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Original Article

Assessment of Spatial – Temporal Variations in Freshwater Pollution by Means of Water Quality Index: A Case Study of Hasanağa Stream Basin (Edirne, Turkey)

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ABSTRACT

In this research, spatial – temporal variations of water quality in the fluvial components of the Hasanağa Stream Basin were evaluated by using the Water Quality Index. Surface water samples were taken from seven stations selected on the basin in the winter seasons of 2019 and 2020. Eleven variables including dissolved oxygen, oxygen saturation, pH, electrical conductivity, total dissolved solids, salinity, turbidity, nitrate, nitrite, phosphate and sulphate were measured in freshwater samples. The Water Quality Index (WQI) and Cluster Analysis (CA) were applied to the detected data in order to determine the differences among the spatial – temporal contamination levels and classify the investigated locations according to their similar water quality characteristics. According to the detected data, the water of the Hasanağa Stream Basin has 1. – 2. Class quality in 2019 and 2. – 3. in 2020, in general. According to the results of WQI, although it was determined that the water quality decreased significantly in 2020, the basin was found to be of "A Grade – Excellent" water quality (<50) in both 2019 and 2020. According to the results of the CA, 3 statistical clusters were formed and they were named as “less polluted zone”, “moderate polluted zone” and “more polluted zone”.

Keywords: Hasanağa stream basin, water quality index, cluster analysis

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INTRODUCTION

Contamination of freshwater resources is a significant environmental problem, because of the increasing world population, the developments of industry and no environmental awareness in society. It is known that one of the main points in the effective management of freshwater resources is the monitoring of the quality of aquatic environments (Arslan et al., 2011; Tokatlı et al., 2014; 2016; Köse et al., 2014; 2016).

Water quality assessment indices are known to be an effective tool in evaluating the quality of water ecosystems. The Water Quality Index (WQI) has achieved increasing significance in the management of freshwater resources and it is one of the most commonly used freshwater quality indices and it is calculated from the perspective of the suitability of water for human consumption (Tyagi et al., 2013; Akter et al., 2016; Sutadian et al., 2016; Mukatea et al., 2019; Ustaoğlu and Tepe, 2019; Varol, 2020; Tokatlı and Ustauğlu, 2020). Describing the suitability of freshwater resources for domestic use especially in terms of the WQI is one of the most convenient ways to describe the current qualities of water ecosystems. The WQI also enables the modifications of policies by various environmental agencies (Akoteyon et al., 2011; Tokatlı and Ustauoğu, 2020; Ustaoğlu and Aydın, 2020; Tokatlı, 2020a).

Multi-statistical methods have been used to evaluate and characterise freshwater resources and they help in the interpretation of complex data matrices and for them to be better understood. Cluster Analysis (CA) is known as one of the most convenient multivariate statistical methods. It assembles the objects based on the similar characteristics they possess (Akın et al., 2011; Varol et al., 2012; Belkhiri and Narany, 2015; Köse et al., 2018; Atıcı et al., 2018; Çiçek et al., 2019; Tokatlı, 2020b).

The Meriç–Ergene River Basin is the main watershed of the Thrace Region of Turkey. The Hasanağa Stream Basin is located in the Edirne Province of Turkey and it is one of the sub–basins of the Tunca River that is one of the main parts of the Meriç–Ergene River Basin. As in many aquatic ecosystems, the Hasanağa Stream Basin is adversely affected by agricultural and domestic discharges. The aim of this study was to determine the spatial and temporal variations of the water quality in this significant watershed by using the WQI.

MATERIALS AND METHODS

Sample collection

In this study, surface water samples were collected from seven stations located on the Hasanağa Stream Basin (3 of them were on the Sinanköy Stream, 3 of them were on the Korucuköy Stream and 1 of them was on the Hasanağa Stream) in the winter seasons of 2019 and 2020. The coordinate information of the locations is given in Table 1 and a map of the study area and the seven selected stations of the basin are given in Figure 1.

Physical – Chemical and Statistical Analysis

Dissolved oxygen (DO), oxygen saturation (OS), pH, electrical conductivity (EC), total dissolved solids (TDS) and salinity variables were determined by using a multi – parameter device (Hach Lange – HQ40D) in the field studies; the turbidity variable was determined by using a turbidimeter device (Hach Lange – 2100Q) in the field studies; nitrate (NO_3), nitrite (NO_2), phosphate (PO_4) and sulphate (SO_4) variables were determined by using a colorimeter device (Hach Lange – DR890) and by using a spectrophotometer device (Hach Lange – DR3900) in the laboratory studies.

