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Research Article

APPLICATION OF FACTOR ANALYSIS TO EVALUATE THE TRACE AND TOXIC METAL CONTENTS OF FISHES LIVING IN MERIÇ RIVER DELTA (THRACE REGION, TURKEY)

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ABSTRACT

Meriç River Delta is located on the Edirne Province of Turkey and has an international importance. Gala and Sığırcı Lakes, which are the main lentic factors of the system, are located in the Meriç River Delta. The aim of the present study was to evaluate the some macro and micro element concentrations in fishes of Gala and Sığırcı Lakes from a statistical perspective by using Pearson Correlation Index (PCI) and Factor Analysis. For this purpose, sodium (Na), magnesium (Mg), aluminum (Al), calcium (Ca), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), selenium (Se), cadmium (Cd) and lead (Pb) bioaccumulation levels in muscle, gill and liver tissues of *Carassius gibelio* (Bloch, 1782), *Carassius carassius* (Linnaeus, 1758), *Scardinius erythrophthalmus* (Linnaeus, 1758), *Cyprinus carpio* Linnaeus, 1758, *Sander lucioperca* (Linnaeus, 1758), *Perca fluviatilis* Linnaeus, 1758 living in both lakes were investigated and detected data were evaluated by using PCI and FA in order to determine the associated contaminants and effective factors on the biotic components of the basin. According to the results of PCI, significant correlations were recorded among the investigated elements at 0.05 and 0.01 significance levels. According to the results of FA, 3 factors, which were named as "Nutrient factor", "Agricultural factor" and "Industrial factor", explained 79% of the total variance.

Keywords: Meriç River Delta, fishes, trace and toxic metals, factor analysis.

1. INTRODUCTION

Statistical methods are being commonly used in ecosystem quality assessment studies. Multivariate statistical methods provide to interpretation of complex data matrices to better understand the contamination levels of the investigated habitats. Factor Analysis is one of the most convenient multivariate statistical techniques and it is commonly used all over the world for many different scientific fields. Principal Component Analysis (PCA) attempts to explain the variance of a large dataset of inter correlated variables with a smaller set of independent variables and Factor Analysis (FA) reduces the contribution of less significant variables and it makes new group of variables detected from PCA (Akın et al., 2011; Tokatlı et al., 2013; 2016; Köse et al., 2015).

Meriç Delta, which was classified as an "A – Class eutrophic wetland", is formed on about 45,000 ha area at the mouth of Meriç River in Turkey. It is known as among the richest aquatic

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habitats not only for Turkey but also for the globe (Elipek et al., 2010; Tokatlı, 2014). Gala Lake was declared as "National Park" in 2005 and allows dwelling many bird species migrating between Europe and Africa. Sığırcı Lake is also has a great importance for especially local fisheries activities. These significant lentic ecosystems are located on the delta (Güher et al., 2011; Tokatlı and Gürbü z, 2014).

The aim of the present study was to evaluate some macro and micro element concentration levels in muscle, gill and liver tissues of economically important fish species living in the delta from a statistical perspective by using Factor Analysis.

2. MATERIAL AND METHODS

2.1. Study area and collection of samples

The map of Meriç River Basin with Gala and Sığırcı Lakes is given in Figure 1. The fish samples were caught by fishermen's nets from Gala [*Carassius gibelio* (Bloch, 1782), *Carassius carassius* (Linnaeus, 1758)] and Sığırcı [*Scardinius erythrophthalmus* (Linnaeus, 1758), *Cyprinus carpio* Linnaeus, 1758, *Sander lucioperca* (Linnaeus, 1758), *Perca fluviatilis* Linnaeus, 1758] Lakes at the summer season of 2016. Than the muscle, liver and gill tissues of each species were dissected in laboratory. The metric characteristics of investigated fish species are given in Table 1.

