Assessment of Water Quality in Mudurnu River Basin Using Regression Models

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Abstract This study was carried out in order to determine the pollutant sources in the area in the Mudurnu River Basin in which the factory discharges and to identify the correlations between the pollutant parameters of the Regression Models.

The water samples taken from 6 stations placed on Mudurnu River for 6 months twice a month. The parameters of Temperature (^{0}C), pH, Ammonium Nitrogen (NH_4-N), Nitrite Nitrogen (NO_2-N), Nitrate Nitrogen (NO_3-N), Kjeldahl Nitrogen, Total Nitrogen, Total Phosphorus (TP), Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD) were analyzed in the water samples. Moreover, the relationships among water quality parameters were assessed using Regression Models.

Model obtained in the regression analysis explained the TKN parameter with the highest rate (86.1%). In contrast, it was observed that the Regression Model had a lower explanation rate for the parameters of NH_4-N, TP and TSS. When these results were examined, it was detected that most of the sources leading to pollution in the Mudurnu River arose from domestic and industrial wastewater discharge.

Key words: Mudurnu river system, Water Quality, Regression Models

1. Introduction

Nowadays, aquatic systems get gradually polluted by domestic, industrial and agricultural waste materials. Aquatic ecosystems are in a much greater danger in the areas in which agricultural, energy industrial activities are concentrated and in urban residential areas. Large-scale infrastructure projects (highways, urbanization, etc.) and mining activities have a direct impact on pollution. Rivers are the first fluvial aquatic systems to be affected by this pollution. Therefore, it is essential to understand the concentration, distribution and sources of pollutants and water quality in order to protect water resources and control water pollution (Wang *et al*., 2017; Islam et. al., 2015; Li et. al., 2011).

The amount of available water per person in Turkey is around 1,500 m^3/year, and thus is among those countries that suffer from water shortage. Turkey, whose population will reach about 100 million in 2030, will become a country suffering from water scarcity with its 1,120 m^3/year of available water per person. All these predictions will be realized on condition that the present resources will be available in the next 20 years without any damages. For this reason, it is necessary that water resources be conserved very well and utilized wisely so that a healthy and adequate supply of water can be maintained for the future generations of Turkey (Oktem and Aksoy, 2014).

The effective management of these water resources requires knowledge on the quality of river water and its variability. Recently, multivariate statistical approaches have become popular in understanding the water quality and the ecological situation. In the scientific literature, various techniques including clustering analysis (CA), principal component analysis (PCA), factor analysis (FA) and discriminate analysis (DA) are used for such studies, because such techniques make it possible to assess temporal and spatial differences in water quality and determine potential sources of water pollution (Barakat et al., 2016; Khan et al., 2016; Phung et al., 2015; Sharma et al., 2015; Varekar et al., 2015; Kumarasamy et al., 2014; Thuong et al., 2013; Ogleni and Topal, 2011; Ogleni and Bayraktar, 2008).

The purpose of this study is to determine the correlation between the data set obtained in the Mudurnu River Basin at the end of the 6-month monitoring program and pollutant parameters using Regression Models.

2. Material and Methods

2.1. The study area: Mudurnu River Basin

The Mudurnu River Basin rises from the southern slopes of the Abant Mountains, and is formed by small springs and streams that gather together. The

section of Mudurnu River, whose total length is 130 km, within the borders of the Sakarya province in Turkey is 65 km long and its total drainage area is 1720 km^2. The study area covers the area of this 65 km-long basin of the Mudurnu River polluted by industrial and agricultural activities. The sampling points were selected by identifying six points that could represent the system the best. There are 25 production plants in this area, which include agricultural fields, residential areas, and plants for textile, food, aluminum, PVC, automotive, beverages, and water refilling facilities. The Mudurnu River sampling points are shown in Figure 1.

