Case Study

Testing of Water Quality Model SISMOD in Alaşehir Creek Sub-basin

Su Kalitesi Modeli SISMOD'un Alaşehir Çayı Alt Havzasında Test Edilmesi

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Abstract

In this study, Simple Stream Water Quality Model (SISMOD), which was developed in Turkey at 2010, was tested for Alaşehir Creek Sub-basin. SISMOD Model is a steady state and one dimensional water quality model. It is simple to develop water quality model on the basin scale and results of the model are useful for the water quality management strategies. The model was run for four periods (November, February, May and August) and for Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Organic Nitrogen (Org-N), Ammonium Nitrogen (NH_4N) & Nitrate Nitrogen (NO_3N) parameters. Alaşehir Creek Sub-basin has water quality and amount problems because of negative effects of anthropogenic activities and climate change. Diffuse loads and point loads were also included as an input in the model. Within scope of the study, calibration and validation studies were manually held on November and February terms respectively. Calibration and validation results were evaluated with using Root Mean Square Error (RMSE), Percentages of Error (pBIAS) and Mean Absolute Error (MAE) Methods that are statistical indices widely used for the water quality model performance evaluation. The developed model was utilized for creating two different scenarios in order to improve water quality of study area. The water quality of the study area was evaluated according to Annex 5 of By-law on Surface Water Quality (OG: 30.11.2012/28483). As a result of this study, SISMOD, a new and simple water quality model, could be used for having limited time and available data for any water area.
Keywords : *Water quality, SISMOD, Simple Stream Water Quality Model, Gediz Basin, Alaşehir Creek*

Öz

Bu çalışmada 2010 yılında Türkiye'de geliştirilmiş ve akarsulara uygulanabilir BaSİt AkarSu MODelleme Programı (SİSMOD) Alaşehir Çayı Alt Havzası için test edilmiştir. SISMOD modeli, kararlı bir durum ve tek boyutlu bir su kalitesi modelidir. Modelin havza ölçeğinde kurulması kolaydır ve model sonuçları su kalitesi yönetimi stratejilerinin belirlenmesinde büyük fayda sağlamaktadır. Model 4 dönem (Kasım, Şubat, Mayıs ve Ağustos) ve Çözünmüş Oksijen (ÇO), Biyolojik Oksijen İhtiyacı (BOİ), Organik Azot (Org-N), Amonyum Azotu (NH_4N) ve Nitrat Azotu (NO_3-N) parametreleri için çalıştırılmıştır. Alaşehir Çayı Alt Havzasında, antropojenik faaliyetler ve iklim değişikliği etkileri nedeniyle su kalitesinde ve miktarında problemler yaşanmaktadır. Yayılı ve noktasal yüklere ilişkin veriler de modele girdi olarak dâhil edilmiştir. Çalışma kapsamında, kalibrasyon ve validasyon manuel olarak gerçekleştirilmiş olup sırasıyla Kasım ve Şubat dönemlerindeki veriler kullanılmıştır. Kalibrasyon ve validasyon sonuçlarının performansı, su kalitesi modeli performans değerlendirmesinde yaygın olarak kullanılan istatistiksel indekslerden Ortalama Karesel Hatanın Karekökü (RMSE), Yüzdesel Hata (pBIAS) ve Ortalama Mutlak Hata (MAE) yöntemleri kullanılmıştır. Su kalitesini iyileştirmek için iki farklı senaryo analizi çalışılmıştır. Çalışma alanının su kalitesi Yerüstü Suyu Kalitesi Yönetmeliği Ek-5'e (RG: 30.11.2012 / 28483) göre değerlendirilmiştir. Bu çalışmanın sonucunda, kısıtlı zamanın ve temin edilebilir verinin olduğu durumlarda yeni ve basit bir su kalitesi modeli olan SISMOD'un kullanılması önerilmektedir.
Anahtar kelimeler: *Su kalitesi, SISMOD, Basit Akarsu Modeli, Gediz Havzası, Alaşehir Çayı*

Introduction

The components of the systems, variables that determine the behavior of these components and the responses of the system to the changes in those variables should be determined by utilization of the integrated basin management approach. In order to prepare river basin management plans effectively, it is necessary to know the temporal and spatial distributions of the predominant factors of pollution of water bodies. In addition, predictions are made for the future and the conceptual relationship between the systems that characterize the basin is revealed (Commission, 2000).

Water quality models are useful tools for identifying the ecological status of water resources and / or for estimating the recovery of the previous ecological state when certain boundary and initial conditions are changed (Lindenschmidt, 2006). River quality models seek to describe the spatial and temporal changes of constituents of concern. They characterize oxygen household, nutrients and eutrophication, toxic materials, and so on (Board and Council, 2000).

River water quality modelling has a long history beginning from 1925 with Streeter and Phelps. Streeter and Phelps described the bacterial decomposition of organic carbon characterized by biochemical oxygen demand (BOD) and its impact on dissolved oxygen conditions (Nas & Nas, 2009). Since then, countries have put on the market their water quality modeling software. Those developed software disseminated in other countries, which also provides models to be tested in a spread wide with numerous practices.

One of these models is Aquatool which is a decision support system comprised from modules such as EVALHID (water quantity module), SIMGES (water allocation module), GESCAL (water quality module) developed in Spain. Aquatool model performance was checked for Jucar River Basin in the east of Spain. The goal of the model is to estimate the effect of increasing the efficiency of several wastewater treatment plants on the water quality of the river. Water quality module was set up for following parameters; conductivity, suspended solids, cBOD, dissolved oxygen, ammonium and nitrates. Sensitivity analysis was performed individually for all the elements, and for all the calibrated coefficients. Finally, verification was carried out to test the behavior of all elements working together. Afterwards, water treatment possibilities, and other actions to improve the water quality in the lower part of the river. It has been estimated that dissolved oxygen, suspended solids and ammonium concentrations will improve respectively from 3.5 to 7.6 mg/l; from 28 to 9 mg/l and from 1.81 to 0.12 mg/l on average (Paredes-Arquiola et al., 2010).

WASP (Water Quality Analysis Simulation Program) which was developed by U.S. Environmental Protection Agency was tested for Altamaha River in Georgia. WASP is a model that calculates hydrodynamic and water quality with the options of one, two, and three-dimensional representation of a system through both vertical and horizontal segmentation. The model was calibrated and validated with data obtained from another project in the river. Average error between model predicted and observed concentrations was 39.8 % for ammonia (NH_3), 23.6 % for NO_3-N, and 7.8 % for dissolved organic nitrogen (DON). Calibration results showed that predicted DN concentrations were the highest for high DN input, high flows, and low and medium temperatures (Kaufman, 2011).

In Kenya Ndarugu River's water quality, to which untreated industrial, domestic and agricultural wastes from coffee and tea factories are discharged, was predicted with QUAL2K. Model was calibrated and validated for flow discharge (Q), temperature (T°), flow velocity (V), BOD_5, DO and NO_3-N parameters. According to results of this study, QUAL2K gives quite accurate results according to field data. Even though there are some minor differences between measured and estimated data, model can be used where financial resources for monitoring are limited (Hadgu et al., 2014).

SISMOD is another water quality model, which was developed in Turkey at 2010 by Assoc. Prof. Ali ERTÜRK. It should be tested for the basin scale and results should be controlled whether it reflects the field data in a statistically acceptable manner.

Therefore, in this study SISMOD model performance was evaluated for river waters of Alaşehir Creek Sub-basin which is an important component of Gediz Basin. Alaşehir Creek Sub-basin has water quality problems in recent years because of uncontrolled discharges of domestic and industrial wastewaters and diffuse loads. SISMOD model results were evaluated with statistical indices to check the errors between measured and simulated data were in acceptable intervals. RMSE, pBIAS and MAE methods were used in this study.

