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Research Article

DRINKING WATER QUALITY ASSESSMENT IN VILLAGES LOCATED IN MERIÇ RIVER BASIN (EDIRNE, TURKEY)

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ABSTRACT

This study was carried out to determine the drinking water quality of İpsala, Keşan, Uzunköprü and Meriç Districts, which are located in the Meriç River Basin in Edirne Province of Turkey. Water samples were collected from 51 villages in autumn season of 2017. Some physical and chemical water quality parameters including dissolved oxygen, oxygen saturation, pH, electrical conductivity (EC), total dissolved solids (TDS), salinity, turbidity, nitrite (NO_2), nitrate (NO_3), phosphate (PO_4) and cyanide (CN) were determined and the results were assessed according to national and international quality criteria. Pearson Correlation Index (PCI) and Principle Component Analysis (PCA) were applied to experimental data in order to determine the significant relations among the investigated parameters and effective factors on groundwater quality of the region. Geographic Information System (GIS) was also used in order to make a visual explanation by presenting distribution maps of investigated parameters. According to data observed, although the investigated parameter levels in drinking water of villages did not exceeded the limit values for drinking, the region has Class I – II water quality in terms of cyanide, nitrite and nitrate parameters; Class II – III in terms of electrical conductivity parameter; and Class III – IV in terms of phosphate parameter in general.
Keywords: Meriç River Basin, Edirne villages, drinking water quality, principle component analysis, MapInfo.

1. INTRODUCTION

Limited freshwater resources are among the most significant and adversely affected components of environment and pollution – contamination caused by anthropogenic activities decreases the quality and potential of these limited freshwater day by day (Çiçek et al., 2013; Tokatlı et al., 2014; Köse et al., 2015).

The Meriç River with a catchment area of more than 53,000 km^2 is the longest river ecosystem of the Balkans (about 480 km long). Unfortunately this significant aquatic habitat is being exposed to an intensive pollution especially by means of agricultural applications around the Meriç River Basin and industrial activities around the Ergene River Basin (Tokatlı, 2015; Tokatlı and Baştatlı, 2016). İpsala, Meriç, Uzunköprü and Keşan Districts, which are briefly explained below, are located on the Meriç River Basin and they are being affected from these contamination factors.

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The aim of this study was to evaluate the drinking water quality of İpsala, Meriç, Keşan and Uzunköprü Districts by a statistical approach using Principle Component Analysis and present the investiga ted parameters visually by using GIS maps.

1.1. İpsala District

İpsala District with a surface area of 753 km² is located in Edirne City in Thrace Region of Turkey. İpsala shows a natural structure consisting of wavy plains with low hills. The northern and eastern sections of the district are elevated between 100 and 300 meters and the western section is covered with the İpsala Plain, which forms a part of the lower Meriç Plain. İpsala District has an economic structure based on especially agriculture. The total area of the province is 66,029 hectares. 49,180 hectares of this area are agricultural land, 950 hectares are forest land and 1,127 hectares are meadow – pasture land. The non – agricultural area is 11,360 hectares. The total population of İpsala District is about 30,000 with 10,000 in the center and 20,000 in the villages (Anonymous, 2016; http://www.edirnekulturturizm.gov.tr; http://www.ipsala.gov.tr; http://www.turkstat.gov.tr/).

1.2. Keşan District

Keşan District is located in the southern half of Edirne City in Thrace Region of Turkey. Its surface area is 1,087 km² and it is the second district of Edirne City in terms of surface area. The major streams are the Muzalı and Doğanca creeks and the district has a natural lake (Büyük Tuzla Lake). There are also eight ponds and a reservoir (Kadıköy Dam Lake) in the district. The district is half – wet in terms of precipitation. Autumn and winter are most rainy seasons for the region. The county economy is predominantly agriculture and animal husbandry. The total area of the province is 108,699 hectares. 52,885 hectares of this area are agricultural land, 43,000 hectares are forest land and 11,519 hectares are meadow – pasture land. The non – agricultural area is 1,295 hectares. The total population of Keşan District is about 80,000 with 60,000 in the center and 20,000 in the villages (Anonymous, 2016; http://www.edirnekulturturizm.gov.tr; http://www.kesan.gov.tr; http://www.turkstat.gov.tr/).

1.3. Uzunköprü District

It is the first place among the districts of Edirne Province in terms of its water basin. The Ergene River that is one of the most important river ecosystems of Thrace Region flows through the middle of the Uzunköprü District and flows into the Meriç River. The Ergene River leaves plenty of organic residues to the Ergene Plain, which covers the middle of the district lands. For this reason, the land of the plain is very fertile and it is suitable for growing all kinds of crops. Irrigated farming is carried out in the Ergene Plain in general and the district is half – wet in terms of precipitation. 60% of the people live in the countryside and provide their subsistence from agriculture. The total population of Uzunköprü District is about 60,000 with 40,000 in the center and 20,000 in the villages (Anonymous, 2016; http://www.edirnekulturturizm.gov.tr; http://www.uzunkopru.gov.tr; http://www.turkstat.gov.tr/).

1.4. Meriç District

Meriç District is located on the south – western edge of Lalapaşa Plateau in the middle part of Edirne City in Thrace Region of Turkey. The surface area is 448 km² and there is no mountain in the district. The highest place is the Karayayla Hill, which is 130 meters uphill. The largest valley in the region belongs is Meriç River and the second largest valley is Ergene River. There are also three streams and their valleys in the plateau. The county is semi – wet with respect to rainfall and the rainfall in autumn is quite high. Subsiste nce in Meriç District is agriculture and animal husbandry in general. The total population of Meriç District is about 15,000 with 3,000 in the center and 12,000 in the villages (Anonymous, 2016; http://www.edirnekulturturizm.gov.tr; http://www.meric.gov.tr; http://www.turkstat.gov.tr/).