Cluster Analysis (CA) and Similarity – Distance Index (SDI) (in terms of Bray Curtis) were applied to the detected data in order to the define the spatial differences of contamination by using the “PAST” package statistical program.

Table 1. Coordinate information of stations.

Station Code	Name of Stream	Coordinate	
		North	East
S1		41.838	26.749
S2	Sinanköy Stream	41.777	26.683
S3		41.719	26.636
K1		41.862	26.700
K2	Korucuköy Stream	41.791	26.657
K3		41.725	26.631
H	Hasanağa Stream	41.732	26.569

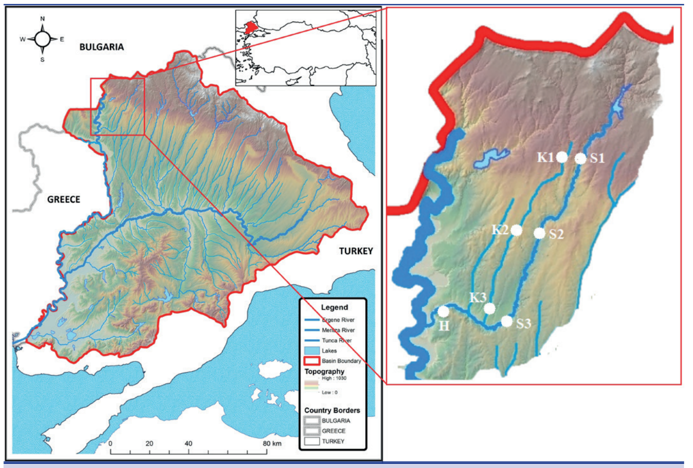

Figure 1. Meriç – Ergene River Basin, study area and selected stations.

Water Quality Index (WQI)

The WQI is an effective method in evaluating the drinking water quality and has commonly been used, especially in recent years (Wang et al., 2017; Tokatlı, 2019c; Ustaoğlu et al., 2020). The following formula was used to calculate the WQI;

$$WQI = \sum \left[W_i \times \left(\frac{C_i}{S_i} \right) \times 100 \right] \quad (1)$$

$$Wi = \frac{w_i}{\Sigma w_i} \quad (2)$$

Where, W_i is relative weight and W_i values are assigned as a maximum of 5 and a minimum of 1, taking into account the relatively significant effects of the toxicants on human health and their significance in terms of potability (Meng et al., 2016). C_i is the trace-toxic element concentration measured in water and the S_i values refer to the standard values determined by TS266 (2005), EC (2007) and WHO (2011) for drinking water. The Standard values (Si) of the investigated parameters with the assigned Wi coefficients in the present application are given in Table 2 (Meng et al., 2016). The scale of WQI is given in Table 3 (Xiao et al., 2019).

Table 2. Standard values, assigned weights and relative weights of parameters.

Variable	Unit	Standart Value (S_i)	Assigned Weight (W_i)	Relative Weight (W_i)
pH		7.5	3	0.111111
EC	µS/cm	1500	4	0.148148
TDS	mg/L	600	4	0.148148
Turbidity	NTU	5	3	0.111111
Nitrate	mg/L	50	5	0.185185
Nitrite	mg/L	3	5	0.185185
Sulphate	mg/L	250	3	0.111111

Table 3. Water quality rating for WQI.

Value	Rating of Water Quality	Usage Possibilities	Grading
< 50	Excellent water quality	Drinking, irrigation, industrial	A
50 – 100	Good water quality	Drinking, irrigation, industrial	B
100 – 200	Poor water quality	Irrigation, industrial	C
200 – 300	Very Poor water quality	Irrigation	D

RESULTS AND DISCUSSION

The results of the detected limnological parameters in the main fluvial components of the Hasanağa Stream Basin in 2019 and 2020 are given in Table 3.

According to the Turkish Regulations (2004; 2015), In the winter season of 2019, the Hasanağa Stream Basin had a 1. Class quality in terms of dissolved oxygen, oxygen saturation, pH, TDS and sulphate parameters and has a 2. Class quality in terms of the EC, nitrate, nitrite and phosphate parameters in general (Uslu and Türkman, 1987). In the winter season of 2020, the basin has a 1. Class quality in terms of dissolved oxygen, oxygen saturation, TDS and sulphate parameters, and has a 2. Class quality in terms of the EC and nitrite parameters and has a 3. Class quality in terms of the pH, nitrate and phosphate parameters in general (Uslu and Türkman, 1987). It was also determined that any investigated locations (except K3 station for turbidity parameter) did not exceed the drinking water standards in terms of the investigated parameters (TS266, 2005; EC, 2007; WHO, 2011).