2.2. Chemical and statistical analysis

Fish samples were dried for 24 h at 105^{o}C and placed (0.50 g 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^{o}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 fish tissues were determined by using the "Agilent 7700 xx" branded Inductively Coupled Plasma – Mass Spectrometer (ICP-MS) device. The element analyses were recorded as means triplicate measurements (ASTM, 1985; EPA, 1998; 2001).

Pearson Correlation Index and Factor Analysis were applied to the results by using the SPSS 17 package program.

Table 1. Some metric characteristics of fishes caught from Meriç River Delta

Locality	Fish Species	Weight (gr ± SD)	Length (mm ± SD)		
			Standart	Fork	Total
Gala Lake	*C. gibelio* (n = 4)	552.5 ± 9.8	243.7 ± 14.2	270.2 ± 15	284.7 ± 18.1
	C. carassius (n = 5)	1166 ± 105	315 ± 16.9	342.2 ± 15.6	385.8 ± 11.1
Sığırcı Lake	*S. erythroph.* (n = 5)	261.6 ± 5.2	241.4 ± 12.1	264.8 ± 12.6	287 ± 13.5
	C. carpio (n = 2)	1115 ± 49.4	306.5 ± 9.1	332 ± 11.3	369.5 ± 7.7
	S. lucioperca (n = 1)	430 ± 0	333 ± 0	362 ± 0	375 ± 0
	P. fluviatilis (n = 3)	189.3 ± 14	198.3 ± 22.5	216.6 ± 16	228.3 ± 20.2