2. MATERIAL AND METHOD

2.1. Study Area and Collection of Water Samples

In this study, groundwater samples were collected in autumn season of 2017 from 51 stations from the drill fountains of the villages located in the İpsala, Keşan, Uzunköprü and Meriç Districts. Groundwater with a volume of three wells was purged before sampling. Drinking water samples were then collected at the outflow of drill pump in polyethylene bottles. Coordinate information and locations and capacities of water sources of selected stations were given in Table 1 and map of Meriç River Basin and investigated area were given in Figure 1.

Table 1. Location properties of villages and capacities of water sources

Station Number	**District**	**Locality**	**Coordinates**		**Structural Information of Water Resources** (Anonymous, 2012)	
			North	South	Capacity (L/sec)	Source Type (wells)
S1	Keşan District	Dişbudak	40.72012	26.57460	-	Drilling
S2		Yayla	40.62822	26.38887	4 L/sec	Drilling
S3		Borağı	40.70750	26.43023	2.5 L/sec	Drilling
S4		Mercan	40.74779	26.60413	3 L/sec	Drilling
S5		Danışment	40.61973	26.42850	3 L/sec	Drilling
S6		Beyköy	40.66763	26.51088	-	Drilling
S7		Orhaniye	40.73180	26.42855	3 L/sec	Drilling
S8		Büyükdoğanca	40.77319	26.58404	-	Drilling
S9		İzzetiye	40.81222	26.64535	7 L/sec	Drilling
S10		Erikli	40.64211	26.45612	17 L/sec	Drilling
S11		Karahisar	40.76458	26.50405	-	Drilling
S12		Çeltikköy	40.68376	26.55570	20 L/sec	Drilling
S13		Şabanmera	40.67849	26.40786	5 L/sec	Drilling
S14		Akhoca	40.71820	26.40434	-	Drilling
S15		Kılıçköy	40.78402	26.55357	-	Drilling
S16	İpsala District	Turpçular	40.94092	26.43437	10 L/sec	Catchment
S17		Hacıköy	40.97936	26.54988	40 L/sec	Drilling
S18		İbriktepe	41.00769	26.50721	-	Drilling
S19		Sultanköy	41.02544	26.45104	40 L/sec	Drilling
S20		Sarıcaali	40.98506	26.38257	15 L/sec	Drilling
S21		İpsala	40.92147	26.38144	-	-
S22		Paşaköy	40.85033	26.32039	6 L/sec	Drilling
S23		Karpuzlu	40.83215	26.29482	-	-
S24		Kocahıdır	40.81130	26.40674	8 L/sec	Drilling
S25		Aliço	40.84104	26.43971	-	-
S26		Esetçe	40.87074	26.44392	15 L/sec	Drilling
S27		Karaağaç	41.06235	26.53022	-	Drilling

S28	Meriç District	Adasaranlı	41.08403	26.35795	15 L/sec	Drilling
S29		Subaşı	41.14356	26.37485	12 L/sec	Drilling
S30		Meriç	41.19035	26.41944	315,360 m^3/year	Bitter well
S31		Umurca	41.20001	26.35920	-	Drilling
S32		Alibey	41.24518	26.35476	-	Drilling
S33		Küpdere	41.22291	26.46626	5 L/sec	Drilling
S34		Akçadam	41.30541	26.53097	7 L/sec	Drilling
S35		Kavaklı	41.23313	26.52256	6 L/sec	Drilling
S36		Yakupbey	41.23989	26.55337	8 L/sec	Drilling
S37		Paşayenice	41.19908	26.55366	6 L/sec	Drilling
S38		Akıncılar	41.19265	26.51727	7 L/sec	Drilling
S39		Küplü	41.10457	26.34976	292,000 m^3/year	Water well
S40	Uzunköprü District	Kırçasalih	41.39338	26.80224	100 m^3/year	Groundwater
S41		Yeniköy	41.33851	26.76877	250,000 m^3/year	Water well
S42		Değirmenci	41.31121	26.70025	4 L/sec	Drilling
S43		Uzunköprü	41.26563	26.68482	470,000 m^3/year	Deep well
S44		Çöpköy	41.21776	26.82452	-	-
S45		Ömerbey	41.26768	26.83598	2 L/sec	-
S46		Sipahi	41.22890	26.89057	-	Drilling
S47		Kavacık	41.18497	26.66849	6 L/sec	Drilling
S48		Kurtbey	41.14359	26.57965	50,000 m^3/year	Drinking well
S49		Hamidiye	41.15265	26.66731	28 L/sec	Drilling
S50		Türkobası	41.09383	26.60723	-	Drilling
S51		Altınyazı	41.07232	26.57499	-	Drilling

Figure 1. Map of Meriç River Basin and investigated residential areas

2.2. Chemical and Physicochemical Analysis

Measurements of pH, electrical conductivity (EC), total dissolved solid (TDS) and salinity parameters were performed by using Hach Portable Multi – Parameter Measurement Device (HQ40D) and turbidity parameter was performed by using Hach Portable Turbidimeter Device (2100Q) during the field studies. Nitrate nitrogen (NO_3^-), nitrite nitrogen (NO_2^-), phosphate (PO_4^{3-}) and cyanide (CN^-) parameters were performed by using Hach Colorimeter Device (DR890) during the laboratory studies.

2.3. Statistical Analysis and ArcGIS

Pearson Correlation Index (PCI) and Principle Component Analysis (PCA) were applied to the results by using the "SPSS 17" package program. The distribution maps (GIS Maps) of parameters were made by using the "MapInfo" package program.

