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Improvement of water quality in over-polluted Niğde Creek in Turkey

B. Tunçsiper

Nigde Ömer Halisdemir University, Faculty of Engineering, Department of Environmental Engineering, TURKEY.
(Corresponding Author's E-mail: tunciperb@gmail.com)

ABSTRACT

Kızılca creek, which is one of the main sources of irrigation water in Niğde (Turkey), was extensively polluted due to high amount of organic matters in the point and non-point pollutant sources. This study aims to remove organic matters and improve water quality of the creek by using a pilot-scale hybrid natural wastewater treatment (NWT) system. The system consists of a combination of settling basin, free water surface constructed wetland, and overland flow (OF) system. The system was installed near the edge of the creek in 2014.
Wastewater samples from the inlet and outlet of all stages of the system were collected and analyzed for temperature, pH, electrical conductivity (EC), dissolved oxygen (DO), and the suspended solid (SS) parameters. The obtained results indicated that the high organic matter loads caused the deterioration of the water quality in the creek. The system could remove up to 80%. The results showed water quality of the creek and the treatment performance of the system were affected by temperature, the DO, and seasonal changes. Consequently, the NWT system can be usefully used useful to decrease solid matters in highly polluted streams and thus improve water quality.

Keywords: Constructed wetland system, land treatment, natural wastewater treatment, overland flow system.

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, storm water channels, urban point pollution sources, and biological oxidizable matters that come from other unknown pollution sources (USEPA, 2002). Natural wastewater treatment (NWT) systems such as constructed wetland (CW) and overland flow (OF) have been used successfully as an alternative in the purification of polluted creeks or streams and treatment of wastewater containing different types of pollutants in many case studies worldwide (Reed et al., 1995; Crites et al., 2006; Kadlec & Wallace, 2009; Kim et al., 2014; Li et al., 2014; Morató et al., 2014).

For the prevention of the creek pollutions like these in Turkey, as the 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, 2017a). High amounts of suspended solid (SS) matter contained in the creek was made the lake eutrophic, by negatively affecting the trophic level of the lake (Tuncsiper, 2016). The high amount of organic matter contained in the over-polluted waters of the creek made the creek anaerobic over time, and thus toxic gasses released by the anaerobic microbial degradation of the SS matters in the stream which becomes anaerobic posed a risk to the environment and human health (Kadlec & Wallace, 2009).

Therefore, in this study, it was aimed to reduce the SS matters in the creek with natural wastewater treatment (NWT) system to be constructed at the edge of the creek and thus improve the water quality of the creek and lake. Pilot-scale NWT system was constructed near the creek in September 2014. 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, 2017b).

In study, with aim to determine the existing organic pollution in the creek/lake and the organic matter or TSS removal efficiency of the pilot system, flowrate-water temperature-pH-dissolved oxygen (DO)-TSS parameters on the sampling points in between the city exit and the lake and the inlet/outlet of the lake and the pilot system are measured monthly.

MATERIALS AND METHODS

Study site and selection of sampling points

Important point sources (see features denoted 1, 2, 3 and 4 on Fig. 1) threatening lake are 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 Kızılca creek is one of the most important feeding (with an average flow rate of 0.43 $m^3 s^{-1}$) 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 lake. Effluents of the OIWTF and NUWTF are discharged to the lake 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 flowrate of the creek is an average of approximately 0.05 $m^3 s^{-1}$ before the NMWTF entrance and 0.43 $m^3 s^{-1}$ after the NMWTF.

