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Correlations between some operation parameters and efficiency evaluation of domestic wastewater treatment plant in Tunceli (Turkey)

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ABSTRACT

The purposes of this work are to monitor certain operating parameters in influent and effluent of domestic wastewater treatment plant in Tunceli, Turkey, to determine the relationships among these parameters, and also to evaluate the effectiveness of the treatment plant. The mean values of the parameters measured in the samples taken from the plant influent like pH, temperature, electrical conductivity, dissolved oxygen, total dissolved solids, suspended solids, the total solids, volatile suspended solid, biological oxygen demand, and chemical oxygen demand, are 7.60 ± 0.07, 11.66 ± 0.74°C, 1,070.75 ± 10.67 μs/cm, 3.78 ± 0.32 mg/L, 524.42 ± 5.28 mg/L, 390.58 ± 40.22 mg/L, 857.50 ± 61.30 mg/L, 496.17 ± 82.30 mg/L, 195.33 ± 8.11 mg/L, and 653.67 ± 42.12 mg/L, respectively. The values of these parameters after the treatment are 7.68 ± 0.08, 10.61 ± 0.70°C, 1,041.25 ± 15.31 μs/cm, 8.38 ± 0.10 mg/L, 510.17 ± 7.49 mg/L, 49.17 ± 8.88 mg/L, 443.08 ± 38.95 mg/L, 152.33 ± 27.95 mg/L, 13.67 ± 2.33 mg/L, and 44.66 ± 12.72 mg/L, respectively. Correlation analyses conducted to explain the potential relationship between the analyzed parameters demonstrated that there were both negative and positive correlations between the influent and effluent operational parameters. Results supported the fact that there were significant improvements in wastewater quality after treatment.

Keywords: Domestic wastewater treatment plant; Tunceli (Turkey); Correlation; Treatment efficiency

1. Introduction

Water is the backbone of the global economy and it has a critical importance for development in all areas that entail human effort. Water is necessary for live systems, industrial processes, agricultural production, and domestic consumption. Available and accessible water quality has immense effects on life standard (and well-being) of an individual, thus, there are extensive global and local efforts to provide clean and reliable water for the increasing population of the world [1–3].

Domestic wastewater is the discharged water from homes, commercial businesses, institutions, and similar facilities. This discharge includes human and animal urine and feces, and the water that originates from bathrooms, washbasins, and lavage, which is called gray water. Although it is colored, looks dirty and contains a certain amount of soluble or non-soluble substances, domestic wastewater is 99% water, and the remaining portion includes organic and

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inorganic substances. In addition, domestic wastewater could contain micro-organisms such as bacteria, protozoa, viruses, and helminthes, which could be pathogenic [4]. Uncontrolled domestic wastewater discharge into lake creates significant algae growth, and causes eutrophication and as the dissolved oxygen (DO) in lower layers is exhausted, large fish and other organisms that require oxygen for survival cease to exist [5,6].

Wastewater treatment facilities are designed and operated to reduce the pollution in wastewater that is generated as a result of human activities, and to minimize its negative effects on human health [7]. Treatment of sewage water necessitates physical, biological, and sometimes chemical methods. A significant factor in prevention and control of lake pollution with effective STP management is to have reliable and accurate information about the pollutant concentrations in wastewater [8]. There are different studies in the literature that scrutinized the influent and effluent characterizations for performance evaluations of wastewater treatment facilities in several locations such as Delhi, India [9], Yola, Nigeria [10], Alice, South Africa [11], Haridwar, India [12], Paralimni and Agia Napa, Cyprus [13], and Leon Province, Spain [14].

Tunceli, Turkey is famous with abundant and clean waters and has important water sources for surrounding cities. But with increasing population, the water sources have been under treat during last decades due to uncontrolled discharges of municipal wastewaters. Biological wastewater treatment facility eventually started to process in 2013 in the city. Terrestrial freshwater resources in Turkey are quite limited due to the climate characteristics of the subtropical zone that it is located at. Thus, it is necessary to protect the existing water resources against pollution. In Tunceli province, treated wastewater is discharged into Uzunçayır Reservoir, which is a significant water resource for the city. Domestic wastewater treatment facility plays an important role in protection of the lake against pollution. This study is the first research to evaluate certain operational parameters in Tunceli domestic wastewater treatment plant influent and effluent and to determine the correlation among these parameters, and additionally to investigate treatment efficacy of plant.