Although many error indices are used for surface water quality models, RMSE and MAE provide easier interpretation of the result due to the results of those indices are in the same unit of the calculated values. RMSE and MAE are close to zero, it means perfect fitting. PBIAS controls the tendency of the simulation results to be greater or less than the results of the observation. The PBIAS value is expected to be zero when it is best matched.

Subsequently, developed model was then used to search two different improvement scenarios so as to improve water quality. Within scope of Scenario 1; Alaşehir, Piyadeler, Kavaklıdere, Kemaliye, Derbent, Avşar, Büyükbelen, Urganlı and Turgutlu Districts' wastewater treatment plants were assumed to be constructed & operated with a 50% decrease in diffuse load concentrations. Whereas advanced treatment process for industrial wastewater, domestic wastewater treatment plants for all direct discharging districts given in Table 3 and 70% decrease for diffuse loads were assumed in Scenario 2. Scenario analysis results were evaluated by classifying according to By-law on Surface Water Quality Annex 5 (OG: 30.11.2012/28483).

Method

Study Area

Gediz Basin is located in the Aegean region, western of Turkey with Gediz River and its branches discharges through the Aegean Sea. North Aegean, covers the area between Susurluk and Küçük Menderes Basin. The basin covers 1,703,394 hectares, which is 2.17 % of the total surface area of Turkey. Alaşehir Creek Sub-basin is located in the south-southeast extension of the Gediz Basin. It covers mainly Alaşehir Creek through the downstream of the basin Alaşehir Creek merges to the Gediz River. Alaşehir Creek and Gediz River, located at the downstream of the Demirkopru Dam, were considered as the main river branch within the scope of this study. Sarıgöl, Alaşehir, Salihli, Ahmetli and Turgutlu districts are within the borders of the basin. The map and google earth view of the study area are shown in Figure 1.

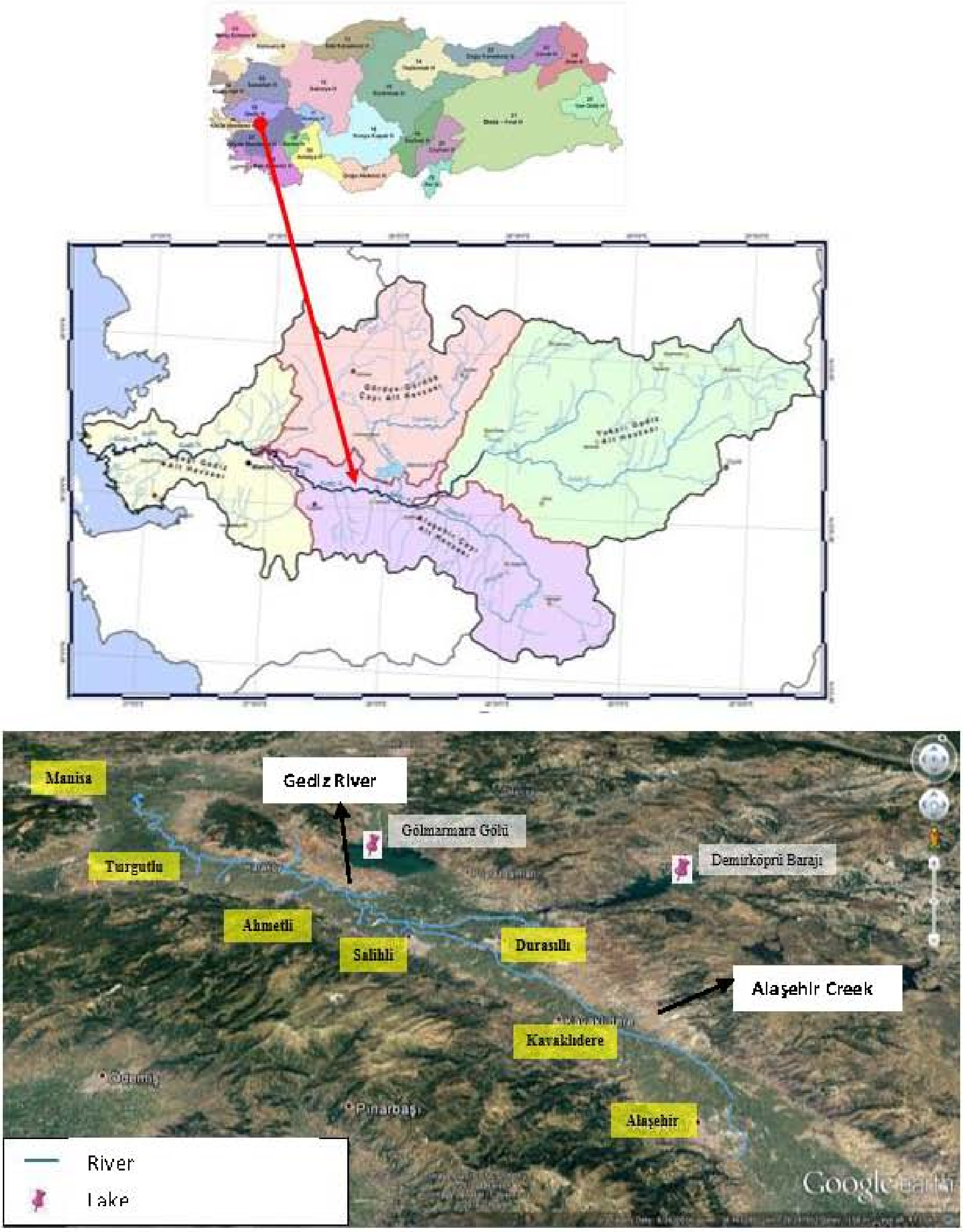

Figure 1. Side view of Alaşehir Creek Sub-basin.

According to four stations data of the years of 2014, 2015 and 2016 obtained from the General Directorate of Meteorology, monthly average temperature (°C) and precipitation values (mm) are given in Table 1 and Table 2. According to results, the highest temperature in the sub-basin is measured as 28.78 °C in August and the lowest temperature is measured as 3.11 °C in December. The highest precipitation is measured as 5.44 mm in December as well.

Table 1
Monthly Average of the Temperature (°C) for the Alaşehir Creek Sub-basin

Station Name	Years/ Months	1	2	3	4	5	6	7	8	9	10	11	12
Ahmetli Station	2014	8.43	8.44	10.96	15.77	19.76	23.29	27.15	28.14	22.37	16.98	11.45	9.55
	2015	6.00	7.49	10.31	13.09	20.92	22.72	27.12	27.20	24.37	17.49	11.84	3.85
	2016	6.01	11.29	11.88	17.81	19.34	26.08	27.50	27.83	22.59	16.59	10.49	3.38
Alaşehir Station	2014	9.04	8.99	11.49	16.30	20.09	23.60	27.63	27.99	22.37	16.98	11.44	9.97
	2015	6.24	7.82	10.23	13.28	21.13	22.19	27.38	27.30	24.27	17.27	11.91	3.94
	2016	6.05	11.73	11.93	18.45	19.22	26.32	27.65	26.70	22.08	16.38	10.48	3.11
Turgutlu Station	2014	8.38	8.46	10.97	15.54	19.63	22.89	26.13	26.57	21.93	17.06	11.21	9.60
	2015	3.89	6.93	10.25	13.15	20.39	22.41	25.98	26.51	23.87	17.20	11.96	3.94
	2016	6.15	11.49	11.01	17.75	19.62	25.98	27.15	27.89	22.43	16.52	10.79	3.63
Salihli Station	2014	9.46	9.47	11.77	16.58	20.54	24.51	28.33	28.78	23.24	17.87	12.10	10.22
	2015	6.45	7.96	10.70	13.95	21.37	23.17	28.37	28.52	25.75	18.65	13.50	5.53
	2016	6.65	12.34	12.41	19.09	20.28	27.53	28.66	28.42	23.74	17.99	11.80	4.34

