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Wastewater Reclamation and Reuse Status in Turkey

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Treated wastewater is being widely used for irrigation purpose all over the world. Reuse of wastewater for agricultural or landscape irrigation is also help to protect environment and to conserve fresh water resources. However, most important consideration is to protect public health in water reuse applications. Thus, microbiological quality of treated wastewater and the criteria used to determine the quality have gained importance. With this study current status of fresh water resources and wastewater treatment in Turkey was documented. Potential needs of wastewater reuse were analyzed. Microbiological quality criteria for agricultural wastewater reuse in the regulations of Turkey were given and compared with the guidelines recommended as common to all Mediterranean countries.

Key Words: Wastewater reuse, Wastewater reclamation, Reuse standards and guidelines, Water quality criteria.

INTRODUCTION

Today World is more than ever subjected to increasing pressure on water resources caused by population growth, urbanization, irrigated agriculture expansion, industrial development and global climatic changes. The situation is exacerbated, particularly by rapid population growth and urbanization in developing countries. New approaches are required to cope with the challenges in water resources development and management to sustain the use of these resources.

Mediterranean basin countries are also facing serious shortages of water in addition to increasing pollution of surface and groundwater. Consequently, severe competition for the limited water resources exists between domestic, industrial and agricultural consumptions. On the other hand, the amount of municipal and industrial wastewaters in the basin is steadily increasing which could be reused after treatment processes.

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Environmental, economic and agricultural benefits of wastewater reuse are numerous and increasingly recognized as an essential management strategy in water scarce areas[1]. In water short regions, reuse of wastewater helps to conserve resources and to protect environment by preventing the pollution of surface and groundwater resources. Wastewater is also a preferential marginal source since its supply is reliable, uniform and the cost is lower compared to other unconventional resources.

Turkey is situated between Asia and Europe forming a natural bridge by linking the two continents. The total land area is 779450 km^2 and divided into two parts, Anatolia in Asia and Thrace in Europe. Turkey has a variety of climates, changing from sub-tropical Mediterranean climate along the coastal areas, to continental climate in the inland regions. The annual precipitation ranges from 250 mm in the central Anatolia to 2200 mm in the eastern Black Sea region. Such great climatological variability prevails mainly due to irregular topographic conditions. Spatial and temporal distribution of precipitation is unequal. About 75 % of the annual precipitation falls in winter and spring seasons. Turkey is characterized by a severe water imbalance due to spatial and temporal variabilities, particularly in the drought and hot summer months and highly urbanized and industrialized western regions. Therefore, treated effluent from wastewater treatment plants is highly considered as an alternative resource in water scarce regions.

The objectives of this study are to document the current wastewater treatment status and to analyze the possibility of treated wastewater reuse for irrigation in Turkey.

WATER RESOURCES AVAILABILITY AND WATER DEMAND

The annual average precipitation in Turkey is 643 mm, corresponding to a total volume of 501200×10^6 m^3/year. The average runoff coefficient is 0.37 and the annual total runoff amounts to 186000×10^6 m^3/year. A certain amount of streamflow must be left in the rivers to safeguard the environment for aquatic life and pollution control and to meet the water rights of neighbouring countries. Consequently, the annual consumable surface water potential is 95000×10^6 m^3/year. Based on the groundwater potential studies, the annual safe yields of groundwater resources is 14000×10^6 m^3/year. On the other hand, 3000×10^6 m^3/year comes from the external rivers originating outside the country borders. Thus, the total annual available water potential of Turkey is 112000×10^6 m^3/year. The available amount of water per capita is 1500 m^3/year[2,7].

The total annual withdrawal of the water resources was 42000×10^6 m^3/year in the year 2000, of which 36000×10^6 m^3/year was surface resources. Annual groundwater withdrawal was about 6000×10^6 m^3/year. Agricultural, domestic and industrial water consumptions were 75, 15 and 10 %, respectively.

In Turkey, approximately 8.5×10^6 ha of cultivated land is classified as economically irrigable area. At the end of 2004, the total irrigated area was 4.9×10^6 ha.