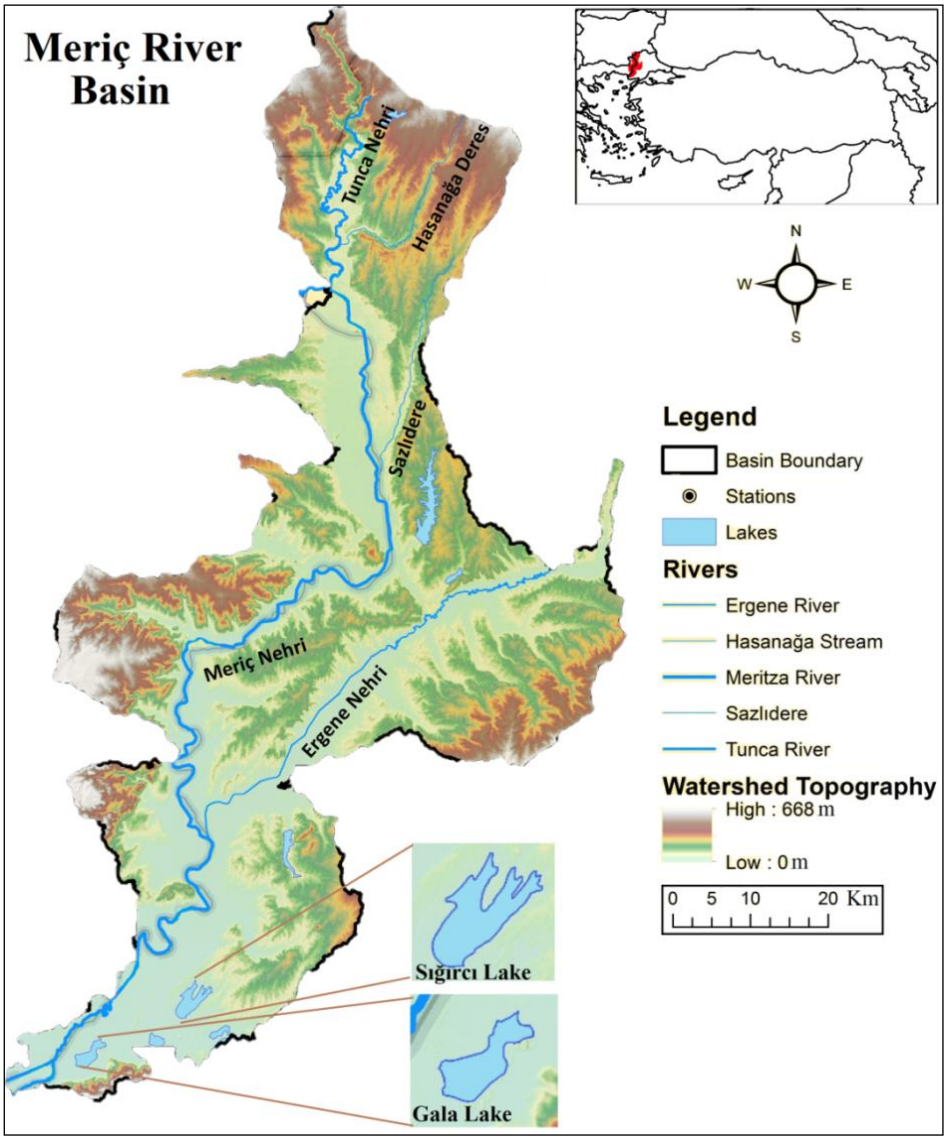

Figure 1. Meriç River Basin and investigated lakes

3. RESULTS

3.1. Pearson Correlation Index (PCI)

Pearson Correlation Index (PCI) was applied to the results in order to determine the relations between the investigated elements. The data of PCI, calculated by using essential, trace and toxic element bioaccumulation levels obtained from muscle, gill, and liver tissues of 5 fish species living in the delta, are given in Table 2 (n=18).

According to the results of PCI, the relations between Na – Mg, Ca, Mn and Fe; Mg – Al, Ca and Mn; Al – Ca, Mn, Fe and Pb; Ca – Mn; Mn – Fe and Pb; Fe – Co and Pb; Co – Se; Se – Cd were directly proportional at the 0.01 significance level. It was also determined that the relations between Na – Al and Co; Mg – Ni and Cu (-); Ca – Fe; Mn – Ni and Ca; Cu – Se were directly proportional at the 0.05 significance level.

Table 2. Results of Pearson Correlation Index and PCI coefficients

	Na	**Mg**	**Al**	**Ca**	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Se**	**Cd**	**Pb**
Na	1											
Mg	**0.67****	1										
Al	**0.56***	**0.60****	1									
Ca	**0.81****	**0.72****	**0.66****	1								
Mn	**0.66****	**0.71****	**0.93****	**0.74****	1							
Fe	**0.61****	0.37	**0.79****	**0.49***	**0.80****	1						
Co	**0.56***	0.17	0.37	0.17	0.44	**0.74****	1					
Ni	0.19	**0.51***	0.33	0.27	**0.53***	0.37	0.17	1				
Cu	-0.19	**-0.49***	-0.22	-0.38	-0.18	0.05	0.23	0.09	1			
Se	.041	-0.06	0.07	-0.06	0.14	0.39	**0.68****	0.16	**0.47***	1		
Cd	-0.01	-0.33	-0.21	-0.24	-0.17	0.14	0.23	0.23	**0.55***	**0.70****	1	
Pb	0.42	0.35	**0.63****	0.38	**0.62****	**0.82****	0.42	0.43	-0.04	0.19	0.25	1

*: correlation was significant at 0.05 level ($p < 0.05$)

**: correlation was significant at 0.01 level ($p < 0.01$)

3.2. Factor Analysis (FA)

Factor Analysis (FA) was applied to the results in order to determine the effective varifactors on fishes living in the delta according to correlated variables. Totally 12 variables among the inorganic parameters detected in muscle, gill, and liver tissues of 5 fish species living in both lakes were used to determine the effective variable factors on the biotic items of the delta (n=18).

The eigenvalues higher than 1 were selected as the criterion for the evaluation of the key components as sources of variance that should be explained from the data used. The Scree Plot, in which the eigenvalues of the principal components are expressed, is given in Figure 2.

