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Reuse potential of urban wastewater treatment plant effluents in Turkey: a case study on selected plants

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Abstract

The paper summarizes the current situation of urban wastewater treatment plants (UWWTP) in Turkey. Results of a detailed survey on the performance of four selected plants were given both in terms of influent and effluent quality and in comparison with the current legislation on discharge limits to receiving waters. All the selected plants were operating efficiently especially according to conventional control parameters and heavy metal content. The suitability of the effluents for irrigation purposes is then evaluated according to the existing national irrigation water quality standards. From the data inventory, it was evident that the current situation is not promising especially regarding the bacteriological parameter, i.e. fecal coliform. The main cause of this problem is either the lack of disinfection units and/or improper operation of the existing ones. Turkey, which has already established its irrigation water quality standards, however, needs to accelerate the reuse of effluents in irrigation in the most proper manner.

Keywords: Wastewater reuse; Agricultural irrigation; Urban wastewater treatment plant; Irrigation water quality standard; Turkey

1. Introduction

There are 81 provinces in Turkey, where governors act as representatives of the central government. Sixteen of these provinces are Greater Metropolitan cities, whose municipalities are allowed to solve their problems with their own budget. Concerning the construction of urban wastewater treatment plants (UWWTPs), the Bank of Provinces (Iller Bankasi) is in charge of tendering, designing and constructing plants, whereas operation and maintenance issues are under the responsibility of the Municipalities.

Only 43 out of the 81 provinces have UWWTPs. A number of 129 UWWTPs are in operation in the country according to the recent

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official records [1]. A total of 28 UWWTPs are located in 12 of the Greater Metropolitan cities serving a population greater than 100,000 (equivalent population). For example, Istanbul Greater Metropolitan City, being the most crowded city of the country, has 13 UWWTPs whereas there are three plants in the highly industrialized province of Kocaeli, in the vicinity of Istanbul. Sixty-two plants distributed among Municipalities of provinces are either constructed in the provinces that are not declared as Metropolitan Cities or in the towns of Metropolitan cities with population >15,000 [2]. Adana Province for example, is a Metropolitan city, bearing two UWWTPs under the control of Greater Municipality, and two more plants in two of its towns. On the other hand, communities are those residential sites with population <15,000. There are 39 such plants in various small communities. Fig. 1 shows the provinces of the country with respect to the number of UWWTPs. In this figure, plate codes of the provinces (ex. TR-01) are given, and the number of UWWTPs in the provinces is shown in parenthesis.

The distribution of these plants according to the applied treatment technology is 40% physical, 55% biological (activated sludge systems, trickling filters), and 5% advanced (nitrogen and phosphorous removal). The effluent discharge methods include discharge to coastal waters, to inland waters, or disposal over land depending on the location of the plants. The effluent quality of the UWWTPs in the country needs to comply with the discharge standards stated in the National Water Pollution Control Regulation [3].

According to a previous study, 22 of these plants have been investigated in detail in terms of their satisfactory operation performance, proximity to agricultural land, and sufficient reuse potential [4]. In the present study, the authors have focused on four UWWTPs with the aim of investigating their treatment performance in more detail to upgrade these treatment plants in order to comply with the national reuse standards for irrigation purposes. The suitability of wastewater for reuse in irrigation is provided with the standards appearing in the Technical Aspects Bulletin of National Water Pollution Control Regulation [5]. The standards contain quality criteria to be used for categorizing agricultural irrigation waters, identifies important parameters and criteria to be followed in assessing wastewaters for their suitability in irrigation. The bulletin stipulates the maximum allowable heavy metal and toxic element concentrations, and the maximum levels of Boron for example, which is one of the most important parameters to be monitored and controlled during the application

