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Control of Water Pollution by Natural Wastewater Treatment in Streams

Bilal TUNCSIPER

Faculty of Engineering, Department of Environmental Engineering, Nigde Ömer Halisdemir University, Nigde-TURKEY

**Sorumlu Yazar (Corresponding Author): tuncsiperb@gmail.com*

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ABSTRACT: *This study aims to prevent excessive pollution and conservation of biodiversity in over-polluted Niğde Creek feeding Akkaya lake. Therefore, a pilot-scale hybrid natural wastewater treatment (NWT) system was constructed at edge of the stream in 2014. The system consisted of settling basin (SB), followed by a free water surface constructed wetland (FWS-CW) and overland flow (OF) bed was fed with contaminated waters of creek. Water samples were collected for temperature, pH, dissolved oxygen (DO), and biochemical oxygen demand (BOD) analysis from 6 different stations chosen in the creek and the lake, and the inputs and outputs of the system. According to the study results, the BOD concentrations in the creek and lake showed significant changes during operation period. While the BOD concentration in the lake was not much affected by the seasonal changes, the BOD concentrations in the creek were higher in the warmer seasons. The study results indicated that the creek was over-polluted due to high organic matter input, and lake became eutrophic. Despite the high organic matter load, the treatment system dramatically reduced the average BOD from 471 mg l^{-1} up to an average of 88 mg l^{-1}. The results indicated that the treatment system might be a very successful treatment application for rehabilitation of the creek ecosystem and thus the improvement of the water quality.*

Keywords: *Overland flow system, conservation of biodiversity, constructed wetland system, natural wastewater treatment.*

Akarsularda Doğal Atıksu Arıtma Sistemleri Kullanılarak Su Kirliliğinin Önlenmesi

ÖZ: *Bu çalışma, Akkaya gölünü besleyen ve aşırı kirletilmiş Niğde deresindeki aşırı kirlenmenin önlenmesi ve biyoçeşitliliğin korunumunu amaçlamaktadır. Bu sebeple, pilot-ölçekli karma bir doğal atıksu arıtma (DAA) sistemi 2014 yılında derenin yakın kenarında inşa edilmiştir. Sistem sırayla çökeltme havuzu (ÇH), serbest yüzey akışlı yapay sulakalan (SYA-YS) ve arazi üzerinden akışlı (AÜA) bir yataktan oluşmuş ve derenin kirletilmiş suları ile beslenmiştir. Su örnekleri; sıcaklık, pH, çözünmüş oksijen (ÇO) ve biyokimyasal oksijen ihtiyacı (BOİ) analizleri için dereden ve gölden seçilen 6 farklı istasyondan ve arıtma sisteminin giriş ve çıkışlarından alınmıştır. Çalışma sonuçlarına göre, dere ve göldeki BOİ konsantrasyonları işletme periyodu süresince önemli değişiklikler göstermiştir. Göldeki BOİ konsantrasyonu mevsimsel değişmelerden fazla etkilenmezken deredeki BOİ konsantrasyonları sıcak mevsimlerde daha yüksek bulunmuştur. Çalışma sonuçları, derenin yüksek organik madde girişinden dolayı aşırı derecede kirletildiğini ve gölün ötrofik hale geçtiğini göstermiştir. Yüksek organik madde yüküne rağmen arıtma sistemi yaklaşık olarak %83 BOİ giderme verimi sağlamıştır. Sonuçlar, arıtma sisteminin dere ekosisteminin rehabilitasyonu ve böylece su kalitesinin iyileştirilmesi için çok faydalı bir uygulama olabileceğini göstermiştir.*

Anahtar Kelimeler: *Arazi üzerinde akışlı sistem, biyoçeşitliliğin korunumu, yapay sulakalan sistemi, doğal atıksu arıtma sistemi.*

INTRODUCTION

Streams or creeks that discharge surface water resources passing through the city's center are polluted and made unusable for useful water use purposes due to agricultural activities, hydrological changes, habitat changes, floods, stormwater channels, urban point pollution sources, and biological oxidisable matters that come from other unknown pollution sources (Anonymous, 2002; Kadlec and Wallace, 2009).