By the year 2030, the economically irrigable area *i.e.*, 8.5×10^6 ha is expected to be fully developed for irrigation. The majority of dams, approximately 730 and all irrigation projects within the river basins will be implemented. The annual available water resources will be completely developed. Based on the long term projections, irrigation water consumption will be 71500×10^6 m^3/year. Annual growth rate of industry will be 4 % and 13200×10^6 m^3/year will be allocated to industrial use. The estimated domestic consumption will rise to 25300×10^6 m^3/year, 23 % of total use[2].

WASTEWATER TREATMENT STATUS AND TECHNOLOGIES

In Turkey, the responsibility of constructing, operating and monitoring the sewage collection and treatment system has been given to the municipalities since 1930. The law released in 1981 on municipality income has brought the concept of constructing sewage treatment plants being financially supported by land and construction owners, which has been further revised in 1985 through the Law of Public Works. The National Water Pollution Control Regulation (TWPCR) dated 1988 dictates the standards of wastewater that are collected through sewerage systems and that are treated either by means of dilution or through satisfactory treatment[3], which was revised in 2004.

Till late 1990's, the National Bank of Provinces has been in charge of realizing wastewater treatment plants within the framework of annual investment programmes according to instructions of the related municipalities. Those constructed plants were then transferred to the municipalities for operation. The General Directorate of Special Protection Areas and General Directorate of Massive Housing deal with the investment of wastewater treatment plants[3].

According to 2002 data, the country is divided into 3227 municipalities, of which 2060 are served by sewerage system (Table-1). The number of municipalities served by wastewater treatment plants is 210. A total number of 140 municipal wastewater treatment plants (MWTPs) are operating in Turkey, which serve up to 39.3 % of the country total population corresponding to 49.9 % of the total municipal population[4].

Among the total number of 140 wastewater treatment plants, 43 of them are physical treatment plants, 94 consists of biological treatment units and 3 bear advanced treatment (Table-2). Although total annual capacity of MWTPs is 2469.9×10^6 m^3, the amount of annual treated sewage is 1379.7×10^6 m^3. 56.3 % of the total treated amount is subjected to biological treatment, 30.2 % to physical treatment and 13.5 % to advanced treatment[4].

TABLE-1
NUMBER OF MUNICIPALITIES AND POPULATION PERCENTAGE SERVED BY SEWERAGE AND WASTEWATER TREATMENT PLANTS IN 2002 [Ref. 4]

Number of municipalities		3227
Municipal population		53421379
Number of municipalities having marine outfalls		46
Sewerage System	Number of municipalities served	2060
	Population served in total municipal population (%)	78.4
MWTPs	Number of municipalities served	210
	Population served in total municipal population (%)	49.9

MWTPs = Municipal wastewater treatments plants.

TABLE-2
STATE OF WASTEWATER TREATMENT PLANTS IN 2002 [Ref. 4]

	Number of plants	Total capacity ($\times 10^6$ m^3/year)	Treated amount ($\times 10^6$ m^3/year)
Physical	43	997.2	416.9
Biological	94	1178.1	777.3
Advanced	3	294.6	185.5
Total	140	2469.9	1379.7

Most of the advanced treatment practices take place in coastal Greater Metropolitan Municipalities like Istanbul, Izmir and Antalya that discharge their effluent to the sea.

Conventional activated sludge and extended aeration activated sludge processes are the most commonly used secondary treatment technologies. These two technologies are followed by pond and trickling filtration systems by 23 and 9 %, respectively[5].

Effluent quality: The current national legislation on effluent quality is specified in Turkish Water Pollution Control Regulations which was approved in 1988[6] and further revised on December 31, 2004[7]. In the legislation, several discharge standards are defined for various receiving bodies. The current effluent discharge standards for domestic wastewater are divided into five groups based on the organic loadings/equivalent population. The groups from 1st to 4th are set for equivalent population less than 1000, 1000-10000, 10000-100000 and more than 100000, respectively. The 5th group is for urban biological treated wastewater effluents with constructed wetlands and stabilization ponds without referring to the population equivalent. For the 4th group, the standard limits for the main parameters of concern pH, TSS, BOD_5 and COD are 6-9, 40 mg/L, 40 mg/L and 120 mg/L, respectively, in 2 h composite sample.

