon, and transported with the help of streams (Liu, Sjen, et al., 2010). For this reason, CaCO3 analyzes should be performed in order to accurately determine metal sources and transport processes in ecological risk studies.

Multiple Element Analysis

Elemental analyzes of lake sediments were performed using an inductively coupled plasma-mass spectrometer (Inductively Coupled Plasma - Mass Spectrometer-ICP-MS).

Enrichment Factor (EF).

EF is used to determine whether the metal accumulation in the sediment comes from anthropogenic or natural sources. EF is obtained by dividing the current metal/reference element ratio by the background metal/reference element ratio. For reference elements, grain size normalization is performed by using conservative elements such as Fe, Al, Ca, Ti and Mn etc., which are generally abundant in rocks. As a result, errors arising from the grain size of the metals are eliminated (Zhang, et al, 2007). In this study, Al was used as the reference element. EF is obtained by dividing the current metal/reference element ratio by the successive metal/reference element ratio.

EF is calculated as follows;

- According to Sutherland (2000);
- EF<2 no enrichment / minimal enrichment,
- EF=2–5 moderate enrichment,
- EF=5–20 significant enrichment,
- EF=20–40 very high enrichment,
- EF>40 indicates extremely high enrichment.

Contamination Factor (CF).

The contamination factor is another tool used to determine the possible human effect on the sediment concentration Hakanson (1980).

CF is calculated as follows;

CF= Ci /CB (Eq. .)

In formula, Ci is concentration of metal and CB is background value of metal.

CF is obtained by dividing the present metal concentration by the background metal concentration. According to Hakanson (1980): • CF<1 low contamination, • 1≤CF<3 moderate contamination, • 3≤CF<6 high contamination, • CF>6 indicates very high contamination.

Geoaccumulation Index (Igeo).

Another method used to reveal the human impact on sediments is the Geoaccumulation index (Müller, 1969). Igeo is calculated as follows;

$$\mathrm{Igeo} = \log_2 \frac{C_m}{1{,}5 * B_m} \qquad \text{(Eq. 2)}$$

In the formula, Cm is the measured concentration of the metal and Bm is the background value of the metal.
Igeo values are interpreted as:

- Igeo= 0 uncontaminated
- 0 <Igeo ≤ 1 uncontaminated/ moderately contaminated,
- 1<Igeo ≤ 2 moderately contaminated,
- 2<Igeo ≤ 3 medium / heavily soiled,
- 3<Igeo ≤ 4 heavily contaminated,
- 4<Igeo ≤ 5 very / extremely contaminated,
- Igeo> 5 heavily contaminated.

2.2.6. Potential Ecological Risk (PER). The potential ecological risk index (PER) developed by Hakanson (1980) was used to make calculate about the potential toxic effects of metals accumulated in the sediment on the ecosystem.
PER is calculated as follows;

$$\mathbf{Eri} = E_f^i \times T_f^i \qquad \text{(Eq. 3)}$$

where is the enrichment factor, and is the response coefficient for toxicity of a single trace metal. Response coefficients used for the metals were as follows: Hg=40, Cd=30, As=10, Cu=Pb=Ni=5, Cr=2, Zn=1, Mn=.,1 Co=5, Tl=10 and V=2 (Hakanson, 1980; Rodriguez-Espinosa et al., 2018; Li et al., 2018).

$$\mathbf{PER} = \sum E_f^i \qquad \text{(Eq. 4)}$$

The risk factor (Eri) calculated separately for each metal and the integrated risk factor (PER) calculated to include all metals are evaluated as follows:

- Eri < 40 low potential ecological risk,
- 40 ≤ Eri <80 moderate potential ecological risk,
- 80 ≤ Eri <160 significant potential ecological risk,
- 160 ≤ Eri <320 high potential ecological risk,
- Eri ≥ 320 very high potential ecological risk,
- PER <150 low ecological risk,
- 150 ≤ PER <300 moderate ecological risk,
- 300 ≤ PER <600 significant ecological risk,
- PER ≥ 600 very high ecological risk.

Pollution Load Index (PLI). ,
The pollution load index (PLI) was calculated to determine the quality of the sediment in terms of metal deposits (Suresh et al., 2011).

PLI is calculated as follows;

PLI= (CF1 x CF2 x …..CFn)1/n (Eq.5)

where CF is the current metal concentration divided by the background metal concentration and n is the number of metals.

Factor Analysis and Spearman's Correlation Analysis.

As known factor analysis (FA) can be defined as a multivariate statistical method that aims to find meaningful new variables (factors, dimensions) by bringing together many interrelated variables. According to Daniel (1988), factor analysis is a technique designed to examine the covariance structure of a group of variables and to explain the relationships between these variables in terms of a much smaller number of unobserved latent variables called factors (Cited by Stapleton, 1997). We performed factor analysis to identify possible sources of metal concentrations obtained from surface sediment samples. Correlation analysis was carried out to reveal the direction, degree and importance of the relationship between variables.