The factor loadings were classified according to loading values as "strong (>0.75)", "moderate (0.75 – 0.50)" and "weak (0.50 – 0.30)" (Liu et al., 2003). The parameter loadings (component matrix) larger than 0.5, which are determined for the 3 factors after the rotation, are given in the spider diagram in Figure 3. The three-dimensional component diagram that refers to the associated variables of the 3 factors is given in Figure 4.

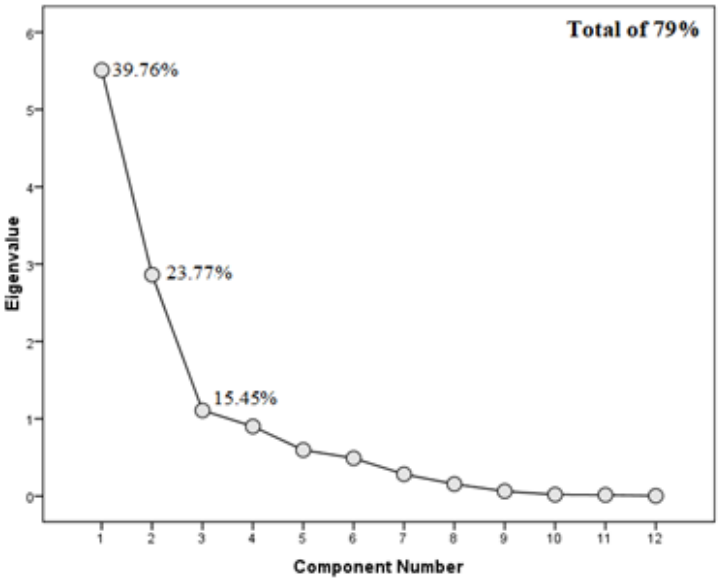

Figure 2. Scree plot of FA

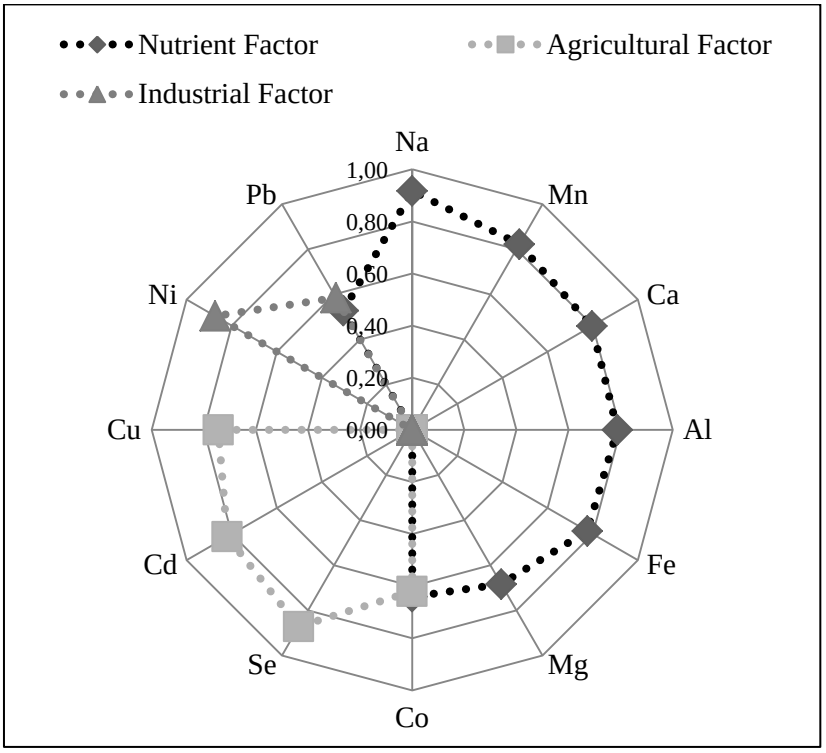

Figure 3. Rotated component matrix

The first factor, named the "Nutrient Factor", explained 39.76% of the total variance, and it is composed of sodium, manganese, calcium, aluminum, iron, magnesium and cobalt. The parameters of sodium, manganese, calcium, aluminum and iron are strong positively loaded for this factor (>0.75), and magnesium and cobalt are moderate positively loaded for this factor (0.75-0.50).

