APPLICATION OF HEAVY METAL POLLUTION INDEX AND HEAVY METAL EVALUATION INDEX TO EVALUATE THE WATER QUALITY OF ÇOKAL DAM LAKE (TEKIRDAĞ, TÜRKIYE): A GIS BASED ASSESSMENT

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Cem Tokatli
Trakya University, Evrenos Gazi Campus, Edirne, **Türkiye**

ABSTRACT

Dam Lakes are artificial stagnant freshwater ecosystems built for various purposes such as irrigation and drinking water supply and flood protection. However, over the years, they can become unusable as a result of various factors such as pollution, sedimentation and excessive use. Çokal Dam Lake is one of the most important dams in the Thrace Region. It was built on the Kocadere Stream between 1997-2002 for irrigation and drinking water supply in the Tekirdağ Province. In this study, surface water samples were collected from the Çokal Dam Lake (2 locations), Aksakal and Çayırlar Streams that are feeding the reservoir and the Kocadere Stream before it falls into the Saros Bay at the output location of the dam in the rainy season (autumn) of 2020. Chromium (Cr), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), cadmium (Cd) and lead (Pb) contents were determined in the collected samples, and the water quality of investigated locations were evaluated by applying some ecotoxicological risk assessment indices. Also Geographic Information System (GIS) was used to provide a visual summary of the applied indices.

Keywords: Çokal Dam Lake, Water quality, Toxic elements, Heavy Metal Pollution Index, Heavy Metal Evaluation Index, Geographic Information System

INTRODUCTION

Toxic metals enter the fluvial and stagnant surface water bodies through industrial or domestic wastewater and surface runoff or drainage water from agricultural lands and they may can cause significant water pollution problems [1 – 3].

Reservoirs are being constructed for irrigation, flood prevention, stream regime regulation and electricity generation. They are being constructed by State Hydraulic Works (DSI) in Türkiye and there are approximately 900 dam lakes in operation in Türkiye [3 – 5].

Çokal Dam Lake is one of the most important dams in the region, which was built between 1997-2002 for irrigation and drinking water supply, on the Kocadere Stream, in the Tekirdağ Province of Thrace Region [6, 7].

The body volume of the dam lake, which is an earth and rock body fill type, is approximately 4.065,000 m^3 and its height from the stream bed is 81 m. At the normal water level, the lake volume is approximately 204 hm^3 and the lake area is 10 km^2. While the dam provides irrigation services to an area of 10,660 hectares, it also provides 14 hm^3 of drinking water annually [6, 7].

Toxic elements such as chromium (Cr), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), cadmium (Cd) and lead (Pb) can diminish mental and central nervous system function; elicit damage to blood composition as well as the kidneys, lungs, and liver; and reduce energy levels. Although they occur naturally on earth, they may enter in large quantities

into the air, soil and water, causing serious damage to living things and the environment as a result of anthropogenic activities. Drinking water is considered one of the main routes of their entry into the human body and numbers of studies have been performed to examine the effects of toxic elements in surface and groundwater ecosystems [8 – 11].
Especially in recent years, various ecotoxicological risk assessment indices have been used to evaluate the synergistic effects of toxic elements, and Heavy Metal Pollution Index (HPI) and Heavy Metal Evaluation Index (HEI) are among the most widely used risk assessment indexes [12 – 14].
The aim of this research was to evaluate the water quality of Çokal Dam Lake basin by applying 2 of the most widely used ecotoxicological risk assessment indices.