3. RESULT AND DISCUSSION

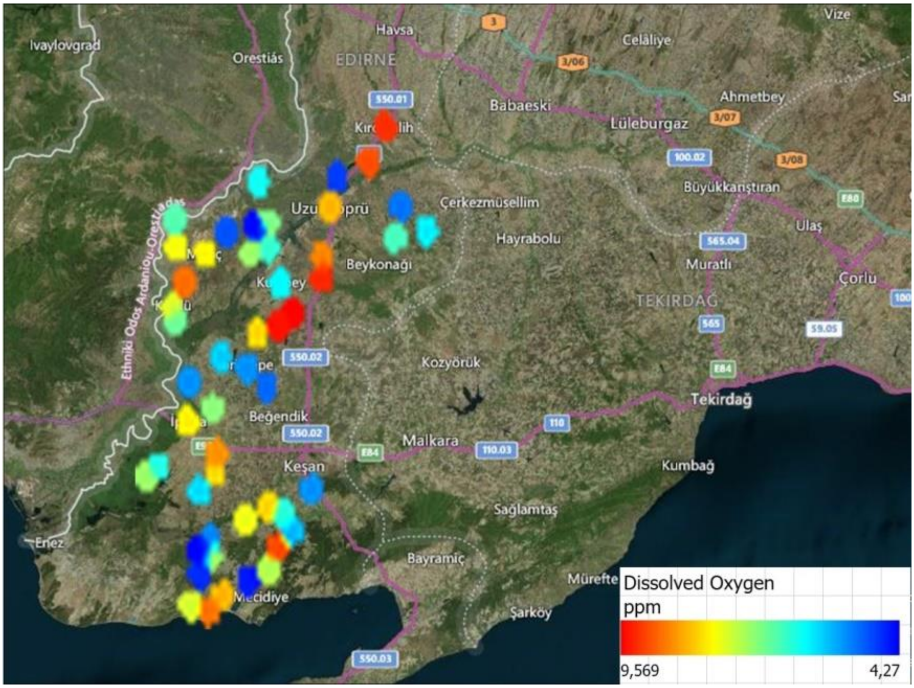
Results of the physicochemical data detected in the drinking water of İpsala, Meriç, Uzunköprü and Keşan Districts with minimum, maximum and mean values and some national and international water quality standards were given in Table 2 and GIS based distribution maps were given in Figure 2, 3 and 4.

Table 1. Results of detected parameters and some limit values

Limit Values and the Results of Present Study		**Parameters**										
		DO (ppm)	**O_2 Sat.** (%)	**pH**	**EC** (mS/cm)	[a]**TDS** (ppm)	**Sal.** (‰)	**Tur.** (NTU)	**NO_3** (ppm)	**NO_2** (ppm)	[b]**PO_4** (ppm)	**CN** (ppm)
Turkish Regulations Water Quality Classes (2015)	**I. Class** (Very Clean)	>8	>90	6.5-8.5	400	500	-	-	5	0.01	0.02	0.01
	II. Class (Less Polluted)	6	70	6.5-8.5	1000	1500	-	-	10	0.06	0.16	0.05
	III. Class (Much Polluted)	3	40	6.0-9.0	3000	5000	-	-	20	0.12	0.65	0.1
	IV. Class (Extremely Polluted)	3>	40>	Out of 6.0-9.0	>3000	>5000	-	-	>20	>0.3	>0.65	>0.1
Drinking Water Standards	**TS266** (2005)	-	-	6.5-9.5	2500	-	-	5	50	0.5	-	-
	EC (2007)	-	-	6.5-9.5	2500	-	-	-	50	0.5	-	-
	WHO (2011)	-	-	-	-	-	-	-	50	0.2	-	-
Drinking Water of İpsala District	**Min**	7.350	87.500	6.920	375.000	187.700	0.190	0.270	0.000	0.000	0.090	0.000
	Max	8.560	99.800	7.620	734.000	373.000	0.370	2.090	5.500	0.025	0.900	0.013
	Mean	**7.931**	**93.642**	**7.210**	**565.583**	**283.842**	**0.282**	**0.599**	**2.758**	**0.011**	**0.448**	**0.003**
	SD	0.442	4.423	0.186	130.867	67.655	0.066	0.504	1.992	0.010	0.349	0.004
Drinking Water of Meriç District	**Min**	5.660	63.800	6.750	198.000	99.000	0.100	0.190	0.300	0.000	0.040	0.002
	Max	8.660	97.100	8.400	1518.000	823.000	0.830	1.750	5.500	0.040	0.900	0.023
	Mean	**7.849**	**88.267**	**7.507**	**859.167**	**455.833**	**0.456**	**0.599**	**2.992**	**0.008**	**0.228**	**0.010**
	SD	0.772	8.458	0.438	402.974	218.355	0.221	0.474	2.317	0.011	0.288	0.006
Drinking Water of Uzunköprü District	**Min**	6.670	68.500	7.290	442.000	258.000	0.260	0.220	0.300	0.000	0.000	0.000
	Max	9.570	98.700	8.260	848.000	509.000	0.510	0.730	5.500	0.032	0.900	0.014
	Mean	**8.374**	**86.367**	**7.740**	**553.583**	**330.833**	**0.329**	**0.465**	**2.050**	**0.013**	**0.398**	**0.004**
	SD	0.922	9.363	0.308	131.828	79.615	0.080	0.140	1.939	0.011	0.361	0.005
Drinking Water of Keşan District	**Min**	4.270	48.200	7.130	615.000	320.000	0.320	0.310	0.000	0.000	0.000	0.000
	Max	8.820	98.900	7.780	1568.000	839.000	0.850	7.330	5.500	0.025	0.440	0.032
	Mean	**7.567**	**85.373**	**7.411**	**1020.533**	**540.667**	**0.540**	**1.067**	**2.533**	**0.010**	**0.106**	**0.013**
	SD	1.242	13.991	0.213	299.922	164.366	0.166	1.806	1.827	0.009	0.122	0.012

[a]Turkish Regulations, 2004; [b]Uslu and Türkman, 1987; Sal. Salinity; Tur. Turbidity; Sat. Saturation