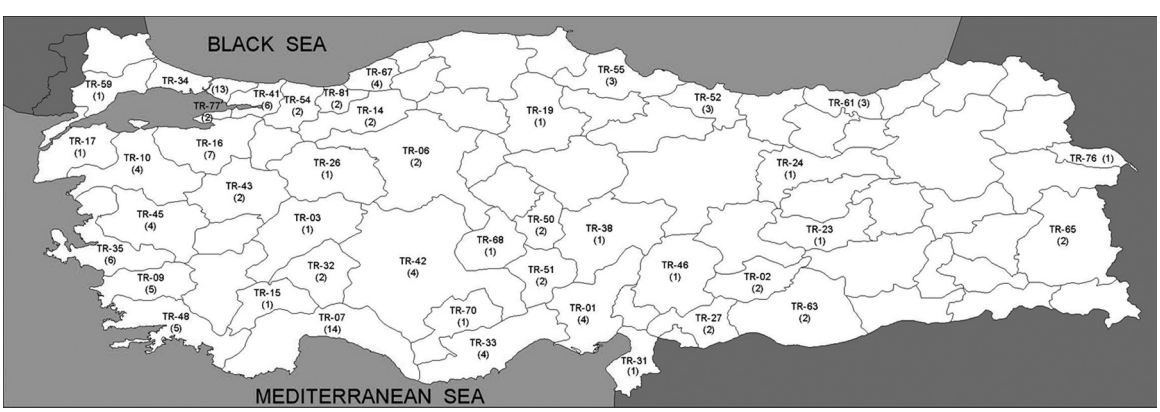

Fig. 1. The distribution of the UWWTP in Turkey: TR-01: Adana-Yumurtalik, TR-38: Kayseri, TR-34: Pasakoy-Istanbul, TR-34 Silivri-Istanbul.

of effluent in irrigation, as well as suitability criteria for industrial effluents in irrigation. Moreover, the bulletin states the criteria for deciding whether domestic wastewaters may or may not be used for irrigation without disinfection.

2. Methodology

During the present study, water sampling and experimental analyses from both the influent and effluent of the treatment plants were accomplished, and the UWWTPs were evaluated based on their design capacities, type of treatment systems, effluent discharge methods and reuse potentials. Grab sampling and experimental analyses along with site visits were performed by The Scientific and Technical Research Council of Turkey – Marmara Research Center (TUBITAK-MRC) under the coordination of Istanbul Technical University (ITU) within the framework of the EC funded MEDAWARE Project where ITU acts as one of the project partners [6].

3. Detailed performance survey of the selected UWWTPs

Two of the selected plants are located in the Greater Metropolitan Istanbul (TR-34). One is the Silivri UWWTP which is an activated sludge biological treatment system with a design capacity of 1350 m^3/day (equivalent population: 7000), the other is the Pasakoy UWWTP with an advanced biological treatment process technology designed as A2/0; anaerobic zone followed by anoxic and then oxic zones (aeration zones). Pasakoy UWWTP has a capacity of 100,000 m^3/day (equivalent population: 250,000). Silivri discharges its effluent to the Sea of Marmara, whereas Pasakoy UWWTP discharges its effluent to the Pasakoy River that finally flows into the Black Sea. The other two plants are located in Kayseri (TR-38) and Adana (TR-01) Greater Metropolitan cities (selected as two provinces playing an important role in Turkey's agricultural activities), with capacities of 110,000 m^3/day (equivalent population: 275,000) and 227,000 m^3/day (equivalent population: 567,500), respectively. Both plants are operated as advanced wastewater treatment systems with nitrogen and phosphorus removal. Kayseri discharges its effluent to Karasu Creek that downstream joins the Kizilirmak River, the longest river in Turkey discharging into the Black Sea. Adana-Yumurtalik UWWTP, located along the Mediterranean Sea shoreline, delivers its effluent to the sea. Some brief information related with the most recent treatment plant performance data of the four selected plants is given in Table 1.

Adana-Yumurtalik UWWTP located along the Mediterranean Sea shoreline discharges its effluent to the sea. Some brief information related with the most recent treatment plant performance data of the four selected plants is given in Table 1.

Table 1 reveals that all the selected plants are operated efficiently especially in terms of organic matter removal. In addition to that, the plants also do not face with any heavy metal problem either. In the national legislation, the receiving water standards are based on organic load/population equivalency. The current standards cover four main parameters without considering the bacteriological status of the effluent. The limits become stricter as the population increases (Table 2). Silivri UWWTP is an example for a population below 10,000, where the current limits to such population are not as strict as those established for a population higher than 10,000 [7,8]. There are five classes of discharge limits based on the population. Silivri UWWTP serves to a population of only 7000, whereas the other three municipalities' UWWTPs serve to a population of greater than 100,000. Corresponding limits for these populations are given in Table 2. Considering these discharge limits, it can be stated that all the four selected UWWTPs comply with the related discharge standards in terms of organic matter. It should also be pointed out that these plants can be categorized under the well operated ones with respect to fulfilling the discharge standards.

Table 1
Influent and effluent water quality of the four selected UWWTPs in Turkey

