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Assessment of wastewater treatment alternatives in metropolitan municipality district: a case study in Turkey

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ABSTRACT

Wastewater pollution has always been a major problem throughout the world. The lack of available water used for drinking, agriculture, farming, etc. has declined through the years. For the past several years, Turkey has been affected by the water pollution crisis. Particularly, together with the Metropolitan Municipality Law dated 07.10.2004 and numbered 5216, adjacent areas of metropolitan cities included new counties, towns, forest villages, and other villages, which in turn necessitated a revision of the current wastewater treatment alternativities. In this paper, domestic and industrial wastewater sources of Kayseri municipalities district were determined and information about the character and formation of the wastewater were provided. To our knowledge this is the first extensive study on wastewater characterization in this district. For this purpose, location of the declared facilities', their wastewater features, and discharging areas were investigated. Wastewater, existing throughout the city was divided into four parts and compared with the discharge standards which were determined by the national and local governments. Contamination levels differ with respect to sectors and the sector with the highest contamination level is found to be the textile industry. The fact that large textile industries became located within the city by expansion of adjacent areas has carried the problem to more serious dimensions. It is also observed that the food industry is important because of its water consumption and high load of organic contamination. Wastewaters of industries which are still discharging into the receiving water body should be connected to the sewerage system as soon as possible.

Keywords: Wastewater pollution; Kayseri; Characterization; Metropolitan municipality

1. Introduction

Lack of clean water has always been an issue of environmental concern all over the world. This issue is particularly stressed in developing countries today. The main sources of water pollution are: industrial (chemical, organic, and thermal wastes), municipal (largely sewage consisting of human wastes, other organic wastes, and detergents), and agricultural (animal wastes, pesticides, and fertilizers) [1]. In recent years, Turkey has been affected by the water pollution crisis. Especially, together with the Metropolitan Municipality Law dated 07.10.2004 and numbered 5,216. Adjacent areas of metropolitan cities included new counties, towns, forest villages, and other

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villages, which in turn necessitated a revision of the current wastewater treatment [2].

Because of this reason, it is necessary to perform a study for the determination of the characteristics and formation of the wastewater in the country in general to solve this wastewater problem in metropolises with the lowest possible cost by using the most convenient technology available in the country [3,4]. Optimizations of both investment and operation cost of the planned wastewater treatment plant depend on very basic information—municipal wastewater characterization and pollution load. Therefore, it will be very helpful to create a data bank which is fed back with necessary operational data provided from all constructed wastewater treatment plants in addition to new data supplied by measurement that are taken for a new wastewater treatment plant [5–7]. Everybody who is dealing with planning or execution of a wastewater treatment plant has to access this data bank before studying applicable process alternatives to decide the most economical one [8,9]. Kayseri is one of the large industrial cities in Turkey (Fig. 1). There are 711 industrial firms present in Kayseri Organized Industrial Zone (KOIZ) and 25 industrial sectors are still present in the center of the city [10].

The main objective of present study was to clarify the situation and to evaluate the contribution of the city's wastewater management planning being undertaken. There are some studies in the literature that examined the determining wastewater profile [11,14]. Pedrero et al. [15] reviewed the fundamentals of agricultural irrigation using treated municipal