A detailed survey was performed, within the framework of a European Commission Euro-Mediterranean Partnership project[5], for quantitative and qualitative data collection from representative plants. The key factors considered for the selection were population served more than 100000, proximity to agricultural land and sufficient reuse potential. The effluent samples were also collected and analyzed and a brief summary of the quality characteristics of secondary effluent is presented in Table-3. The results reveal that most of the MWTPs which participated in the study appeared to provide satisfactory secondary treatment, thus complying with the EC Directive 91/271 and Turkish legislation for wastewater disposal.

TABLE-3
SOME PHYSICOCHEMICAL CHARACTERISTICS OF SECONDARY EFFLUENT FROM VARIOUS WASTEWATER TREATMENT PLANTS IN TURKEY [Ref. 5]

	pH	EC (μS/cm)	COD (mg/L)	TSS (mg/L)	TKN (mg/L)	TP (mg/L)	SAR	Cl^- (mg/L)	SO_4^{2-} (mg/L)	Boron (mg/L)
Average	7.5	2824.7	101.8	30.2	24.6	11.1	51.2	679.1	174.8	0.342
Median	7.4	1484.5	96.5	28.0	22.7	6.7	24.3	163.5	108.5	0.265
Min.	6.6	620.0	17.0	2.0	1.2	0.5	6.6	44.0	37.0	0.028
Max.	8.2	13000.0	285.0	60.0	94.0	63.0	168.9	3740.0	684.0	1.180
90^{th} perc.	8.0	9052.0	232.1	58.5	56.4	17.2	161.4	3010.2	506.5	0.816

Effluent COD concentrations from secondary treatment were in the range from 17 to 285 mg/L, with 78 % of the samples having a COD of less than 125 mg/L. Some higher COD concentrations indicate that the corresponding MWTPs have operational problems. On the other hand, SAR, EC and Cl which are very important parameters for agricultural and landscape reuse have considerably high values, particularly for the coastal area treatment plants, more likely due to seawater intrusion into the sewerage systems. SAR which is a parameter used to evaluate the effect of sodium content of water on soil physical characteristics has values ranging between 6.6 and 168.9. Average, median and even minimum values of SAR were found very high. As a measure of the water salinity, EC values were detected above limits for the majority of agricultural crops, in 60 % of the treatment plants. The high chloride concentrations analyzed, that ranged from 44-3740 mg/L may also cause secondary effluent unsuitable for agricultural reuse. The results reveal that the main challenge for reusing treated wastewater in agriculture is salinity.

WASTEWATER REUSE POTENTIAL AND CRITERIA

The need for water reuse in Turkey is mainly due to scarcity of water resources, periodically faced in drought years. Water scarcity is particularly exacerbated by rapid urbanization and industrialization and higher per capita water consumption as a result of socio-economic welfare of the western part of Turkey.

Out of 26 river basins (Table-4), Marmara basin is the most populated and industrialized region with a population density of 518 capita/km^2. Other crowded basins are Gediz and Sakarya with population densities of 230

TABLE-4
SOME CHARACTERISTICS OF DRAINAGE BASINS OF TURKEY [Ref. 8]

Name	Population (million) (2000)	Area (km^2)	Population density (capita/km^2)	Mean annual rainfall (mm)	Average runoff (×10^6 m^3/year)	Economically irrigable area (net) (×1000 ha)
Meric-Ergene	0.98	14560	67	604.0	1330	146
Marmara	12.48	24100	518	728.7	8330	83
Susurluk	2.64	22399	118	711.6	5430	180
Northern Aegean	0.75	10003	75	624.2	2090	90
Gediz	4.13	18000	230	603.0	1950	179
Small Meander	0.58	6907	84	727.4	1190	29
Great Meander	1.93	24976	77	664.3	3030	314
Western Mediterranean	1.06	20953	51	875.8	8930	136
Antalya	1.88	19577	96	1000.4	11060	149
Burdur Lakes	0.23	6374	46	446.3	500	43
Akarcay	0.50	7605	66	451.8	490	33
Sakarya	6.10	58160	105	524.7	6400	374
Western Black Sea	1.96	29598	66	811.0	9930	101
Yesilirmak	3.00	36114	83	496.5	5800	331
Kizilirmak	4.17	78180	53	446.1	6480	626
Konya (closed)	3.05	53850	57	416.8	4520	492
Eastern Mediterranean	1.77	22048	80	745.0	11070	99
Seyhan	2.29	20450	112	624.0	8010	311
Orontes	1.33	7796	171	815.6	1170	97
Ceyhan	1.55	21982	71	731.6	7180	510
Euphrates	6.91	127304	54	540.1	31610	1741
Eastern Black Sea	2.88	24077	120	1198.2	14900	2
Coruh	0.43	19872	22	629.4	6300	30
Aras	0.81	27548	29	432.4	4630	273
Van (closed)	0.87	19405	45	474.3	2390	92
Tigris	3.35	57614	58	807.2	21330	662
Total	67.63	779452	87	642.6	186050	7123