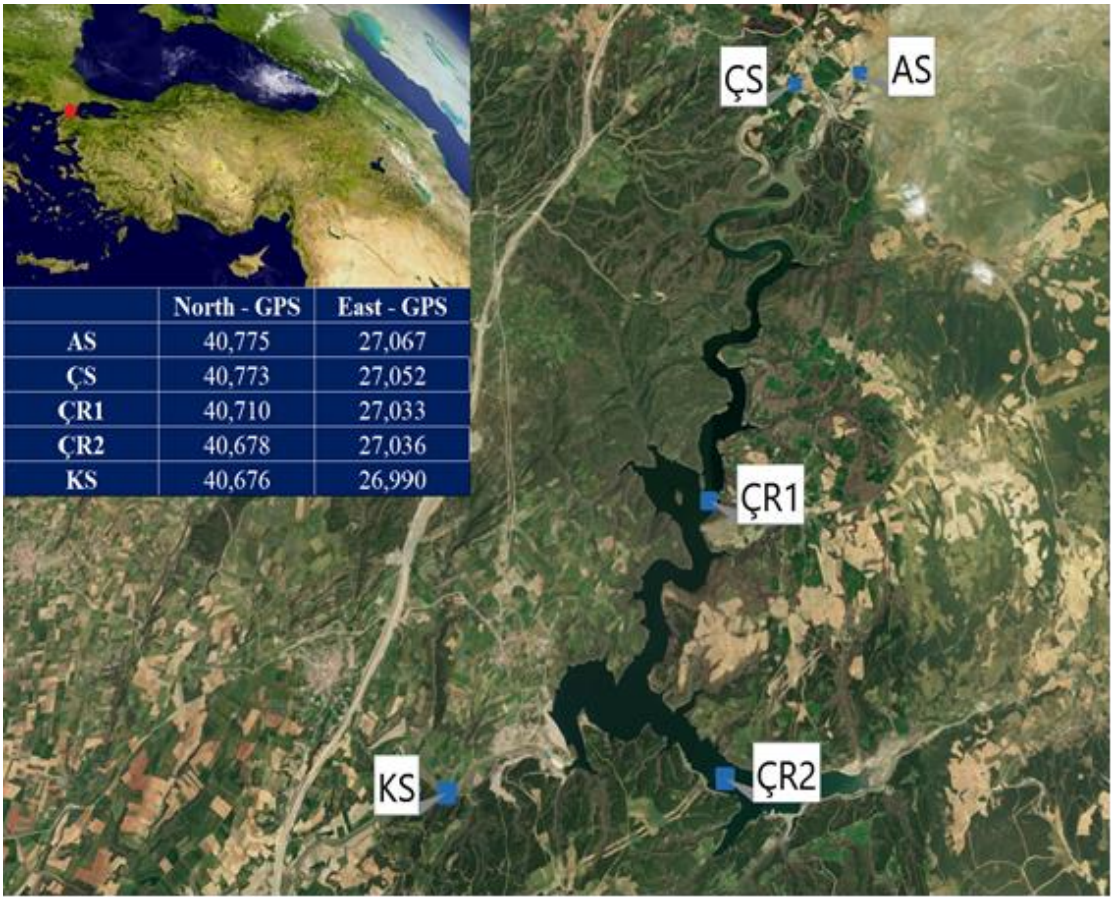
MATERIALS AND METHODS

Collection of Surface Water Samples

consisted fluvial ecosystem at the output of the reservoir is named as Kocadere Stream and it flows into the Gulf of Saros.
Surface water samples were collected from the Çokal Dam Lake (2 selected locations), Aksakal and Çayırlar Streams that are feeding the reservoir and the Kocadere Stream before it falls into the Saros Bay at the output location of the dam in the rainy season (autumn) of 2020. The maps of study area and the selected stations with the coordinate information are given in Figure 1.

Element Analysis

pH values of surface water samples (one liter) were set to 2 by means of adding 2 ml of HNO3 into each. Then the samples were filtered by means of a cellulose nitrate filter (0.45 μm) and their volumes are made up to 50 ml with ultrapure water. Toxic element levels were determined by using an ICP – MS device (Agilent 7700 xx) in Thrace University in an international accreditation certificated laboratory and the element analyses were recorded as means of triplicate measurements (TS EN / ISO IEC 17025) [15].