Results and Discussion
Sediment Characterization, Distribution of Metals and TOC, Carbonate and CDP Distribution

The average concentrations of metals (µg/gr) in Lake Gala are as follows, in order of decrease; Fe>Al>Mn>Cr>Zn>Ni>Pb>Cu>As>Cd>Hg. The smallest values for all metals except Cd, Cr and Hg were determined in station 5 (Table 1). Require minimum value for Cd. At 8, ist for Cr. 4 and also for Hg. It was found in 6. Except for Cr and Hg, the highest values were determined in the 3rd station. The highest value for Cr was seen at the 6th station, and the highest value for Hg was at the 2nd station.

Table 1. Elemental concentrations of the samples taken from Lake Gala, measured as a result of ICP - MS.

	Cu	Pb	Zn	Ni	Mn	Fe	As	Cd	Cr	Al	Hg
1	12.88	16.15	36.0	31.6	1399	13900.00	8.8	0.12	31.6	11700.00	0.029
2	14.18	18.04	37.9	35.3	1569	15600.00	9.8	0.16	32.9	13100.00	0.036
3	16.52	20.83	44.9	40.2	2229	18100.00	11.3	0.17	43.4	14700.00	0.033
4	8.56	12.22	27.4	24.3	1211	10600.00	5.8	0.11	21.7	8800.00	0.023
5	3.63	7.61	17.3	10.0	387	6200.00	2.5	0.03	25.9	4400.00	0.016
6	6.03	8.56	23.0	15.2	706	8900.00	3.0	0.05	47.2	6500.00	0.010
7	9.19	13.53	30.9	26.0	1553	12300.00	5.3	0.12	26.5	9700.00	0.019
8	4.86	7.65	18.9	14.3	666	8400.00	2.9	0.02	33.6	5700.00	0.013
9	5.52	8.30	21.5	16.2	614	9800.00	3.2	0.06	39.2	6700.00	0.015
10	9.23	11.45	28.3	24.2	1054	11600.00	5.3	0.09	35.5	9100.00	0.019
ort	9.06	12.43	28.61	23.73	1138.8	11540.00	5.79	0.09	33.75	9040.00	0.02
min	3.63	7.61	17.30	10.00	387.00	6200.00	2.50	0.02	21.70	4400.00	0.01
max	16.52	20.83	44.90	40.20	2229.0	18100.00	11.3	0.17	47.20	14700.00	0.04

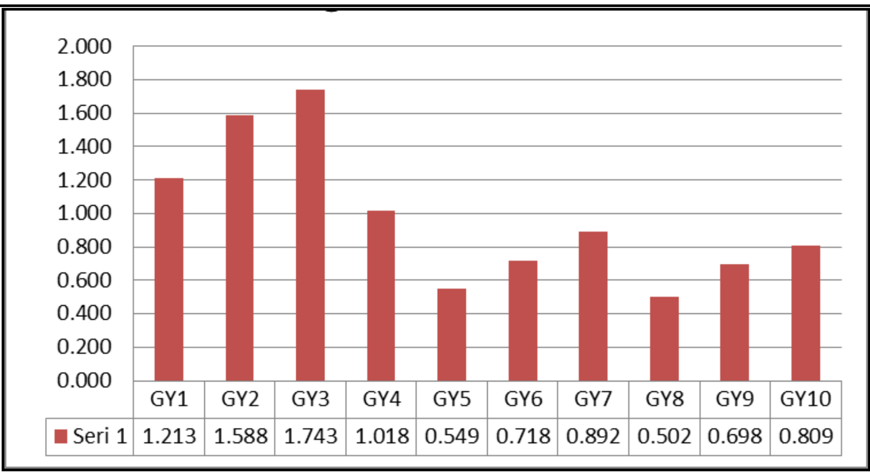

Fig. 2. Lake Gala Surface Samples Organic Carbon Levels Chart.

TOC content ranges from 0.50% to 1.74%, with an average value of 0.973%. The smallest TOC value was found at 0.50% ist8, while the maximum value was found at 1.74% ist3 (Figure 2). The presence of TOC in the sediment content positively affects the transport of metals to the environment. When the Lake Gala sediment samples are examined, it is seen that the metal concentrations are high in parallel with the TOC levels in the first 4 stations. Especially high Al and Fe concentrations are important.

CaCO3, which plays an important role in the transport of metals (Liu et al., 2010), was measured in the range of 2.68-26.58%. The smallest value was determined at ist5 and the largest value was determined at ist2 and 3 (Figure 3). The presence of CaCO3 in the sediment content positively affects the metal transport to the environment. When the Lake Gala sediment samples are examined, it is seen that the metal concentrations and TOC levels are high in parallel with the CaCO3 levels in the first 4 stations. Especially high Al and Fe concentrations draw attention.