and 105 capita/km^2, respectively[8]. High densities indicate the location of major industries, service sectors and intensive agriculture. Therefore, water consumptions are very high in these basins and generally demand is equal or even higher than the supply in drought periods.

On the other hand, over-populated and highly industrialized basins generate the maximum amount of wastewater. Owing to this, the majority of treatment plants are located in the more industrialized, densely populated regions and tourism centers of the south-western coasts. Economically irrigable area in Marmara, Gediz and Sakarya basins are 83000, 179000 and 374000 ha, respectively. Approximately, two-thirds of this area has irrigation infrastructure. Treated wastewaters could be reused as a supplementary source in irrigated areas of the water scarce basins, so that a part of fresh water currently used for irrigation of agricultural crops would be saved.

Water standards for water reused in agriculture in Turkey have been stipulated in the Technical Aspects Bulletin linked to the Turkish Water Pollution Control Regulation issued in 1991[9]. Since ensuring public health and safety is a starting point for any kind of water reuse application, microbiological parameters have received the utmost attention in water reuse regulations[10]. Microbiological quality determination of treated wastewater is based on faecal coliforms in the Turkish regulations and the limit varies between 0 and 1000 cfu/100 mL. For treated wastewater reuse in agriculture, microbiological quality limit has been defined as 1000 faecal coliform/100 mL along with some restrictions and requirements have been set on the type of vegetation, the irrigation and the treatment techniques (Table-5).

TABLE-5
BASIC REQUIREMENTS AND TECHNICAL LIMITS FOR CONTROLLING AGRICULTURAL REUSE OF WASTEWATER [Ref. 9]

Crops	Technical limits
Orchards and vineyards	- Sprinkler irrigation is prohibited. - Fruits which have fallen down should not be eaten. - Faecal coliform numbers should be < 1000/100 mL.
Fiber and seed crops	- Surface or sprinkler irrigation can be applied. - Biologically treated and chlorinated wastewaters can be used for sprinkler irrigation. - Faecal coliform numbers should be < 1000/100 mL.
Fodder, industrial, non-raw eaten crops and ornamentals	- Surface irrigation can be applied, physical treatment is needed.

TABLE-6
RECOMMENDED MICROBIOLOGICAL AND PHYSICOCHEMICAL CRITERIA FOR WASTEWATER REUSE IN TURKEY (ADOPTED FROM [Ref. 11 and 12])

	Water category and reuse applications	Quality criteria	Treatment expected to meet the criteria
1st	a) residential reuse: garden irrigation b) Urban reuse: irrigation of parks, golf courses, sport fields, green belts. c) Landscape and recreational impoundments (incidental contact is allowed)	I.N.[a] ≤ 0.1[h] eggs/L; FC or *E. coli*[b] ≤ 200[d] cfu/100 mL; TSS[c] ≤ 10 mg/L	Secondary treatment + filtration + disinfection
2nd	a) Irrigation of vegetables (surface or sprinkler irrigated), green fodder and pasture for direct grazing, sprinkler irrigated fruit trees. b) Landscape impoundments (contact with water is not allowed)	I.N.[a] ≤ 0.1[h] eggs/L; FC or *E. coli*[b] ≤ 1000[d] cfu/100 mL TSS[c] ≤ 20 mg/L; (≤ 150[f])	Secondary treatment or equivalent[g] + filtration + disinfection or Secondary treatment or equivalent[g] + either storage or well-designed series of maturation ponds or filtration percolation
	c) Industrial reuse (except for food industry)	FC or *E. coli*[b] ≤ 1000[d] cfu/100 mL; TSS[c] ≤ 20 mg/L; (≤ 150[f])	
3rd	Irrigation of cereals and oleaginous seeds, fiber and seed crops, dry fodder, green fodder without direct grazing, crops for canning industry, industrial crops, fruit trees (except sprinkler-irrigated)[e], plant nurseries, ornamental nurseries, wooden areas, green areas with no access to the public.	I.N.[a] ≤ 1 eggs/L; FC or *E. coli* – none required; TSS[c] ≤ 35 mg/L; (≤ 150[f])	Secondary treatment or equivalent[g] + a few days storage or Oxidation pond systems
4th	a) Irrigation of vegetables with surface and subsurface trickle systems using practices guaranteeing absence of contact between reclaimed water and edible part of vegetables. b) Irrigation of crops in category III with trickle irrigation system (such as drip, bubbler, micro sprinkler and subsurface). c) Irrigation with surface trickle irrigation systems of greenbelts and green areas with no access to the public. d) Irrigation of parks, golf courses, sport fields with sub-surface irrigation systems.	None required	Pretreatment as required by the irrigation technology, but not less than primary sedimentation