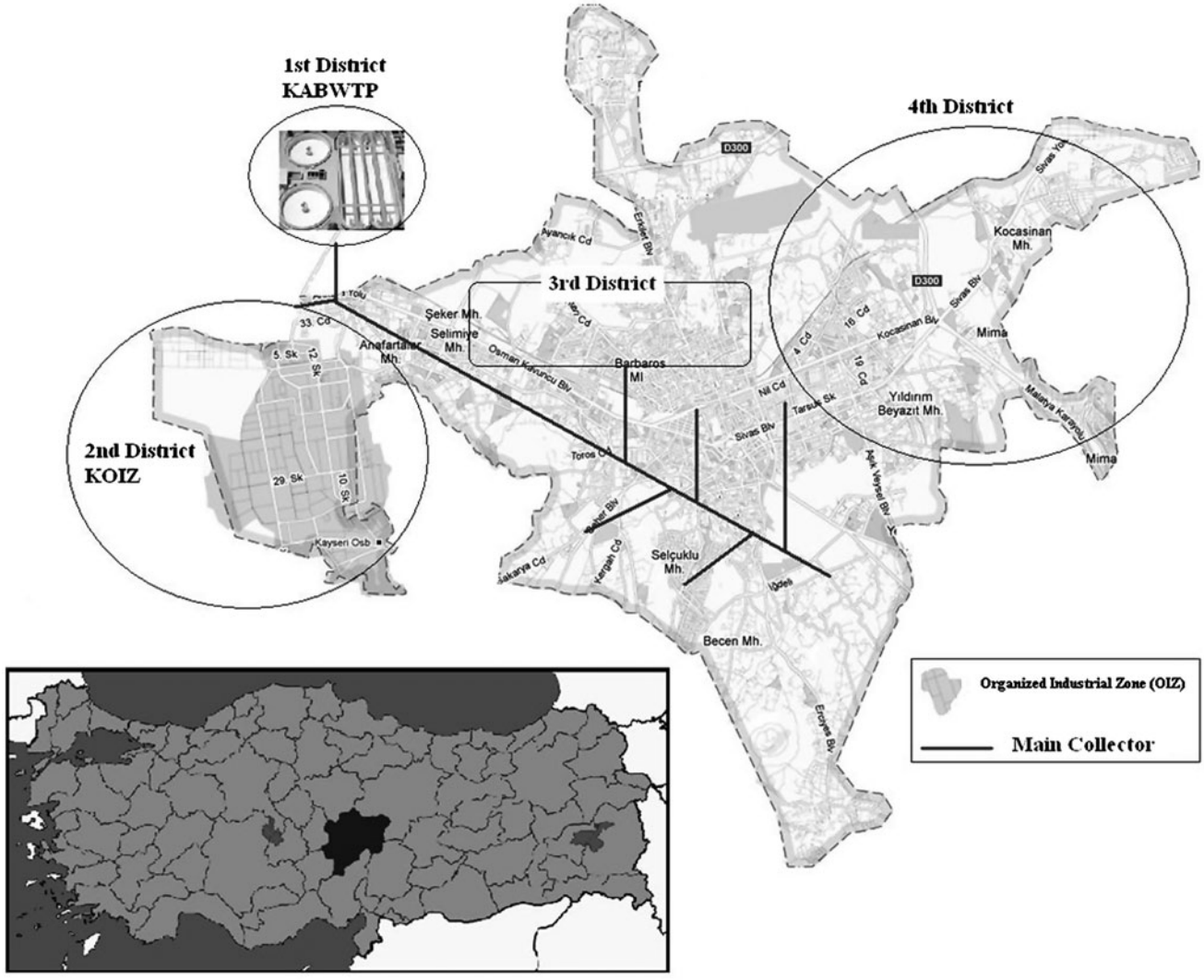

Fig. 1. Location of pollution source in the metropolitan area of Kayseri.

wastewater and the status of municipal wastewater reuse in Greece and Spain. Aggeli et al. [16] proposed reuse of treated municipal wastewater model for in the central square (plaza) of the city of Agrinion. The studies conducted on pollution profile and wastewater treatment alternatives in Turkey, for instance Çiner and Eker [17] presented wastewater characterization and chemical pretreatment of the wastewater originating from a medium-scale OIE located in Sivas (SOIE), in the northeast Turkey. Talinli et al. [18] determined pollution profile and wastewater treatment alternatives for organized industrial estates.

Unlike the previous studies [12–14], domestic and industrial wastewater sources of Kayseri (Within municipal boundaries) were determined and information about character and formation of the wastewater were provided. For this purpose, location of the declared facilities', their wastewater features, and discharging areas were investigated. Wastewater, existing throughout the city was divided into four parts and compared with the discharge standards determined by the national and local governments. One year data set (2007–2008) received from Kayseri Water and Sewerage Administration (KWSA) and Provincial Department of Environment and Forestry (PDEF) of the composite sample analysis results were considered to generate the pollution profile. In terms of wastewater and pollution, textile and metal market appears to get the most important rate. On the other hand, most industries' discharge limits are seen to supply the limits of the regulations.