For the prevention of the creek pollutions like these in Turkey, as creeks were converted into reinforced concrete channels in terms of the work, done in most cases for rehabilitation, ecological structure and biodiversity have been destroyed and the dimensions of the pollution have been increased over time (Tuncsiper, 2017).

The Akkaya dam is an important source of irrigation water for Nigde city and especially Bor district, and is highly polluted by point and non-point pollution sources. The most important point sources polluting the lake are the Kızılca creek, the effluents of Nigde Municipality Wastewater Treatment Facility (NMWTF), Organized Industrial Wastewater Treatment Facility (OIWTF), and Nigde University Wastewater Treatment Facility (NUWTF). The non-point pollutant sources are organic pollutants in surface runoffs inside the feeding area of the basin (Tuncsiper, 2017). In addition to the domestic wastewaters of Nigde city, because the creek waters and wastewaters of Aktaş-Gümüşler-Fertek districts were also connected to the treatment plant, capacity of the NMWTF had become inadequate over time. Water quality in the downstream part of the creek receiving illegal discharges and adequately untreated wastewaters of the NMWTF due to the high flow rates was pretty impaired.

High amounts of organic pollutants (BOD) contained in the creek was made the lake eutrophic, by negatively affecting the trophic level of the lake (Tuncsiper, 2017). The high amount of organic matter contained in the over-polluted waters of the creek made the creek anaerobic over time, and thus toxic gases released by the anaerobic microbial degradation of the organic matter requiring biological oxygen demand (BOD) in the stream which becomes anaerobic posed a risk to the environment and human health. Therefore, in this study, it was aimed to reduce organic matters in the creek with the NWT system to be constructed at the edge of the creek, and thus improve the water quality of the creek and lake. In September 2014, a hybrid natural wastewater treatment (NWT) system was constructed near the creek to reduce organic pollution. In general, the system consisted of a combination of sedimentation basin (SB)-free water surface constructed wetland (FWS-CW)-overland flow (OF) systems was fed with the over-polluted water of the creek (Tuncsiper, 2016).

This study presents some results of the phase of "The treatment of the Kızılca creek that pollutes the Akkaya reservoir by natural wastewater treatment method" named TUBITAK project (Tuncsiper, 2016) in terms of BOD removal. In this study, with aim to determine the existing organic pollution in the creek/lake and the organic matter or BOD removal efficiency of the hybrid system, flows rate-water temperature-pH-dissolved oxygen (DO)-BOD parameters on the sampling points in between the city exit and the lake and the inlet/outlet of the lake and hybrid system are measured monthly.

MATERIAL AND METHODS

Hybrid NWT system configuration

The prototype NWT system was combined with SB, the FWS-CW with filter material, and the OF system. The system generally consists of four stages. The first stage comprises a feeding basin (FB), the second one comprises the SB system, the third one comprises the FWS-CW system, and the fourth one comprises OF system, respectively. The simplified flow diagram of the NWT system is shown in Figure 2.

The FWS-CW system was designed S-shaped in a manner to represent the convoluted structure of the creek. It was divided into 7 regions based on its twist points. In order to further improve removal efficiency of organic matters, in April 2015, twist places of the system were equipped with filtration layer that serves as a biofilter. System was planted with the young shoots of *Phragmites communis* (macrophytes) growing in the creek edge. The OF system, which was consisted of washed sand in a depth of about 5 cm, was designed to be able to provide an extra organic matter removal in outflows of the FWS-CW system. It was planted with *Italian ryegrass*.