2. Materials and methods

2.1. Description of the facility

The present wastewater treatment facility is located in Tunceli (Turkey) at the following geographical coordinates: 39˚03´58.0´´N 39˚31´17.4´´E (Fig. 1). The plant is operational since the end of 2013 with a daily treatment capacity of 9,000 m^3/d. Since there is no industry in the city, wastewater treated at the plant demonstrates domestic-quality wastewater characteristics. During the facility planning, effluent quality parameters have been determined as biological oxygen demand (BOD) (<30 mg/L), total phosphorous (2 mg/L), total nitrogen (<15 mg/L), suspended solids (SS) (<20 mg/L), and pH (6–9). The plant includes physical treatment, biological treatment, and sludge removal facilities. Any chemical except the cationic polymer used in the plant sludge disposal process is not used in the plant. Wastewater initially passes through coarse and fine screens, and aerated grit chamber, and then mixed with return activated sludge, and sent to biological phosphorus unit with anaerobic conditions. Wastewater that enters the distribution structure from the biophosphorus pool is transferred to the extended aeration activated sludge system designed as an oxidation pit. Following the biological treatment, treated wastewater is precipitated in final settling pool and transferred to the discharge channel. Treatment plant effluent is discharged into Uzunçayır Reservoir, which is 80 m from the plant, with a pipe system.

2.2. Sampling and analysis

Wastewater samples used in the study were obtained from treatment facility influent and effluent during December 2014–February 2015. Two-hour composite samples proportional to the flow rates were collected by hand. A total of 24 samples (12 influents and 12 effluents) were procured for the study. pH, temperature, DO, electrical conductivity (EC), and total dissolved solids (TDS) values were determined on the spot using a Thermo Orion 5 Star multi-parameter device. BOD measurements were conducted with Aqua Lytic AL606 BOD device. Chemical oxygen demand (COD) was conducted with a Hach Lange DR890 model spectrophotometer. SS, total solids (TS), and volatile suspended solid (VS) were measured with standard methods (American Public Health Association (APHA) [15].

2.3. Statistical analysis

Correlations between the parameters were determined with SPSS version 18.0 software (using Spearman correlation coefficients). Independent two-sample t-test was used to determine the statistical difference

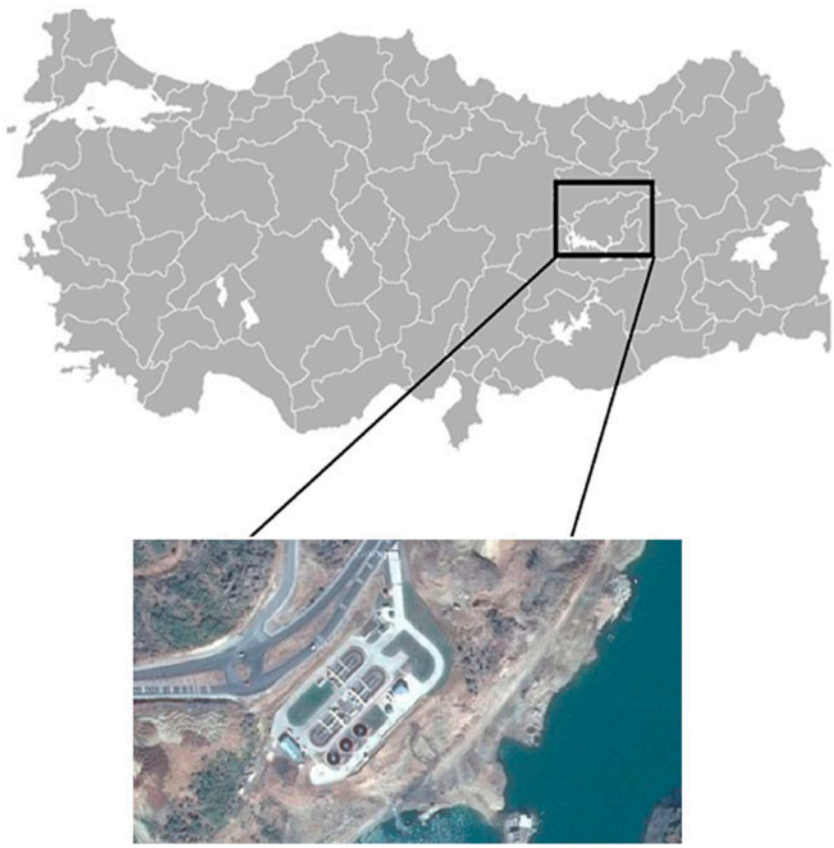

Fig. 1. Tunceli domestic wastewater treatment plant.
Source: Satellite picture adopted from Map data © 2016 Google.

between influent and effluent values. The differences were considered significant at $p < 0.05$ or $p < 0.01$ levels. Results were presented as mean ± standard deviation.