Table 2
Monthly Average of the Precipitation (mm) for the Alaşehir Creek Sub-basin

Station Name	Years/ Months	1	2	3	4	5	6	7	8	9	10	11	12
Salihli Station	2014	0.94	0.66	0.94	1.69	0.64	1.99	0.00	0.07	1.01	0.62	0.85	4.79
	2015	3.79	2.79	1.53	1.38	1.35	1.44	0.14	0.60	0.39	0.79	1.50	0.03
	2016	4.07	0.99	3.20	0.03	0.78	0.00	0.00	0.64	0.89	0.20	3.08	0.70
Ahmetli Station	2014	0.02	0.00	0.94	2.39	0.91	1.33	0.00	0.00	0.35	0.68	0.79	5.44
	2015	3.40	2.44	1.69	1.08	1.33	2.62	0.01	0.34	0.40	0.81	1.48	0.02
	2016	4.48	1.40	3.17	0.11	0.95	0.22	0.05	0.58	0.41	0.05	2.58	0.68

Land use percentages of Alaşehir Creek Sub-basin is given in Figure 2. As seen from the graph, 62% of the basin areas are used for agricultural purposes. This enormous value of percentage reasons to high diffuse pollution of the basins' river waters.

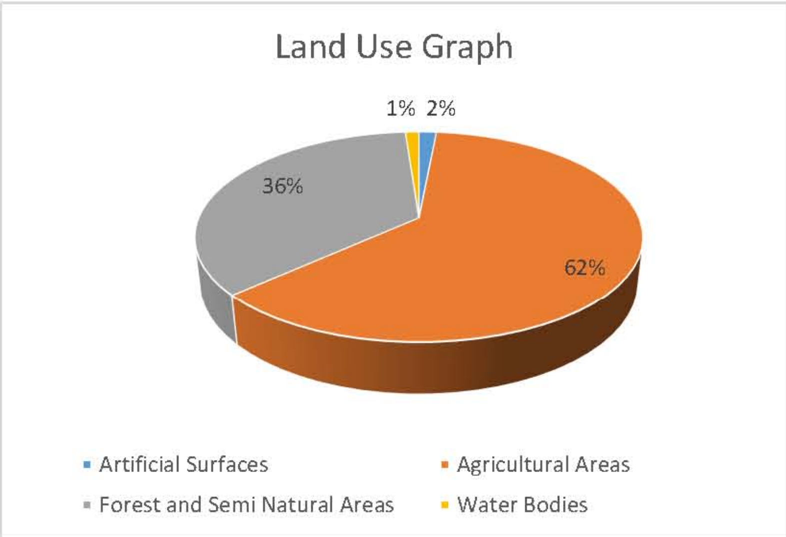

Figure 2. Alaşehir Creek Sub-basin land use percentages

Furthermore, the basin is also under a point source pressure originates from industries and domestic wastewater. Some of its districts such as Alaşehir, Ahmetli, Durasıllı and Salihli have an already operating urban wastewater treatment plants. However, Alaşehir Wastewater Treatment Plant's capacity and technology is not satisfactory. One of the most important pressure is direct discharge of Turgutlu district's wastewater. Other districts discharge their wastewater to the Alaşehir Creek and its tributaries (Table 3).

Table 3
Districts in the Model Study Area and Their Discharge Type

District/Village Names	Discharge Type	District/Village Names	Discharge Type
Alaşehir District	Urban WWTP	Saruhanlı District*	-
Kavaklıdere	Direct Discharge	Büyükbelen	Direct Discharge
Kemaliye	Direct Discharge	Gümülceli	Direct Discharge
Piyadeler	Direct Discharge	Koldere	Direct Discharge
Salihli District	Urban WWTP	Selendi District*	-
Durasıllı	Urban WWTP	Hacıhalliler	Direct Discharge
Sart	Direct Discharge		
Taytan	Direct Discharge		
Yılmaz	Direct Discharge		
Ahmetli District	Urban WWTP	Sarıgöl District	Direct Discharge
Turgutlu District	Direct Discharge		
Avşar	Direct Discharge		
Derbent	Direct Discharge		
Urganlı	Direct Discharge		

*Note.** District centers are not located in the study area

The other important pressure in the basin is industrial discharges. Especially in Salihli and Alaşehir districts, industrial activities are seen intensively. There is an organized industrial zone in Salihli which has its own WWTP. There are olive oil production facilities and raisin mills in the basin. Olive oil production facilities in the basin operates in November, December and January months by using 3 phase olive oil extraction process. This type of production process reasons also production of wastewater. In addition, there aren't any landfills through the basin; all solid wastes are being dumped.

SISMOD

SISMOD divides the system into river reaches. A new reach should be created for each point load. There are three types of streams in the SISMOD model network. These are defined as the headwater reach, the standard reach and the downstream reach. Many initial sections can be defined in a model network. The downstream reach is the reach where the model network ends and the entire flow is exited. A model network can have only one downstream reach.

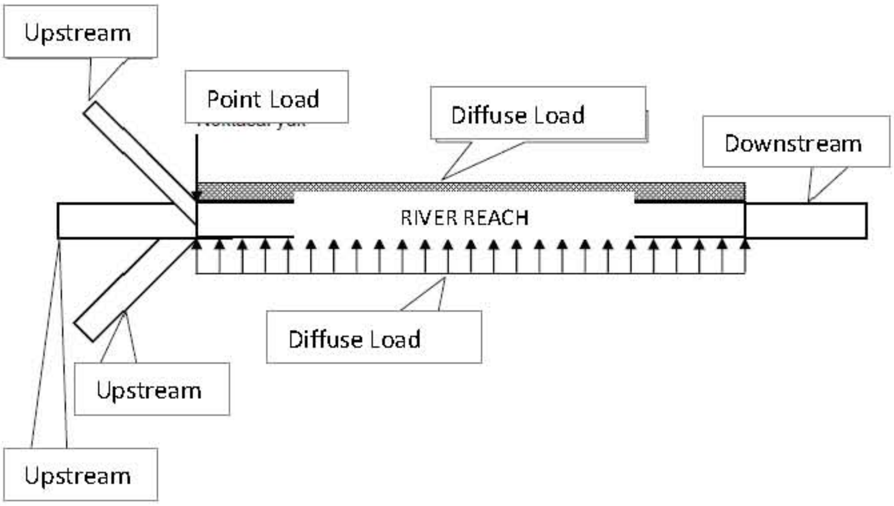

Figure 3. River reaches and components.

Hydraulic calculations are carried out according to the assumptions that the flow in the river is steady and uniform. SISMOD includes a hydraulic module that calculates according to local uniform flow assumption for steady state flows. Hydraulic calculations can be made for triangular, rectangular, trapezoidal and irregular cross sections. Water quality module have the ability to calculate parameters of DO, BOD, OrgN, NH_4N, NO_3N, Organic Phosphorus (Org P) and Phosphate (PO_4P). Water quality calculation are made by taking into account the oxygen level. Suitable equations according to aerobic and anaerobic conditions can be used.

However as all water quality models, SISMOD have some limitations as well. Since it is a simple model, it does not contain unsteady state flow conditions and assumes that uniform flow conditions are valid for the water bodies. The homogeneity of the stream along the cross-section also determines the complexity of the model to be used. If the cross-section of the stream does not change significantly, the assumption of uniform flow will not increase the error (Martin & McCutcheon, 2018).