2. Methodology

During the present study, in order to determine the wastewater profiles and current wastewater treatment alternatives, existing wastewater sources were divided into four main districts, according to the city's position (Fig. 1). In the collection of inventory, wastewaters of a total of 19 industries, 14 of which were from the 3rd district and five were from the 4th district were evaluated.

In order to improve the knowledge obtained from the industries control questionnaire forms as used previously conducted KWSA. The industries selected with respect to some characteristics, such as the production capacities of the facilities, the number of the employee, water consumption, and their location [18,20]. Experimental analyses results were obtained, which are performed by PDEF, KWSA, and Turkish Standards Institute in regular periods and according to the standard methods [21]. Wastewater analyses of the industries are conducted on composite samples of 2 h in accordance with the sector parameters which are given in Turkish Water Pollution Control Legislation (e.g. weekly or monthly) [22].

2.1. Current situation in the region

The study was conducted on wastewaters generated within the metropolitan municipality district of Kayseri. Industrial and commercial activities in Kayseri, which is located in the central Anatolia, have always been at the forefront. The city has undergone a dense industrialization recent decades, which was followed by a rapid increase in population and an irregular urbanization. Study areas assessed in four districts as follows:

2.2.1. First district

Wastewater generated in the center of the city goes to the Kayseri advance biological wastewater treatment plant (KABWTP) (Fig. 1).

2.2.2. Second district

KOIZ wastewater, such as a single channel. (This wastewater goes to the KABWTP with the discharge channel). The region is one of the largest industrial regions in Kayseri. The KOIZ is located about 14 km south of Kayseri city. It was established in 1986 and its area is approximately 23.5 km^2. Until the beginning of 2013, the KOIZ sent the wastewater to KABWTP, and then began to use their own central treatment plant. The present study evaluated for the period before 2013.

2.2.3. Third district

Industries which are located at the center of the city discharge the wastewater to the KWSA's main discharge channel. (Wastewater goes to the KABWTP with the main discharge channel).

2.2.4. Fourth district

Industries which are located at the center of the city discharge the wastewater to directly receive water body. (Selected as the five characteristic industries.)

3. Evaluation and results

3.1. First district

Three counties, 19 towns, nine forest villages, and 32 villages are added in the new limits of the city.

Population values increased approximately 1.5 times in the region which has expanded 10 times its previous area. Collected wastewaters are treated in KABWTP which is approximately 20 km away from the city center and serves a population equivalent to 800,000 at the first level and a yield of 110,000 m^3/d dry air wastewater. The process schema of the plant is given in Fig. 2 and the input and output values are provided in Table 1.

Considering additional small residential areas which are newly added in the adjacent area of the city, the adjacent area of metropolitan municipality is divided into seven watersheds. In the watersheds, considering the differences in altitude between the central residential areas, connection of these residential areas to the main collector is planned where a connection to the wastewater treatment plant is possible. Local solutions are planned for places where it is not possible to discharge the wastewater to KABWTP because of reasons such as topography, distance to main collector, etc. In Fig. 3, residential areas that could be connected to the main collector or others which are planned to have independent treatment execution are given [21].

Except for large counties, new residential areas are distant from each other and have lower population. Establishment of small scale wastewater treatment plants are suggested in areas with population higher than 1,000. For the smaller residential areas, natural treatment is suggested to be exercised in the districts having appropriate lands. Within this context, 5 small scale wastewater treatment plants that are found to be appropriate to build by the KMWSD are given in Table 2.