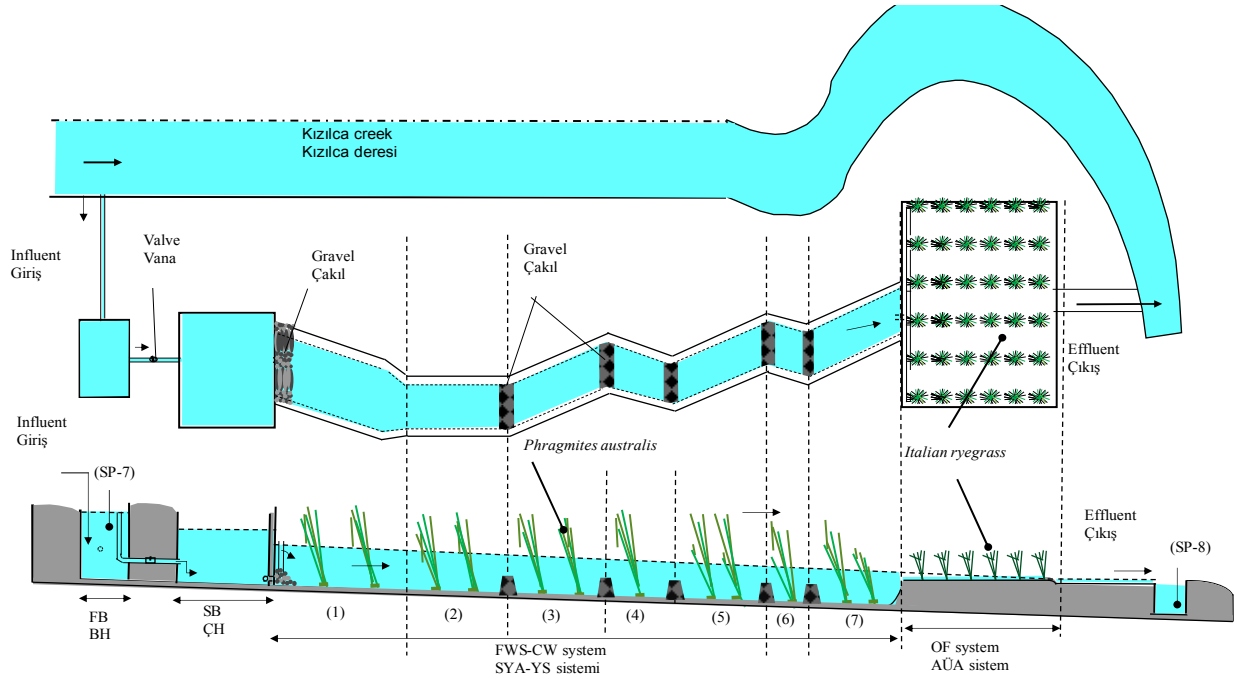

Figure 1. Schematic diagram of the hybrid NWT (SP-7 and SP-8 are sampling locations) system.
Şekil 1. Karma DAA (ÖN-7 ve ÖN-8 örnekleme noktaları) sisteminin şematik diyagramı.