Parameter	Silivri-Istanbul (TR-34)		Pasakoy-Istanbul (TR-34)		Kayseri (TR-38)		Adana (TR-01)	
	Infl.	Effl.	Infl.	Effl.	Infl.	Effl.	Infl.	Effl.
pH	7.51	6.95	7.66	6.92	7.73	7.4	7.51	7.55
COD, mg/L	620	60	410	30	325	70	674	37
BOD_5, mg/L	275	30	120	15	130	25	199	15
TN, mg/L	61.6	55	93	38	92.5	51.2	58.4	26
TKN, mg/L	60.2	15.5	92.4	10.6	92	43.1	58.2	16
NH_4^+-N, mg/L	42.8	14	72.8	10	87.8	36.1	30.36	12.2
TP, mg/L	23.83	14.43	13.95	3.99	5.48	2.24	13.7	5.47
TSS, mg/L	326	25	540	30	274	20	274	7
TDS, mg/L	1015	953	682	600	1020	760	805	600
Salinity, %	0.7	0.6	0.4	0.3	0.7	0.5	0.4	0.3
NO_3^--N, mg/L	1.38	39.5	0.18	27.5	0.46	8.1	0.23	10.05
Cl^-, mg/L	158	257	110	110	197	182	178	175
SO_4^{-2}, mg/L	125	118	87	110	103	125	112	106
Alkalinity, mg $CaCO_3$/L	560	197	405	165	495	390	408	205
EC_w, µS/cm	1693	1588	1496	1090	1376	900	1320	987
Na^+, mg/L	185	225	115	120	177	188	146	77
K^+, mg/L	20.1	22.8	32.5	23.2	33.5	31.4	19.77	9.8
Mg^{2+}, mg/L	22.5	26.6	12.8	10.7	22.5	20	31	28
Ca^{2+}, mg/L	72.5	74.8	138	79	110	77.8	96	63
T Cr, mg/L	<0.02	<0.02	0.22	<0.02	<0.02	<0.02	<0.02	<0.02
Cd, mg/L	<0.02	<0.02	0.22	<0.02	<0.02	<0.02	<0.02	<0.02
Ni, mg/L	<0.05	<0.05	<0.05	<0.05	0.2	0.19	<0.05	<0.05
Fe, mg/L	0.547	0.102	3.35	0.258	2.17	0.138	1.618	0.042
Zn, mg/L	0.203	0.058	0.389	0.072	0.934	0.141	0.246	0.03
Pb, mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Hg, mg/L	0.0002	0.0001	0.0007	0.0002	0.0006	0.0003	0.0002	<0.0001
B, mg/L	<0.05	<0.05	<0.05	<0.05	0.515	<0.05	<0.05	<0.05
F. coliforms, CFU/100 mL	36×10^4	4600	$>10^6$	6000	$>10^6$	600	25×10^4	11×10^3
T. coliforms CFU/100 mL	42×10^4	5400	$>10^6$	50,000	$>10^6$	1250	$>10^6$	16×10^3

4. Evaluation of effluent quality of the selected UWWTPs regarding the national irrigation water quality standards

Sustainability of irrigation in contemporary agricultural practices in Turkey is being adversely affected by some constraints: restrictions on soil, water and energy resources, changes in economic conditions and infrastructure, lack of environmental consciousness and public awareness, and insufficient irrigation management. Turkey already approved its irrigation water quality standards on 1991 covering five quality classifications (Table 3) [5]. Furthermore, the country has also fixed the maximum heavy metal and toxic substances concentrations in irrigation water within the same bulletin. It also refers to the technical

Table 2
Discharge standards of domestic wastewater to receiving waters in Turkey [3]

Parameter	Composite sample (2 h), Pop. 1000–10,000	Composite sample (24 h), Pop. 1000–10,000	Composite sample (2 h), Pop. >100,000	Composite sample (24 h), Pop. >100,000
BOD_5, mg/L	50	45	40	35
COD, mg/L	160	110	120	90
TSS, mg/L	60	30	40	25
pH	6–9	6–9	6–9	6–9

limitations and related aspects of wastewater reuse in agriculture as Turkey is still an agricultural country despite its efforts on industrial development. Unfortunately, no conscious and/or official reuse of effluent in irrigation has been practiced for effluents discharged from these treatment facilities. However, indirect use as irrigation water is preferred by the farmers in the regions. In practice, the discharges go to receiving water bodies, which users then experience water withdrawals. Table 3 categorizes the effluent discharges of the selected four UWWTPs according to their suitability as irrigation water in terms of some water quality parameters, whereas Table 4 refers to the compliance of the heavy metal concentrations with the current related regulation. From Table 3, it can be concluded that the effluents of the selected UWWTPs are not suitable for agricultural irrigation purposes due to at least one significant water quality parameter that is the fecal coliform. Some of the UWWTPs do not even have disinfection units as their final polishing treatment stage. In those having disinfection units, satisfactory and efficient operation is rarely

Table 3
The suitability for agricultural irrigation of the effluent of the selected UWWTPs according to national irrigation water quality standards