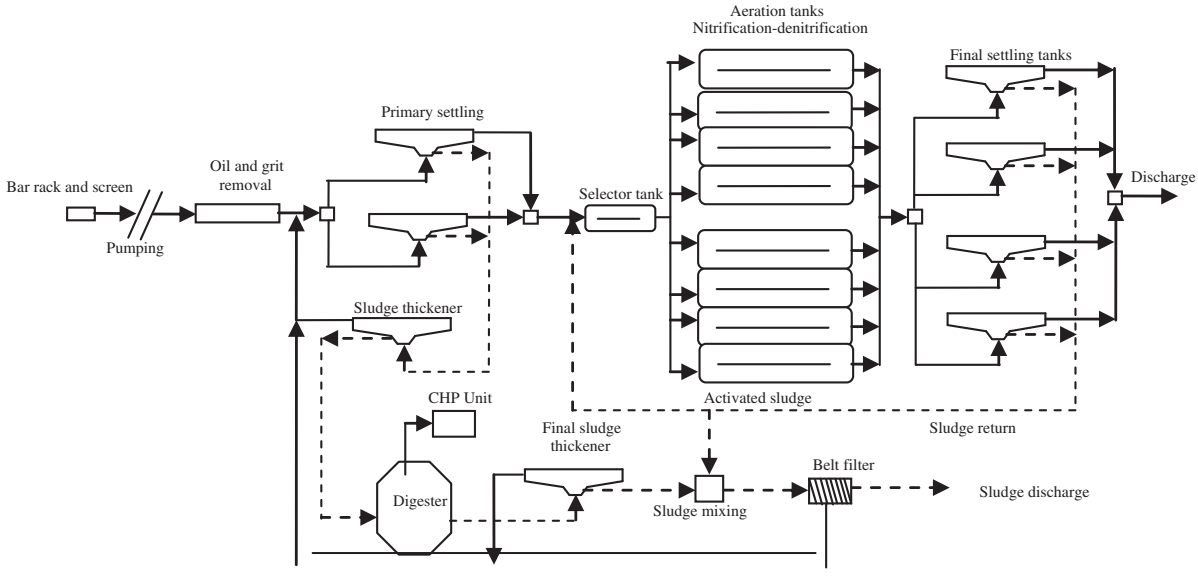

Fig. 2. KABWTP process schema [23].

Table 1
KABWTP's analysis results and discharge standards of domestic wastewater to receiving water body in Turkey [23]

Parameter	Infl mg/l	Infl kg/d	Effl mg/l	Effl kg/d	Efficiency %	Composite sample mg/l (2 h) Pop. >1,00,000	Composite sample mg/l (24 h) Pop. >1,00,000
BOD_5	210	23,100	20	2,200	90	40	35
COD	382	42,000	70	7,700	82	120	90
TSS	464	51,340	20	2,200	96	40	25
TN	83	9,140	15	1,870	80	–	–
TP	17	1,905	2	220	88	–	–