Another limitation is that model simulates substance transport by taking into account only advection by ignoring the effect of dispersion. According to literature dispersion effect can be neglected in rivers where the pollution load is consistent. However, some regional conditions may occur in some large rivers where the velocity decreases and the dispersion in the pollutant transport is prominent. This is usually occurs at the downstream of the rivers, where they approach to the transitional water bodies. In these regions, the water velocity may decrease to zero. Therefore; In water environments, such as transitional waters where dispersion is important, modeling only by advection may not yield accurate results (Chaiwiwatworakul et al., 2005).

SISMOD's other important limitation is that nitrogen and phosphorus cycles are not connected to each other through primary productions as it happens in real systems. In a study done in Orinoco River Stream, because of turbidity, depth and relatively fast flowing conditions, less yield of phytoplankton production is observed such as 4-43 mg C m^{-2} day^{1} (Lewis, 1988).

Moreover, another study reveals that periphyton biomass increases with increasing water velocity until it reaches to a critical speed. The critical speed is between 20 cm/s and 50 cm/s. Periphyton biomass begins to diminish as a result of physical disintegration and periphyton displacement after reaching critical speed (Ahn et al., 2013).

Therefore it is seen that SISMOD model's technical characteristics are enough when compared to literature.

Conceptual Model

In order to evaluate basin's water quality in terms of DO, modelling parameters were selected as DO, BOD, Org N, NH_4N and NO_3N.

The features such as altitude, bottom slope, side slope and bottom width of the river bodies were used from the hydromorphological monitoring data conducted within the "Project on Basin Monitoring and Determination of Reference Areas" which is completed in 2013 by the Ministry of Forestry and Water Affairs (abolished in 2018). Due to the lack of up-to-date data, Google Earth satellite imagery of water bodies had also been used.

Spatial and point loads data were obtained from the "Project on Implementation of Total Maximum Daily Load (TMDL) Approach in Gediz Basin". For some industries, instead of performing measurements, similar sectors of industries' measurements were used. Point source discharges were also obtained from TMDL Project where taken from Environmental Permit License documents of industries provided by Provincial Directorates of Ministry of Environment and Urbanization.

Annually total diffuse loads were gathered from the "Project on Determination of Sensitive Areas of Basins and Water Quality Targets in Turkey" which was completed by the Ministry of Forestry and Water Affairs (abolished in 2018). Since study area water quality was monitored monthly, annually diffuse loads were distributed to monthly values by using base flow ratios belonging to each months. This calculation was held by the help of SWAT Baseflow Program using flow observation stations data of the General Directorate of State of Hydraulic Works (DSI).

Water quality data was measured for November, February, May and August months so that SISMOD was run for 4 periods. When the measured data was evaluated, in November period the downstream of the basin and in August period the upstream of the basin were dry. Model boundary area is shown in Figure 4. Totally, 246 km of water bodies were modeled and during modelling 61 reaches were segmented according to point source discharge and typological characteristics of water bodies.

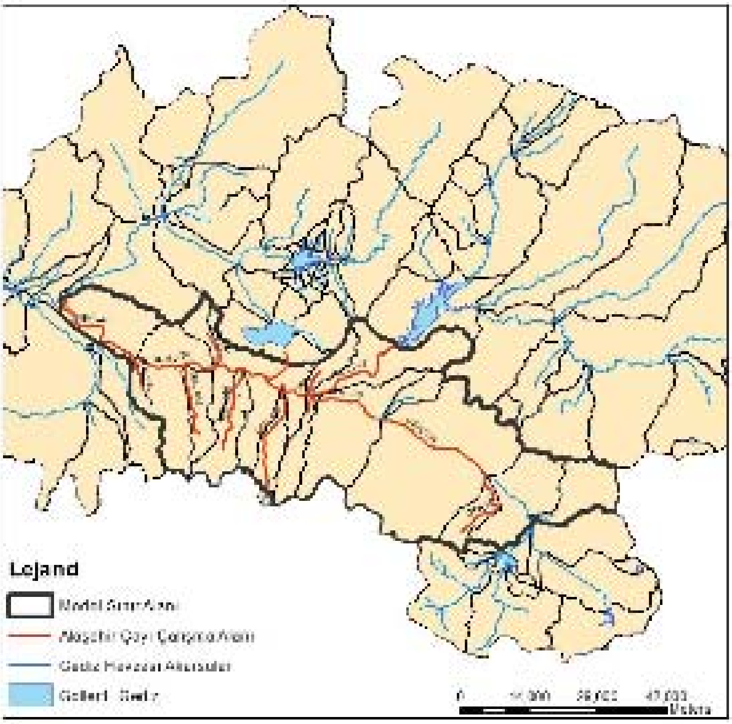

Figure 4. Model boundary area.

Water Quality Improvement Scenarios

After the conceptual model was constituted, water quality improvement scenarios were defined and scenario models were run for the study area. Two scenarios were studied. Scenario 1 focused on only already planned domestic wastewater treatment plants to be constructed & operated and diffuse pollution to be decreased by 50% assumptions. Scenario 2 focused on an advanced treatment process for industrial wastewater, constructing domestic wastewater treatment plants for all the districts discharging directly and 70% decrease in diffuse loads assumptions.

In Alaşehir, Piyadeler, Kavaklıdere, Kemaliye, Derbent, Avşar, Büyükbelen, Urganlı and Turgutlu Districts wastewater treatment plants are being planned or constructed. In scenario analysis only Alaşehir and Turgutlu WWTPs were planned as extended aeration activated sludge system and the remainings were planned as a conventional activated sludge process.

Results & Discussion

Calibration of the model was carried out manually and systematically. When the data of the 4 periods were examined, it was seen that the flow was at average values on May month. For this reason, its calibration was held at 4 different measurement points for the May period. Error evaluation indices as RMSE, pBIAS and MAE for each parameters are provided in Table 4.

According to model performance results for calibration period, DO parameters' RMSE and MAE values were 1.11 and 0.77 respectively. Since these values were closer to each other, it was understood that there was a little difference between mean errors and individual errors for DO parameter. This showed that the individual errors were in the average and there were no major deviations. RMSE and MAE values of BOD and TKN parameters had the similar results as DO parameter.

When the pBIAS results were evaluated, the most accurate result was obtained for BOD parameter with 13.88% error. Percentage of error for DO parameter was -23.24% and for TKN parameter -20.78%.

Table 4
Evaluation of Calibration Period (May) Error for Water Quality Parameters

Parameter	RMSE (mg/L)	PBIAS (%)	MAE (mg/L)
DO	1.11	-23.24	0.77
BOD_5	5.62	13.88	3.71
TKN	4.73	-20.78	4.15

The model was validated for February period. RMSE, pBIAS and MAE for each parameters are given in Table 5. In the validation period, DO parameters' RMSE and MAE values were 1.96 and 1.45 respectively. RMSE and MAE results of BOD and TKN parameters were also close each other as in DO parameter. It was found out that there was a little difference between mean errors and individual errors such as calibration period.

According to pBIAS results, the most accurate result was calculated for BOD parameter as in calibration period. Percentage of error for DO and TKN parameter were respectively 19.62% and 24.90%.

Table 5
Evaluation of Validation Period (February) Error for Water Quality Parameters

Parameter	RMSE (mg/L)	PBIAS (%)	MAE (mg/L)
DO	1.96	19.62	1.45
BOD_5	1.65	-3.87	1.47
TKN	1.18	-24.90	1.12

The water quality has improved greatly during August, a dry period. This is the result of releasing water with high DO and low BOD concentrations from Demirköprü Dam and Marmara Lake to the study area from. When the graph of November period was examined, it was seen that BOD level increased to 60 mg/L in the main river branch which was also observed for NH4N and Org N parameters. This was obviously result of olive oil extraction industries process in November.