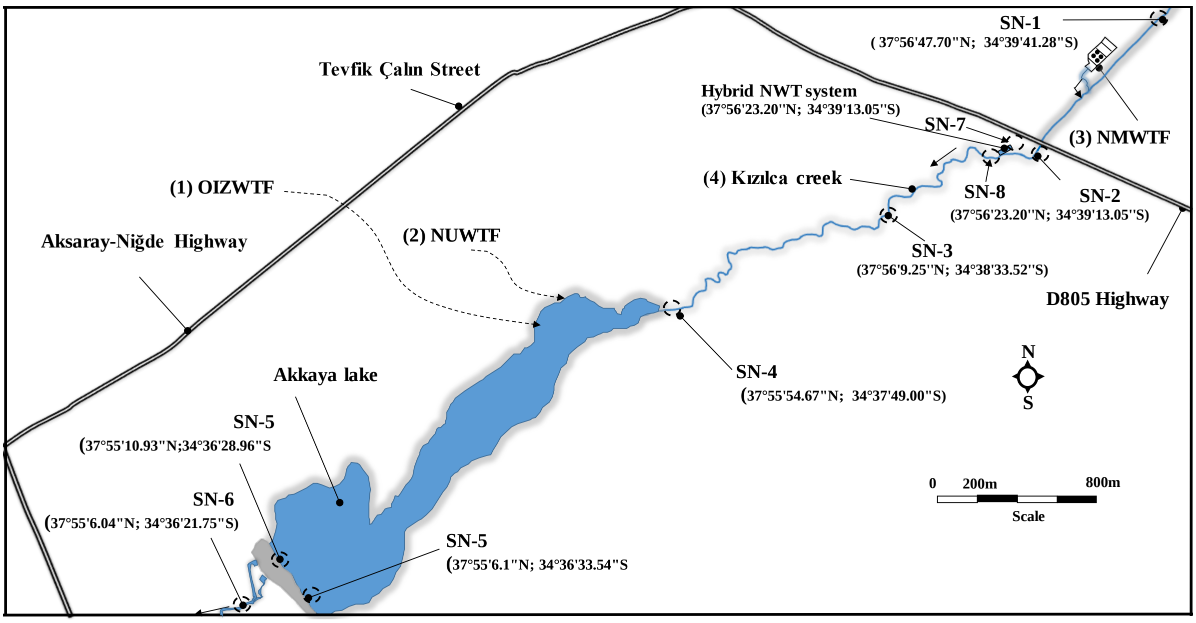

Figure 1. View of layout plan of the study area and sampling points.

Sampling points were selected in accordance with the item C of the article 10th article of the sampling and analysis methods notice in Water Pollution Control Regulations (TWPCR, 2009) and the coordinates of these points were determined by GPS and processed on the map. The samples were taken from 4 different points (SN-1, SN-2, SN-3, and SN-4) before the entrance of the creek into the lake, 2 different points (SN-5) in the lake, the out (SN-6) of the lake, and the inlet (SN-7) and outlet (SN-8) of the NWT 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.

Configuration of pilot-scale NWT

To reduce organic matter load in Nigde creek, pilot-scale NWT system in a manner that will represent the natural structure of a certain part of the creek was constructed at the edge of the creek in 2014 and operated for about 7 months. The pilot system was combined with the 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 Fig. 2.

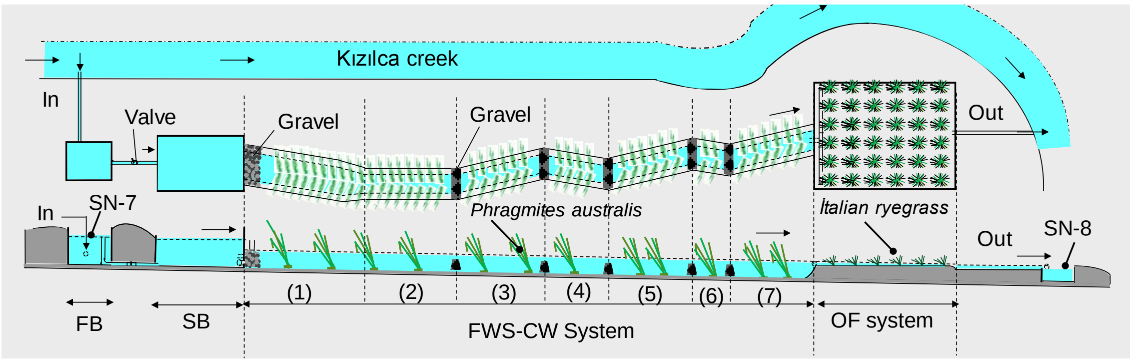

Figure 2. Schematic diagram of the hybrid NWT (SN-7 and SN-8 are sampling locations) system.

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. The 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 *İtalian ryegrass*.

Physicochemical analysis of samples

Water temperature, electrical conductivity (EC), dissolved oxygen (DO), and pH were measured at each sampling point by using in-situ multiple water quality gauge (WTW inolab-IDS multi 9430). Total suspended solids (TSS) was analyzed using gravimetric method (SM-2540-B) according to standard methods (Standard Methods for the Examination of Water and Wastewater, 1998).

RESULTS AND DISCUSSION

Variations in the TSS concentrations of the creek and lake water

The average annual values of the flow, the EC, the DO, and the TSS parameters in the creek and lake was in Table 1. As shown in Table 1, because the effluents of the NMWTF were discharged to the creek at the SN-2, its flow-rate at the SN-1 increased from 0.25 m^3 s^{-1} to 0.83 m^3 s^{-1}. In addition, the flow-rate of the SN-6 was higher than other sampling points, because it was taken just ahead (about 200 m) of the point where the lake was discharged to the creek. While the pH and water temperatures did not change much, the EC-the DO-the TSS values showed significant differences over the length of the creek.