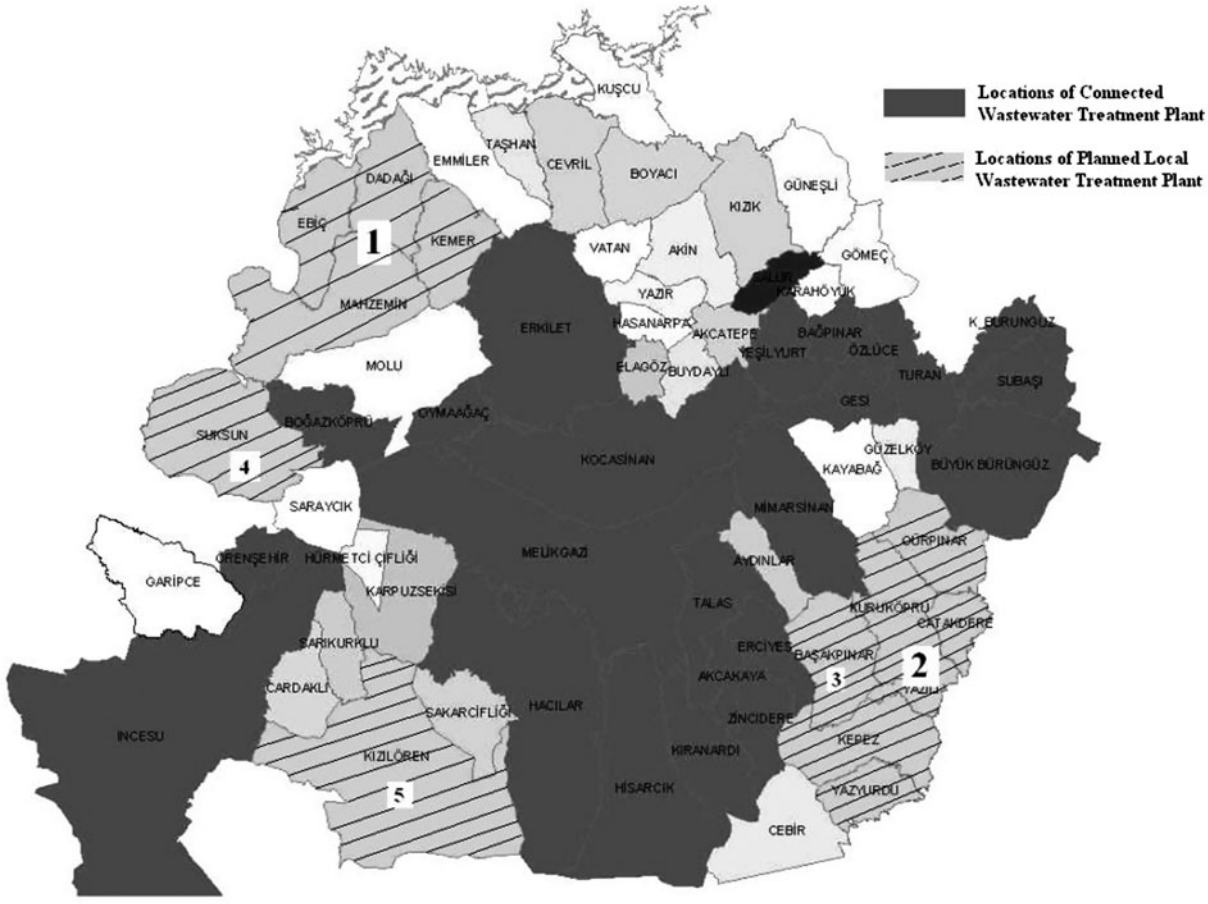

Fig. 3. Limit of Kayseri metropolitan municipality and planned local wastewater treatment plants [2].

Table 2
Planned local wastewater treatment plants [23]

Number	Place	1997 Years of census	2000 Years of census	Selected populations	2nd stage	Flow rate, m^3/d
1	Yemliha	4,302	5,200			
	Ebiç	1,443	1,929			
	Kemer	324	228			
	Dadağı	345	230			
	Mahzemin	1,845	2,199			
	Total	**8,259**	**9,786**	**11,000**	**20,000**	**1,100**
2	Çatakdere	431	561			
	Gürpınar	2,002	2,204			
	Kuruköprü	2,330	2,562			
	Yazyurdu	448	591			
	Kepez	1,899	2,476			
	Yazılı	170	303			
	Total	**7,280**	**8,697**	**11,000**	**20,000**	**1,100**
3	Başakpınar	3,270	3,532	5,000	7,500	500
4	Kızılören	3,195	5,124	6,000	10,000	600
5	Süksün	2,395	2,093	3,000	–	300

Table 3
Wastewater characteristic of KOIZ [10,24]

Parameter, mg/l	Annual average					EPA (2004) [25]	WPCL*(Table 25) [22]
	2001	2005	2006	2007	2012		
COD	700	1960	1,700	1845	1,750	–	4,000
TSS	780	600	1,800	1,754	1,000	–	1,000
BOD_5	450	550	700	653	–	–	–
TKN	23	40	25	23	30	–	–
T-P	9	12	13	11	11	–	–
Oil and grease	15	150	–	–	130	–	250
T-Cr	0.45	1.20	2.00	1.00	–	0.1	3
Cr^{+6}	0.33	0.16	1.00	0.43	–	–	–
Zn	2.00	6.00	2.50	2.10	–	2.0	10
Hg	–	0.10	0.065	–	–	–	0.1
Pb	0.53	1.70	2.00	0.40	–	5.00	3
Cd	–	0.25	0.18	–	–	0.01	1
Cu	0.30	0.50	0.50	0.50	–	0.2	2

*Water Pollution Control Legislation.