The second factor, named the "Agricultural Factor", explained 23.77% of the total variance and it is composed of cobalt, selenium, cadmium and copper parameters. Selenium and cadmium parameters are strong positively loaded for this factor (>0.75), while cobalt and copper parameters are moderate positively loaded for this factor (0.75-0.50).

The third factor, named the "Industrial Factor", explained 15.45% of the total variance and this factor composed of the nickel and lead parameters. The nickel parameter is strong positively loaded for this factor (>0.75) and the lead parameter is moderate positively loaded for this factor (0.75-0.50).

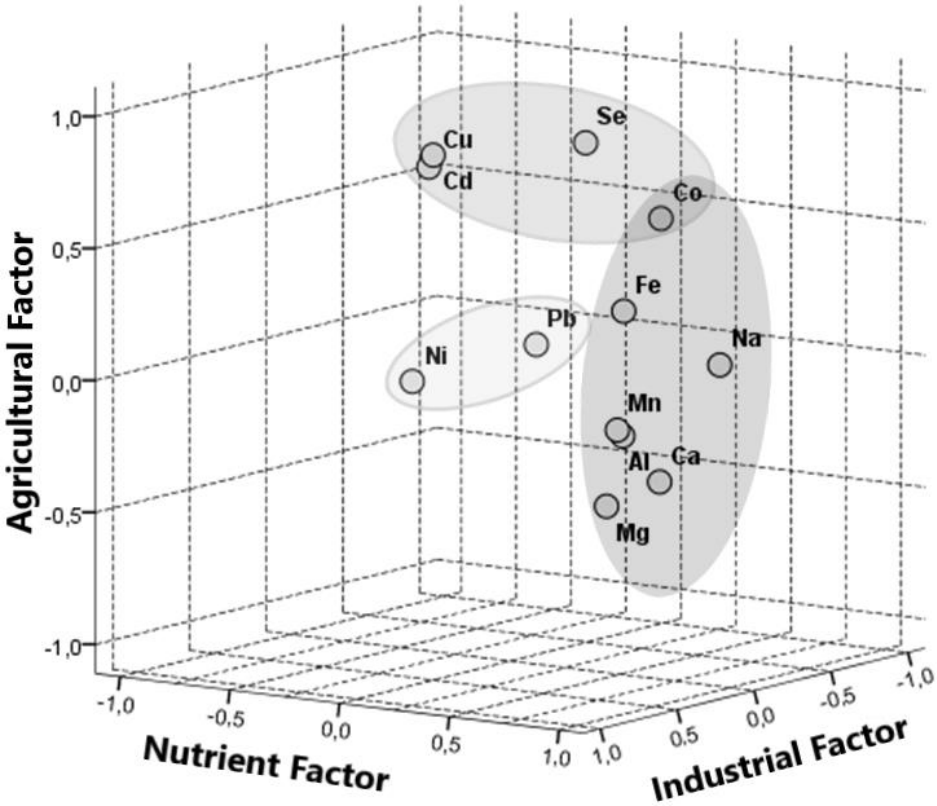

Figure 4. Component plot in rotated space

3. DISCUSSION

Most of the calcium, magnesium and sodium, which are known as the basic components of life, are supplied from the rock layers in water environment. The mentioned ions are dissolved from these structures and transported to the lakes and rivers. Cobalt, iron and manganese are also known as essential mineral nutrients and geological structure is important in the transition of

these elements to the water (Tanyolaç, 2009; Wetzel, 2011; Newman, 2015). It was reported that significant correlations between specific trace and toxic elements may reflect similar levels of contamination in water environment or release from the same sources of pollution (Li et al., 2009; Tokatlı, 2017). In the present study, significant relations were determined among these nutrient elements according to the results of PCI, and also sodium, manganese, calcium, aluminum, iron, magnesium and cobalt elements were found to be as the significant components of "Nutrient Factor" with moderate – strong parameter loadings. Therefore, the main bioaccumulation source of these essential elements in fishes living in the Meriç Delta may be the geological structure of the basin.