According to the model results, annual average values showed that 64%, 38% and 58% of water bodies were in IV. Class respectively for parameters of DO, BOD and TKN. Water bodies were in III. Class with 48% rate for BOD parameter. For TKN parameter, 38 % of water bodies were in III. Class.

Model results of DO, BOD and NH_4N parameter concentrations for the main river branch are given in Figure 5, Figure 6 and Figure 7 for November, February and August periods.

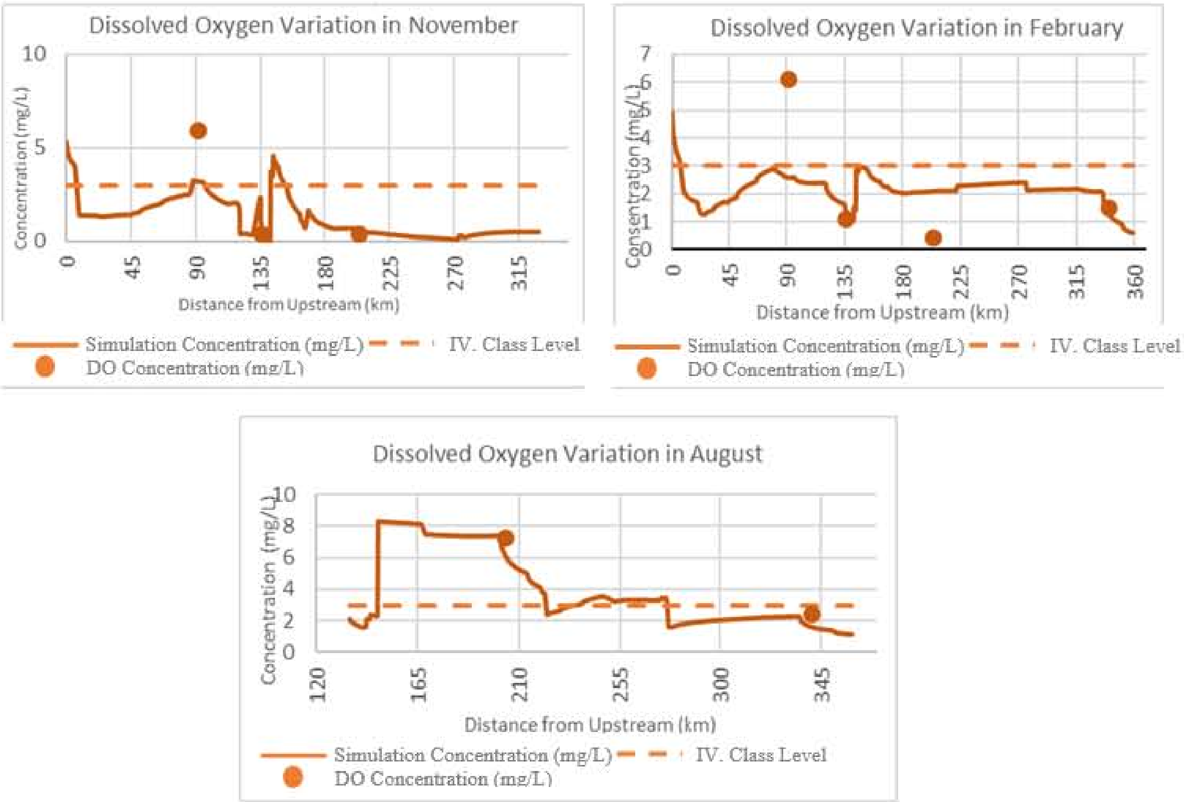

Figure 5. November, February and August Dissolved Oxygen Concentration through the main river branch.

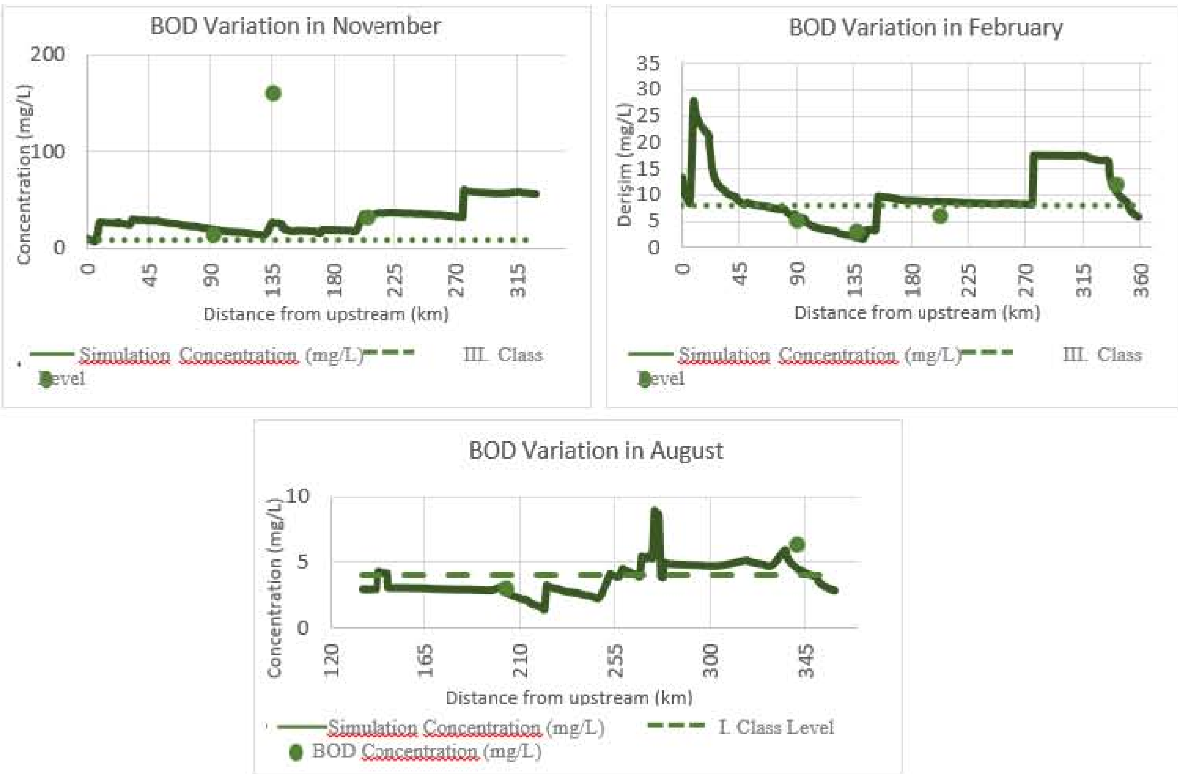

Figure 6. November, February and August BOD concentration through the main river branch