Parameter	Silivri-Istanbul (TR-34)	Pasakoy-Istanbul (TR-34)	Kayseri (TR-38)	Adana (TR-01)	National irrigation water quality classification* [5]				
					I	II	III	IV	V
pH	(I)	(I)	(I)	(I)	6.5–8.5	6.5–8.5	6.5–8.5	6.0–9.0	<6.0 >9.0
BOD_5, mg/L	(II)	(I)	(I)	(I)	0–25	25–50	50–100	100–200	>200
TSS, mg/L	(II)	(II)	(I)	(I)	20	30	45	60	>100
TDS, mg/L	(III)	(III)	(III)	(III)	0–175	175–525	525–1400	1400–2100	>2100
NO_3^--N, mg/L	(IV)	(III)	(II)	(II)	0–5	5–10	10–30	30–50	>50
SAR	(IV)	(II)	(IV)	(II)	<10	10–18	18–26	>26	
Cl^-, mg/L	(III)	(I)	(II)	(II)	0–142	142–249	249–426	426–710	>710
SO_4^{-2}, mg/L	(I)	(I)	(I)	(I)	0–172	172–336	336–575	576–960	>960
EC_w, µS/cm	(III)	(III)	(III)	(III)	0–250	250–750	750–2000	2000–3000	>3000
B, mg/L	(I)	(I)	(I)	(I)	0–0.5	0.5–1.12	1.12–2.0	2.0	–
F. coliforms, CFU/100 mL	(V)	(V)	(IV)	(V)	0–2	2–20	$20–10^2$	$10^2–10^3$	$>10^3$

*Quality classes of irrigation water: I: Perfect for reuse as irrigation water; II: Satisfactory; III: Usable; IV: Usable with care; V: Not suitable, improper.

Table 4
Effluent heavy metal concentration of the selected UWWTPs and the corresponding national standards

Parameter	Silivri-Istanbul		Pasakoy-Istanbul		Kayseri		Adana		National standards [5]
	Value	Comment	Value	Comment	Value	Comment	Value	Comment	
B, mg/L	<0.05	S*	<0.05	S*	<0.05	S*	<0.05	S*	5.0
Cd, mg/L	<0.02	S*	<0.02	S*	<0.02	S*	<0.02	S*	0.01
Cr, mg/L	<0.02	S*	<0.02	S*	<0.02	S*	<0.02	S*	0.1
Fe, mg/L	0.102	S*	0.258	S*	0.138	S*	0.042	S*	5.0
Pb, mg/L	<0.1	S*	<0.1	S*	<0.1	S*	<0.1	S*	5.0
Ni, mg/L	<0.05	S*	<0.05	S*	0.19	S*	<0.05	S*	0.2
Zn, mg/L	0.058	S*	0.072	S*	0.141	S*	0.03	S*	2.0

*S = Satisfactory.

achieved due to their high energy consumption and disinfecting chemicals requirements. On the other hand, boron (another significant parameter used in irrigation water standards) does not cause significant problems in the selected treatment plants like in some other existing UWWTPs in Turkey. Only in some regions of the country, boron causes some irrigation water problems. Sulfate concentrations together with the BOD_5 values lie below the stated limits of Class I water in all samples performed; however, chloride values demonstrate various classes of use. Conductivity and TDS values represent Class III properties in all the selected plants. From Table 4, it is obvious that none of the selected UWWTPs face to any heavy metal problem indicating that there is no industrial wastewater intrusion to the UWWTPs.

5. Discussion and conclusions

In order to reduce the environmental and health impacts of wastewater reuse, countries have adopted several standards and guidelines that differ from each other even at the regional level. Practice of wastewater reuse mainly depends on a country's economy, infrastructural status covering wastewater treatment capacity and capability, educational level, climate, water supply, balance between water requirement and demand, intensity of agricultural activities, population, social habits like cultural and religious prejudice, and many other factors [9]. While most of the developed countries have established low risk guidelines or standards based on a high technology/high-cost approach, many developing countries have adopted an approach based on WHO guidelines that refer to low-cost technologies and focus on health risks. However, the current situation in some developing countries is the direct use of untreated wastewater for irrigation without taking into account the stated guidelines and standards, and associated risks. On the other hand, there are no legislative regulations at the European level concerning wastewater reuse so far, apart from the Urban Wastewater Treatment Directive (91/271/EEC) which advises to reuse wastewater "whenever appropriate" [10].

Even though the national irrigation water quality standards has been active since 1991, reuse of treated wastewater for irrigation has not been considered consciously till now as the country has not yet experienced severe water shortages. In the nearest future, wastewater reuse will be one of the most important environmental issues in Turkey [11]. Therefore, detailed surveys like the

one presented in this paper need to be extended. As an initial step towards effluent use in irrigation, the existing UWWTPs must either efficiently operate their disinfection units and/or add such facilities to their treatment systems. The existing plants have to overcome this major deficiency. Moreover, it is important that the farmers are informed on the safe use of effluents in irrigation, if done under serious control and monitoring of the effluent quality. Public awareness and training is another important issue that should be considered by the legal local and/or governmental related authorities.

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