Nitrate is caused by the oxidation of ammonia, which occurs as a result of the decomposition of proteins contained in animal and vegetable wastes, and especially nitrate fertilisers used in agricultural areas. A small amount of nitrate in clean waters is the most common form of nitrogen in streams (Wetzel, 2001; Manahan, 2011). Nitrite is an intermediate in biological oxidation from ammonium to nitrate, and it may have oxidised to nitrate or reduced to ammonia. It is mostly low in natural waters. Nitrite can reach high densities in low oxygenated waters with organic pollution and suggests sewage contamination if it is found in high amounts. The most important sources of nitrite in soils and waters are organic substances, nitrogenous fertilisers and some minerals (Wetzel, 2001; Manahan, 2011). Phosphorus is a significant essential element for plant growth. It is necessary for crop production and is commonly used in fertilisers. It is known as one of the main elements that increase the nutrient enrichment of surface waters and cause the ageing of lakes or streams (Wetzel, 2001; Manahan, 2011). The reason for the quite high nitrate, nitrite and phosphate values detected in the water of some basin components may have been the applied intensive agricultural fertilisers in the region.

CA was applied to the data in order to obtain the similarity groups among the investigated localities on the Hasanağa Stream Basin according to their similar water quality characteristics. The diagram of CA calculated by using the WQI scores of locations is given in Figure 2 and the calculated similarity coefficient of locations are given in Table 4.

According to the results of CA, 3 statistically significant clusters were formed. Cluster 1 (C1) was named as a "less contaminated zone" and corresponded to the stations S1 and K1; Cluster 2 (C2) was named as a "moderate contaminated zone" and corresponded to the station H, S2, S3 and K2; Cluster 3 (C3) was named as a "more contaminated zone" and corresponded to the station of K3.

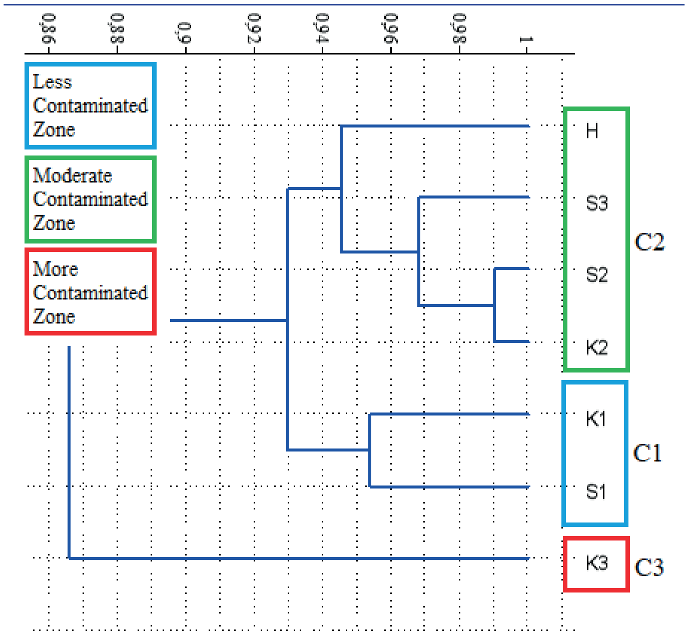

Figure 2. CA diagram.

Table 4. Similarity coefficients of locations.

	S1	S2	S3	K1	K2	K3	H
S1	1.000						
S2	0.942	1.000					
S3	0.910	0.968	1.000				
K1	0.954	0.951	0.936	1.000			
K2	0.942	0.990	0.968	0.941	1.000		
K3	0.806	0.862	0.894	0.851	0.862	1.000	
H	0.884	0.941	0.954	0.930	0.941	0.920	1.000

The Monomial and multinomial risks of pH, EC, TDS, turbidity, nitrate, nitrite and sulphate parameters in the water of the Hasanağa Stream Basin were determined for all the investigated habitats and seasons by using the WQI and the detected data are given in Table 4 and Figure 3.

According to the results of WQI, the values of the overall WQI were within the permissible limits (<100), and all the investigated stations on the Hasanğa Stream Basin in all the seasons were found as "A grade – Excellent" in water quality characteristics. It was also determined that the risk sequence of the investigated parameters in the surface water of the basin is as follows; pH > TDS

Table 3. Physical and chemical data detected in 2019 and 2020.