Copper is a reddish metal naturally found in rocks, in soil, in water and a little in the air. It is an essential element in low concentrations for all organisms, including human. The transition of copper to the environment can occur in many ways, but the most important of these is the production and use of phosphate – based fertilizers (ATSDR, 2004). Phosphate rock is known as the raw material of phosphate fertilizers and it is generally imported from abroad to Turkey. It is clearly revealed by scientific researches that cadmium contents of the raw materials used in Turkey are much more than they should be (Emiroğlu et al., 2013). Edirne Province contains very large and productive agricultural lands including especially most important paddy fields of Turkey. About 35% of total rice production of Turkey is being supplied from Meriç Plain (Anonymous, 2012; Tokatlı, 2014). As a result of using excessive amount of phosphate fertilizers unconsciously in especially paddy agriculture conducted around the Meriç River Basin, compounds of phosphate rock and phosphate – based fertilizers accumulated on the upper surface of the soil are being transported into to the streams, lakes and reservoirs by the irrigation and also by the rain. Selenium and cobalt are also known as agricultural origin essential elements and they can easily emitted to soil and water and accumulate in aquatic organisms and agricultural crops by application of fertilizers, which are known to be intensively used around the Meriç River Basin. Accumulation of Se and Co in agricultural drainage waters have been documented in many river basins (ATSDR, 2003; 2004). In this study, copper, cadmium, selenium and cobalt elements were found to be as the significant components of "Agricultural Factor" with moderate – strong parameter loadings.

Lead is found in the earth's crust in small amounts, however over 90% of Pb in aquatic ecosystems are associated with anthropogenic activities. Lead is known as a toxic metal even in very low concentrations and it has no known function in biochemical processes. Although the deposits of lead – containing dust from the atmosphere are important in lead accumulation in the nature, waste water from industries are the main sources of lead in surface water (ATSDR, 2007; Tokatlı et al., 2012). Nickel may release into the atmosphere during nickel mining and by industries that make nickel or use it, nickel alloys, or nickel compounds. These industries also may discharge Ni in waste water and it can be easily mixed into surface waters (ATSDR, 2005; Tokatlı et al., 2014). Ergene River is located in the Thrace Region of Turkey ant it is the main tributary of Meriç River. It has been documented that there are about 1,000 industrial companies on Ergene River Basin (Tokatlı, 2014; 2015). Contamination on Ergene River Basin caused from industrial applications conduced on especially near the settlement areas like Lüleburgaz, Çorlu and Saray Districts is one of the major toxic metal bioaccumulation problems of fishes living in the delta. In this study, nickel and lead elements were found to be as the significant components of "Industrial Factor" with moderate – strong parameter loadings.

4. CONCLUSIONS

In the present study, some trace and toxic element bioaccumulation levels in muscle, gill and liver tissues of fishes living in Meriç River Delta were evaluated by using Factor Analysis (FA).

According to the results of FA, 3 statistically effective factors named as "Nutrient factor", "Agricultural factor" and "Industrial factor" on element contents of fish tissues were identified by

using a large number of inorganic data. The results of this study reveal that agricultural runoff caused from especially paddy fields around the basin and the industrial discharges caused from Ergene River are the main risk factors for the biotic components of the Meriç River Basin. If such contamination persists, contents of toxicants in fishes may reach the critical levels.

In conclusion, multistatistical methods are necessary for a sophisticated evaluation because of obtained large numbers of data and difficulty of the interpretations of all the parameters. Results of the present study reveal the benefits of statistical approaches and also Factor Analysis even in biotic components of the ecosystems and in element bioaccumulation studies.

Acknowledgement

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