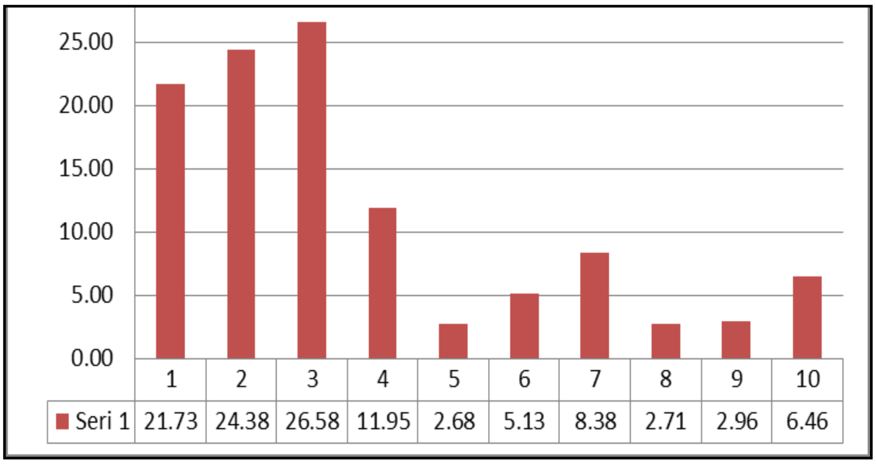

Fig. 3. Lake Gala Carbonate distribution in surface sediments.

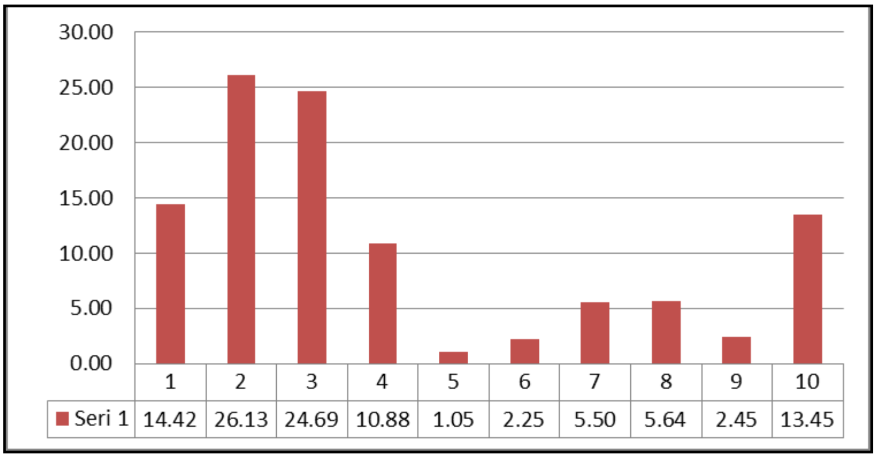

Fig. 4. Chlorophyll Decomposition Products Levels of Lake Gala Surface Samples

CDP values represent the primary production of lakes as well as the role of plants in transporting metals from water to sediment. CDP concentration was found between 1.05-26.13µg/gr in the surface sediment (Figure 4). The average value is 10.65µg/gr. The presence of CDP in lake sediments indicates that metals taken up by plants are transported to the sediment via dead plant residues. When the Lake Gala sediment samples are examined, it is seen that the metal concentrations, TOC and CaCO3 levels are high in parallel with the CDP levels in the first 4 stations. High metal concentrations in these 4 stations are associated with high TOC, CaCO3 and CDP levels in the environment.

Enrichment Factor

The average enrichment factor of the metals in Lake Gala, in descending order, is as follows; Hg>Mn>Cd>Cr>Zn>Pb>As>Ni>Cu>Fe. In general, the highest enrichment values were observed at station 5 (Figure 5). The mean enrichment for Cu values was 0.84, and minimal enrichment occurred at all stations (Cu<2). The mean enrichment for Pb values was 1.08, and minimal enrichment occurred at all stations (Pb<2). The mean enrichment for Zn values was 1.26, and minimal enrichment occurred at all stations (Zn<2). For Ni values, the mean enrichment was 0.87, and minimal enrichment occurred at all stations (Zn<2).

When the Mn values are examined, the average value is 4.64 and the enrichment is at a moderate level, while the stations with the highest enrichment value are the stations 7, 3 and 4, where significant enrichment has occurred (5<Mn<20) (Fig. 6). The mean enrichment for Fe values was 0.72 and minimal enrichment occurred in all stations (Fe<2). The average enrichment for As values was 0.95, and minimal enrichment occurred at all stations (As<2). The average enrichment for Cd values was 1.78, and the highest enrichment was at stations 4,7,2 and 3 (2<Cd<5). The average enrichment for Cr values is 1.26 and only station 6 has a moderate enrichment with a value of 2.17. While the mean enrichment for Hg values showed significant enrichment with 10.32; the highest enrichments occurred at stations 5, 2 and 4 (5<Hg<20). The mean for Al values was 1.40 and minimal enrichment occurred at all stations (Al<2).