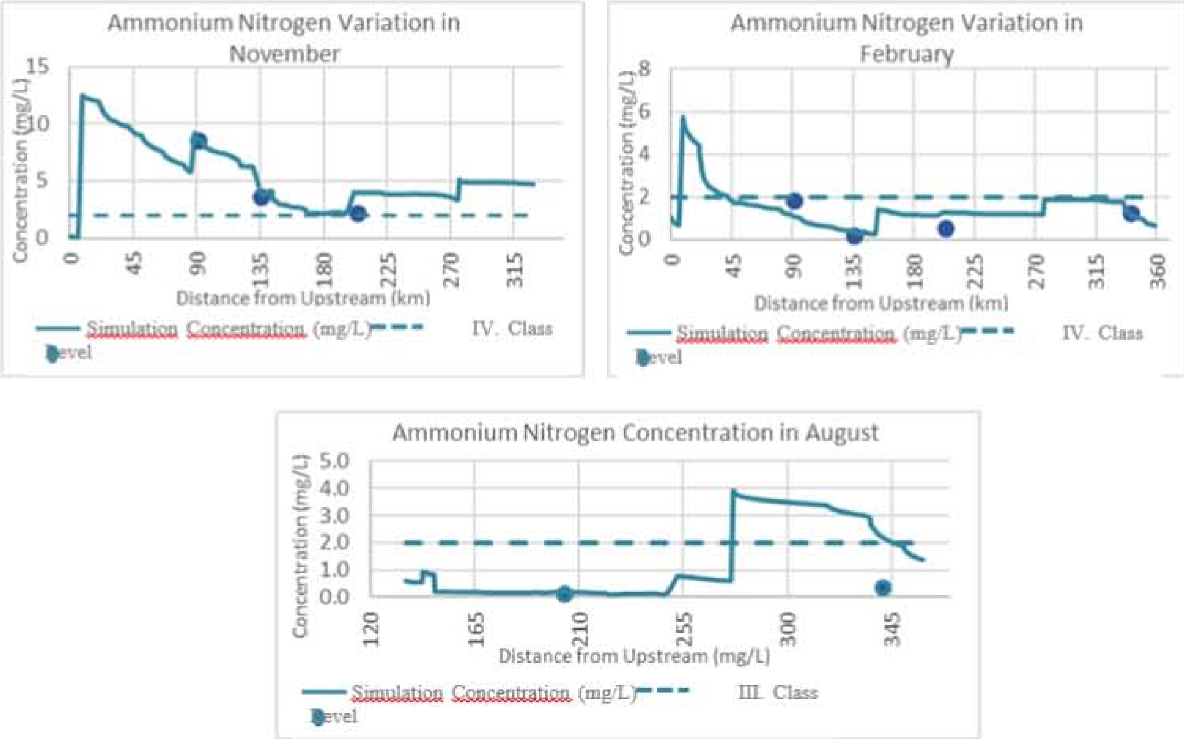

Figure 7. November, February and August NH4N Concentration through the main river branch.

Results of scenario analysis showed that the best improvement percentage was obtained for BOD parameter. Approximately 80% of water bodies were in I. Class according to Scenario 2 situation. TKN parameter results showed a less improvement since 86.56 % of water bodies

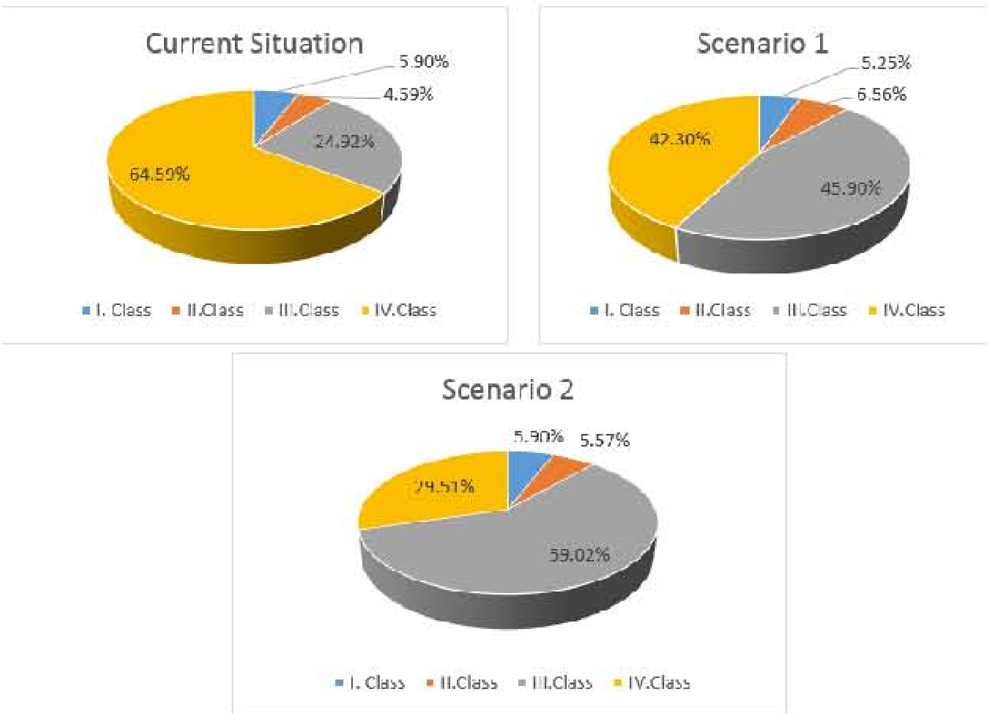

Figure 8. Water quality class percentages for DO parameter.

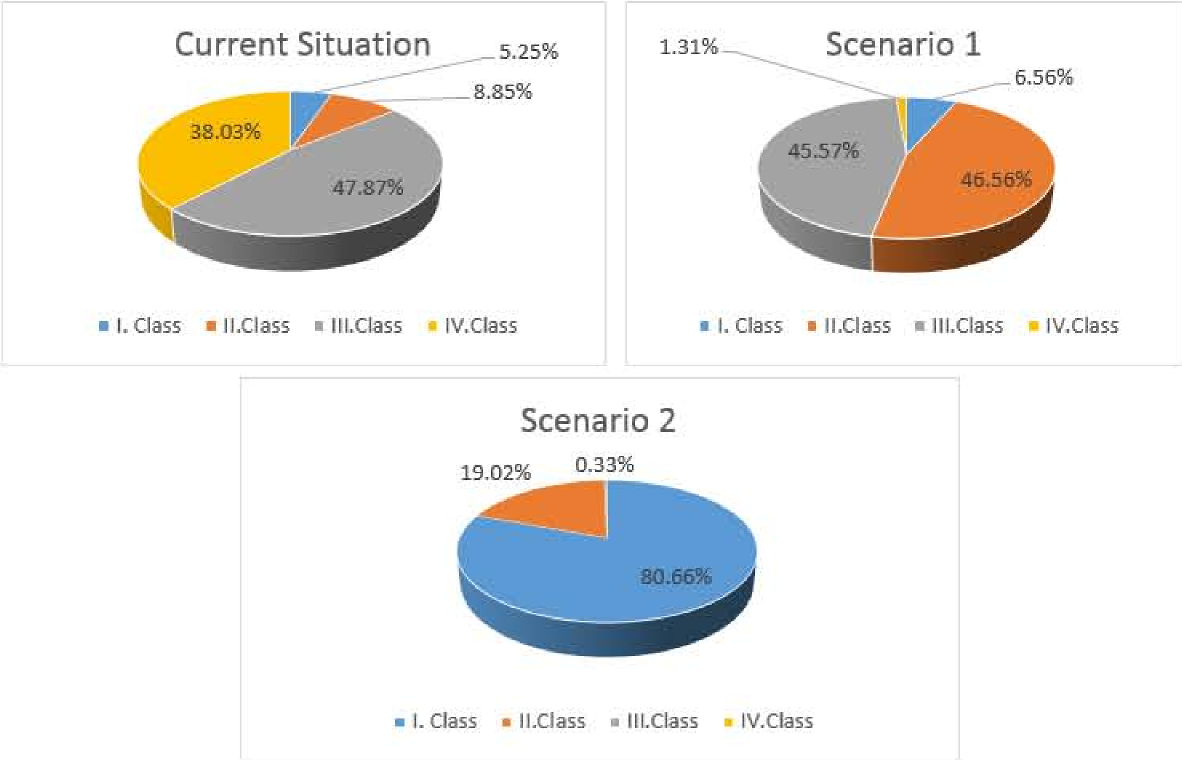

Figure 9. Water quality class percentages for BOD parameter.