Table 1. The average annual values of the flow, the EC, the DO, and the TSS parameters in the creek and lake.

	Sampling Pints	Parameters			
		Flow-rate (m^3 s^{-1})	EC (μS cm^{-1})	DO (mg L^{-1})	TSS (mg L^{-1})
The creek	SN-1	0.25	784±89	2,28±0,69	10±4.3
	SN-2	0.83	1102±55	0,33±0,15	422±248
	SN-3	0.80	1190±80	0,23±0,10	473±269
	SN-4	0.79	909±88	0,91±0,16	348±213
	SN-6	1.17	803±85	1,16±0,17	5±1.2
The lake	SN-5		666±99	4,55±1,12	246±95

± implies standard deviation values.

The pH values, which ranged from 7.0 to 8.1, was very close to neutral at all sampling points. The DO was found at the highest value (2.28 mg L^{-1}) in the first sampling point (the SN-1) where that the creek was least polluted. The values of the DO in the SN-2 sampling point where the outlet waters of the NMWTF are discharged and in the SN-3 sampling point where which the agricultural activities are carried out decreased considerably. The DO values of the SN-1 and 3 were found to be very low because there were agricultural activities at the SN-2 and the effluents of the NMWTF was discharged to the creek in the SN-2. These results indicated that the creek was over-polluted in terms of the TSS at the SN-2 and 3 sampling point, and thus wastewater of the NMWTF and agricultural activities was an important factor in the pollution of the creek.

The pH values, which ranged from 7.0 to 8.1, was very close to neutral at all sampling points. The DO was found at the highest value (2.28 mg L^{-1}) in the first sampling point (the SN-1) where that the creek was least polluted. The values of DO in the SN-2 sampling point where the outlet waters of the NMWTF are discharged and the SN-3 sampling point in which the agricultural activities are located have decreased considerably. The DO values of the SN-1 and 3 were found to be very low because there were agricultural activities at the SN-2 and the effluents of the NMWTF was discharged to the creek in the SN-2. These results indicated that the creek was over-polluted in terms of the TSS at the SN-2 and 3 sampling point, and thus wastewater of the NMWTF and agricultural activities was an important factor in the pollution of the creek.

The annual average DO in the lake was 4.6 mg L^{-1} and the lake water was at the second and third class water quality level in terms of the DO (TWPCR, 2004). Because this value is below the limit value (<5 mg L^{-1}) for eutrophication control (TWPCR, 2004), the use for various purposes the lake water seems to be risky