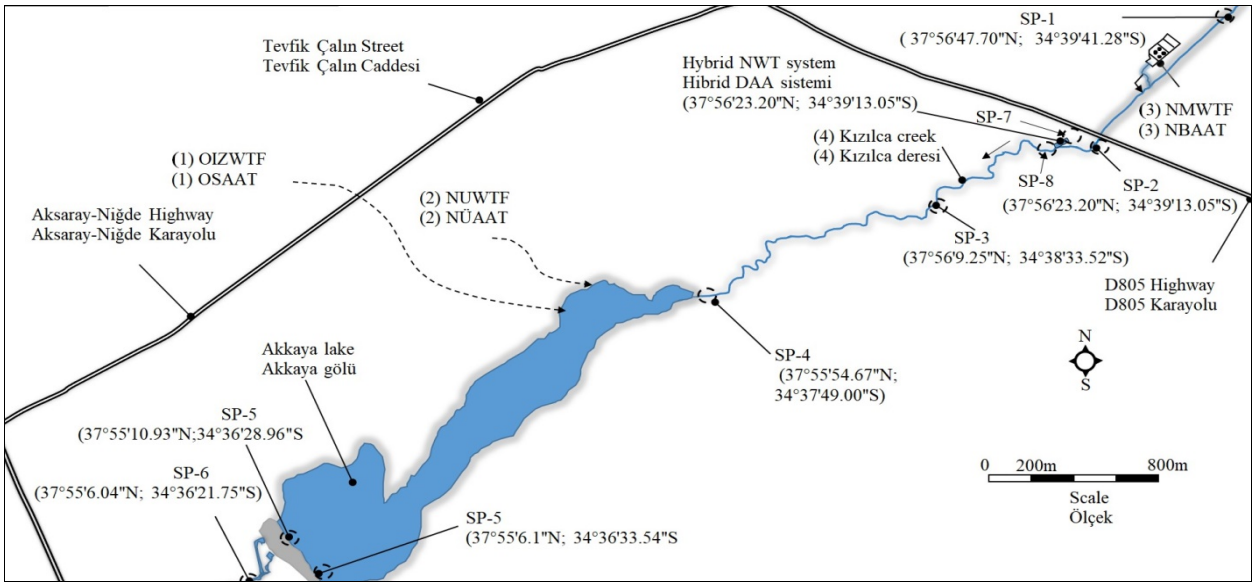

Figure 2. View of layout plan of the study area and sampling points.
Şekil 2. Çalışma alanı ve örnekleme noktalarının yerleşim planı.

Study site and selection of sampling points

Important point sources (see features denoted 1, 2, 3 and 4 on Figure 1) threatening lake is water discharged from Organized Industrial Zone Wastewater Treatment Facility (OIZWTF), Nigde University Wastewater Treatment Facility (NUWTF), Nigde Municipality Wastewater Treatment Facility (NMWTF), and Kızılca creek.

The creek is one of the most important feeding (with an average flow rate of 0.43 m^3s^{-1}) and polluting sources of the lake (Nigde, Turkey).

The creek is about 27 km long within the borders of Nigde city, and it flows into the dam. Effluents of the OIWTF and NUWTF are discharged to the dam from the campus area of the Nigde University. The creek waters are bypassed to the NMWTF on the Channel Street at the out of the city and then the creek waters are discharged to the creek again after being treated together with the domestic wastewater. Therefore, the flow-rate of the creek is an average of approximately 0.05 m^3/s before the NMWTF entrance and 0.43 m^3s^{-1} after the NMWTF.

Sampling points was selected in accordance with the item C of the article 10th article of the sampling and analysis methods notice in Water Pollution Control Regulations (Anonymous, 2009) and the coordinates of these points were determined by GPS and processed on the map.

The samples were taken from 4 different points (SP-1, SP-2, SP-3, and SP-4) before the entrance of the creek into the lake, 2 different points (SP-5) in the lake, the out (SP-6) of the lake, and the inlet (SP-7) and outlet (SP-8) of the hybrid treatment system. Samples taken from about 30-40 cm below of water's surface of the creek and lake were homogenized by mixing and analyzed monthly for about 1 year between October 2014 and September 2015.

Physicochemical analysis of samples

According to standard methods (Anonymous, 1999), physicochemical water quality parameters (temperature, the DO, and the pH) were measured at each sampling point by using in-situ multiple water quality gauge (WTW inolab-IDS multi 9430). The temperature, the DO, and the pH were made according to Electromagnetic method (Standard Method 4500-H+B), Laboratory and Field Method (Standard Method 2550 B), and Membrane Electrode Method (Standard Method 4500-OG), respectively. Biochemical oxygen demand (BOD) was analyzed using a close respirometric unit WTW OxiTop IS 6. The OxiTop is based on pressure measurement in a closed system. The CO_2 formed in OxiTop is absorbed by NaOH to form a vacuum and the resulting vacuum is measured as mg l^{-1} of the BOD.

RESULTS AND DISCUSSION

Variations in the BOD concentrations of the creek and lake water

The average annual values of physicochemical parameters in The Kızılca creek and Akkaya lake were shown in Tab1e 1. As shown in Table 1, during operation period, while the average air temperature in the study area is 14.7 ^oC (Anonymous, 2014), the average water temperature of the creek and lake is 16.5 ^oC and 18.3 ^oC respectively.

