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Research Article

Use of the Potential Ecological Risk Index for Sediment Quality Assessment: A Case Study of Dam Lakes in the Thrace Part of the Marmara Region

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ABSTRACT

Ergene River Basin, which is known as a critically contaminated habitat, is located in the Thrace Part of the Marmara Region of Turkey. Altınyazı, Karaidemir, Kayalıköy, Kırklareli, Sultanköy and Süloğlu Dam Lakes are located in the Ergene River Basin in the Thrace Region, which has very large agricultural lands because of rich soil and many freshwater resources. They were constructed by DSİ (State Water Works) in order to provide irrigation and drinking water and flood protection. The aim of this study was to evaluate the sediment quality of these artificial lentic ecosystems by investigating a total of 25 essential and toxic element accumulations and evaluate the ecological risks of toxic metals on the reservoirs by using Potential Ecological Risk Index (R_I). Sediment samples were collected in the spring season (rainy) of 2018 from 15 stations and element concentrations were investigated by using an ICP-MS. According to the results of R_I, cadmium, lead and arsenic were found to be the highest ecological risk factors for the basin reservoirs.

Keywords: Thrace Region, Ergene Basin, Lentic Habitats, Toxic Metals, Sediment Indices

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INTRODUCTION

Rapid growth of population, developments of industry and lack of environmental awareness cause significant environmental problems and decrease the freshwater quality (Köse et al., 2014; Tokatlı et al., 2016). Lacustrine habitats (artificial or natural) are among the most vulnerable freshwater bodies to pollution due to their exposure to point (eg. municipal and industrial wastewater) and non-point (eg. run-off from agricultural land) contamination sources in their drainage basins (Çiçek et al., 2014; Tokatlı et al., 2017a).

It is clearly documented that sediment may pose a serious risk factor on the water quality through the complicated biogeochemical exchanges. Therefore, the investigation of the sediment quality is an essential and prime component of aquatic ecosystem assessment research (Farombi, et al. 2007, Yu et al. 2011; Çiçek et al., 2019). Many indices have been developed to evaluate the environmental and ecological risks of toxic elements in surface sediments and one of the most widely used sediment indices is Potential Ecological Risk Index (R_I) (Çiçek et al., 2013; Tokatlı et al., 2017b; Maanan et al., 2018).

The Thrace Region of Turkey, which is located on the north – west part of the Marmara Region, is known as an agricultural region and there are very large agricultural lands because of its quite rich soil and numbers of freshwater resources. The Ergene River Basin, which is the most important river basin of the Thrace Region, contains many industrial enterprises on its watershed and as well as the majority of these facilities are located on the upstream of the basin. Therefore, in addition to the agricultural pressure, industrial activities are also one of the significant pollution

factors for the basin (Tokatlı, 2015; Sarı et al., 2016; Tokatlı and Baştatlı, 2016). Altınyazı, Karaidemir, Kayalıköy, Kırklareli, Sultanköy and Süloğlu Dam Lakes are located on the Ergene River Basin and they are the most important reservoirs of the Thrace Region. They were constructed by DSİ (State Water Works), on the Basamaklar, Poğaça, Teke, Şeytandere, Manastır and Süloğlu Streams respectively in order to provide irrigation and drinking water and also flood protection for the local settlements (http://www.dsi.gov.tr/). But as many freshwater ecosystems, these reservoirs are also being affected by especially agricultural and domestic pressure.

As many freshwater ecosystems, all these reservoirs are being adversely affected by especially agricultural and domestic pressure. The aim of this study was to reveal that pressure on these six significant artificial lentic habitats located on the Ergene River Basin by determining macro – micro element accumulations in sediment samples and evaluate the sediment quality by using Potential Ecological Risk Index.

