

**APPLICATION OF GIS FOR AN ECOTOXICOLOGICAL RISK
ASSESSMENT OF HEAVY METALS IN WATER OF TWO SIGNIFICANT
DAM LAKES LOCATED IN MARMARA REGION, TÜRKIYE**

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ABSTRACT

Reservoirs, which are mainly being used for irrigation and drinking water supply and flood protection, are among the most significant lacustrine freshwater habitats. However, they are adversely affected by anthropogenic contamination pressure especially in recent years. Atikhisar and Alibey Dam Lakes are two of the most important reservoirs in the Marmara Region. They were built for irrigation and drinking water supply in the Çanakkale and İstanbul Provinces. In this study, surface water samples were collected from the inputs and output regions of Atikhisar and Alibey Dam Lakes (total of 4 locations) in the dry season (end of summer) of 2022. Mercury (Hg), nickel (Ni), selenium (Se), barium (Ba), arsenic (As), cadmium (Cd), strontium (Sb) and boron (B) contents were determined in the collected samples, and the water quality of investigated locations were evaluated by applying some ecotoxicological risk assessment indices including Heavy Metal Pollution Index (HPI) and Heavy Metal Evaluation Index (HEI). Also, Geographic Information System (GIS) was used to provide a visual summary of the applied indices. As a result of the study, the reservoirs found as "Low heavy metal contamination" in terms of applied HPI and "Low contamination" in terms of applied HEI. It was also determined that the heavy metal pollution ranking of the dams in terms of applied indices were as follows: Alibey Dam Lake > Atikhisar Dam Lake.

Keywords: Atikhisar Dam Lake, Alibey Dam Lake, Toxic elements, Ecotoxicological Risk Assessment Indices, Geographic Information System

INTRODUCTION

Heavy metals are hazardous inorganic pollution factors that are toxic even at very low levels. They may enter to the water environment through industrial or domestic wastewater and surface runoff or drainage water from agricultural [1 – 3]. Especially in recent years, heavy metals, which are an important stress factor in aquatic ecosystems, can reach humans through the food chain [3 – 5].

Atikhisar Dam is a dam built between 1971-1975 for irrigation and flood control purposes in Çanakkale, on Sarıçay Stream. The body volume of the dam, which is an earth body fill type, is 1.990.000 m³, its height from the riverbed is about 43 meters, the lake volume at normal water level is 40 hm³, and the lake area at normal water level is 3.30 km². It provides irrigation service to an area of 5200 hectares [6].

Alibey Dam is a dam built between 1975-1983 on Alibey Stream in İstanbul for the purpose of supplying drinking, utility and industrial water. The body volume of the dam, which is an earth body fill type, is 1.930.000 m³, its height from the riverbed is about 30 m, the lake volume at normal water level is 66.80 hm³, and the lake area at normal water level is 4.66 km². It provides 39 hm³ of drinking water per year [7].

Heavy metals such as nickel, arsenic and cadmium 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. They occur naturally on earth's crust, but as a result of anthropogenic activities, they may enter in large quantities into the water habitats, causing serious damage to living things. 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].

Various ecotoxicological risk assessment indices have been used to evaluate the synergistic effects of heavy metals. 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 Atikhisar and Alibey Dam Lakes by applying two of the most widely used ecotoxicological risk assessment indices in order to provide a summary of synergistic effects of heavy metals and by using Geographic Information System (GIS) in order to provide a visual summary of detected indices data.

MATERIALS AND METHODS

Collection of Surface Water Samples

Surface water samples were collected from the input and output locations of Atikhisar and Alibey Dam Lakes (total of 4 stations) in the dry season (end of summer) of 2022. 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].