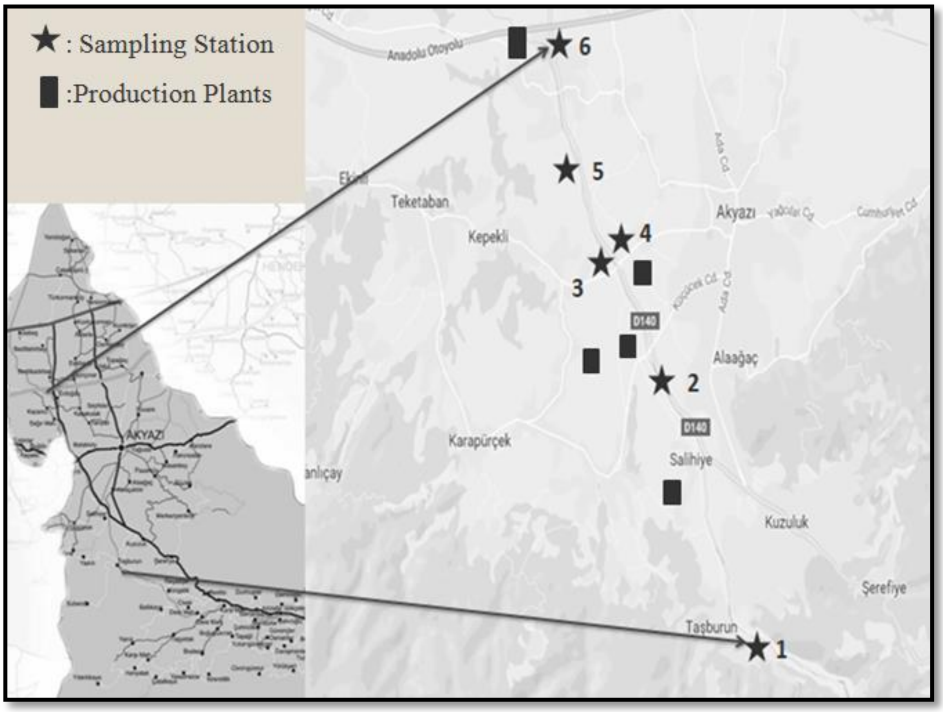

Figure 1. The Mudurnu River sampling points.

Table 1. The Averages and Deviations of Chemical Parameters

	^{0}C	pH	TKN	NH_4-N	NO_2-N	NO_3-N	TN	TP	TSS	BOD	COD
Valid N	72	72	72	72	72	72	72	72	72	72	72
Missing	0	0	0	0	0	0	0	0	0	0	0
Average	18.653	7.014	.383278	.154653	.074528	1.20514	1.62569	.132361	257.36	3.808	7.918
Std. Deviation	3.0909	.3137	.2801115	.1371402	.0579042	.297809	.232105	.0624949	231.025	.3863	1.3764

The first sampling point is in the town of Taşburun, in a site where wastewater discharges of the factories located in the area has not started yet. Wastewater discharge from treatment facilities of the factories starts after the second sampling point. The third sampling point is a tributary, the Küçücek Creek. Agriculture and livestock breeding are extensively practiced in the area in which this sampling point is located. The fourth sampling point is in the area where the Mudurnu River and the Küçücek Creek join. The fifth and sixth sampling points are located in the downstream of the river basin where the sampling is carried out.

2.2. Methods

Water samples were collected twice a month for 6 months (May 2016–October 2016) in the Mudurnu River Basin. The analyses of Temperature, pH, Ammonium Nitrogen (NH_3-N), Nitrite Nitrogen (NO_2-N), Nitrate Nitrogen (NO_3-N), Total Kjeldahl Nitrogen (TKN), Total Nitrogen (TN), Total Phosphorus (TP), Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD) were carried out on the water samples that were collected in accordance with standard methods (APHA-AWWA, 2012).

All the mathematical and statistical computations were conducted using the SPSS 21.0 (SPSS, 2012).

3. Results and Discussion

3.1. Averages and Deviations of Chemical Parameters

In this study, a total of 72 samples were gathered from the sampling site in a period of 6 months. The average values and standard deviations of the parameters measured in the Mudurnu River Basin are given in Table 1.

As it can be seen, the average values of the measured parameters are Temperature (18.6^{0}C), pH (7), TKN (0.3 mg/L), NH_4-N (0.1 mg/L), NO_2-N (0.07 mg/L), NO_3-N (1.2 mg/L), TN (1.6 mg/L), TP (0.1 mg/L), TSS (257 mg/L), BOD (3.8 mg/L) and COD (7.9 mg/L).

3.2. Relationships between Chemical Parameters

According to the correlation matrix, there is a positive relationship between the parameters of TKN and TN (0.509) and a negative one between TKN and NO_3-N (-0.744) and TSS (-0.436). Moreover, positive relationships are seen between the parameters of NO_3-N and NH_4-N (0.236) and between TP and NO_2-N (0.521). On the other hand, there is a negative correlation between TSS and TN (-0.292). A positive relationship is observed between TP and TSS (0.334) and a negative one between TP and COD (-0.237). Finally there is a significant positive relationship between COD and BOD (0.682) (Table 2).

3.3. Regression Analysis between Parameters

The purpose of regression analysis is to detect to what extent the determined parameters are affected by each other and the extent to which the parameters are determinant for one another.

The NO_2-N parameter was measured at high concentrations at all the sampling sites. According to the Inland Water Resources Quality Criteria of the Water Pollution Control Regulations, the Mudurnu River Basin is placed in Class IV when the NO_2-N parameter is taken into consideration.