3. Results and discussion

Wastewater samples were collected from the plant influent and effluent to analyze several parameters and the results are presented in Table 1. pH value has primary significance in determination of the quality of wastewater effluent [16]. Wastewater pH varied between 7.30 ± 0.02 and 7.78 ± 0.09 before the treatment (mean = 7.60 ± 0.07) and between 7.33 ± 0.04 and 7.89 ± 0.11 (mean = 7.68 ± 0.08) after the treatment. All measurements demonstrated that both treated and untreated wastewaters were slightly alkali. Obtained effluent pH values were within the accepted range (7.0–8.5) by World Health Organization (WHO) and standards for drinking and agricultural water (6.5–8.5) [17,18]. Furthermore, European Union (EU) sets the protection limits for fishing and aqueous life as pH 6.0–9.0 [19].

Temperature is an important water quality parameter due to its impact on other parameters. Temperature affects the dissolvability of oxygen in water, and thus, its condition within water [20]. It also affects the sensitivity of aqueous organisms against toxic substances, in addition to the toxicity of certain chemicals [20,21]. Measurements conducted in the study showed that influent temperatures varied between 8.72 ± 1.30 and 13.27 ± 0.17˚C (mean = 11.66 ± 0.74˚C) and treated effluent temperatures varied between 7.35 ± 0.31 and 12.37 ± 0.06˚C (mean = 10.61 ± 0.70˚C). Low temperatures reflect the fact that the study was conducted during winter months. All temperatures were lower than the discharge standard (40˚C) determined by WHO for wastewater discharge into lakes [18].

EC value reflects the amount of dissolved ions in the water and used to determine the suitability of water for irrigation. Measurements conducted in the study showed that influent wastewater EC values varied between 1,055.75 ± 5.37 and 1,077.25 ± 57.78 μS/cm (mean = 1,070.75 ± 10.67 μS/cm) and effluent values varied between 1,010.75 ± 44.64 and 1,067.02 ± 5.61 μS/cm (mean = 1,041.25 ± 15.31 μS/cm). Water

Table 1
Influent and effluent values for the parameters traced in the wastewater treatment facility

Parameter	December		January		February		Monthly influent average for whole year	Monthly effluent average for whole year
	Influent	Effluent	Influent	Effluent	Influent	Effluent		
pH	7.30 ± 0.02	7.33 ± 0.04	7.72 ± 0.17	7.82 ± 0.61	7.78 ± 0.09	7.89 ± 0.11	7.60 ± 0.07	7.68 ± 0.08
Temperature (°C)	8.72 ± 1.30	7.35 ± 0.31	13.02 ± 0.13	12.11 ± 0.12	13.27 ± 0.17	12.37 ± 0.06	11.66 ± 0.74	10.61 ± 0.70
EC (μs/cm)	1,077.25 ± 28.88	1,010.75 ± 44.64	1,079.25 ± 16.62	1,067.02 ± 5.61	1,055.75 ± 5.37	1,046.02 ± 3.85	1,070.75 ± 10.67	1,041.25 ± 15.31
DO (mg/L)	2.05 ± 0.37	8.03 ± 0.18	4.38 ± 0.82	8.62 ± 0.08	3.66 ± 0.22	8.52 ± 0.13	3.78 ± 0.32	8.38 ± 0.10
TDS (mg/L)	527.75 ± 14.36	495.25 ± 21.83	528.75 ± 7.96	522.75 ± 2.69	516.75 ± 2.59	512.50 ± 1.93	524.42 ± 5.28	510.17 ± 7.49
SS (mg/L)	519.75 ± 94.12	82.02 ± 3.71	340.05 ± 14.35	49.51 ± 10.51	312.11 ± 16.09	16.02 ± 4.14	390.58 ± 40.22	49.17 ± 8.88
TS (mg/L)	1,084.05 ± 57.55	397.20 ± 84.30	617.04 ± 39.61	515.25 ± 62.26	871.50 ± 15.21	417.51 ± 55.11	857.50 ± 61.30	443.08 ± 38.95
VS (mg/L)	833.50 ± 71.80	241.25 ± 48.23	193.25 ± 5.21	122.04 ± 46.05	461.75 ± 20.36	93.75 ± 7.76	496.17 ± 82.30	152.33 ± 27.95
BOD (mg/L)	194 ± 7.02	13 ± 1.71	182 ± 7.23	18 ± 2.35	210 ± 10.35	10 ± 1.42	195.33 ± 8.11	13.67 ± 2.33
COD (mg/L)	687 ± 17.42	29 ± 2.56	570 ± 20.25	69 ± 4.63	704 ± 22.86	33 ± 2.66	653.67 ± 42.12	43.66 ± 12.72

with a EC value of 750–2,250 μS/cm is considered as high salinity water [22]. High EC value is considered as high salinity and high mineral content. It also reflects the highest concentration of dominant ions, which result from dissolution and ion exchange in water.