St.	DO ppm	O2Sat %	pH	EC ms/cm	TDS ppm	Sal. $\%_0$	Tur. NTU	NO_3 ppm	NO_2 ppm	PO_4 ppm	SO_4 ppm
Winter Season of 2019											
Parameters *											
S1	12.26 1. Class	108.3 1. Class	7.89 1. Class	303 1. Class	208 1. Class	0.21	4.53	1.73 1. Class	0.007 1. Class	0.041 2. Class	39 1. Class
S2	12.53 1. Class	109.9 1. Class	7.74 1. Class	482 1. Class	340 1. Class	0.34	2.44	7.29 2. Class	0.047 2. Class	**0.176 3. Class**	51 1. Class
S3	12.20 1. Class	107.0 1. Class	7.70 1. Class	541 2. Class	382 1. Class	0.38	2.27	7.60 2. Class	0.025 2. Class	0.087 2. Class	54 1. Class
K1	12.71 1. Class	111.8 1. Class	7.73 1. Class	513 2. Class	360 1. Class	0.36	2.90	8.48 2. Class	0.015 2. Class	0.084 2. Class	71 1. Class
K2	10.91 1. Class	96.7 1. Class	7.77 1. Class	448 2. Class	311 1. Class	0.31	2.02	**12.80 3. Class**	0.037 2. Class	0.052 2. Class	32 1. Class
K3	12.20 1. Class	103.0 1. Class	7.65 1. Class	559 2. Class	409 1. Class	0.41	7.90	**10.60 3. Class**	0.041 2. Class	0.151 2. Class	40 1. Class
H	11.74 1. Class	96.2 1. Class	7.19 1. Class	541 2. Class	409 1. Class	0.41	4.46	7.97 2. Class	**0.077 3. Class**	**0.163 3. Class**	80 1. Class
Min	10.91	96.20	7.19	303	208	0.21	2.02	1.73	0.01	0.04	32.00
Max	12.71	111.80	7.89	559	409	0.41	7.90	12.80	0.08	0.18	80.30
Mean	12.08	104.70	7.67	483	345	0.35	3.79	8.07	0.04	0.11	52.51
SD	0.60	6.26	0.22	88	70	0.07	2.08	3.42	0.02	0.05	17.72
Winter Season of 2020											
Parameters *											
St.	**DO ppm**	**O2Sat %**	**pH**	**EC ms/cm**	**TDS ppm**	**Sal. $\%_0$**	**Tur. NTU**	**NO_3 ppm**	**NO_2 ppm**	**PO_4 ppm**	**SO_4 ppm**
S1	11.51 1. Class	113.3 1. Class	**9.35 4. Class**	643 2. Class	387 1. Class	0.39	1.75	9.10 2. Class	0.005 1. Class	**0.640 3. Class**	50 1. Class
S2	10.01 1. Class	99.6 1. Class	**9.48 4. Class**	630 2. Class	390 1. Class	0.39	2.05	**22.40 4. Class**	0.009 1. Class	**0.760 4. Class**	51 1. Class
S3	9.79 1. Class	95.3 1. Class	**9.39 4. Class**	6472. Class	406 1. Class	0.41	3.01	**24.30 4. Class**	0.036 2. Class	**1.210 4. Class**	64 1. Class
K1	9.23 1. Class	89.3 2. Class	**9.10 4. Class**	601 2. Class	416 1. Class	0.32	1.88	**15.10 3. Class**	0.011 2. Class	0.070 2. Class	17 1. Class
K2	8.64 1. Class	83.4 2. Class	**8.73 3. Class**	676 2. Class	431 1. Class	0.43	2.48	**23.70 4. Class**	0.021 2. Class	0.150 2. Class	27 1. Class
K3	7.57 2. Class	73.1 2. Class	**8.60 3. Class**	827 2. Class	528 2. Class	0.53	4.65	**24.30 4. Class**	**0.065 3. Class**	**0.370 3. Class**	43 1. Class
H	9.98 1. Class	97.2 1. Class	**8.76 3. Class**	694 2. Class	437 1. Class	0.44	2.59	**20.20 4. Class**	0.054 2. Class	0.130 2. Class	73 1. Class
Min	7.57	73.10	8.60	601	387	0.32	1.75	9.10	0.01	0.07	17.00
Max	11.51	113.30	9.48	827	528	0.53	4.65	24.30	0.07	1.21	73.00
Mean	9.53	93.03	9.06	674	427	0.42	2.63	19.87	0.03	0.48	46.43
SD	1.23	12.78	0.36	73	48	0.06	0.99	5.76	0.02	0.42	19.59

St.: Stations; Sal.: Salinity; Tur.: Turbidity; Min: Minimum; Max: Maximum; SD: Standard Deviation; *3. – 4. Class water qualities are given in bold

> turbidity > EC > nitrate > sulphate > nitrite for 2019 and pH > TDS > nitrate > EC > turbidity > sulphate > nitrite in general.