TS266 – Turkish Standards Instıtute; EC – European Communities; WHO – World Health Organization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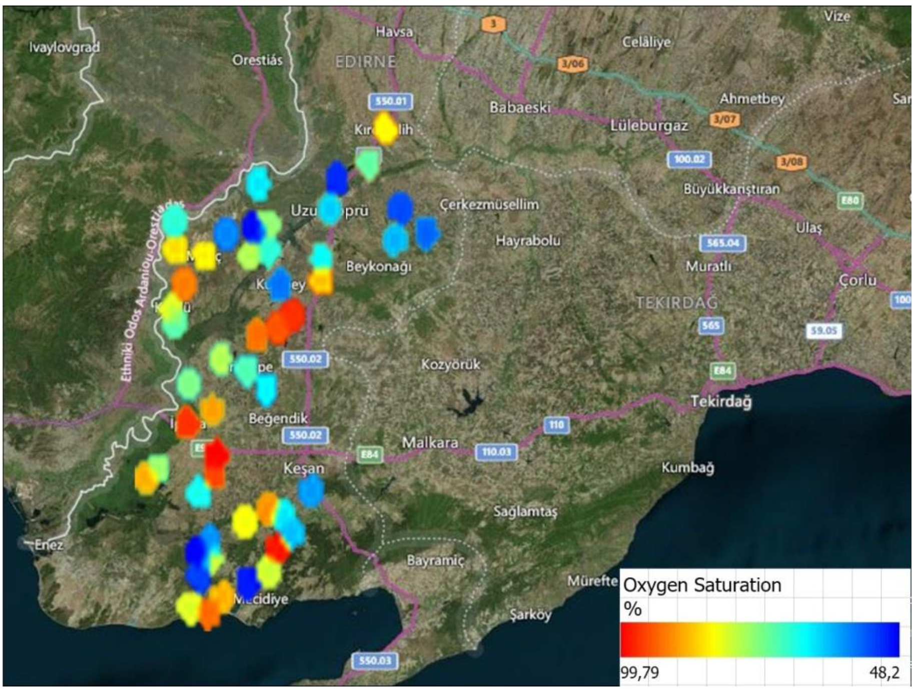
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Oxygen Saturation
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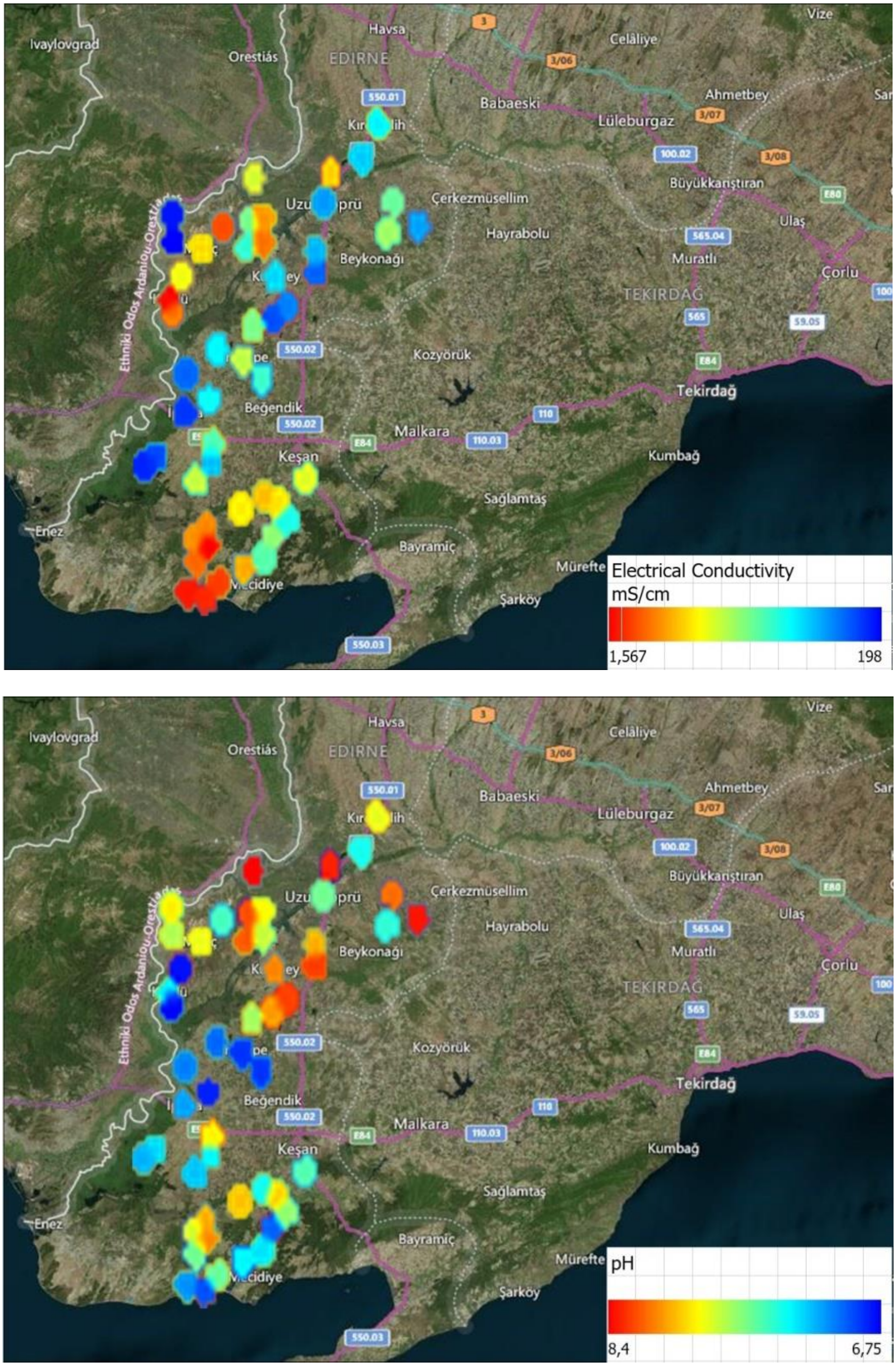
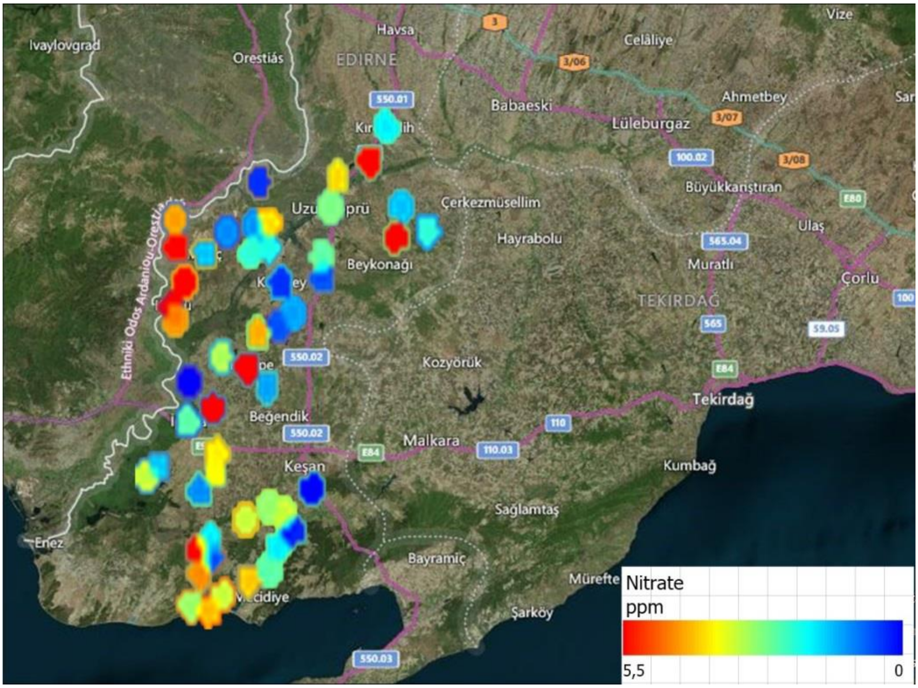