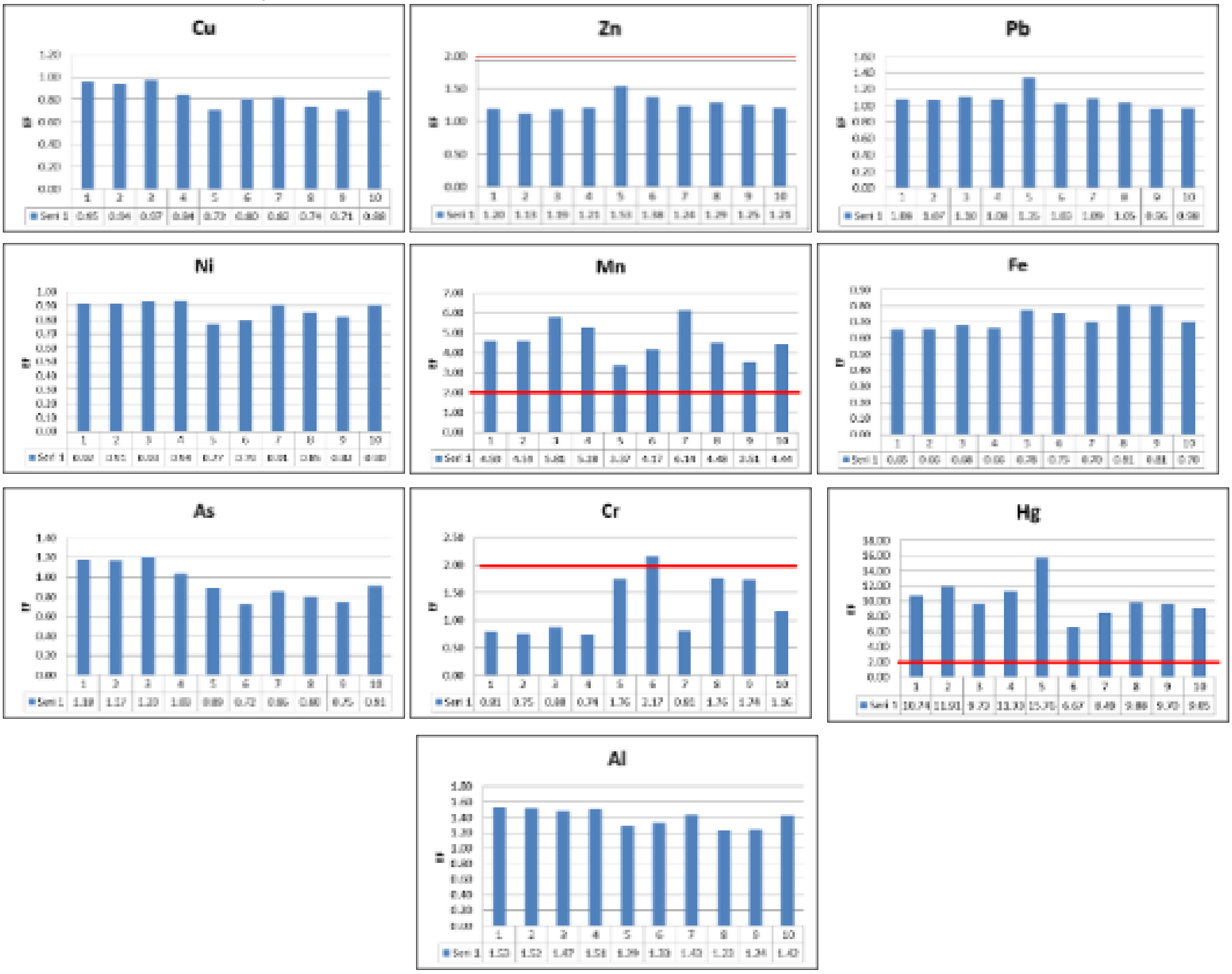

Fig.5. Element-based Enrichment Factor graphs of stations in Lake Gala.

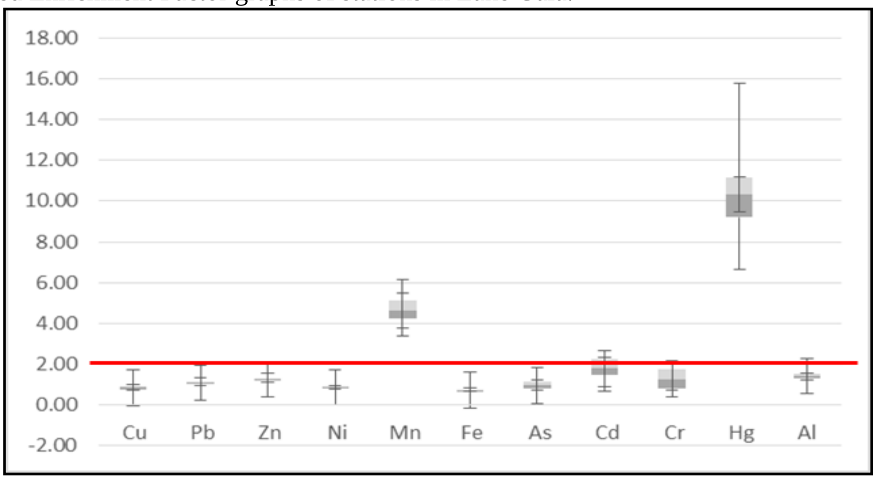

Fig. 6. Element-based Enrichment Factor Box and Whisker chart of Lake Gala.