	North - GPS	East - GPS
AS	40,775	27,067
ÇS	40,773	27,052
ÇR1	40,710	27,033
ÇR2	40,678	27,036
KS	40,676	26,990

Figure 1. Çokal Dam Lake Basin and selected stations

Calculation of Risk Assessment Indices

Heavy Metal Pollution Index (HPI) (formulas 1 and 2) and Heavy Metal Evaluation Index (HEI) (formula3) are being calculated according to the following formulas:

$$HPI = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i} \quad (1)$$

$$Q_i = \sum_{i=1}^{n} \frac{M_i}{S_i} \times 100 \quad (2)$$

$$HEI = \sum_{i=1}^{n} \frac{H_C}{H_{MAC}} \quad (3)$$

“Qi” is the sub – index of the toxic element, “Wi” is the unit weight of the ith parameter, “Mi” is the monitored values of toxic metals, “Si” is the standard values of the parameter [16] and n is the number of parameters considered. Water quality ratings for applied HPI are given in Table 1.

"Hc" is value observed for each parameter and "Hmac" indicates the value of maximum admissible concentration (MAC) for each parameter [16]. Water quality ratings for applied HEI are given in Table 1.

Table 1. Water quality ratings for indices

Value	Rating of Water Quality	Usage Possibilities
Heavy metal pollution index (HPI)		
< 100	Low heavy metal contamination	Suitable
> 100	High heavy metal contamination	Not suitable
Heavy Metal Evaluation Index (HEI)		
< 10	Low contamination	Suitable
10 – 20	Medium contamination	Not suitable
> 20	High contamination	Not suitable

RESULTS AND DISCUSSION

Monomial and multinomial risks according to HPI and HEI for the surface water resources of Çokal Dam Lake Basin were calculated separately for all the investigated fluvial and lacustrine ecosystems.

The monomial index scores of all the investigated locations are given in Table 2. The results of multinomial index scores of all the applied ecological risk assessment indices are shown in Figure 2 and Figure 3 as GIS based distribution maps.

According to the results of HPI and HEI, surface water of the Çokal Dam Lake Basin components posed "low heavy metal contamination" and "low contamination" respectively.

According to monomial regulators of HPI, the risks of investigated toxic elements may be sorted as As > Pb > Cd > Ni > Cr > Zn > Cu, in general.

According to monomial regulators of HEI, the risks of investigated toxic elements may be sorted as As > Ni > Pb > Cd > Cr > Zn > Cu, in general.

According to the results of multinomial HPI and HEI, the risks of investigated components for Çokal Dam Lake basin may be sorted as

Çayırlar Stream > Aksakal Stream > Kocadere Stream > Çokal Reservoir, in general.

Arsenic is a potentially toxic and carcinogenic element. Many industrial processes contribute to arsenic contamination of the environment. Exposure of arsenic may cause many of health problems for human [17 – 21].

In the present research, although the multinomial results of applied ecotoxicological indices were below the critical limit levels, arsenic was found as the most critical element among the investigated toxicants for all the investigated freshwater habitats in the Çokal Dam Lake Basin. Agricultural applications and generally applied monocultural practices conducted almost all around the reservoir is thought to be the main cause of these detected relatively high arsenic risk.