DO values that were measured during the study for influent and effluent were between 2.05 ± 0.37 and 4.38 ± 0.82 mg/L (mean = 3.78 ± 0.32 mg/L), and between 8.03 ± 0.18 and 8.62 ± 0.08 mg/L (mean = 8.38 ± 0.10 mg/L), respectively. Dissolved oxygen is a significant quality control factor for water and a measure of organic substance pollution. The effects of wastewater discharge to a surface water source are determined considerably by the oxygen equilibrium of the system and the presence of oxygen in a system is necessary for the survival of biological organisms. For aqueous life to sustain, DO concentration should be at least 5 mg/L. While under this level of concentration aqueous biological life is affected adversely, concentrations below 2 mg/L result in the death of most fish [23]. Measured DO values in the current study were well above the standard.

Similar to EC, TDS is a measure of salinity in water. High TDS in waters causes osmotic stress and could be toxic for freshwater animals and affects osmoregulatory abilities of the organisms. In addition, TDS is a significant agricultural water quality parameter related to soil salinity. It was reported that soil salinity is generally determined by irrigation water salinity and plant growth, crop yield and the quality of the produce are affected by the TDS concentration of the irrigation water [1]. TDS values that were measured during the study for wastewater treatment plant influent and effluent varied between 516.75 ± 2.59 and 528.75 ± 7.96 mg/L (mean = 524.42 ± 5.28 mg/L), and between 495.25 ± 21.83 and 522.75 ± 2.69 mg/L (mean = 510.17 ± 7.49 mg/L), respectively. All treated wastewater TDS values that were found in the study were lower than the WHO standard for discharge of wastewater into surface waters (850 mg/L) [18].

SS is a measure of particles that float in the wastewater and under certain situations; it is the measure of water clarity. While the influent SS values varied between 312.11 ± 16.09 mg/L and 519.75 ± 94.12 mg/L (mean = 390.58 ± 40.22 mg/L), effluent SS values varied between 16.02 ± 4.14 mg/L and 82.02 ± 3.71 mg/L (mean = 49.17 ± 8.88 mg/L). Wastewater are classified in the literature based on SS as follows: An SS value of lower than 100 mg/L is considered as poor; an SS value higher than 100 mg/L but lower than 220 mg/L is considered as intermediate; and an SS of higher than 200 mg/L is considered as strong

Table 2
Correlations among influent parameters of Tunceli domestic wastewater facility

	pH	Temperature	EC	DO	TDS	SS	TSS	VSS
pH	1.00							
Temperature	0.690[a]	1.00						
EC	−0.095	−0.202	1.00					
DO	0.105	0.224	0.309	1.00				
TDS	−0.105	−0.189	0.998[b]	0.326	1.00			
SS	−0.650[a]	−0.844[b]	−0.088	−0.287	−0.081	1.00		
TS	−0.531	−0.680[a]	−0.105	−0.622[a]	−0.130	0.643[a]	1.00	
VS	−0.518	−0.618[a]	−0.207	−0.543	−0.228	0.606[a]	0.949[b]	1.00

[a]Correlation is significant at the 0.05 level (2-tailed).
[b]Correlation is significant at the 0.01 level (2-tailed).

Table 3
Correlations among effluent parameters of Tunceli domestic wastewater facility

	pH	Temperature	EC	DO	TDS	SS	TSS	VSS
pH	1.00							
Temperature	0.780[b]	1.00						
EC	−0.172	−0.113	1.00					
DO	−0.593[a]	0.476	−0.033	1.00				
TDS	−0.175	−0.099	0.998[b]	−0.056	1.00			
SS	−0.699[a]	−0.646[a]	0.133	−0.607[a]	−0.140	1.00		
TS	−0.154	0.035	−0.042	0.453	−0.056	0.049	1.00	
VS	−0.627[a]	−0.549	0.172	−0.626[a]	0.168	0.424	−0.102	1.00

[a]Correlation is significant at the 0.05 level (2-tailed).
[b]Correlation is significant at the 0.01 level (2-tailed).