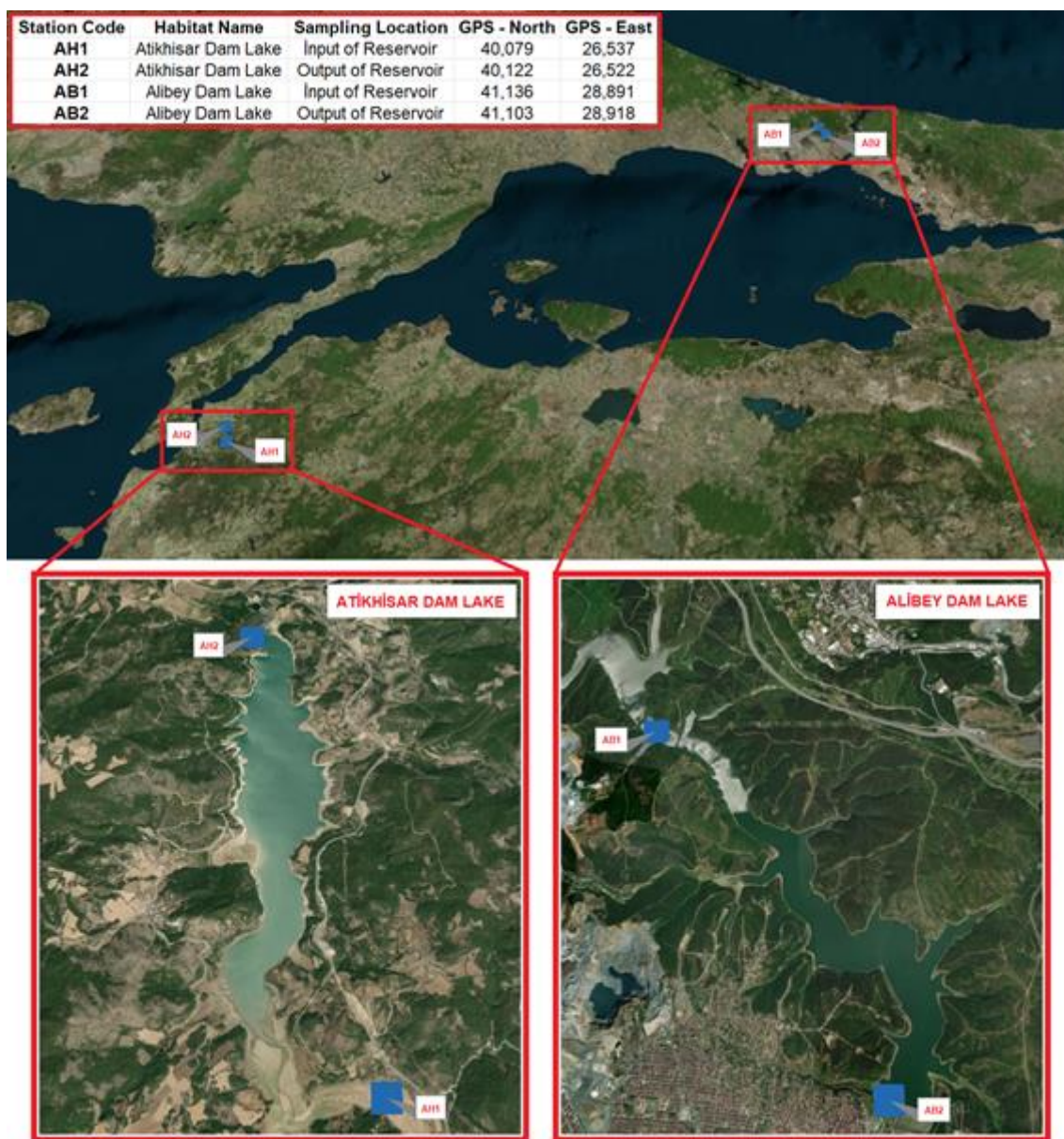


Figure 1. Study area and selected stations

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:

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

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

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

“ Q_i ” is the sub – index of the toxic element, “ W_i ” is the unit weight of the i th parameter, “ M_i ” is the monitored values of toxic metals, “ S_i ” 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.

“ H_c ” is value observed for each parameter and “ H_{mac} ” 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 water of Atikhisar and Alibey Dam Lakes were calculated separately for all the investigated stations. The monomial index scores of all the investigated locations are given in Figure 2. The results of multinomial index scores of all the applied ecological risk assessment indices are shown in Figure 3 as GIS based distribution maps.

According to the results of applied ecotoxicological indices, water of the Atikhisar and Alibey Dam Lakes posed “low heavy metal contamination” in terms of HPI and “low contamination” in terms of HEI.

According to monomial regulators of HPI, the risks of investigated toxic elements may be sorted as $As > Hg > Sb > Cd > Ni > Se > Ba > B$, in general. According to monomial regulators of HEI, the risks of investigated toxic elements may be sorted as $As > Ba > Hg > Ni > B > Sb > Se > Cd$, 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 toxicant, in general. Agricultural applications and generally applied monocultural practices conducted around the reservoirs is thought to be the main cause of these detected relatively high arsenic risk.

According to the results of multinomial HPI and HEI, the risks of investigated reservoirs may be sorted as Alibey Dam Lake > Atikhisar Dam Lake, in general. The fact that Alibey Dam Lake is located in a highly populated and industrially developed region like İstanbul is thought to be the main reason for detected higher HPI and HEI values than Atikhisar Dam Lake.