Because the water in the lake was stagnant and the water surface of the lake was exposed to sunlight is slightly higher than those of the creek. Annual average pH values in the creek and the lake were found at approximately the same levels (7.3). These values show that the creek and lake are basic. *Phytoplanktons* can increase the pH value by consuming carbon dioxide (CO_2) in the environment as a result of photosynthesis (Boyd, 1990).

While the average annual DO at the creek was 0.98 mg l^{-1}, this value was found to be naturally higher (4.55 mg l^{-1}) in the lake water that is cleaner than the creek water. The DO values below 1,0 mg l^{-1} shows that the creek are extremely contaminated with septic discharges. The variation of the BOD concentrations depending on the pH, the DO, and the water temperature in the creek and lake are shown in Figure 3. As you can see in Figure 3, the BOD concentrations in the creek and lake showed significant changes during working period. While the BOD concentrations in the lake are not much affected by the seasonal changes probably due to the dilution, the BOD concentrations in the creek were higher in the warmer seasons probably due to the higher organic matter loads. The pH was between 7.0 to 8.0 and it changed too little. Probably slight pH increases may be due to the diffusion of the certain ions or dissolve inorganic matters during the colder seasons. While the DO values in the SP-2,3,4 varied between approximately 0.1 and 1.0 mg l^{-1}, these values for the SP 1,5,6 ranged from 1.0 to 6.9 mg l^{-1} possibly due to lower organic matter concentrations.

Table 1. The average annual values of some physicochemical parameters and BOD in Kızılca creek and Akkaya lake.
Çizelge 1. Kızılca deresi ve Akkaya gölündeki bazı fizikokimyasal parametrelerin ve BOİ'nin yıllık ortalama değerleri.

		Parameters (Parametreler) Annual average values (Yıllık ortalama değerler)				
	Sampling Points Örnekleme Noktaları	Flow-rate Debi ($l\ d^{-1}$)	Water temp. Su sıcaklığı (^oC)	pH	DO ÇO ($mg\ l^{-1}$)	BOD BOİ ($mg\ l^{-1}$)
The Kızılca creek Kızılca deresi	SP-1	246	17.0±8.3	7.30±0.13	2.28±0.69	10±4.3
	SP-2	826	17.1±8.6	7.23±0.23	0.33±0.15	422±248
	SP-3	799	15.9±7.9	7.70±0.30	0.23±0.10	473±269
	SP-4	791	17.3±8.0	7.25±0.14	0.91±0.16	348±213
	SP-6	1165	15.2±5.9	7.26±0.13	1.16±0.17	5±1.2
The Akkaya lake Akkaya gölü	SP-5		18.3±8.4	7.30±0.23	4.55±1.12	246±95

± implies standard deviation values (± standart sapma değerlerini göstermektedir)