Figure 2. Dissolved oxygen, oxygen saturation, EC and pH distributions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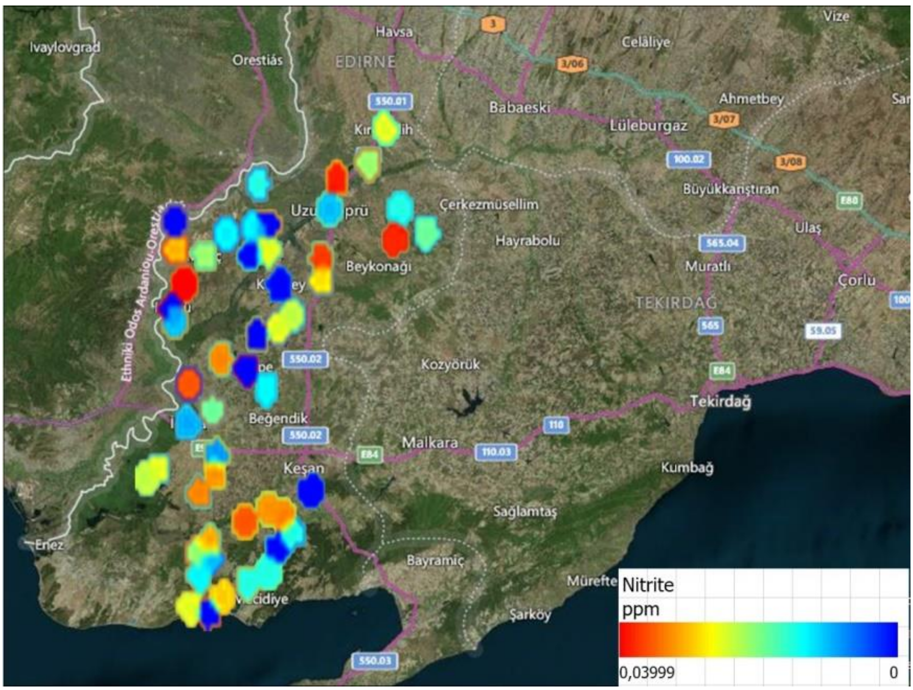
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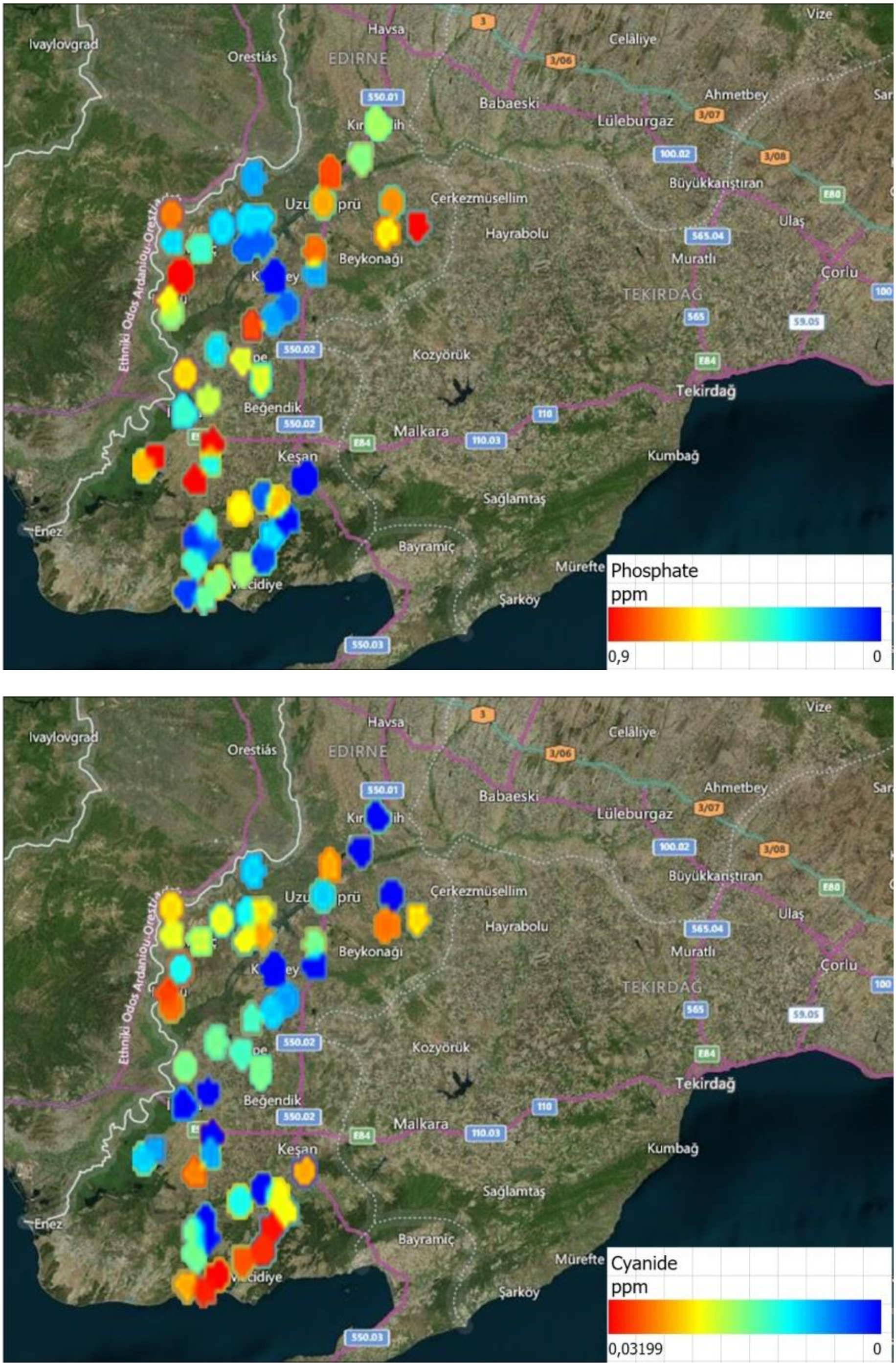
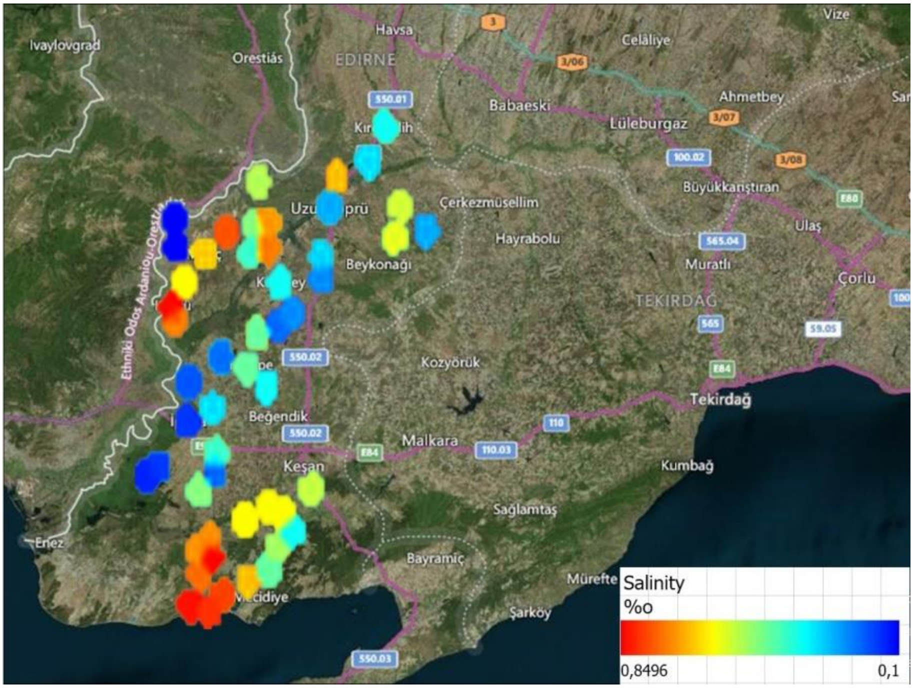