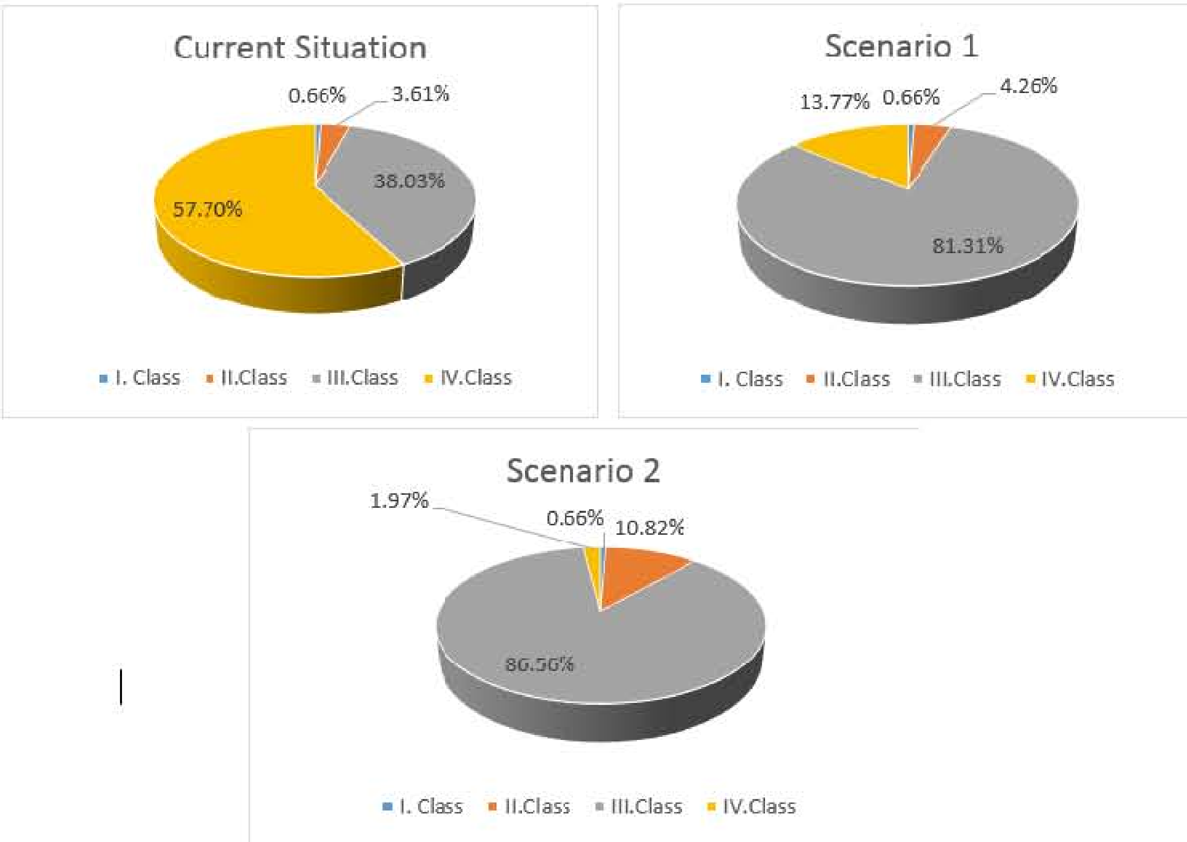

Figure 10. Water quality class percentages for TKN parameter.

Conclusion

Within this study the performance of SISMOD model, developed in Turkey, was tested to Alaşehir Creek Sub-basin of the Gediz Basin. Alaşehir Creek Sub-basin was not only under domestic and industrial pressures but also diffuse pollution especially arising from agricultural activities.

When the results of accuracy were examined, it was seen that estimated data reflected the measured data in an acceptable manner. SISMOD is an applicable model for the basin studies. The model gives the best results for BOD and DO parameters. For the nitrogen components, the model results are satisfactory but the model would give better results with a basin specific calculation of diffuse source input.

We tested SISMOD model for current situation than used it for two different scenarios. According to those results the best improvement ratios were obtained for BOD parameter. We found out that even though IV. Class water percentages decreased for all parameters, still water quality improvements were not enough for DO and TKN parameters. This shows us that not only local improvements but also some measurements should be taken in the upstream side of the study area. Once upstream basin's water quality improved, headwater concentrations will be lower and therefore improvements will be higher as expected.

For the future studies, it is recommended long term period monitoring of water quality and advance of the model with updated data. This will provide more accurate model results. Point sources concentrations were taken from similar sectors of industries' measurements. Especially industrial point sources' discharge concentrations should be measured for at discharge point. Thereby model results will reflect the field data more accurately. Furthermore this study was held with the diffuse source data obtained from "Project on Determination of Sensitive Areas of Basins and Water Quality Targets in Turkey" which was completed by the Ministry of Forestry and Water Affairs (abolished in 2018). Diffuse load data obtained from basin specific calculations used in literature with some assumptions will provide more accurate results for the nitrogen components.

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Extended Turkish Abstract
(Genişletilmiş Türkçe Özet)

Su Kalitesi Modeli SİSMOD'un Alaşehir Çayı Alt Havzasında Test Edilmesi

Bu çalışmanın maksadı: Türkiye'de geliştirilmiş olan ve akarsulara uygulanabilen BaSİt AkarSu MODelleme Programı (SİSMOD) ile Alaşehir Çayı Alt Havzası için su kalitesi modeli kurularak, modelin performansının değerlendirilmesidir.

SİSMOD akım yönünde, tek boyutta, basit hidrolik ve su kalitesi hesapları yapabilen diğer yazılımlarla tümleşik olarak çalışabilecek şekilde tasarlanmış, kullanımı kolay bir su kalitesi modelleme yazılımıdır. Türkiye'de Doç. Dr. Ali ERTÜRK tarafından geliştirilen model (Sürümü 0.9.5) açık kaynak kodludur ve Fortran yazılım dilinde oluşturulmuştur.

Söz konusu modelin uygunluğunun değerlendirilebilmesi maksadıyla su kalitesini etkileyen süreçler araştırılarak, literatürde yer alan su kalitesi modelleri ve uygulamaları incelenmiştir. Su kalitesi modellemesi uygulamalarının performans değerlendirme kriterleri irdelenmiştir. SİSMOD modelinin havza bazında test edilmesi öncesinde yeteneklerinin yanı sıra bazı sınırlamalara da sahip olduğu görülmüştür. Söz konusu sınırlayıcı özelliklerin hangi durumlarda yanlış sonuçların çıkmasına sebep olacağı değerlendirilmiştir.

Sınırlayıcı özelliklerinden biri hidrolik hesapların, kararlı durum altında üniform akım kabulü ile yapılmasıdır. Ancak her bir hesap elemanında en kesit özelliklerine göre farklı hız ve derinlik hesabı yapmaktadır.

Bir diğer sınırlayıcı özelliği ise yalnızca adveksiyon ile madde taşınımının benzetimini yapmakta, dispersiyonun etkisini göz ardı etmesidir. Akarsularda dispersiyon prosesinin kirletici taşınımı açısından önemi adveksiyona oranla daha düşüktür. Dispersiyon etkisi kirlilik yükünün sürekli olduğu nehirlerde ihmal edilebilmektedir. Ancak bazı büyük nehirlerde hızın azaldığı ve kirletici taşınımında dispersiyonun öne çıktığı bazı bölgesel koşullar oluşabilmektedir. Bu genellikle nehirlerin mansabında, denize veya halice yaklaştığı yerlerde olmaktadır. Bu bölgelerde suyun hızı sıfıra kadar düşebilmektedir. Bu nedenle; dispersiyonun önemli olduğu, akarsuların denize ulaştığı geçiş suları gibi su ortamlarında yalnızca adveksiyon ile taşınıma göre modelleme yapmak doğru sonuçlar vermeyebilmektedir.