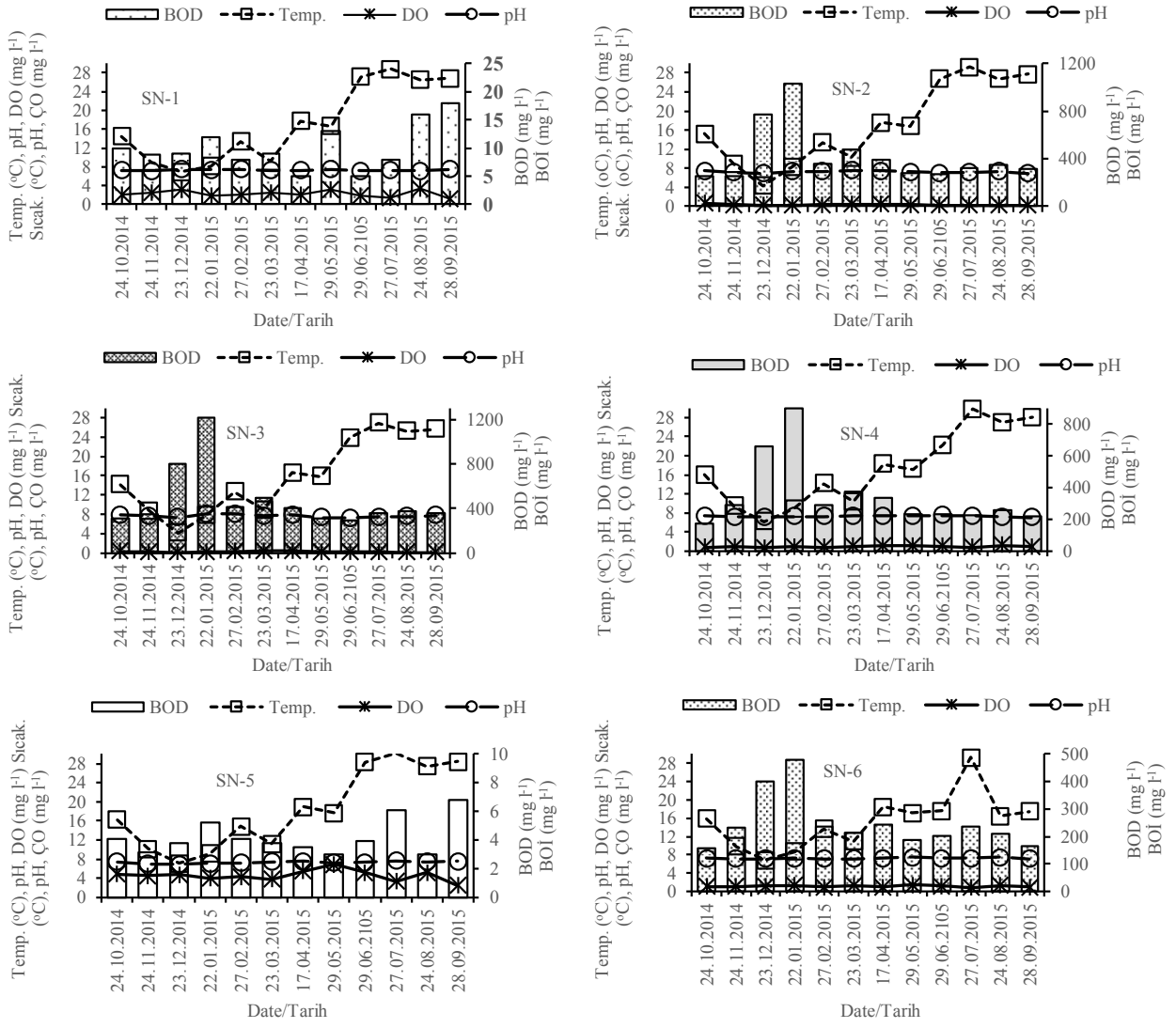

Figure 3. The variation of the BOD concentrations depending on the pH, the DO, and the water temperature in the creek and lake.
Şekil 3. Dere ve göldeki BOİ konsantrasyonlarının pH, ÇO ve su sıcaklığına bağlı olarak değişimi.

Change of the BOD concentrations along the creek were shown in Figure 4. As shown in Figure 4, the average BOD concentrations varied considerably throughout the length of the creek. The BOD concentrations in the SP-1 near the out of the city were found to be quite low because there was no excessive pollution, compared to other points. The BOD concentrations at this point are closer to those in the lake. The BOD concentration (average 422 mg l^{-1}) in the second sample point (SP-2) taken just behind the point (SP-1) where the effluents of the NMWTF are discharged to the creek considerably increased probably due to undertreated discharge waters of the NMWTF. The BOD concentration (average 473 mg l^{-1}) in the third sample point (SP-3) taken after the point (SP-2) where the effluents of the NMWTF were discharged to the creek increased a bit more. This is possibly due to organic pollutants entering the creek from surface runoffs inside the feeding area of the basin.

The BOD concentration (348) in the SP-4 and also in the SP-6 where the lake waters are discharged to the creek considerably reduced compared to the previous sampling points probably due to the dilution of organic pollutants along the creek' length.