MATERIALS AND METHODS

Study Area and Collection of Samples

Sediment samples were collected from 15 stations selected on the reservoirs in the rainy (spring) season of 2018. Topographic map of Ergene River Basin and Altınyazı, Karaidemir, Kayalıköy, Kırklareli, Sultanköy and Süloğlu Dam Lakes and selected stations on the reservoirs are given in Figure 1. Sediment samples were collected form the upper 10 cm of sediments with an ekman grab sampler in 1 L sterile glass bottles and kept at 4 ^{0}C until the chemical analysis.

Chemical Analysis

Sediment samples were dried for 3 hours at 105 °C. Samples were placed (0.25 gr of each sample) in Pyrex reactors of a CEM Mars Xpress 5 microwave digestion unit. $HClO_4$:HNO_3 acids of 1:3 proportions were inserted in the reactors respectively. Samples were mineralized at 200 °C for thirty minutes. Afterwards, the samples were filtered in such a way as to make their volumes to 100 ml with ultra – pure distilled water. The element levels in the sediment samples were determined by using the "Agilent 7700 xx" branded Inductively Coupled Plasma – Mass Spectrometer (ICP – MS) device at the Trakya University Technology Research and Development Application and Research Center (TÜTAGEM). The center has an international accreditation certificate within the scope of TS EN / ISO IEC 17025 issued by

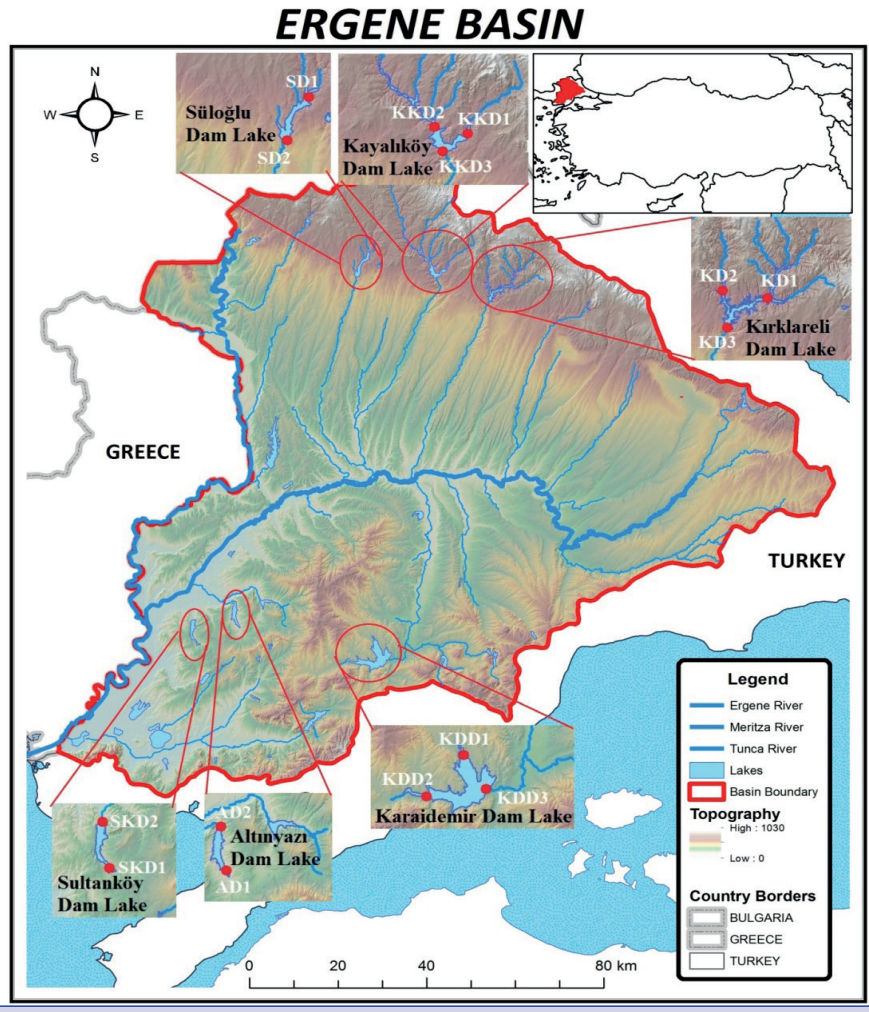

Figure 1. Topographic map of Ergene River Basin and selected stations.