[(a)]I.N.: intestinal nematodes, (No. Eggs/L): *Ascaris and Trichuris* species and hookworms; the guideline limit is also intended to protect against risks from parasitic protozoa; [(b)]FC and *E. coli* (cfu/100 mL): Faecal coliforms or *Escheria coli* (cfu: colony forming unit/100 mL); [(c)]TSS: Suspended solids; [(d)]Values must be conformed at the 80 % of the samples per month, minimum number of samples 5; [(e)]In the case of fruit trees, irrigation should stop two weeks before fruit is picked off the ground. Sprinkler irrigation should not be used; [(f)] Stabilization ponds; [(g)] Such as advanced primary treatment; [(h)] As very few investigations, if any, have been carried out on how to reach < 0.1 nematode egg/L, this criterion is considered a medium term of objective and is provisionally replaced by < 1 nematode egg/L.

A recent concern is to establish a unified guideline for the Mediterranean countries the standards of which can be achieved with a wastewater treatment technology applicable in all developing countries, that is, low in cost and affordable for most. The objective is to unify wastewater recycling and reuse regulations around the Mediterranean basin that would contribute to secure economic and tourism exchange in the region[11].

Common guidelines on water reuse in all Mediterranean countries have been proposed (Table-6) by Bahri and Brissaud[12], mainly based on recommended revised microbiological guidelines by Blumenthal *et al.*[13]. The main differences between the Turkish and the recommended standards for the Mediterranean region are the absence of the helminth eggs parameter and the specification of the minimum treatment technology requirement to meet the water quality limits for certain water reuse applications. The Mediterranean guidelines, recommended as common to all Mediterranean countries by Bahri and Birssaud[12] are proposed to be adapted in Turkey. However, recommended guidelines should be assessed by several field applications in order to determine their appropriateness to the background level of Turkey[14].

Conclusion

Water resources availability is relatively high in Turkey, when compared with other south-eastern Mediterranean countries. However, water imbalance is often experienced, particularly in highly populated and industrialized western and coastal regions, due to increased water demand. Tourism is rapidly developing and creating extra demand in these regions during summer months. The continued increase of demand from all sectors can only be met through an integrated water resources management programme which includes the reuse of unconventional waters.

In Turkey, treated wastewaters are mainly used in small scale landscape and agricultural irrigation. The wastewater is indirectly reused in agriculture, since in most cases treated wastewaters are discharged into rivers, whose water is used for irrigation. Some of the municipal wastewater treatment plants (MWTPs) are discharging treated wastewaters to ephemeral streams and after infiltration to aquifer, groundwater is pumped by farmers from adjacent wells for local irrigation. This is also a way of indirect reuse. Large scale application of wastewater reuse projects are under consideration for water scarce basins. There is no industrial or other reuse case of treated effluents.

On the other hand, the MWTPs can serve about 50 % of municipal population. Total annual capacity of plants is 2469.9×10^6 m^3. Out of them, 56 % is treated by biological systems and they are generally located in the water scarce basins, like Marmara, Sakarya and Gediz. Therefore, it is expected that in the near future large scale wastewater reuse projects for irrigation or other reuse options will gain importance.

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