According to the results obtained the study, it was determined that the creek was in very low quality standards (Class IV) in terms of the BOD concentration according to Table 1 and 2 in the WPCR (Anonymous, 2004). So, the over- polluted creek posed a significant threat to the Akkaya lake because it leaded to eutrophication of the lake.

Variations in the BOD concentrations of the NWT system

As shown in Figure 5, the prototype system dropped the BOD from 471 to 88 mg l^{-1}. While the temperature and the pH inside the system did not change much, the average DO concentrations increased from 0.3 mg up to 1.0 mg at the exit of the system. The FWS-CW system provides additional oxygen because of atmospheric reaeration and submerged vegetation (Anonymous, 2000; Crites et al., 2004; Kadlec and Wallace, 2009). For these reasons, the DO concentrations in the effluent of the hybrid system were higher than influent. Hydraulic loading rates (HLRs) reported for large-scale combined NWT systems such as the CW and OF systems in series in the literature vary greatly and they are much lower than the HLR applied in this study.

The HLRs were commonly given in the range of 0.003-0.3 $m^3/m^2/d$ for the NWTs (Crites and Tchobanoglous, 1998). In this study, despite the prototype system operates in extremely high hydraulic loads (0.1 to 1.7 $m^3/m^2/d$), and a much higher average influent BOD concentration of 471 mg l^{-1}, the removal (82%) of organic matter (the BOD) are quite satisfactory and close to the performances (85%-95%) of the NWT systems that treat the less polluted streams in literature (Anonymous, 2006; Kadlec and Wallace, 2009; Wen et al., 2007). These results indicated that prototype system might be a very successful treatment application for rehabilitation of stream ecosystem and thus improvement of water quality.

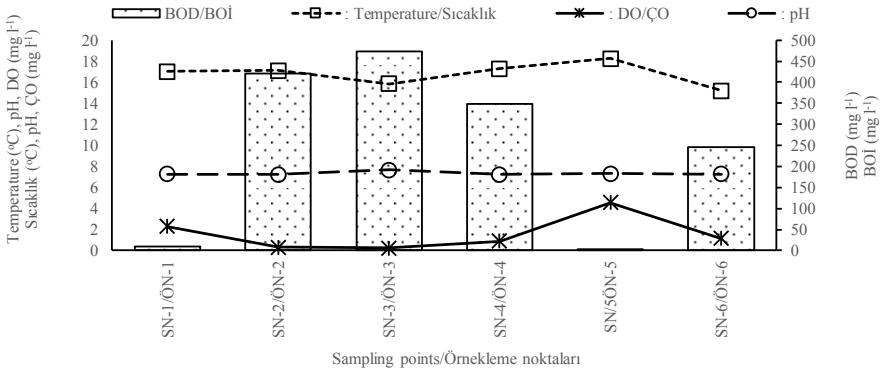

Figure 4. Change of the BOD concentrations along the creek.
Şekil 4. Dere boyunca BOİ konsantrasyonlarının değişimi.

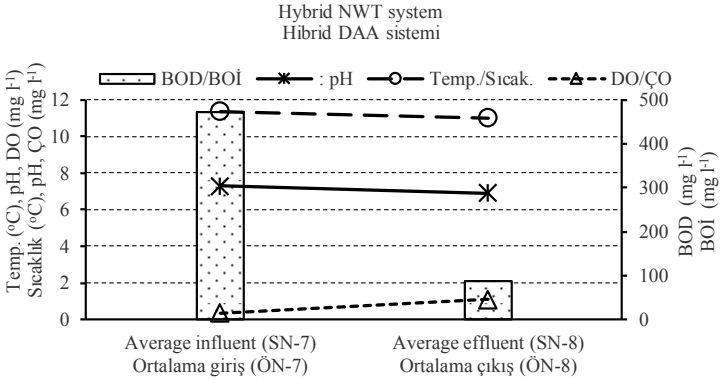

Figure 5. The variation of the average influent and effluent BOD concentrations of the hybrid system as a function of pH, DO, and water temperature.
Şekil 5. Karma sistemin ortalama giriş ve çıkış BOİ konsantrasyonlarının pH, ÇO ve su sıcaklığına bağlı olarak değişimi.