TÜRKAK (representative of the World Accreditation Authority in Turkey). The element analyses were recorded as means triplicate measurements (EPA, 1998; 2001).

Potential Ecological Risk Index (R_I)

The Potential Ecological Risk Index was developed to evaluate the ecological risks in sediment samples in order to control the aquatic contamination. The methodology is based on the assumption that the sensitivity of the aquatic system depends on its productivity. According to the toxicity of toxic elements and the response of the environment, it was introduced to evaluate the degree of heavy metal pollution in sediments. The Potential Ecological Risk Index (R_I) can be calculated with the following formula (Hakanson, 1980);

$$R_I = \sum E_r^i \qquad E_r^i = T_r^i C_f^i \qquad C_f^i = C_0^i / C_n^i$$

Where

"R_I" is calculated as the sum of all risk factors for heavy metals in sediments,
"E_r^i" is the monomial potential ecological risk factor,
"T_r^i" is the toxic response factor for a given substance (Table 3),
"C_f^i" is the contamination factor, "C_0^i" is the concentration of metals in the sediment and
"C_n^i" is a reference value for metals (Table 3).
The scale of "R_I" was given in Table 1.

Table 1. Scale used to describe the risk factors of E_r^i and R_I (Hakanson, 1980)

Assessment of potential ecological risk			
E_r^i	Potential ecological risk for monomial factor	R_I	Potential ecological risk for multinomial factors
< 40	Low ecological risk	< 95	Low ecological risk
40 – 80	Moderate ecological risk	95 – 190	Moderate ecological risk
80 – 160	Considerable ecological risk	190 – 380	Considerable ecological risk
160 – 320	High ecological risk	> 380	Very high ecological risk
> 320	Very high ecological risk		

Table 2. Macro – micro element accumulations in artificial lacustrine habitats in the Ergene River Basin

Elements (mg/kg)	Northern Dam Lakes								Southern Dam Lakes						
	Süloğlu		Kırklareli				Kayalıköy		Karaidemir			Altınyazı		Sultanköy	
	SD1	SD2	KD1	KD2	KD3	KKD1	KKD2	KKD3	KDD1	KDD2	KDD3	AD1	AD2	SKD1	SKD2
Li	35.4	94.4	97.3	115.4	80.0	148.9	199.9	345.1	113.5	149.6	56.3	162.1	225.5	104.6	103.7
Be	5.627	10.648	23.524	11.582	22.043	25.019	17.532	11.224	8.573	10.567	5.341	13.304	13.948	18.119	25.215
B	60.752	61.216	71.660	56.383	45.305	41.864	68.680	214.041	60.285	79.271	60.052	66.166	59.285	60.839	62.013
Na	2164	2526	1770	1905	1766	3503	66520	6454	1984	2778	1836	2788	4940	4454	6546
Mg	7128	35674	33100	25628	30043	60812	461190	146237	24480	72214	9210	76187	136871	57818	58488
Al	17011	98996	88745	92120	96885	204821	340876	173009	71847	116657	28218	95666	163288	138604	175258
K	6323	56044	34535	18592	39543	23928	55484	37016	32644	43227	9079	12240	17747	23371	34860
Ca	38058	56341	86844	28625	79668	119225	2550992	2452257	25136	83399	17020	667195	1717582	999325	593793
V	103.1	333.0	297.1	210.9	252.8	930.1	788.9	828.8	229.3	372.8	83.6	230.2	521.7	661.1	649.2
Cr	78.6	186.9	136.8	98.4	83.0	777.1	407.3	747.6	105.6	271.0	62.9	562.9	741.4	362.4	358.5
Mn	7252	15320	5145	5950	27466	50640	49649	28806	5249	21485	3165	11373	27047	37169	24108
Fe	24292	136429	198733	130505	169889	252457	322705	181380	121044	220464	37568	119719	232243	133792	114280
Co	63.9	99.2	107.8	77.8	158.4	725.9	1095.5	222.2	89.9	181.7	28.2	206.9	568.0	644.6	272.7
Ni	56.5	105.9	103.8	51.6	73.6	1519.5	4171.6	1094.7	69.6	309.4	28.5	1410.7	2417.7	1239.0	619.2
Cu	31.2	135.9	436.6	58.6	135.3	504.5	464.0	257.8	81.1	345.9	22.2	142.3	257.3	220.0	228.0
Zn	410	601	1254	585	716	891	1045	595	600	1178	321	696	850	564	612
As	18.623	20.341	28.661	21.710	729.450	89.164	53.428	40.698	12.181	33.600	9.372	13.653	42.091	69.270	59.219
Se	116	113	110	107	110	112	109	113	105	104	106	108	106	112	118
Sr	126	297	198	132	268	1117	10938	8000	128	625	93	1476	3381	1421	1405
Mo	48.205	47.912	47.325	46.616	52.408	46.586	47.070	212.363	45.042	47.974	45.111	43.762	44.164	43.571	45.329
Cd	1.170	2.225	12.517	1.788	3.818	6.235	5.144	7.594	1.428	3.577	0.585	1.772	3.320	3.181	2.995
Sb	0.461	0.845	2.052	0.427	0.534	0.660	0.463	183.661	1.182	1.187	0.441	0.471	0.335	0.562	0.671
Ba	709	2615	1252	499	3440	6796	9378	3311	731	3411	504	1124	3462	5688	4449
Tl	0.589	3.007	3.475	1.690	2.234	4.885	1.882	6.383	2.271	2.287	0.939	1.027	2.142	1.222	1.793
Pb	166	360	1764	355	529	1145	434	431	204	398	72	138	417	620	504