wastewater. TS and VS value measurements for the influent varied in the ranges of 617.04 ± 39.61–1,084.05 ± 57.55 mg/L, and 193.25 ± 5.21–833.50 ± 71.80 mg/L (mean = 857.50 ± 61.30 and 496.17 ± 82.30 mg/L), respectively, and for the treated effluent varied in the ranges of 397.20 ± 84.30–515.25 ± 62.26 mg/L, and 93.75 ± 7.76–241.25 ± 48.23 mg/L (mean = 443.08 ± 38.95 and 152.33 ± 27.95 mg/L), respectively. Treatment facility treatment yields for SS, TS, and VS were 87, 48, and 69%, respectively.

The main focus of wastewater treatment plants is to reduce BOD and COD in the effluent that would be discharged into natural waters. If high BOD effluent is discharged into a river or a stream, bacteria growth in the river would accelerate and the oxygen levels would decrease. Thus, oxygen could be reduced to levels that are fatal for most fish and aqueous insects [24]. COD is a measure of the total oxygen amount required for the oxidation of all organic matter into carbon dioxide or water [11,12].

BOD and COD values for the treatment facility influent varied in the ranges of 182 ± 7.23–210 ± 10.35 mg/L and 570 ± 20.25–704 ± 22.86 (mean = 195.33 ± 8.11 and 653.67 ± 42.12 mg/L), respectively, and for the treated effluent varied in the ranges of 10 ± 1.42–18 ± 2.35 mg/L and 29 ± 2.56–69 ± 4.63 (mean = 13.67 ± 2.33 and 43.66 ± 12.72 mg/L), respectively. An approximate treatment yield of 93% was obtained for both BOD and COD. BOD and COD concentrations in effluent samples were lower than the WHO standards for wastewater discharge into surface waters of 50 and 1,000 mg/L [20].

Correlations between the influent and effluent parameters were studies and the results are presented in Tables 2 and 3. While there was a moderate positive significant correlation between pH and temperature in the influent ($r = 0.690$, $p < 0.05$), there was a moderate significant negative correlation between pH and SS ($r = −0.650$, $p < 0.05$). In the effluent, while there was a strong positive significant correlation between pH and temperature ($r = 0.780$, $p < 0.01$) and moderate positive significant correlation between pH and DO ($r = 0.593$, $p < 0.05$) in the influent, there were moderate negative significant correlations between pH and SS ($r = −0.699$, $p < 0.05$) and between pH and VS ($r = −0.627$, $p < 0.05$). In addition to pH, there were strong negative significant correlations between temperature and SS ($r = -0.844$, $p < 0.01$) and moderate negative significant correlations between temperature and TS ($r = -0.680$, $p < 0.05$) and between temperature and VS ($r = -0.618$, $p < 0.05$) in the influent. Moreover, in the effluent there was a moderate negative significant correlation between temperature and SS ($r = -0.646$, $p < 0.05$). Between EC and TDS, there was a very strong positive significant correlation both in the influent and effluent ($r = 0.998$, $p < 0.01$). While there was a moderate negative significant correlation between DO and TS in the influent ($r = -0.646$, $p < 0.05$); in the effluent, in addition to pH, DO was negatively and moderate significantly correlated to SS ($r = -0.607$, $p < 0.05$), and to VS ($r = -0.626$, $p < 0.01$). In the influent, in addition to pH and temperature, there was a moderate positive significant correlation between SS and TS ($r = 0.643$, $p < 0.05$) and a moderate negative significant correlation between SS and VS ($r = -606$, $p < 0.05$), and there was a moderate positive significant correlation between SS and VS ($r = 0.544$, $p < 0.05$) in the effluent. There was also a very strong positive significant correlation between TS and VS in the influent ($r = 0.949$, $p < 0.01$).

4. Conclusion

Certain parameters were analyzed in Tunceli domestic wastewater treatment plant influent and effluent samples and the effluent was characterized. Assessment of the parameters analyzed for the treatment plant demonstrated that facility effluent pH was slightly alkali, influent and effluent temperature values were similar, close to the seasonal temperatures. It was determined that effluent DO values were quite good. There were no significant reductions in EC and TDS values. Mean removal values for SS, TS, and VS were 87, 48, and 69%, respectively. Average removal efficiency of BOD and COD in this treatment plant was determined as 93%. It was determined that facility effluent values were acceptable based on WHO discharge standards. As a result, treated water could safely be discharged into Uzunçayır Reservoir (Tunceli, Turkey). However, treatment performance of the plant should be continuously controlled.

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