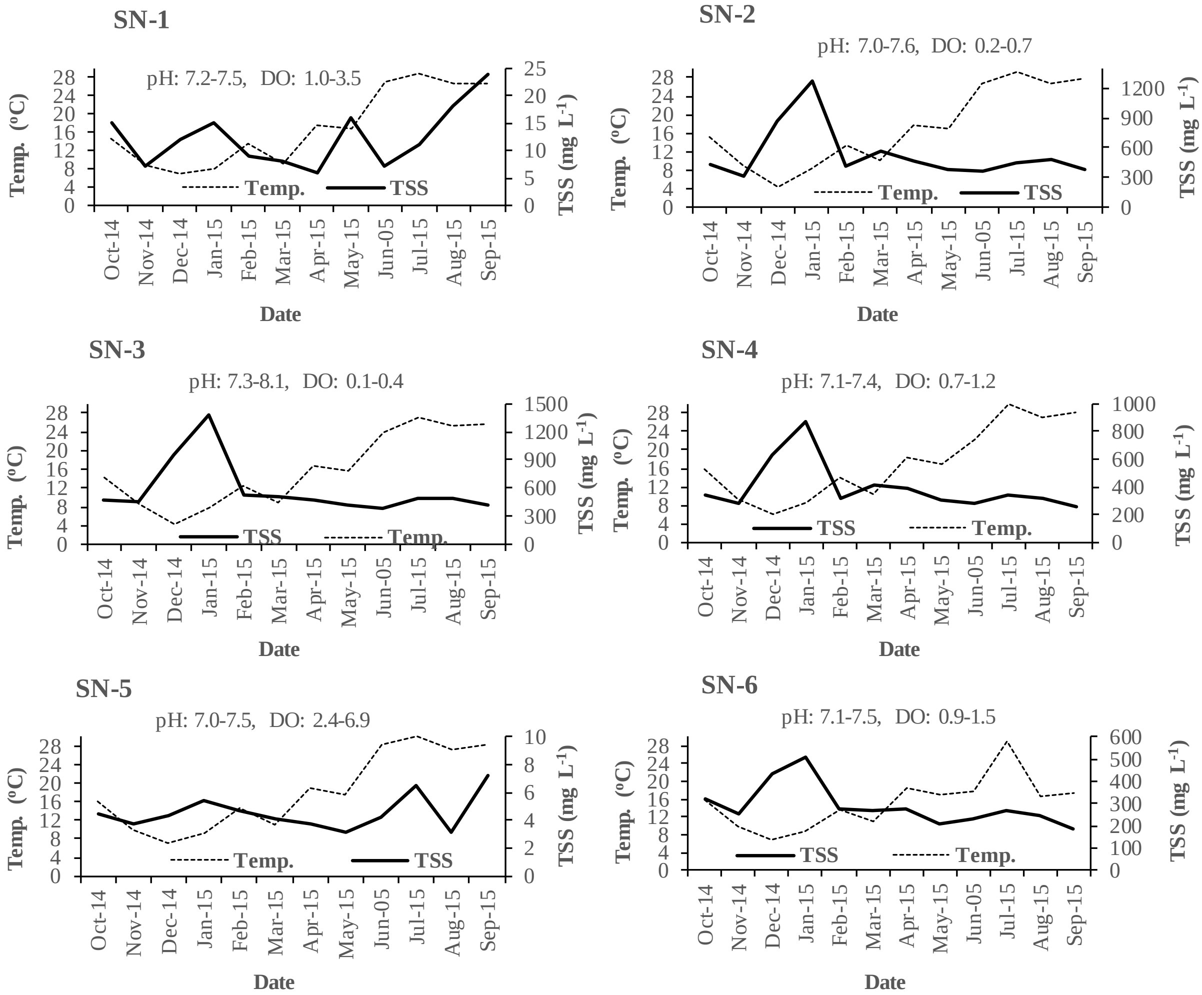

Figure 3. The variation of the BOD concentrations depending on the pH, the DO, and the water temperature in the creek and lake.

The DO values in the final sampling point (the SN-6) was slightly higher than the other sampled points as it was taken just ahead (about 200 m) of the point where the clean waters of the lake were discharged. While the annual average value of SN-1 was 784 µS cm^{-1}, this value increased up to approximately 1102 µS cm $^{-1}$ at SN-2, probably due to the high amount of dissolved substances in the discharge waters of the NMWTF (Özpınar, 2007). The EC values in the SN-3 was high, probably due to the entry of drainage waters containing high organic matter to the creek from agricultural areas after rainy days. The EC values from the SN-3 sampling point toward the downstream part of the creek reduced, probably due to the dilution that occurred along the length of the creek. Because the SN-5 sampling point was taken from the lake, the EC values were found lower compared to the values at the creek, due to probably the high dilution of organic pollutants in the lake. The annual average EC value in the lake water is approximately 666 µS cm $^{-1}$, and the lake water was at the second class water quality level in terms of the EC (TWPCR, 13). While the EC value increases with the evaporation of the creek and lake waters during the summer and the inflow of polluted water to the creek and lake waters, it decreases with the precipitation, snow and ice melting, and the inflow of the fresh water containing very low dissolved organic matter (Göksu, 2003). As shown in Table 1, the EC values are higher, while the DO values are lower in the regions where the creek is over-polluted. This is presumably due to the biodegradation of high amounts of dissolved organic matter contained in polluted-creek (Tepe & Mutlu, 2004).

As shown in Fig. 3, the TSS in the warmer seasons were found to be higher when compared to the colder seasons. This is probably due to the higher evaporation and the high SS matter to the creek and lake input during the summer period. The variation of the TSS concentrations along the creek was shown in Figure 4. As shown in Fig. 4, the average TSS concentrations were found at the lowest value of 10 mg L^{-1} in the first sampling point (the SN-1) where that the creek was least polluted. The average TSS concentrations in the SN-2 where the outlet waters of the NMWTF are discharged and in the SN-3 that the agricultural activities were carried out increased considerably.

These results indicated that the creek was over-polluted in terms of the TSS at the SN-2 and 3 sampling point, and thus wastewater of the NMWTF and agricultural activities was an important factor in the pollution of the creek. In addition, the average TSS concentrations from the SN-3 sampling point toward the downstream part of the creek declined steadily, probably due to the dilution of the organic matters.