In a study performed in the catchments of the Emet and Orhaneli Streams, the water quality of the basin was evaluated by using the WQI. According to the results of this investigation, being significantly different from the present investigation, the general trend of the WQI for Emet and Orhaneli Streams was found to be of a heavily polluted water quality (WQI > 300) (Omwene et al., 2019).

Table 4. Monomial and multinomial results of applied WQI.

Parametre	Sinanköy Stream			Korucuköy Stream			Hasanağa Stream
	S1	S2	S3	K1	K2	K3	H
Winter Season of 2019							
pH	11.689	11.467	11.407	11.452	11.511	11.333	10.652
EC	2.993	4.760	5.343	5.067	4.425	5.521	5.343
TDS	5.136	8.395	9.432	8.889	7.679	10.099	10.099
Turbidity	10.067	5.422	5.044	6.444	4.489	17.556	9.911
Nitrate	0.641	2.700	2.815	3.141	4.741	3.926	2.952
Nitrite	0.043	0.290	0.154	0.093	0.228	0.253	0.475
Sulphate	1.742	2.244	2.400	3.173	1.422	1.787	3.569
WQI	**32.310**	**35.279**	**36.596**	**38.259**	**34.495**	**50.474**	**43.001**
Winter Season of 2020							
pH	13.852	14.044	13.911	13.481	12.933	12.741	12.978
EC	6.351	6.222	6.390	5.936	6.677	8.168	6.854
TDS	9.556	9.630	10.025	10.272	10.642	13.037	10.790
Turbidity	3.889	4.556	6.689	4.178	5.511	10.333	5.756
Nitrate	3.370	8.296	9.000	5.593	8.778	9.000	7.481
Nitrite	0.031	0.056	0.222	0.068	0.130	0.401	0.333
Sulphate	2.222	2.267	2.844	0.756	1.200	1.911	3.244
WQI	**39.270**	**45.070**	**49.081**	**40.283**	**45.870**	**55.591**	**47.437**

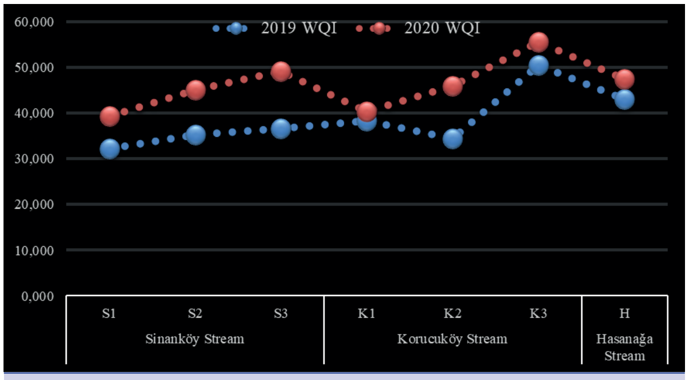

Figure 3. Spatial – temporal comparison of WQI scores.

In another study performed in the same watershed, the groundwater quality of the Ergene River Basin was evaluated by using the WQI. According to the results of this research, as similar to the present research, the investigated element accumulations in the groundwater of the basin were recorded within the range of human consumption standards (Tokatlı, 2019).

In a study performed in the Black See Region of Turkey, the WQI was used to assess the surface water qualities. As similar to the data of the current study, it was reported that the investigated Turnasuyu Stream has an excellent water quality in terms of the WQI (Ustaoğlu et al., 2020).

In a study conducted abroad in the city of Nagpur (India), The WQI was applied to determine the quality of different surface water resources. According to the results of this study, as different of the results of the present study, the calculated WQI for the various lakes studied showed poor water quality (Puri et al., 2011).

CONCLUSION

In the present research, the temporal and spatial change of the water quality of the Hasanağa Stream Basin including the Sinanköy, Korucuköy and Hasanağa Streams were evaluated by using the Water Quality Index (WQI) and Cluster Analysis (CA). As a result of this research, the water quality of the basin was found to have significantly decreased over time and it has a 1. – 2. Class water quality in 2019 and has a 2. – 3. Class water quality in 2020 in general. As a result of the WQI, the basin was found as having "A Grade – Excellent" water quality (<50) in both 2019 and 2020. As a result of CA, 3 statistically significant clusters were formed and the locations investigated were classified as "less polluted zones", "moderate polluted zones" and "more polluted zones". For the protection and sustainability of this important aquatic system, it is necessary to constantly monitor and raise the awareness of local people in agricultural activities.

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Disclosure: -

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