CONCLUSION

Water quality in the downstream part of the creek receiving illegal discharges and adequately untreated wastewaters of the NMWTF due to the high flow rates was pretty impaired. Therefore, high BOD loads contained in the creek was made the lake eutrophic, by negatively affecting the trophic level of the lake.

The high amount of organic matter (the BOD) contained in the over-polluted waters of the creek made the creek anaerobic over time, and thus toxic gases released by the anaerobic microbial degradation of the organic matter requiring biological oxygen demand (BOD) in the stream which becomes anaerobic posed a risk to the environment and human health.

Therefore, a prototype NWT system was constructed at edge of the creek for polishing of highly organic matter effluents from over-polluted Nigde creek. The hybrid NWT system designed to reduce organic matters in the creek decreased the BOD from 471 to 88 mg l^{-1} with a removal efficiency of 83%, despite the high HLR of average 2.3 $m^3/m^2/d$. The results indicated that prototype system might be a very successful treatment application for rehabilitation of stream ecosystem and thus improvement of water quality.

Improvement of water quality and rehabilitation of stream ecosystem will also protect biodiversity.

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REFERENCES

Anonymous. 1999. Metropolitan Waterworks Authority. https://www.mwa.co.th/download/file_upload/SMWW_1000-3000.pdf.

Anonymous. 2000. EPA. United States Environmental Protection Agency. Wastewater technology fact sheet free: water surface wetlandshttps://www3.epa.gov/ npdes/pubs/free_water_surface_wetlands.pdf.

Anonymous. 2002. EPA. United States Environmental Protection Agency. Implementation guidance for ambient water quality criteria for bacteria. https://nepis.epa.gov/Exe/tiff2png.cgi/20003PSB.PNG?-r+75+-g+7+D%3A%5CZYFILES%5CINDEX%20DATA%5C00THRU05%5CTIFF%5C00000486%5C20003PSB.TIF.

Anonymous. 2004. Su Kirliliği Kontrol Yönetmeliği. Resmi Gazete. From: http: // www.resmigazete.gov.tr /eskiler /2004/12/20041231.htm#9.

Anonymous. 2006. TETRA TECH-Environmental Management. http://www.tetratech.com/en/environmental-management.

Anonymous. 2009. Su Kirliliği Kontrol Yönetmeliği-Remi Gazete: Numune alma ve analiz metodları. From: https://www.csb.gov.tr/db/cygm/editordosya/.

Anonymous. 2014. Türkiye Hava Durumu. From: http://www.accuweather.com/tr/tr/nigde/319795/january-weather/319795?monyr=1/1/2015&view=table.

Boyd, C. E. 1990. Water Quality in Ponds for Aquaculture. Birmingham Publishing Company, Birmingham, Alabama.

Crites, R. W., Reed, S. C., and R. K. Bastian. 2004. Land Treatment Systems for Municipal and Industrial Wastes, McGraw-Hill Companies, USA.

Crites, R. W., and G. Tchobanoglous. 1998. Small and Decentralized Wastewater Management Systems, McGraw-Hill, New York, NY.

Kadlec, R. H., and S. D. Wallace. 2009. Treatment Wetlands, Second Ed., CRC Press, Boca Raton, FL USA.

Tuncsiper, B. 2016. The treatment of the Kızılca creek that pollutes the Akkaya reservoir by natural wastewater treatment method, TUBITAK. Project Number. 113Y589, 2014-2016.

Tuncsiper, B. 2017. Investigation of bacteriological contamination in Kızılca (Karasu) Creek feeding Akkaya reservoir and solution proposals to reduce contamination. Journal of Tekirdağ Agricultural Faculty. 14 (1): 28-37.

Wen, C. G., Chen, T. H., Hsu, F. H., Lu, C. H., Lin, J. B., Chang, C. H., Chang, S. P., and C. S. Lee. 2007. A high loading overland flow system: Impact on soil characteristics, grass constituents, yields and nutrient removal. Chemosphere 67: 1588-600.