As a result, significant enrichment at all stations for Hg concentrations in Lake Gala; There is moderate enrichment for Mn and Cd (stations 2,3,4) concentrations. For all elements, there is an intense input at stations 5, 4, 2, and 3. The increase observed in element concentrations and enrichment values indicates the human impact in the region.

Contamination Factor

As a result of the evaluations made on the samples in Lake Gala, the CF values are as follows;

Hg>Mn>Cd>Zn>Cr>Pb>As >Al>Ni >Cu >Fe (Figure 7). For Cu, moderate contamination was observed at station 3, and low accumulation was observed at all remaining stations. Medium level contamination was detected in Pb 2nd and 3rd stations, and low level contamination was detected in other stations.

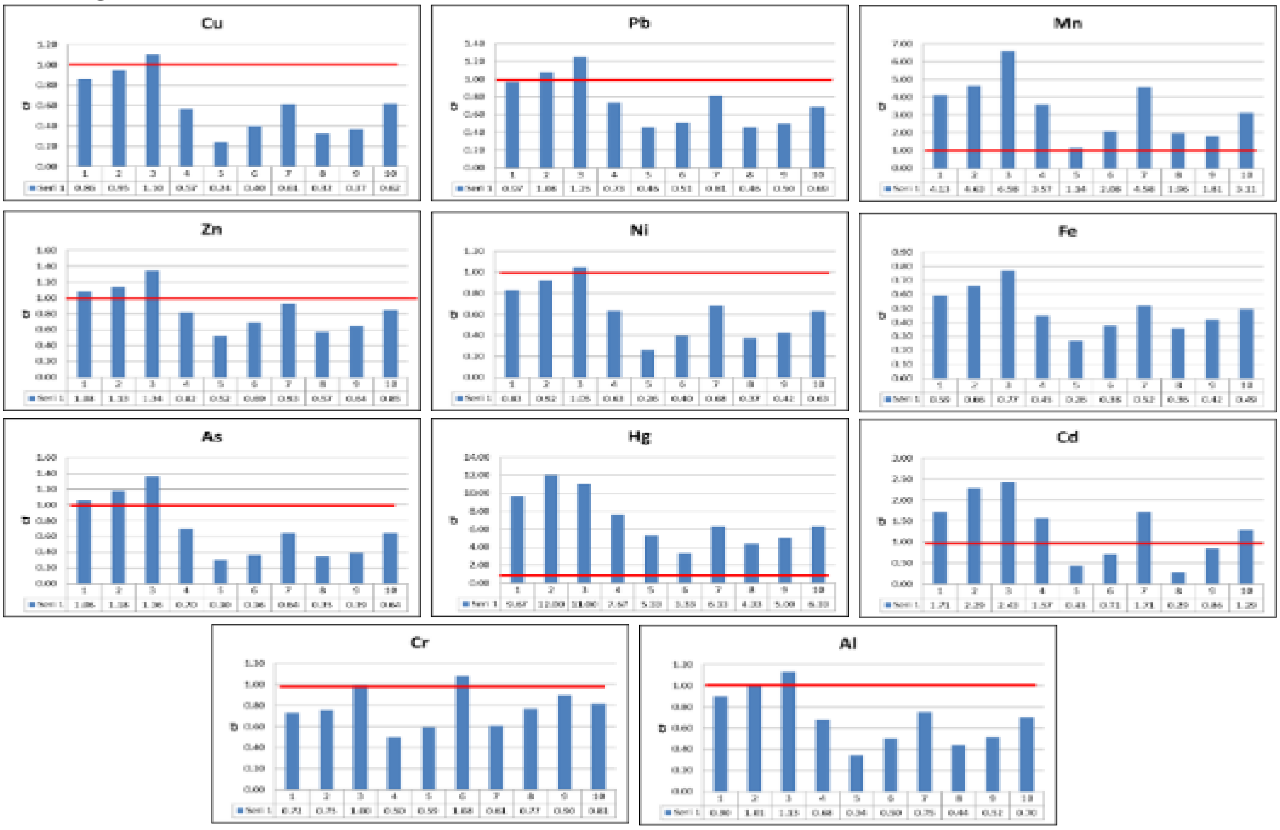

Fig. 7. Element-based Contamination Factor graphs of stations in Lake Gala.