Table 4
Industrial classification and working information [26]

Category	Sector type according to WPCL*	Employee	Flow rate, (m^3/d)
Textile-1	Table 10.3 Textile confectionary	903	2,000
Textile-2	Table 10.3 Textile	728	100
Metal finishing-1	Table 15.1.a Iron and steel	274	50
Metal-2	Table 15.17 Metal foundry	125	1.5
Metal-3	Table 15.6 Metal	50	10
Chemistry	Table 15.10 Accumulator	40	5
Metal-4	Table 15.3 Galvanization	434	60
Electric	–	719	50
Machine-1	Table 15.5 Metal produce	1,174	250
Machine-2	Table 15.5 Metal	453	250
Food production	Table 5.11 Food	10	–
Textile-3	Table 10.4 Washing	38	100
Constructing	Table 7.5 Cement	15	15
Metal-5	Table 15.11 Glazing	40	–

*Water Pollution Control Legislation.

3.2. Second district

Organized industrial zone is continuing its development in an area of approximately 11 million m^2 with low agricultural efficiency that is 14 km away from the Kayseri city center. In the KOIZ, the average wastewater yield originated from the industrial operations was 15,000 m^3/d in 2004, while it has now reached to 30,000 m^3/d [10]. Within the scope of organized industry, wastewaters originating from the processes are given to KABWTP via the existing sewerage line (Fig. 1) (before 2013). The wastewater treatment plant built in 2013 and treated wastewater has discharged to Kızılırmak River by means of Vanvanli Creek and Karasu Creek. Wastewater characterization of the KOIZ which is assessed as a single channel is given in Table 3.

3.3. Third district

These industrial establishments which were located in non-residential areas of Kayseri as of the date they started operating have now begin to be located within

Table 5
Wastewater characteristics of selected industry during 2007–2008 (mg/l) [22,26]

Category	pH	BOD5	COD	TSS	TKN	Oil and grease	T–Cr	Pb	Zn	Cu	Ni	Fe	Cd
Textile-1	7.6	–	225	64	–	6	<DL	–	–	–	–	–	–
Textile-2	7.8	147	316	87	–	14	<DL	–	–	–	–	–	–
Metal-1	6.9	–	150	24	–	6	–	0.672	0.713	<DL	–	–	–
Metal-2	7.2	162	325	114	55.6	6	–	0.48	4.5	0.25	1.71	–	–
Metal-3	6.5		91	24	23	10	<DL	–	–	–	–	–	–
Chemistry	6.9	–	30	2	16	9	–	0.31	–	0.01>	0.61	–	0.01>
Metal-4	8	–	260	4	–	–	–	–	0.165	–	–	–	0.01>
Electric	7.4	170	420	202	–	–	–	–	–	–	–	–	–
Machine-1	6.8	45	113	32	6.33	3	0.68	–	–	0.098	0.007	–	0.009
Machine-2	6.6	67	132	45	7.5	11	0.048	–	–	0.08	0.009	–	0.003
Food production	7.1	–	1,422	–	–	32.5	–	–	–	–	–	–	–
Textile-3	9.5	–	298	22	5.43	25	0.21	–	–	–	–	–	–
Constructing	7.2	–	–	53	–	–	–	–	–	–	–	–	–
Metal-5	8	–	1,310	858	21.87	38	0.96	0.161	0.01>	0.01>	0.68		0.011

Note: DL: detection limit.

Table 6
Industries are given permission to discharge [22,26]

Selected representative industries	Sector type according to WPCL	Current State*	Number of sampling during year
Food industry	Table 5–1 Flour and macaroni production	A	2
Food industry (Feeding stuff)	Table 5–6 Meat packing industry	A	2
Trout farm	Table 5–13 Field fishery	B	2
Wastewater treatment plant	Table 21–4 Domestic wastewater	B	4
Ostrich production	Table 5–6 Meat packing industry	B	3
Textile industry	Table 10–1 Textile (fiber production)	B	3
Mining industry	Table 20–1 Other industrial wastewater	B	3
Electric industry	Table 21–1 Domestic wastewater	B	3
Leather industry	Table 12 Leader goods	B	4
Machine industry	Table 13–8 Paper, carton production	B	3
Marble industry	Table 7–1 Mining industry	B	3
Metal industry	Table 15–15 Metal production	B	3

Note: *conducted by the Provincial Department of Environment, A: discharge permission is expired; the discharge permission will be renewed. B: ongoing discharge permission.

the urbanized territory as a consequence of irregular expansion of the city in the last couple of years. Discharging the wastewater of these industries, which are outside the organized industry zone directed to the discharge channel of KWSA (Fig. 1). Controlling of these establishments is again realized by KWSA which also periodically analyzes their wastewaters. Industrial distribution of the 14 firms located inside the adjacent area with respect to TWPCL is given in Table 4 [22]. Average results of the annual analyses which belong to the samples collected by KMWSD from the industries during 2008 are given in Table 5.