RESULTS AND DISCUSSION

Essential and toxic element accumulations detected in sediments of reservoirs located in the Ergene River Basin are given in Table 2. The Potential Ecological Risk Index monomial (E^i_r) and multinomial (R_I) for each station selected on the dam lakes located on the Ergene River Basin were identified and all the results are given in Table 3.

According to the results of monomial potential ecological risk index (E^i_r), all the investigated toxic elements posed "low ecological risk" on the reservoirs. The Potential Ecological Risk Index for monomial regulators indicted that the intensity of the investigated toxic metals can be followed as Cd > Pb > As > Cu > Cr > Zn. According to the results of multinomial potential ecological risk index (R_I), all the investigated stations exhibited "low ecological risk". The Potential Ecological Risk Index for multinomial regulators indicted that the ecological risks of the system can be followed as Kırklareli Dam Lake > Kayalıköy Dam Lake > Sultanköy Dam Lake > Altınyazı Dam Lake > Karaidemir Dam Lake > Süloğlu Dam Lake (Figure 2).

Cadmium is an agricultural origin toxic metal and it is known that it can be easily emitted to soil and water by using phosphate fertilizers. Cadmium, which may accumulate in aquatic organisms and agricultural crops, can also bind strongly to organic matter and be taken up by plant life and can be included in the food chain. It is clearly known that pesticides have a significant impact on lead and arsenic transition to the water, soil and sediment and also fertilizers contain significant quantities of zinc and copper (ATSDR, 2004; 2005a; 2005b; 2007). The Thrace Part of the Marmara Region is known as a significant agricultural zone in Turkey and has very large agricultural lands because of its rich soil and much ground – surface freshwater resources. In the present study, as a result Potential Ecological Risk Index, cadmium, lead and arsenic, which are known as agricultural origin toxicants, were found to be the most risky elements for the sediments of dam lakes located in the Ergene River Basin. The most significant anthropogenic sources of chromium in freshwater ecosystems is known as industrial activities, which are being intensively performed around the upstream of the Ergene River Basin (especially in the Çorlu and Çerkezköy Distrits) (ATSDR, 2000). According to the results of the Potential Ecological Risk Index, chromium did not pose a significant risk factor for the sediments of the investigated reservoirs. These results reflect that the dam lakes of the Thrace Region are not being affected significantly by the intensive industrial activities conducted around the Ergene River Basin.