Figure 3. Nitrate, nitrite, phosphate and cyanide distributions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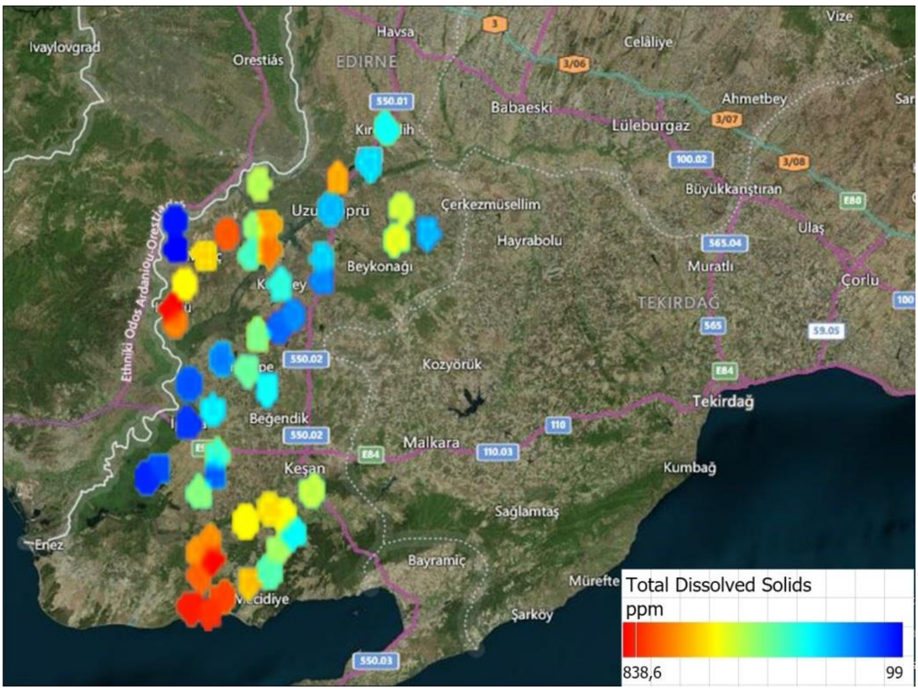
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Total Dissolved Solids
ppm
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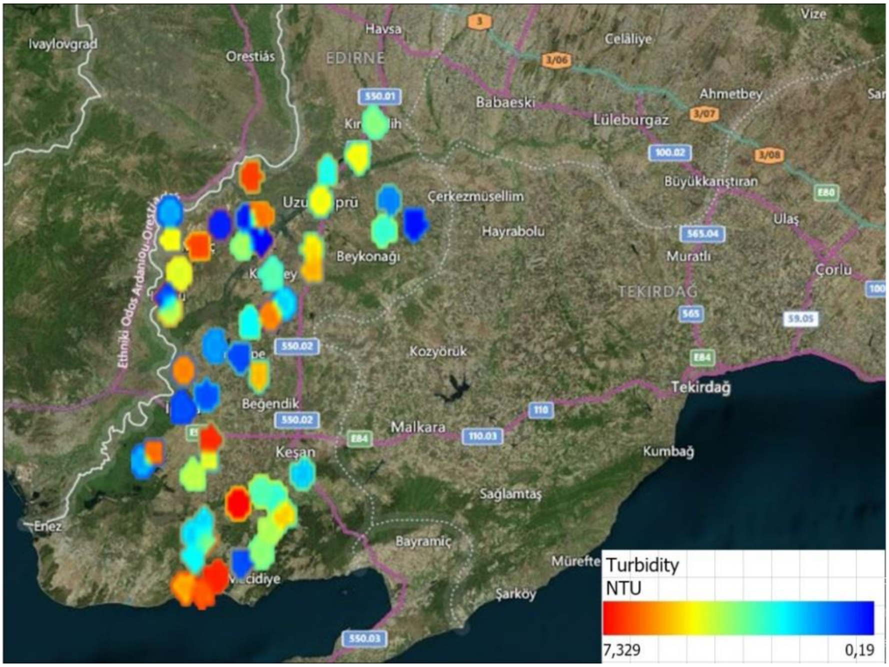