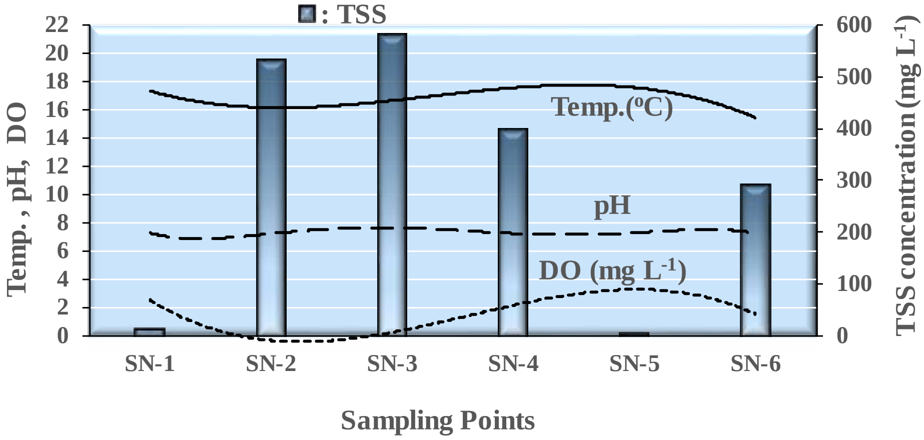

Figure 4. Change of the TSS concentrations along the creek.

Variations in the TSS concentrations of the NWT system

A pilot-scale NWT system was built at the edge of the creek to prevent the existing organic matter pollution in the Kızılca creek in 2014. The variation of average influent and effluent TSS concentrations (mg L^{-1}) in the system operated for about 7 months is shown in Figure 5. The DO concentrations at the entry and the exit of the system was average 0.3 mg L^{-1} and 1.4 mg L^{-1}, respectively. The pH range of the system is between 7.3-7.6 and close to neutral.

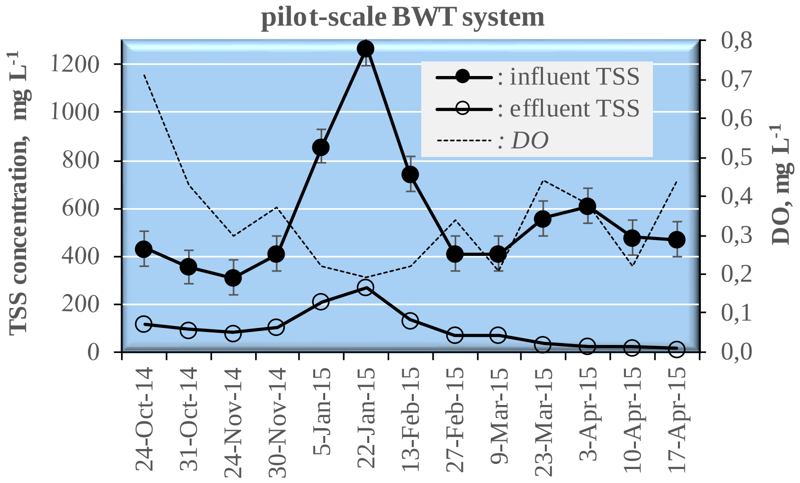

Figure 5. The variation of the average influent and effluent DO and TSS concentrations of the NWT system during the operation period.

The average influent and effluent TSS concentrations of the NWT system at an average water temperature of 11 ^{o}C were 563 mg L^{-1} and 96 mg L^{-1}, respectively. So, the system was able to remove the TSS up to approximately 83%. In previous studies (Reed et al., 1995; Crites et al., 2006; Kadlec & Wallace, 2009; Kim et al., 2014; Li et al., 2014; Morató et al., 2014), the TSS removal efficiencies in combined NWT systems consisting of the CW and OF systems ranged from 80 to 95%. In this study, despite higher TSS load (about 563 mg L^{-1}) compared to the other studies (below about 150 mg L^{-1}), the TSS removal of the NWT system was within the range of values in the literature. The results, it is seen that the NWT system produces the TSS below the discharge criteria to the receiving waters (TWPCR, 2004).

CONCLUSIONS

In this study, the existing SS pollution potential in the Kızılca creek and the Akkaya lake was investigated. As a result of the study, it was seen that the creek was extremely polluted in terms of SS matter. Since the creek was discharged to the lake at a high flow-rate of 0.80 m^3 s^{-1}, the high TSS load on the lake was seen as an important threat source in the pollution of the lake. Therefore, a plot-scale NWT system was installed at the edge of the creek to reduce the existing organic matter load.

The NWT system reduced the existing pollution in terms of the TSS. The system reduced the amount of TSS in the creek from an average 563 mg L^{-1} up to 96 mg L^{-1}. The results showed that the combined NWT systems to be installed at the edge of the creek might significantly reduce the existing organic matter load on the creek, and thus the water pollution of the creek and lake might be improved.

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