SİSMOD azot ve fosfor döngülerini gerçek sistemlerde olduğu gibi birbirlerine birincil üretim üzerinden bağlamamaktadır. Akarsularda; algler, yüksek bitkiler (makrofitler) ve bazı bakteriler ile tek hücreli canlılar birincil üreticilerdir. Akarsularda birincil üreticilerin varlığı, o akarsuyun hızına yani hidrolik bekleme süresine bağlıdır. Hızlı akan ve hidrolik bekleme süresi 3-7 günden daha az olan nehir suları için birincil üretim azot ve fosfor konsantrasyonuna etkisi ihmal edilebilir seviyede olmaktadır. Türkiye akarsuları genel olarak eğimin ve rakımın yüksek olması nedeni ile yüksek hızda akmaktadır ve hidrolik bekleme süresi kısalmaktadır. Bu süre ise birincil üreticilerin büyüme hızından düşük olduğu için birincil üretim ihmal edilebilir seviyededir.

SİSMOD'un test edilmesi için Alaşehir Çayı Alt Havzası seçilmiştir. Söz konusu havza Ege Bölgesinde Gediz Havzasında yer almaktadır. Alaşehir Çayı'nın tamamı ve Gediz Nehri'nin bir kısmı havza içerisinde kalmaktadır. Sarıgöl, Alaşehir, Salihli, Ahmetli ve Turgutlu ilçeleri havza sınırlarında yer almaktadır.

Gediz Havzası'nın önemli bir kolu olan Alaşehir Çayı Alt Havzası'nda yer alan akarsu kütlelerinin kalitesinin değerlendirilmesi maksadıyla çözünmüş oksijen (ÇO), biyokimyasal oksijen ihtiyacı (BOİ), amonyum azotu (NH_4-H), nitrat azotu (NO_3-N) ve organik azot (Org-N) değişkenleri SİSMOD ile modellenmiştir. Kasım, Şubat, Mayıs ve Ağustos dönemleri için kurulan model, Mayıs dönemi için kalibre edilmiş, diğer dönemlere de uygulanarak kurulan modelin doğrulaması yapılmıştır.

Kalibrasyon (Mayıs) ve validasyon (Şubat) performans değerlendirmesinde yaygın olarak kullanılan istatistiksel indekslerden Ortalama Karesel Hatanın Karekökü (RMSE), Yüzdesel Hata (pBIAS) ve Ortalama Mutlak Hata (MAE) yöntemleri kullanılmıştır.

Kalibrasyon performans sonuçlarına göre ÇO parametrelerinin RMSE ve MAE değerleri sırasıyla 1.11mg/L ve 0.77 mg/L'dir. Bu değerlerin birbirine yakın olması ÇO parametresi için bireysel hatalar ile ortalama hatalar arasındaki farkın az olduğunu göstermektedir. Bireysel hatalar ortalama değerlerde olmakta ve önemli sapmalar olmamaktadır. BOİ ve TKN parametrelerinin RMSE ve MAE değerleri de ÇO parametresi ile benzer sonuçlara sahiptir. PBIAS sonuçları değerlendirildiğinde, en düşük hata oranı %13.88 ile BOİ parametresi için elde edilmiştir. ÇO parametresi için hata yüzdesi %-23.24 ve TKN parametresi için ise %-20.78'dir.

Validasyon performans sonuçlarına göre ise ÇO parametresi RMSE ve MAE değerleri sırası ile 1.96 mg/L ve 1.45 mg/L'dir. ÇO, BOİ ve TKN parametrelerinin RMSE ve MAE değerleri de birbirlerine yakın olup ortalama hatalar ve bireysel hatalar arasında küçük bir fark olduğu bulunmuştur. PBIAS sonuçlarına göre, kalibrasyon periyodunda olduğu gibi hata oranının en düşük olduğu parametre BOİ'dir. ÇO ve TKN parametresi için hata yüzdeleri sırasıyla % 19.62 ve % 24.90 olarak hesaplanmıştır.

Model sonuçlarına göre; çalışma alanındaki su kütleleri ilgili parametreler bazında 30.11.2012 tarihli ve 28483 sayılı Resmi Gazete'de yayımlanarak yürürlüğe giren Yerüstü Su Kalitesi Yönetmeliği Ek-5'de verilen su kalitesi sınıf kıstaslarına göre değerlendirilmiştir.

Mevcut durum sonuçlarına göre dört dönemin ortalama değerlerine bakıldığında ÇO, BOİ ve TKN parametrelerine göre sırası ile su kütlelerinin %64, %38 ve %58'i IV. Sınıf olmaktadır. BOİ parametresine göre su kütlelerinin %48'i III. Sınıf su kütlesidir. TKN parametresine göre ise III. Sınıf su kütleleri oranı %38 olmaktadır.

Su kalitesinin iyileştirilmesi maksadıyla iki tane senaryo modeli çalışılmıştır. Senaryo 1'de mevcut durumda planlaması yapılan atıksu arıtma tesislerinin kurulması ve yayılı kaynaklardan gelen yüklerin %50 oranında azaltılması varsayımı yapılmıştır. Senaryo 2'de ise endüstriyel atıksu arıtma tesislerinde ileri arıtmanın eklenmesi ve doğrudan deşarj edilen evsel atıkların tamamının arıtılması ile yayılı yüklerin %70 oranında azaltılması varsayımı yapılmıştır.

Senaryo modellerinin sonuçlarına göre ise alınan önlemler sonucunda en çok iyileşme BOİ parametresinde gözlemlenmiştir. Senaryo 1'e göre su kütlelerinin %6,56'sı I. Sınıf iken Senaryo 2'ye göre %80,66'sı I. Sınıf olmaktadır. ÇO parametresine göre ise Senaryo 2 ile su kütlelerinin %59,02'si III. Sınıf olup IV. Sınıf su kütlelerinin yüzdesi %64,59'dan Senaryo 2 ile %29,51'e düşmektedir. TKN parametresine göre ise IV. Sınıf su kütleleri yüzdesi %1,97'lere düşmekte olup III. Sınıf su kütleleri oranı %86,56 olmaktadır.

Çalışma sonucunda, kalibrasyon ve validasyon değerlendirme kıstasları kabul edilebilir düzeylerde olduğundan SISMOD modelinin havza bazında modelleme çalışmalarında kullanılabileceği ortaya konulmuştur. Bununla birlikte Alaşehir Çayı Alt Havzası su kalitesinin iyileştirilmesi maksadıyla yapılan Senaryo 1'e göre ÇO, BOİ ve TKN parametreleri bazında IV. sınıf su kütleleri yüzdelerinde ciddi oranlarda azalma olmaktadır. Senaryo 2 incelendiğinde ise BOİ parametresi bazında yüksek oranda iyileşmeler olmasına karşın ÇO ve TKN parametreleri bazındaki iyileşmeler istenilen düzeyde olmamaktadır.

Söz konusu çalışmanın geliştirilmesi maksadıyla, modelin uzun dönem su kalitesi izleme verileri ile güncellenmesi önerilmektedir. Uzun dönem verileri ile modelin daha doğru sonuçlar vereceği düşünülmektedir. Bu çalışmada kullanılan yayılı yük verisi mülga Orman ve Su İşleri Bakanlığı tarafından tamamlanan "Türkiye'de Havza Bazında Hassas Alanların ve Su Kalitesi Hedeflerinin Belirlenmesi" Projesinden alınmıştır. Modelin daha doğru sonuçlar verebilmesi için yayılı yükün daha doğru tahmin edilmesi gerekmektedir.