In a study performed in the Gala Lake National Park (Meriç – Ergene River Basin) in Turkey, the Potential Ecological Risk Index was used to evaluate the sediment quality. As a result of this study, similar to the present study, cadmium was found to be the most risky element for the Gala Lake (Tokatlı, 2017). According to the results of another Potential Ecological Risk Index application conducted in Seydisuyu Stream Basin, similar to the results of the present study, chromium and cadmium were reported as the most risky elements for the Seydisuyu Stream Basin (Tokatlı et al., 2017b). Soliman et al. (2015) assessed the potential ecological risks of heavy metals in sediments of the Mediterranean coast in

Table 3. Toxic metal risk index values in sediments of the reservoirs

Dam Lakes	Stations	E^i_r						R_I	Multinomial Mean
		As	Cr	Cu	Pb	Zn	Cd		
Süloğlu	SD1	0.012	0.003	0.005	0.033	0.005	0.070	0.129	**0.192**
	SD2	0.014	0.006	0.023	0.072	0.008	0.133	0.255	
Kırklareli	KD1	0.019	0.005	0.073	0.353	0.016	0.751	1.216	**0.761**
	KD2	0.014	0.003	0.010	0.071	0.007	0.107	0.213	
	KD3	0.486	0.003	0.023	0.106	0.009	0.229	0.855	
Kayalıköy	KKD1	0.059	0.026	0.084	0.229	0.011	0.374	0.784	**0.654**
	KKD2	0.036	0.014	0.077	0.087	0.013	0.309	0.535	
	KKD3	0.027	0.025	0.043	0.086	0.007	0.456	0.644	
Karaidemir	KDD1	0.008	0.004	0.014	0.041	0.008	0.086	0.159	**0.208**
	KDD2	0.022	0.009	0.058	0.080	0.015	0.215	0.398	
	KDD3	0.006	0.002	0.004	0.014	0.004	0.035	0.065	
Altınyazı	AD1	0.009	0.019	0.024	0.028	0.009	0.106	0.194	**0.291**
	AD2	0.028	0.025	0.043	0.083	0.011	0.199	0.389	
Sultanköy	SKD1	0.046	0.012	0.037	0.124	0.007	0.191	0.417	**0.397**
	SKD2	0.039	0.012	0.038	0.101	0.008	0.180	0.378	
Monomial Mean		**0.055**	**0.011**	**0.037**	**0.100**	**0.009**	**0.229**		
***C^i_n**		15.00	60.00	30.00	25.00	80.00	0.50		
***T^i_r**		10.00	2.00	5.00	5.00	1.00	30.00		

*Reference values (C^i_n) and toxicity coefficients (T^i_r) values of heavy metals (Hilton et al., 1985)
E^i_r is the monomial and R_I is the multinomial heavy metal Potential Ecological Risk Index