It was determined that all the sampling locations that were measured had second quality water with respect to the parameter of BOD, while the first sampling site had second quality water and the other sampling sites had third quality water in terms of TP. In terms of the TKN parameter, only the third sampling site had second quality water but the other sites had first quality water, and for the parameter of NH_4-N, the first and third sampling sites showed the characteristics of first quality, while the other sites that of second quality. In terms of the parameters of Temperature, pH, COD and NO_3-N, all the sampling sites have first quality water.

It was also understood that there was a highly significant positive relationship between COD and BOD (0.682). These are the highest relationships specified in the correlation matrix. The Regression Model obtained in the regression analysis explained the TKN parameter with the highest rate (86.1%) (Table 3). In contrast, it was observed that the Regression Model had a lower explanation rate for the parameters of NH_4-N, TP and TSS.

Table 2. Correlation Analysis of Chemical Parameters

		^{0}C	pH	TKN	NH_4-N	NO_2-N	NO_3-N	TN	TP	TSS	BOD	COD
^{0}C	Pearson Korelasyon	1										
	Sig. (2-tailed)											
pH	Pearson Korelasyon	,187	1									
	Sig. (2-tailed)	,116										
TKN	Pearson Korelasyon	,321**	-,229	1								
	Sig. (2-tailed)	,006	,053									
NH_4-N	Pearson Korelasyon	,092	-,012	-,131	1							
	Sig. (2-tailed)	,440	,924	,272								
NO_2-N	Pearson Korelasyon	-,068	-,231	,139	-,071	1						
	Sig. (2-tailed)	,568	,050	,243	,552							
NO_3-N	Pearson Korelasyon	-,090	,198	-,744**	,236*	-,172	1					
	Sig. (2-tailed)	,455	,095	,000	,046	,149						
TN	Pearson Korelasyon	,330**	-,073	,509**	,146	,259*	,037	1				
	Sig. (2-tailed)	,005	,544	,000	,220	,028	,756					
TP	Pearson Korelasyon	-,157	-,102	-,021	-,031	,521**	-,082	-,009	1			
	Sig. (2-tailed)	,187	,393	,859	,799	,000	,491	,943				
TSS	Pearson Korelasyon	-,191	,109	-,436**	,054	,154	,216	-,292*	,334**	1		
	Sig. (2-tailed)	,107	,361	,000	,652	,195	,069	,013	,004			
BOD	Pearson Korelasyon	,228	,127	,043	-,001	,060	,106	,175	-,195	-,094	1	
	Sig. (2-tailed)	,054	,288	,721	,991	,615	,375	,141	,101	,431		
COD	Pearson Korelasyon	-,091	,195	-,026	,008	,088	,198	,218	-,237*	-,090	,682**	1
	Sig. (2-tailed)	,445	,100	,830	,950	,462	,096	,066	,045	,454	,000	

**. Korelasyon anlamlıdır 0.01 level (2-tailed).

*. Korelasyon anlamlıdır 0.05 level (2-tailed).

Table 3. Model Summary of Regression Analysis of the TKN Parameter

Model	R	R Square	Adjusted R Square	Estimated Standard Error	Durbin–Watson Statistic
1	.932[a]	.869	.861	.104348	2.002

a. Determiners: (Constant): TSS, NO_2-N, NO_3-N, TN

b. Dependent Variable: TKN

The NH_4-N parameter was explained by the TKN and TN parameters by 5.2%. The NO_2-N parameter was affected by the parameters of pH, TKN and NO_3-N negatively and by TN, TP and COD positively. The explanatory power of the Regression Model generated was 44% and it was observed that the most effective parameters on the parameter of NO_2-N were TKN, NO_3-N and TN.
The TP parameter was explained by the parameters of COD, TSS and NO_2-N by 38%. The TP parameter was affected by the parameters of TSS and NO_2-N positively and by the COD parameter negatively. It was observed that the most effective parameter on TP was NO_2-N.
The parameter of TSS was explained by 27.5% by the Regression Model generated with the parameters of TKN and TP. The TSS parameter was affected by TKN negatively and by TP positively.

4. Conclusions

This study was carried out in order to determine the pollutant sources in the area in the Mudurnu River Basin in which the factory discharges were severe and also in the downstream and upstream of that area and to identify the correlations between the pollutant parameters of the Regression Models.

When these results were examined, it was detected that most of the sources leading to pollution in the Mudurnu River arose from domestic and industrial wastewater discharge. However, pollution that emerge from extensive activities of livestock breeding and agriculture cannot be overlooked. According to the results of the analysis, it was observed that the greatest amount of pollution leaked into the Mudurnu River through plant zones. The sectors of textile, food, aluminum and automotive caused high levels of pollution.
High levels of nitrite in rivers points to a sudden domestic/industrial wastewater discharge. Even low concentrations of the nitrite parameter are known to be toxic for aquatic life. Therefore, this parameter in particular needs to be paid attention in the studies carried out in rivers and rehabilitation operations should be performed in order to lower high concentrations.

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