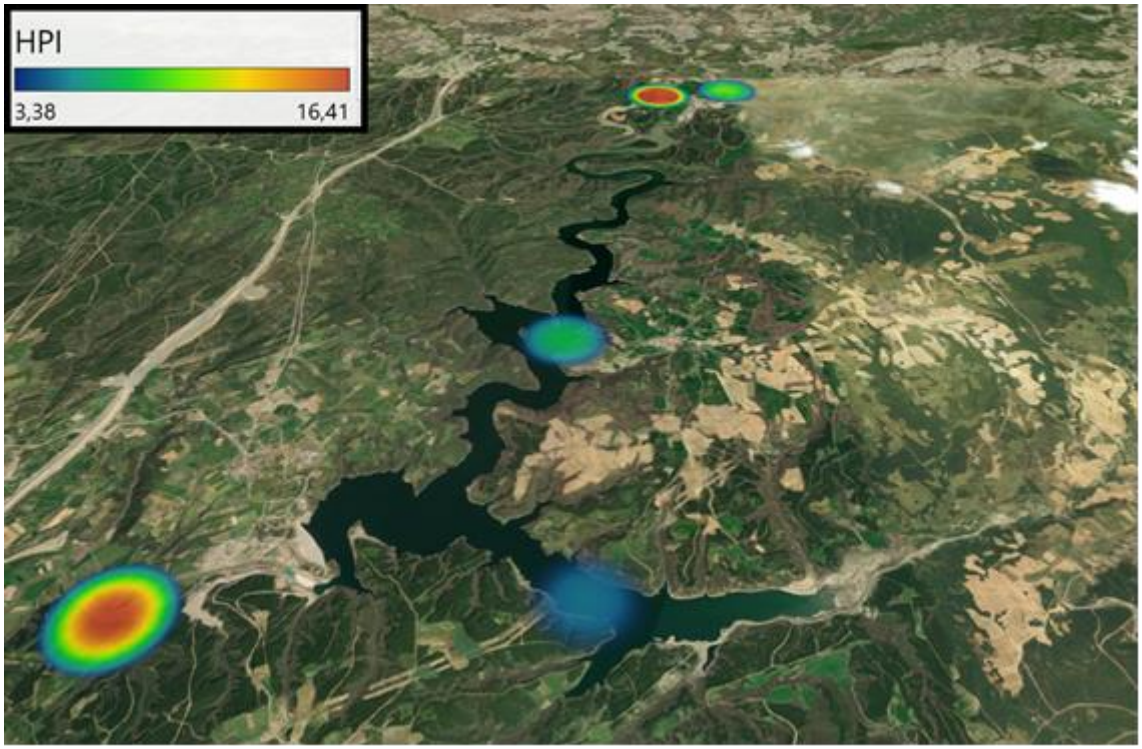


Figure 2. Multinomial results of applied HPI

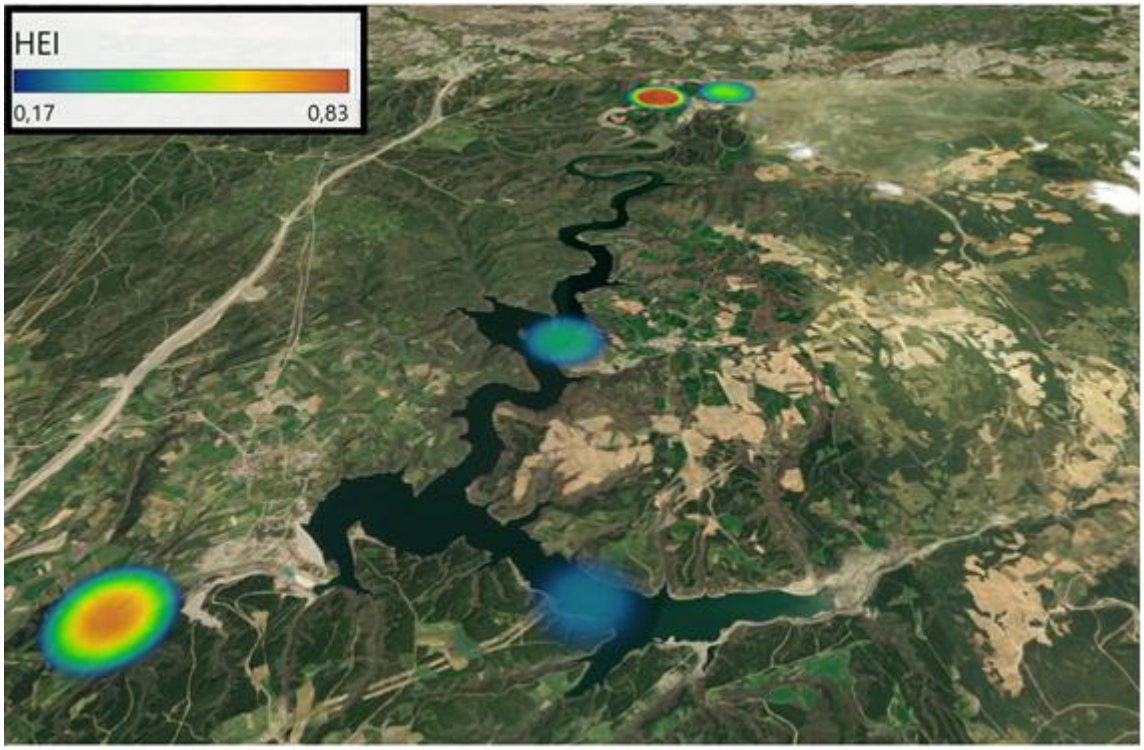


Figure 3. Multinomial results of applied HEI

Table 2. Monomial HPI and HEI coefficients for toxicants

	Monomial HPI Scores					Monomial HEI Scores				
	AS	**ÇS**	**ÇR1**	**ÇR2**	**KS**	**AS**	**ÇS**	**ÇR1**	**ÇR2**	**KS**
Cr	0.020	0.133	0.015	0.046	0.174	0.004	0.029	0.003	0.010	0.038
Ni	0.325	0.589	0.130	0.168	0.232	0.099	0.179	0.039	0.051	0.071
Cu	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.001
Zn	0.000	0.000	0.000	0.000	0.000	0.002	0.006	0.002	0.002	0.002
As	7.661	21.987	5.314	3.019	11.935	0.333	0.956	0.231	0.131	0.519
Cd	0.477	0.376	0.764	0.594	3.225	0.010	0.008	0.017	0.013	0.070
Pb	1.059	1.554	1.192	1.251	1.284	0.046	0.068	0.052	0.054	0.056

In order to evaluate the heavy metal contamination status in waters of the of the Çokal Dam Lake Basin, the levels of calculated HPI and HEI values obtained from the current research were compared with those reported by previous investigations in Türkiye (Table 3).

The average levels of HPI and HEI values detected in the water of Çokal Dam Lake Basin in the current research were higher than detected in the waters of Ponds and Dam Lakes of Thrace Region, Meriç River and tributaries – groundwater resources of Ergene River Basin, while they were lower than detected in the waters of Lakes of Thrace Region, Gala Lake, Çorlu Stream and Ergene River [22 – 25].

These findings revealed that the concentrations of heavy metal concentrations of different fluvial and lacustrine surface water and groundwater habitats varied significantly as a result of anthropogenic activities and natural sources.