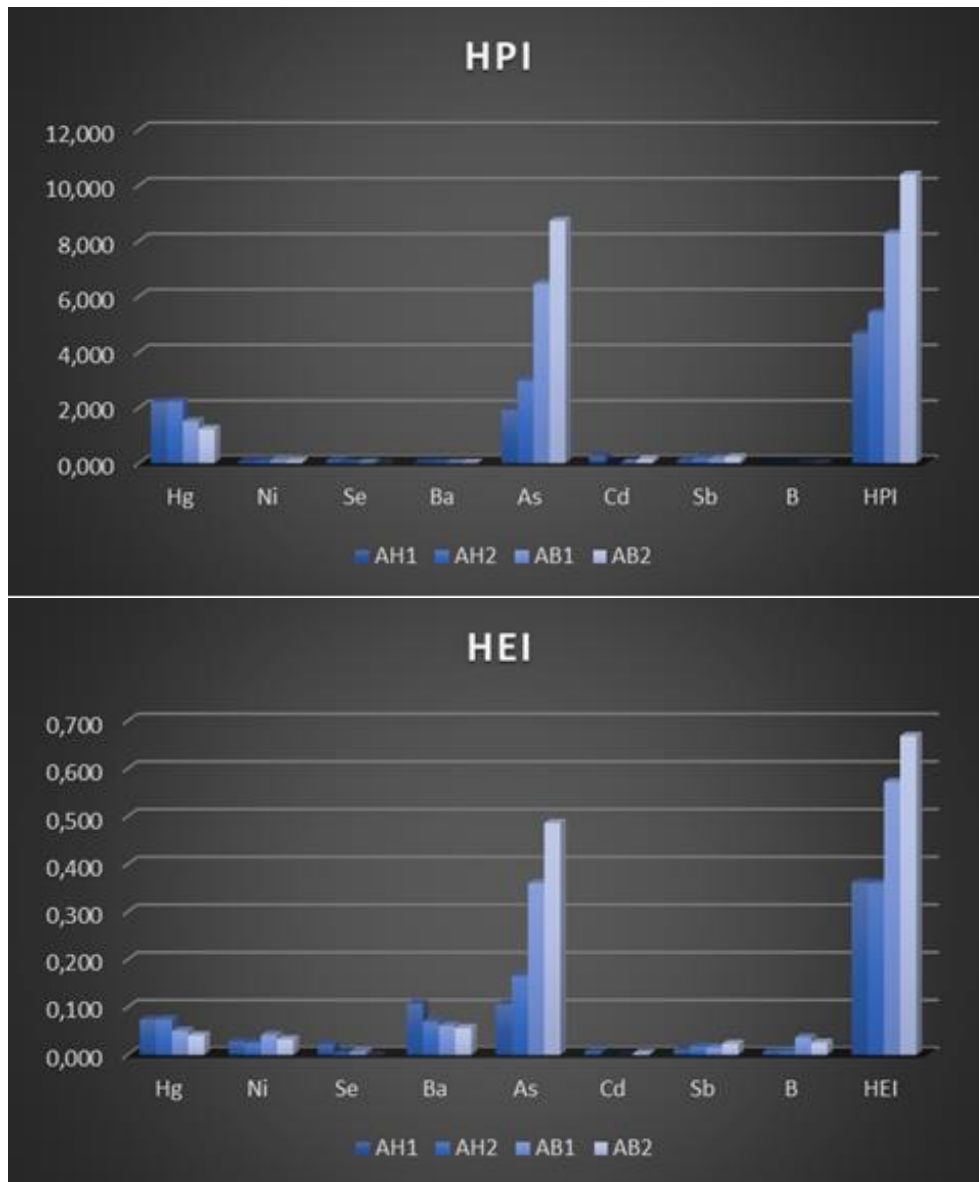


Figure 2. Monomial HPI and HEI coefficients for heavy metals

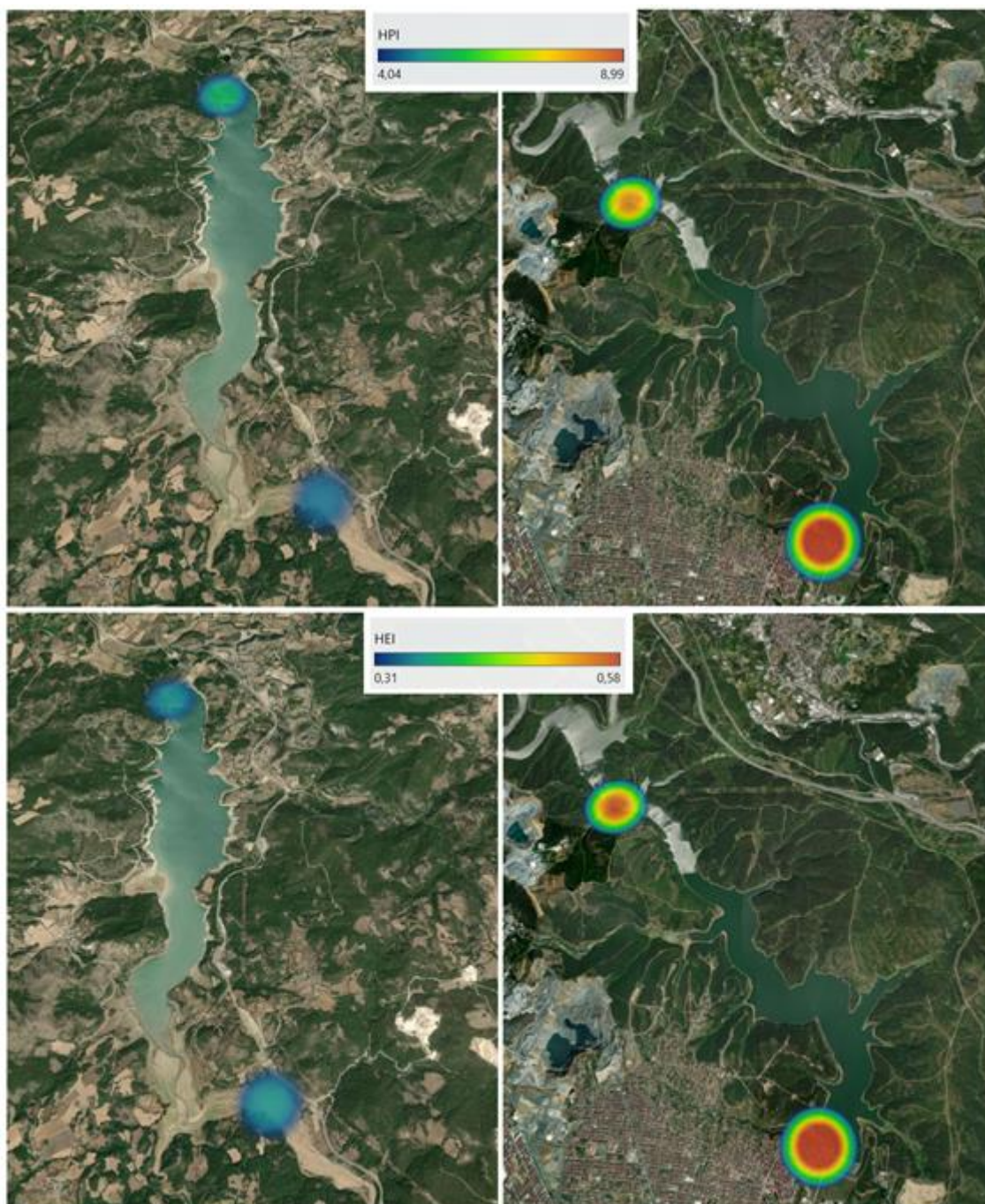


Figure 3. GIS maps of multinomial results of applied HPI and HEI

In order to evaluate the heavy metal contamination status in waters of the Atikhisar and Alibey Dam Lakes, the levels of calculated HPI and HEI values obtained from the current research were compared with those reported by previous investigations in Türkiye (Table 2).

The average levels of HPI and HEI values detected in the water of Atikhisar Dam Lake in the current research were lower than all the compared freshwater ecosystems. The average levels of HPI and HEI values detected in the water of Alibey Dam Lake in the current research were lower than detected in the waters of Pond and Lakes of Thrace Region, Gala Lake, Çorlu Stream and Ergene River, while they were higher than detected

in the waters of Atikhisar Dam Lake, Dam Lakes of Thrace Region, Meriç River and tributaries – groundwater resources of Ergene River Basin [22 – 25].

These findings revealed that the levels of heavy metal contaminations 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
Atikhisar Dam Lake	5.04	0.36	Current Research
Alibey Dam Lake	9.32	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]

CONCLUSION

In this study, some widely used toxic element risk assessment indices were used to evaluate and compare the water qualities of Atikhisar and Alibey Dam Lakes. As a result of this study, the selected sampling locations on the Atikhisar Dam Lake were found as relatively less contaminated, while the selected sampling locations on the Alibey Dam Lake were found as relatively more contaminated, in general. It was also determined that arsenic was found as the relatively most critical toxicant among the investigated heavy metals. It was also determined that all the investigated reservoirs 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 these significant dam lakes, which is of great importance especially for the people living in the region, it is recommended to continuously monitoring the accumulation levels of heavy metals in water, sediment and biotic factors.

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