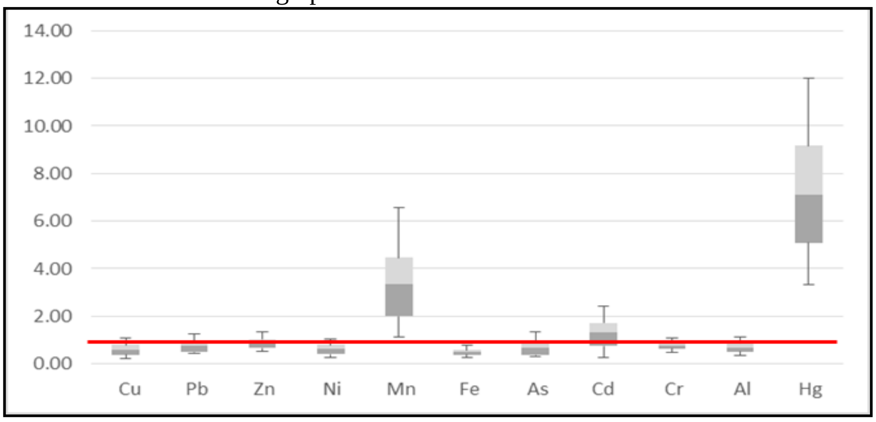

Fig. 8. Element-based Contamination Factor Box and Whisker chart of Lake Gala.

1,2,3 for Zn with the same situation. For Ni at the stations, moderate contamination was observed only in the 3rd station, and low-level contamination was observed in the remaining stations. When we look at Mn, very high contamination (6.58) was observed at Station 3, high contamination was observed at Station 1,2,4,7 and 10, and moderate contamination was observed at stations 5,6,8 and 9. Low contamination was observed at all stations for Fe. Medium level contamination was observed in As 1,2 and 3 stations, and low level contamination was observed in the others. For Cd, low level contamination was detected at 5, 6, 8 and 9 stations, and moderate contamination was detected at the remaining 6 stations. Cr; low-level contamination was observed at stations 3 and 6, and the remaining stations were medium-level. When we look at Al, it is medium at stations 2 and 3; low contamination was observed in all other stations. If Hg is 5,6,8 and 9th stations, high contamination levels were observed, while very high contamination levels were observed in other stations.

As a result, very high contamination observed for Hg and high contamination values observed for Mn pose a remarkable threat to the ecosystem. In addition, there is moderate contamination for Cd (Fig. 8).

Geoaccumulation Index

Considering the studied elements in Lake Gala, the average geoaccumulation value is 2.13 for Hg and 0.98 for Mn (Fig. 9). In this case, it was seen that it was moderately / very contaminated for Hg, and uncontaminated / moderately contaminated for Mn. The highest value for Hg is 3 (station 2), at the moderate/highly contaminated level. The highest value for Mn is 2.13 (Station 3), at medium/highly polluted level. In addition, there is an uncontaminated/moderately polluted state for Cd at stations 1,2,3,4 and 7.

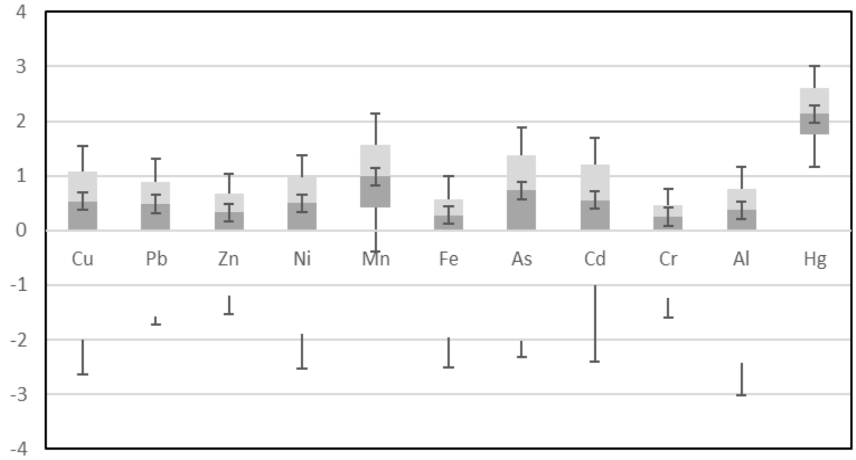

Fig. 9. Box and Whisker graph of element-based Geoaccumulation index of Lake Gala

Ecological Risk Index (Eri) and Potential Ecological Risk Index (PER)

The limit value for Eri values is 40, and when it exceeds this value, there is a Potential Ecological Risk for the element in question (Figure 10). The descending order of the metals according to the calculated Eri values is as follows; Hg > Cd >As >Pb >Ni >Cu >Cr >Zn. Looking at the Eri values; while the average of Hg poses a potential ecological risk with 343.08, there is a very high ecological risk in terms of Hg in the first 3 stations, and an important potential ecological risk in the 6th station. While there is a low potential ecological risk with a Cd average of 39.86, when we look at the station basis, there is a moderate potential ecological risk for Cd at stations no 3,2,1,7 and 4. In terms of Potential Ecological Risk, when all heavy metals are evaluated as an integrated, the limit value is 150, and this threshold value has been exceeded for all stations when viewed on a station basis. The average PER value of the stations is 343.08 and there is a significant potential ecological risk (Figure 5.10.). The minimum value is 167.79 and the maximum value is 577.76. While there is a significant potential ecological risk at stations 1,2,3,4,7 and 10 in terms of PER values; there is a moderate potential ecological risk for stations 5, 6, 8 and 9. The highest values were measured at stations 2,3 and 1, respectively.