Table 3. Comparison of HPI and HEI values in current study with other aquatic habitats

Aquatic Habitat	**HPI**	**HEI**	**Reference**
Çokal Dam Lake Basin	12.71	0.62	Current Research
Thrace Region Lakes	17.83	0.90	[22]
Thrace Region Reservoirs	7.06	0.40	[22]
Thrace Region Ponds	10.47	0.60	[22]
Gala Lake	55.98	3.50	[23]
Çorlu Stream	22.60	3.45	[24]
Meriç River	5.06	0.36	[25]
Ergene River	13.18	1.43	[25]
Ergene River Basin Tributaries	8.31	0.77	[25]
Ergene River Basin Groundwater	8.32	0.53	[25]

CONCLUSIONS

In this research, some widely used toxic element risk assessment indices were used to evaluate the surface water quality of Çokal Dam Lake Basin components. As a result of this study, lentic habitats of the basin were found as relatively less contaminated components of the basin, while the lotic habitats were found as relatively more contaminated components. According to the results of Heavy Metal Pollution Index (HPI) and Heavy Metal Evaluation Index (HEI), it was also determined that arsenic was found as the relatively most critical toxicant among the investigated toxic elements. It was also determined that Çokal Dam Lake Basin found as "Low heavy metal contamination" and "Suitable for consumption" in terms of applied HPI and "Low contamination" and "Suitable for use" in terms of applied HEI.

In line with the data of the current investigation, in order to maintain the sustainability of this significant dam lake basin, which is of great importance especially for the people

living in the region, it is recommended to continuously monitoring the accumulation levels of toxic metal in water, sediment and biotic factors.

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