3.4. Fourth district

There are a total of 23 industrial establishments in Kayseri city center that discharge their wastewaters to the receiving water body. The Provincial Department of Environment conducts the wastewater analyses of these establishments in accordance with the water contamination control directive sampling and analysis methods notification. Tracking and controlling of discharge permissions are again conducted by the Provincial Department of Environment. Industrial distributions of the establishments according to

Table 7
Wastewater characteristics of industry samples during 2008* [26]

Parameter (mg/l)	Mining industry	Food industry	Trout farm	Metal industry
pH	6.6	7.2	–	7.1
TSS	–	12	–	2
COD	36	54	16	20
BOD_5	–	–	–	–
Oil and Grease	8	–	–	7
Fe	–	–	–	1.12
Zn	–	–	–	3.85

Note: DL: detection limit, all values are well below the Water Pollution Control Legislation.

TWPCL and the establishments that have discharge permission are given in Table 6.

There are 23 industrial establishments operating in Kayseri and trout farm, food industry, metal and mining establishments outnumber the other industries. Representative industry is selected from each group and annual average wastewater analysis results of selected industries obtained in 2008 are given in Table 7 [26].

4. Conclusions

In this study, existing wastewater resources along the limits of metropolitan municipality are separated into four main districts with respect to their location in the city and then they are evaluated (with respect to the criteria given above). Domestic wastewater generated from the city is treated in KABWTP in accordance with the directives. Treated wastewater is an important source of water and nutrients for many farmers in semi-arid Anatolian region. Therefore, the use of wastewater in irrigation helps to reduce downstream health and environmental impacts that would otherwise result if the wastewater were discharged directly into surface water body. Table 1 clearly indicates that the effluent wastewater of treatment plant is suitable for use in agricultural irrigation.

Small residential areas which are newly included in the provincial limits are analyzed in seven watersheds according to their locations in the adjacent area. In the watersheds, considering the differences in levels between the central residential areas, connection of these residential areas to the main collector is planned, where it is possible to connect to the wastewater treatment plant. Local solutions are planned by the municipality for places where it is impossible to direct wastewater to KABWTP because of reasons such as topography, distance to main collector, etc.

Wastewaters coming from the industries in the organized industry zone are collected in a channel and treated in a central treatment plant (KABWTP) until the beginning of 2013. However, the existence of small residential areas within the provincial limits and the fact that new establishments will start operating in KOIE has become a net indicator of capacity problems that will arise in the central wastewater treatment plant in the future. Wastewaters of the organized industry zone should be discharged after they are collected within the district and treated in a central treatment facility. Looking at the value in Table 3, wastewater is suitable for use in agricultural irrigation in all parameters except for copper and iron. This problem has been eliminated from the operation of the treatment plant in 2013.

A comprehensive study should be conducted in the district to determine the central treatment units and identify the characteristics of wastewaters which would be accepted for treatment. With central treatment both spatial and economical benefits will be realized. On the other hand, wastewaters of a total of 19 industries 14 of which are discharging into the channel and five of which are discharging into the receiving water body and none of which has been included in the evaluation for Kayseri up to now are analyzed. Contamination levels differ with respect to sectors and the sector with the highest contamination level is found to be the textile industry. The fact that large textile industries became located within the city by expansion of adjacent areas has carried the problem to more serious dimensions. It is also observed that the food industry is important because of its water consumption and high load of organic contamination. It is observed that discharge of important sectors, such as metal industry and other industries are sufficient when it is compared with the standard determined by KWSA. Wastewaters of industries which are still discharging into the receiving water body should be connected to the sewerage system as soon as possible. Hence, these industries will benefit from the advantages of central treatment, since they will be conducting treatments in accordance with the KWSA standards. In the end, an opportunity for a treatment with lower cost will arise.

Acknowledgments

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