Pollution Load Index (PLI).

PLI values calculated for Lake Gala are between 0.00 and 36.04. The average value is 4.60 (Fig. 11). Considering that the limit value is “1”, the pollution in Lake Gala is quite alarming.

Factor Analysis Results

Factor analysis was performed to identify possible sources of metal concentrations obtained from surface sediment samples. It is possible to collect the studied elements under two factors (Figure 12). The first factor is Cu, Pb, Zn, Ni, Mn, Fe, As, Cd, Al and Hg source and transport processes are common. The second factor is the element Cr (Table 2).

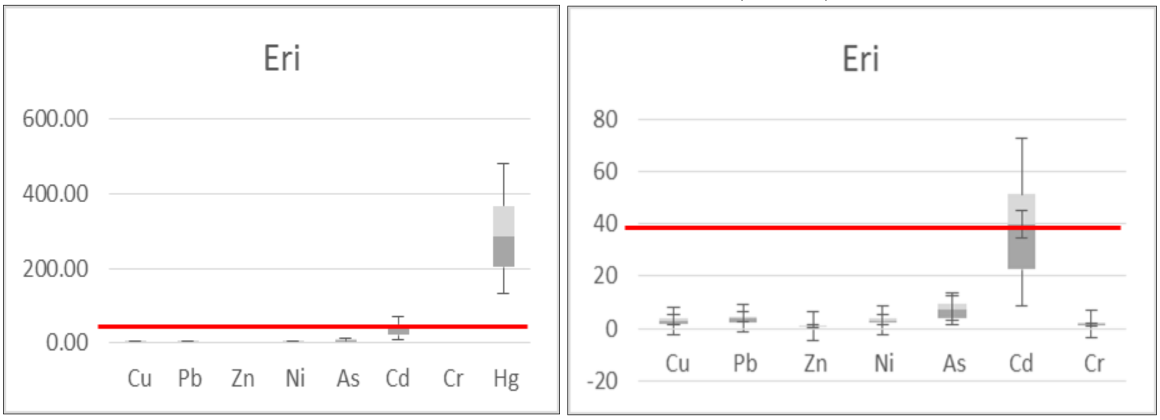

Fig. 10. Box and Whisker graph of the element-based Potential Ecological Risk index of Lake Gala.

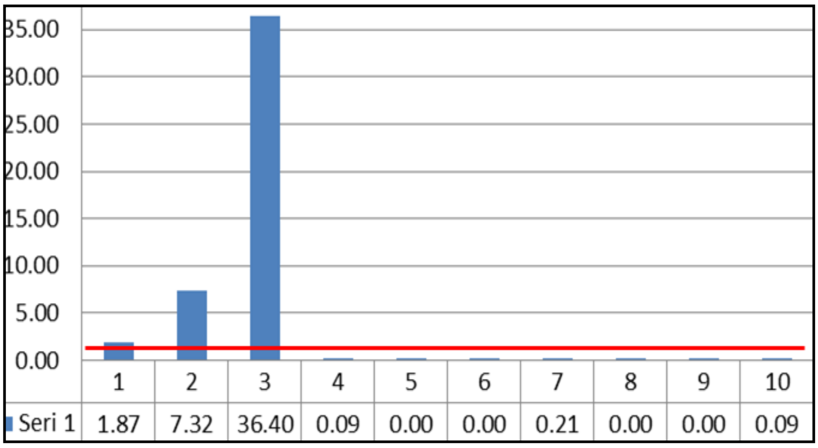

Fig. 11. Station-based Pollution load index graph of Lake Gala.
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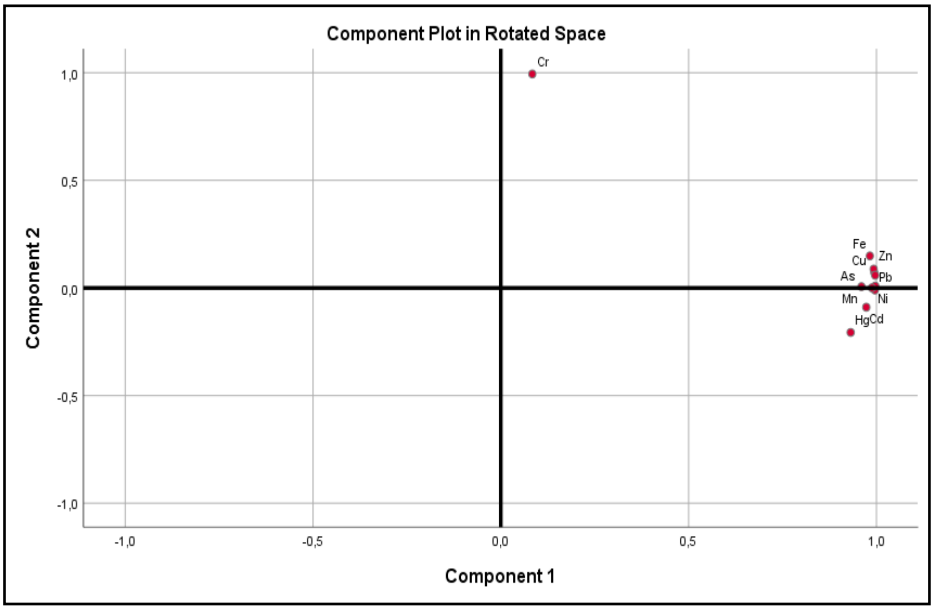