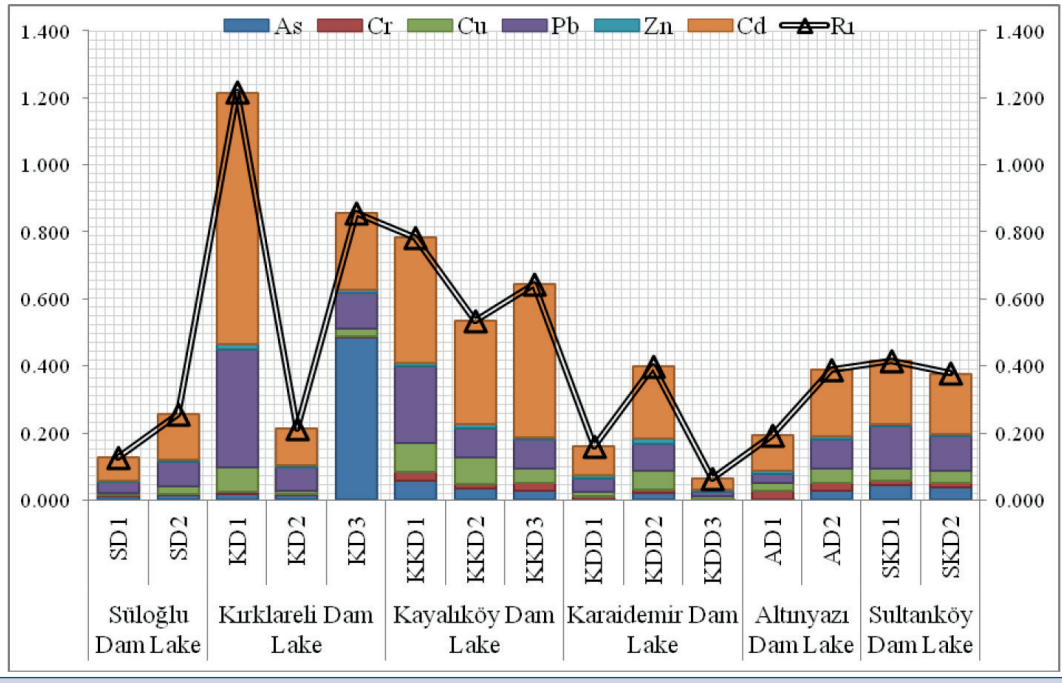

Figure 2. Values of Potential Ecological Risk Index.

Egypt and, similar to the present study, the risk assessment of this study showed that Cd had the highest ecological risk (Er = 21.52), followed by Pb (Er = 3.01), while Zn had the lowest risk (Er = 0.23).

In a study performed in Turkey, cadmium contents of different fertilizer samples taken from different fertilizer factories were investigated. It was reported that cadmium residues of many fertilizers used in Turkey were found to be over the limit values notified for fertilizers. It is known that phosphate rocks are the main ingredient of phosphate fertilizers and they are being imported from abroad to Turkey (Köleli and Kantar, 2005). Cadmium concentrations of these imported phosphate rocks are much more than what they should be. As a result of using phosphate fertilizers based of these imported phosphate rocks, significant amounts of cadmium are being accumulated on the land surface and also being moved to surface and groundwater resources (Emiroğlu et al., 2013).

The Thrace Region is known as one of the most productive lands in Turkey. Rice and sunflower are the two main crops produced in the region. Edirne City is also known as the most important city for rice production in Turkey. But unfortunately, agricultural applications carried out in the basin have been generally performed in the form of monoculture applications for many years (Helvacıoğlu et al., 2015). This situation causes the decrease of soil quality and increase in the use of fertilizers, and may be the reason for the detected quite high cadmium accumulations in regional sediments.

CONCLUSIONS

In this study, the Potential Ecological Risk Index was used to evaluate the sediment quality of the most significant artificial lacustrine habitats of the Ergene River Basin. According to results of Potential Ecological Risk Index, cadmium, lead and arsenic were found to be the highest ecological risk factors for the dam lakes and the ecological risk levels of the investigated reservoirs were recorded as; Kırklareli > Kayalıköy > Sultanköy > Altınyazı > Karaidemir > Süloğlu in general. The data of this research reveals that agricultural runoff caused by pesticide and fertilizer applications because of mainly monoculture practices conducted almost all around the region was the main ecological risk for the sediment qualities of the reservoirs located in the Ergene River Basin. Also, the present study clearly presents the necessity and availability of sediment indices on freshwater sediment quality assessment studies. In order to improve the sediment qualities of these significant artificial lentic ecosystems, monoculture practices in agricultural applications should be changed and the local people should be encouraged to use polyculture practices. Also, the uninformed use of chemical fertilizers and pesticides should be avoided by giving the necessary training to the farmers.

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Conflict of Interest: The author has no conflicts of interest to declare.

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