Figure 4. Salinity, TDS and turbidity distributions

3.1. Pearson Correlation Index (PCI)

The relations between the levels of investigated parameters in drinking water resources of residential areas located in the Meriç River Basin were determined by using Pearson Correlation Index (PCI) (n = 51 for all parameters) and results of PCI were given in Table 3.

Table 3. PCI coefficients

	DO	O_2Sat	pH	EC	TDS	Sal	Tur	NO_3	NO_2	PO_4	CN
DO	1										
O_2Sat	**.909****	1									
pH	-.053	**-.285***	1								
EC	-.240	-.170	-.139	1							
TDS	-.223	-.198	-.084	**.993****	1						
Sal	-.214	-.189	-.085	**.993****	**.999****	1					
Tur	.148	.181	.133	.078	.066	.069	1				
NO_3	-.120	-.057	**-.374****	.137	.135	.129	.009	1			
NO_2	.058	.031	-.013	-.117	-.100	-.096	.183	.078	1		
PO_4	.035	.008	.088	-.272	-.255	-.257	.019	.179	.271	1	
CN	-.024	.021	-.252	**.430****	**.421****	**.424****	.006	.187	-.127	-.112	1

O_2Sat – Oxygen saturation; DO – Dissolved oxygen, Sal – Salinity, Tur – Turbidity
*Correlation is significant at the 0.05 level ($p<0.05$); **Correlation is significant at the 0.01 level ($p<0.01$)

According to results of PCI, the relations between oxygen saturation – dissolved oxygen (+); nitrate – pH (-); EC – TDS (+), salinity (+) and cyanide (+); TDS – salinity (+) and cyanide (+);

salinity – cyanide (+) levels were directly proportional at the 0.01 significance level. It was also found that the relations between oxygen saturation – pH (-) levels were directly proportional at the 0.05 significance level.

3.2. Principle Component Analysis (PCA)

Principle Component Analysis (PCA) is one of the most powerful multivariate statistical methods. It facilitates the interpretation of large data sets and widely used in water quality evaluation (Kazi et al., 2009; Tokatlı et al., 2014; Tokatlı, 2017).

In the present application, PCA was used to detect the effective factors on drinking water resources of İpsala, Keşan, Meriç and Uzunköprü Districts. A total of 11 variables were used to detect the factors (n = 51 for all parameters).

Result of Kaiser – Meyer – Olkin (KMO) test that presents the measure of sampling adequacy was 0.538, which means that the sampling adequacy was enough for the present application (>0.5) and also the factor loadings were classified according to their loading values as “strong (>0.75)”, “moderate (0.75 – 0.50)” and “weak (0.50 – 0.30)” (Liu et al., 2003).

Eigenvalues higher than one were taken as criterion for assessing the principle components. According to rotated cumulative percentage variance, 4 factors explained 75.1% of the total variance (Table 4). Factor loadings after rotation for 4 components were given in Table 5.