Fig. 12. Factor (Component) Analysis Chart of Lake Gala.
Table 2. Lake Gala factor analysis numerical data.

	Component	
	1	2
Cu	**.995**	.052
Pb	**.995**	-.030
Zn	**.994**	.068
Ni	**.997**	-.011
Mn	**.960**	-.013
Fe	**.985**	.129
As	**.988**	-.019
Cd	**.971**	-.109
Cr	.104	**.992**
Al	**.997**	.039
Hg	**.927**	-.225

Correlation Analysis

In the analysis of Lake Gala, if the P(sig) value is less than 0.05, there is a significant relationship between these two variables. This analysis does not give the cause and effect relationship between the two variables, but gives the case of moving together. There is a direct proportionality between them, as the environment increases, the other variable also increases. For example; when Ni element concentrations are examined, there is a positive correlation between Cu, Pb, Zn, Mn, Fe, As, Cd, Al and Hg elements. In addition, when the values of the Cr element are examined, there is no relationship between other elements. In this case, it is understood that the Cr element enters the environment from a different source (Table 3).

Table 3. Spearman's Correlation table of the elements detected in Lake Gala.

	Cu	Pb	Zn	Ni	Mn	Fe	As	Cd	Cr	Al	Hg	CaCO3	CDP	OC	PER	PLI
Cu	1															
Pb	,000	1														
Zn	,000	,000	1													
Ni	,000	,000	,000	1												
Mn	,000	,000	,000	,000	1											
Fe	,000	,000	,000	,000	,000	1										
As	,000	,000	,000	,000	,000	,000	1									
Cd	,000	,000	,000	,000	,000	,000	,000	1								
Cr	,627	,881	,726	,934	,960	,777	,934	,947	1							
Al	,000	,000	,000	,000	,000	1	,000	,000	,777	1						
Hg	,002	,002	,002	,001	,004	,001	,000	,000	,424	,001	1					
CaCO3	,000	,000	,000	,000	,000	,000	,000	,000	,934	,000	,001	1				
CDP	,001	,003	,002	,005	,002	,001	,001	,009	,907	,002	,002	,002	1			
OC	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,000	,005	1		
PER	,002	,001	,001	,000	,002	,000	,000	,000	,511	,000	,000	,000	,002	,000	1	
PLI	,000	,000	,000	,000	,000	1	,000	,000	,777	1	,001	,000	,002	,000	,000	1

Conclusion

The average concentrations of metals in Lake Gala (µg/g) are Fe>Al>Mn>Cr>Zn>Ni>Pb>Cu>As>Cd>Hg, respectively. TOC content ranges from 0.50% to 1.74%, with an average value of 0.97%.

$CaCO_3$, which plays an important role in the transport of metals, was measured in the range of 2.68-26.58%. CDP concentration was found between 1.05-26.13µg/gr in the surface sediment. The average value is 10.65µg/gr. The presence of CDP in lake sediments indicates that metals taken up by plants are transported to the sediment via dead plant residues.

Significant enrichment at all stations for Hg concentrations in Lake Gala; There is moderate enrichment for Mn and Cd (stations 2,3,4 and) concentrations. The increase observed in element concentrations and enrichment values indicates the human impact in the region, and poses a threat to the ecosystem.

The very high contamination observed for Hg and the high contamination values observed for Mn pose a remarkable threat to the ecosystem. There is also moderate contamination for Cd.

Considering the studied elements in Lake Gala, the average geoaccumulation value is 2.13 for Hg and 0.98 for Mn. In this case, it was seen that it was moderately / very contaminated for Hg, and uncontaminated / moderately contaminated for Mn. In terms of Potential Ecological Risk, when all heavy metals are evaluated as an integrated, the limit value is 150, and this threshold value has been exceeded for all stations when viewed on a station basis. The average PER value of the stations is 343.08 and there is a significant potential ecological risk. PLI values range from 0.00 to 36.04. The average value is 4.60. Considering that the limit value is "1", the pollution in Lake Gala is at an alarming level.

Our results reveal that it is possible to collect the studied elements under two factors. The first factor is Cu, Pb, Zn, Ni, Mn, Fe, As, Cd, Al and Hg source and transport processes are common. The second factor is the element Cr.

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