Table 4. Total variances explained in FA

Component	**Initial Eigenvalues**			**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.546	32.232	32.232	3.546	32.232	32.232	3.313	30.114	30.114
2	1.953	17.754	49.986	1.953	17.754	49.986	2.033	18.478	48.593
3	1.451	13.190	63.175	1.451	13.190	63.175	1.519	13.808	62.401
4	1.312	11.927	75.102	1.312	11.927	75.102	1.397	12.701	75.102

Table 5. Rotated component matrix

Parameters	**Factor**			
	1	**2**	**3**	**4**
Salinity	**,973**	-,118	,039	-,049
EC	**,972**	-,113	,071	-,069
TDS	**,971**	-,128	,041	-,050
CN^-	**,512**	,089	,390	-,135
O_2 Saturation	-,104	**,962**	,131	,007
DO	-,145	**,934**	-,028	,033
pH	-,084	-,217	**-,804**	,131
NO_3^-	,110	-,151	**,747**	,302
NO_2^-	-,068	,025	,021	**,759**
PO_4^{3-}	-,316	-,109	,176	**,622**
Turbidity	,247	,319	-,324	**,545**

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization

Factor 1 explained 30.1% of total variance and it was related to the variables of EC, TDS, salinity and cyanide parameters. EC, TDS and salinity were strong; cyanide parameter was moderate positively loaded with this factor (Table 5).

Factor 2 explained 18.4% of total variance and it was related to the variables of dissolved oxygen and oxygen saturation parameters. All parameters were strong positively loaded with this factor (Table 5).

Factor 3 explained 13.8% of total variance and it was related to the variables of pH and nitrate parameters. pH parameter was strong negatively; nitrate parameter was strong positively loaded with this factor (Table 5).

Factor 4 explained 12.7% of total variance and it was related to the variables of nitrite, phosphate and turbidity parameters. Nitrite parameter was strong; phosphate and turbidity parameters were moderate positively loaded with this factor (Table 5).

4. DISCUSSION

According to the criteria of Turkish Regulations identified for Turkey (Water Pollution Control Regulation in Turkey), Uzunköprü District has Class I water quality in terms of total dissolved solids, dissolved oxygen, oxygen saturation and pH parameters; Class I – II in terms of cyanide, nitrite, nitrate and electrical conductivity parameters; and Class III – IV in terms of phosphate parameter (Uslu and Türkman, 1987; Turkish Regulations, 2004; 2015).

According to the criteria of Turkish Regulations identified for Turkey (Water Pollution Control Regulation in Turkey), Meriç District has Class I water quality in terms of pH parameter; Class I – II in terms of cyanide, nitrite, nitrate, total dissolved solids, dissolved oxygen and oxygen saturation parameters; Class II – III in terms of electrical conductivity parameter; and Class III – IV in terms of phosphate parameter (Uslu and Türkman, 1987; Turkish Regulations, 2004; 2015).

According to the criteria of Turkish Regulations identified for Turkey (Water Pollution Control Regulation in Turkey), Keşan District has Class I water quality in terms of pH parameter; Class I – II in terms of cyanide, nitrite, nitrate and total dissolved solids parameters; and Class II – III in terms of phosphate, electrical conductivity, dissolved oxygen and oxygen saturation parameters (Uslu and Türkman, 1987; Turkish Regulations, 2004; 2015).

According to the criteria of Turkish Regulations identified for Turkey (Water Pollution Control Regulation in Turkey), İpsala District has Class I water quality in terms of total dissolved solids, dissolved oxygen, oxygen saturation and pH parameters; Class I – II in terms of cyanide, nitrite, nitrate and electrical conductivity parameters; and Class III – IV in terms of phosphate parameter (Uslu and Türkman, 1987; Turkish Regulations, 2004; 2015).

EC is a measure of ability of water to pass an electrical current and it is affected by the presence of dissolved solids. TDS, which depends mainly on the solubility of rocks and soils, is defined as the quantity of dissolved material in water. Also salinity is defined as the total of all salts dissolved in water. EC, TDS, and salinity parameters in water are closely related and these parameters may indicate general water quality. Discharges to groundwater may change the EC, TDS and salinity levels. Sewage water and especially irrigation practices are known as significantly effective factors on these parameters (Wetzel, 2001; Manahan, 2011). In this study, significant relations were determined among EC, TDS and salinity parameters ($p<0.01$) and according to the results of PCA, first factor (F1), which was related to the variables of EC, TDS and salinity, was the most effective factor on the groundwater quality in Meriç River Basin. The main reason of the recorded quite high values of EC, TDS and salinity may be intense irrigation practices around the basin and the filtration from septic tanks in villages.

It is clearly known that organic and inorganic fertilizers used in agricultural activities increase the level of nitrogen and phosphorus compounds in water and soil especially in rural areas (Wetzel, 2001; Manahan, 2011). Although they may occur naturally in some of groundwater ecosystems, the main sources of nitrogen and phosphorus compounds in groundwater are anthropogenic activities including mainly; nitrogen – phosphate rich fertilizers that is common around the basin, animal feedlots that is also common in the investigated area; and municipal wastewater, sludge and septic tanks that are being used at everywhere in the region (Self and Waskom, 2013; Tokatlı, 2014). According to the results of PCA, "Factor Agriculture" (F4) was defined as an effective factor on the groundwater quality of the basin, which was related to the variables of nitrite and phosphate.

5. COCNLUSIONS

In this study, drinking water quality of İpsala, Meriç, Keşan and Uzunköprü Districts located on the Meriç River Basin were investigated. Also Principle Component Analysis and Geographic Information System (GIS) were applied to detected data in order to evaluate the results properly. According to detected data, organic contents in drinking water resources of the region were detected in quite high levels and also the groundwater were detected as slightly salty. According to results of PCA, 4 effective factors on drinking water quality of the region were identified by using a large number of physical and chemical water quality data.

In conclusion, rice and sunflower are the main crops produced in Meriç River Basin and Edirne City is known as the most important region on rice production in Turkey. The water leached through from these paddy and sunflower fields are contaminated by pesticides and fertilizers, which are being used intensively in especially İpsala, Uzunköprü, Meriç and Keşan Districts in order to reduce the effects of monoculture farming ongoing for many years. These pollution factors reach to the groundwater resources of the system by filtering from the soil.

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